SOCIAL-ECOLOGICAL SYSTEMS OF SHEEP RANCHING, RECREATION, AND LARGE CARNIVORES ON MULTIPLE-USE U.S. PUBLIC LANDS

by

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Abstract

The multiple use policy on over 441 million acres of public lands mandates "the management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people." Most contentious among these uses has been the debate surrounding the 257 million acres of public lands used for ranching in the American West. Conflicts over rangeland access and management have recently been heightened by the reintroduction and recovery of large carnivores and the rise of recreational use. Spatial and temporal partitioning have been shown to minimize conflicts but the geospatial information that could model, predict, and allow the geographically specific management of conflict in a multiple-use system is a lacuna in the literature. This knowledge gap, and the causes and solutions of conflict, can best be understood in the broader context of their social dimensions.

I use the social-ecological systems framework (SESF) to create a contextualized causal map of flows between sheep ranching, large carnivore conservation, and recreation on public lands in an Inter-mountain West community. Using data from sheep fitted with GPS trackers to quantitatively support ethnographic information, I spatialize the SES with a partial suitability model for sheep grazing. This is a step toward a geographical tool that combines models of carnivore occupancy and recreational use to predict and prevent conflict between multiple uses. In combination with an understanding of the SES, this tool can increase adaptive capacity in

resource management by enabling quantitative, spatially explicit social and ecological cost-benefit analyses at appropriate scales.

Dedication

To the Wild, and those who love it.

Acknowledgements

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Introduction

The debate over the use of America's public lands was initiated at their inception and continues to escalate today as competing interests and industries vie with our need to preserve ecosystem services for access to an ever-dwindling supply of undeveloped territory. The multiple use policy on over 441 million acres (Vincent et al., 2017) of public lands managed by the Bureau of Land Management (BLM) and the US Forest Service (USFS) mandates "the management of the public lands and their various resource values so that they are utilized in the combination that will best meet the present and future needs of the American people" (Federal Land Policy and Management Act, 1976). Most contentious among these uses has been the debate surrounding the 251 million acres of public lands used for ranching in the eleven conterminous states of the American West, where 46.4% of land is federally owned ("Grazing Stat. Summ. FY 2016," 2017; Vincent et al., 2017). Centuries of conflict over rangeland access and management have recently been heightened by the reintroduction and recovery of large carnivores (formerly extirpated to protect ranching interests) and the rise of recreational use, creating the urgent need to examine if and how ranching, recreation, and wildlife conservation can co-exist in the same spaces. Spatial and temporal partitioning, which can enable the coexistence of humans and wildlife (Carter et al., 2012; Mech, 2017; A. D. Miller et al., 2017; Šálek et al., 2015) and of recreation types (A. D. Miller et al., 2017), are feasible strategies for managing multiple uses; but the geospatial information that could model, predict, and allow geographically specific adaptive management is a knowledge gap. Social and historical causes contribute to this knowledge gap. Analyses that consider the social and contextual dimensions and drivers of use and conflict on multiple-use public lands are necessary to improve multiple-use management.

The cumulative impacts of multiple uses of publically-owned rangelands have been inadequately examined in part because the feedbacks between social and ecological components are also inadequately understood. These feedbacks stymie the effective production and application of knowledge in multiple-use management and necessitate the development and adoption of a framework that explicitly includes social-ecological interactions. Here I use the social-ecological systems framework (SESF) (Binder et al., 2013; Hinkel et al., 2014) to contextualize and map the direction and influence of interactions between sheep ranching, large carnivore conservation, and recreation on public lands in the Inter-mountain West community of Blaine County, Idaho. By identifying the causal pathways that have led to current outcomes, I highlight the interventions most likely to increase systemic adaptive capacity. Using data from sheep fitted with GPS collars to quantitatively support information obtained in ethnographic research, I spatialize the SES with a suitability model for sheep grazing that includes anthropogenic influence. Although building such a tool is beyond the scope of this study, this model is a first step toward a geographical tool to predict and prevent conflict between multiple uses and users which could support quantitative, scale-appropriate social, ecological, and spatial cost-benefit analyses of management strategies on multiple use lands.

I first provide brief overviews and an historical perspective of the primary agencies responsible for managing ranching, recreation, wildlife, and conflict on public lands; and the origins of the multiple-use mandate. Then, I summarize historical influences and the contemporary states of sheep ranching; large carnivores and their ecological and social significance; and the interactions between ranching and large carnivores in the Inter-mountain West. Next I provide social and economic information as well as details on ranching, recreation, and large carnivore management in the study area of Blaine County, Idaho. This background provides the context necessary to understand the current system state in the study area. Following this, I review my methodological approach and the methods used in this research and then present the results. The discussion that follows examines these results in a broader national and disciplinary context and includes challenges, questions, and recommendations for future research. I conclude with a brief summary of my key findings. Additional information may be found in the appendix, as noted in the text.

Background

History of BLM and USFS Land Management

In the century following its founding the United States of America possessed surpluses of sparsely settled land ceded to the public domain by European powers and (after considerable negotiation and political maneuvering) individual states. Eager to generate revenue for the young country, the U.S. Congress of the Confederation and later the U.S. Congress allowed their sale and regulation with the Land Ordinance of 1785 and the U.S. Constitution, respectively. During the period of Westward expansion the public lands were increased and the U.S. government, eager to distribute their growing population and stimulate agricultural production, encouraged their conquest, settlement and development by European-Americans. Often remote from governance, public lands and resources were commonly used by the public as their regulation, patrol, and use continued to be debated and developed. The General Land Office was created in 1812 to manage and administer the acquisition, survey and particularly the sale (also called disposal) of public lands. Since that time the U.S. has established a multiplicity of land-management agencies that vary in their evolving missions and jurisdictions. Public-lands ranching occurs on lands managed by the Bureau of Land Management (BLM), which was formed in part from the agency created to manage ranching; and the U.S. Forest Service (USFS). Additional land management agencies include the National Park Service (79.8 million acres), the Fish and Wildlife Service (89.1 million acres), and the Department of Defense (11.4 million acres) (Vincent et al., 2017).

The General Land Office was established in 1812 to oversee the development, sale, and use of public lands. It was the General Land Office that managed lands sold under the 1916 Stock Raising Homestead Act, which offered a 640-acre homestead section of public land to ranchers and contributed to a ranching boom in the West that lasted roughly the 100 years between 1840 and 1940. Millions of acres of public lands thus privatized were later subdivided and sold. This land had previously been determined unfit for other uses, and the subsurface rights remained in the public trust. Ranchers typically herded livestock through remaining adjacent public lands to supplement forage. The rapid rise of ranching and agriculture created by the Westward expansion led to the equally rapid degradation of ecological and social stability. Violent and organized conflict over grazing and water rights (particularly cattle versus sheep ranchers) were common; this period of disputes is referred to as the "range wars." Near the peak of sheep ranching, the 1934 Taylor Grazing Act created the Grazing Office to manage public lands ranching and reduce both human confrontation and overgrazing. Ten years later, the General Land Office and the Grazing Office were merged to create the BLM, which would oversee all sale, development, and uses on all public lands (Bureau of Land Management, n.d.).

The contemporary BLM is still a division of the Department of the Interior and manages 245 million acres of surface and 700 million acres of subsurface land, making it the nation's largest land management agency in terms of acreage (U.S. Bureau of Land Management, n.d.). Those critical of the degree of BLM's liaison with commercial interests have referred to it as the "Bureau of Livestock and Mining" but it is charged with permitting and overseeing nearly every use of these lands and their resources including mining, energy development, timber, livestock grazing, outdoor recreation, and the conservation of natural and cultural resources. These lands have designations and features that include wilderness areas, national monuments, trails, scenic rivers, artifacts, and historic sites. In 2008 the National Landscape Conservation System Act added the duty to "conserve, protect, and restore nationally significant landscapes that have outstanding cultural, ecological, and scientific values for the benefit of current and future generations" on designated BLM lands, creating additional opportunities for recreation and conservation (National Landscape Conservation System Ac>, 2008). The recent sale of BLM-managed public lands has reversed the 20th-century trend of maintaining and increasing the public lands base, while the planned relocation of its headquarters from Washington, D.C. to Colorado has been the focus of both praise and protest in a controversy centered on the motivations for the move.

The U.S. Forest Service was initially created to manage National Forests, and does so today; but what that means has changed. The Forest Reserve Act of 1891- a rider on a bill revising several public-lands laws-authorized the presidential designation of public lands in the West as what by 1905 were known as national forests. Inspired by calls to safeguard sources of timber and other forest products for the country and as a source of revenue for its government, the Forest Reserve Act did not specify the purpose of the reserves or set guidelines for their management. The majority were created in the relatively undeveloped lands of the West, and those who were living there raised the strongest objections to the restrictions now placed on large swathes of forest. The Organic Act of 1897 has been characterized as compromise legislation couched in the public lands debates of the era (Bassman, 1974), and in part its purpose was to placate those objectors to extensive Federal landholdings with the suspension of several publically contentious reserve designations and increased regulations on reserve creation and management. It set criteria for forest reserves including timber production, forest, and watershed protection; and set penalties for unlawful use, while maintaining access for development that included mining, the construction of necessary public and private roads, railways, and the passage of the public pending their compliance with regulations. In some areas the boundaries of the forests were drawn after their settlement, and the use of public buildings- i.e. schools and churches- within them was permitted. Personal domestic use of forest products by residents of reserved areas continued to be explicitly allowed, and although recreation was not a specified use it was encouraged by building campgrounds for public enjoyment, following the example of the National Parks emphasis on developing recreational opportunities. Again following the parks, Forest Reserve lands were also leased to private enterprises for the development of recreational facilities including hot springs and hotels (Williams, 2005). Sheep grazing, but not the pasturing of other livestock, was initially prohibited on Forest Service lands on the grounds that it was "found injurious to the forest cover, and therefore of serious consequences in regions where the rainfall is limited"; permitted sheep grazing was first allowed only in Washington and Oregon, where rainfall was more plentiful (Organic Act of 1897, 1897).

National forests were jointly managed by the General Land Office, the US Geological Survey (both divisions within the Department of the Interior) and the Bureau of Forestry (United States Department of Agriculture) until the unification and re-christening of all three divisions under the USFS in 1905. This period marks the beginning of professionalization of the USFS, and its decentralization via the creation of regional offices. In 1907 the Fulton Amendment transferred the power to create reserves from the president to the Congress and restricted their creation in several states with heavy lobby pressure. Concerns over Federal land-grabbing were not unfounded; conservationist-minded president Roosevelt, who had earlier reversed a previous reserve designation under public pressure, hastily sequestered over sixteen million acres of Western reserves the day before the Fulton Amendment was slated to pass (Williams, 2005).

Multiple-use on U.S. Public Lands

The USFS focused on meeting the demand for timber created by world wars but in the subsequent post-war booms found itself pressured to expand access to other resources, particularly recreation (Williams, 2005). The policy of multiple use was formalized with the 1960 Multiple-Use Sustained-Yield Act (MUSY), according to which the national forests "shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes" (Multiple-Use Sustained-Yield Act of 1960, 1960). It was left to the USFS to impartially determine which uses were compatible in a given area, though in practice priority of use was and is influenced by political and economic interests. The principles of MUSY and the USFS set a precedent and continued a conflict- strict conservation versus use- that defines the present-day management of public lands.

The initial obligations of the USFS to manage wildlife consisted of assisting State-run efforts. Complaints and a lawsuit brought by hunters over objections to forestry practices that potentially damaged wildlife populations led to the 1970 National Forest Management Act, which required research-based management informed by public participation and reinforced the idea of sustained yields of multiple uses and products including wildlife and fish (National Forest Management Act, 1976; U.S. Bureau of Land Management, 2005). The USFS focuses on conservation and restoration of wildlife habitat and monitors but does not typically manage wildlife populations directly.

Burgeoning environmental awareness was reflected in the legislation of the 1960s and 1970s, most notably with the passage of the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). The Federal Land Policy and Management Act (FLPMA), passed in 1976, defines the mission and to some extent the methods of the current BLM and

USFS. It codifies organizational structure, terms for the sale and exchange of public lands, their lease for grazing, and the Congressional declaration of multiple use: that "the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use" (Federal Land Policy and Management Act 1976, s.1701). These objectives are to be achieved through the coordinated efforts of state, local, and federal management agencies and with participation from the public. FLPMA mandates a continuing inventory of public lands and the values of the resources therein, but does not specify methods or metrics for determining these values nor for assigning priority when uses conflict.

Public Lands Sheep Ranching

The use of public lands for sheep ranching continues to decline, mirroring national trends of decline in the sheep ranching industry that began in the late 1940s (figure 1). The replacement of wool by synthetic fabrics, increasing production costs, competition from Australian and New Zealand markets, and changing American dietary habits all contributed to the decline of the sheep industry after the second world war (K. M. Berger, 2006). Idaho's sheep industry peaked in the 1930s with around 2.6 million head of sheep and lambs in the state; in 2020 there were 230,000 head (National Agricultural Statistics Service, 2020). Sheep ranchers today follow the same transhumance pattern, sheltering their animals at the home ranch for 2-3 months as they lamb before moving to higher elevations with spring green-up. In the autumn ranchers herd their sheep back to the lowlands, where they will graze as they complete the loop back to the ranch. A typical group of sheep, called a band, consists of approximately 1,000 animals; each band is supervised and accompanied by 1-2 sheep herders throughout their journey.

Under this permitting system ranchers lease allotments of thousands of acres of land assessed by federal managers for a permit cost plus a fee based on the 1989 value of grazing lands, the market value of hay and the amount of forage 5 sheep can eat in a month (called an animal unit month, or AUM). The fees for renting public land are considerably lower than those for renting privately, although direct comparison is complicated by factors that include forage quality, availability of water, and cost of transport. The public fee was $1.35 per AUM in 2019 (the lowest it can fall under the fee formula used for its calculation) (U.S. Bureau of Land Management, 2019). Private rangeland grazing lease fees vary widely but were estimated at $14.50-$16.04 per AUM in 2011 (Rimbey et al., 2014). One operator may use multiple allotments in a year; typically these are adjacent. Grazing allotments are transferrable and taxable assets.

Within allotments managed by the USFS, sheep ranchers follow Annual Operating Instructions (AOIs), plans developed by rangeland agents with consideration of habitat features and conditions and input from the ranch operators. AOIs specify the general route the sheep will take through the allotment and how many animals are permitted to graze in a given area for how many days. The AOIs contain a description of the area and, more recently, maps depicting boundaries and the proposed grazing routes. On BLM allotments there is no specified grazing route but grazing time within the allotment and other regulations are detailed in Annual Management Plans (AMPS). Here I refer collectively to AOIs and AMPs as grazing plans. Ranchers must adhere to regulations and restrictions specified by the grazing plans with the intent to preserve rangeland resources and conditions including regulations on riparian areas, bedding locations and durations, recreation trails, and management of wildlife conflict.

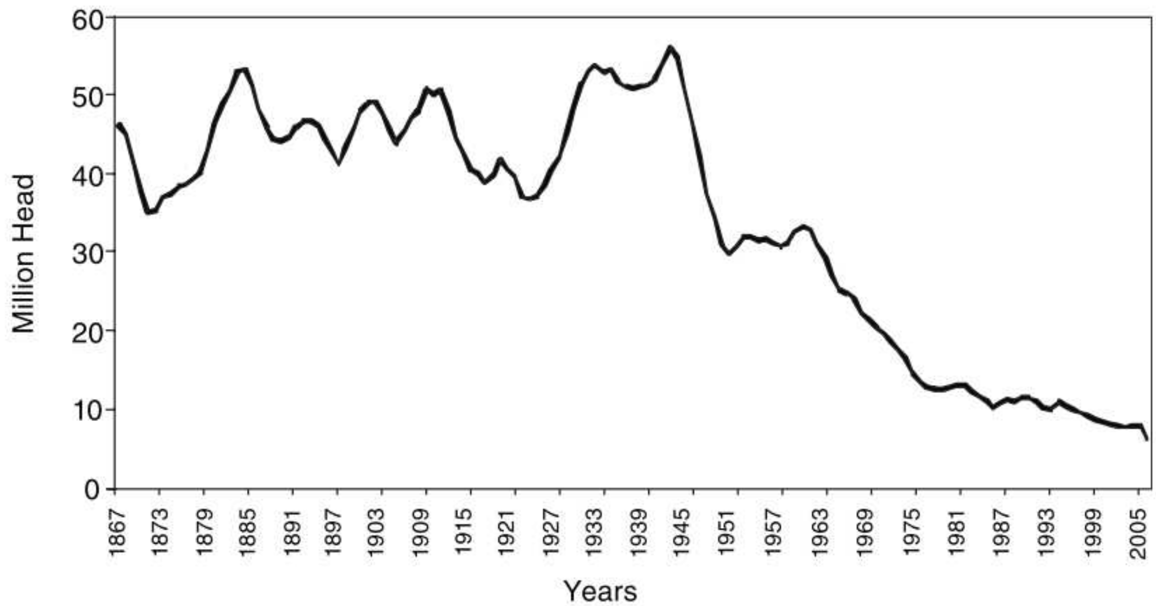

Figure 1. *U.S. sheep and lamb inventories (January 1), 1867–2007. In spite of subsidies intended to increase American wool production and a shift in focus from wool to meat as the main product of sheep ranching, the trend of contraction in the industry that began in the late 1940s continues. Reproduced from* (National Research Council, 2008).

Considerable debate surrounds the impact of sheep grazing on rangelands. Ranchers have been viewed as partners in maintaining healthy range conditions by controlling brushy build-up that can become fuel for wildfires, targeting invasive species in a low-impact alternative to chemical pesticides and controlled burning (Bailey et al., 2019), and aiding wildlife by digging wells or installing water troughs. Grazing may also negatively alter plant and wildlife distribution and abundance and damage riparian areas and soils. It is beyond the scope of this work to reach a definitive conclusion on the impacts of sheep grazing; as suggested elsewhere, the ecological impacts are specific to the ecological community and its conditions (Krausman et al., 2009).

Carnivores in the Inter-mountain West

Large carnivores, most notably wolves, have become symbols of wild and wilderness because they exist where humans are not: however, this is a result of extirpative efforts rather than a *de facto* attribute (J. V. Martin, 2015; Swenson et al., 2001; Woodroffe, 2000). Although sensitive to anthropogenic disturbance (Darnell Baker & Leberg, 2018) carnivores have adapted to living in human-dominated landscapes primarily in places where humans have adapted to living with them, a key component of sustainable coexistence (Carter & Linnell, 2016). Spatial and temporal niche partitioning (i.e., avoidance of one another in space and time) are effective coexistence strategies at fine spatial scales (Carter et al., 2012; J. Martin et al., 2010; Mech, 2017; Šálek et al., 2015) though this can indirectly effect other trophic levels in ways we are only beginning to understand (Rogala et al., 2011). Adaptability is both promising and challenging for large carnivore conservation, for while it enables the utilization of more habitat it also brings humans and carnivores into conflict over their shared spaces and conflicting interests.

Large carnivores are primary predators that kill and consume other species but are not routinely killed for consumption. In the Inter-mountain West region they include grey or timber wolves *(Canis lupus)*, black and grizzly bears *(Ursus americanus, U. arctos)*, Canada lynx and bobcat *(Lynx canadensis, L. rufus)*, wolverine *(Gulo gulo)*, and mountain lion *(Puma concolor)*. The coyote, *Canis latrans*, is sometimes counted among large carnivores and sometimes among the mesocarnivores (carnivores of intermediate body size and trophic position, such as red foxes *(Vulpes vulpes)*). While generalizations can be made management and coexistence strategies must also be specific to the species and the ecological context of large carnivores, as there are considerable intra-species variations in their spatial and temporal distribution, diet, and behavior determined by resource availability, social structure, seasonality, habituation, and habitat type.

Terrestrial large carnivores are strongly interactive species that shape ecological communities both directly and indirectly through trophic and non-trophic interactions. Alterations in the abundance or distribution of strongly interactive species effect those of multiple other species in the ecological community (Soule et al., 2005). Effect strength refers to the magnitude of the effect of one individual on the local population of another species or process, and large carnivores have comparatively large effect strengths with regard to other species. Effect strengths depend upon the unique species traits of both carnivores and their prey (Atkins et al., 2019; Ripple et al., 2014), geospatial variation (B. Miller et al., 2001) and biophysical variables (Borer et al., 2005; Hunter & Price, 1992; Ritchie et al., 2012). Ecological theory predicts that large carnivores may have both stabilizing and destabilizing effects on ecological communities. Weak interactions (weak effect strengths, as above) between species dampen and distribute the effects of consumer-resource interactions, and collective weak effects may counteract those few stronger "keystone effects" that have been observed in strongly interactive species. Large carnivores- most of which are adaptable generalists- may promote community diversity (which has been linked to adaptability and resilience) by propagating weak interactions and varied energetic pathways through the suppression of competitive dominance among prey species (Ripple et al., 2014) and mesocarnivores. When suppression of competitive dominance is relaxed, interaction strength at lower trophic levels increases and compensatory food web dynamics can cause shifts in the populations of other species (J. Estes et al., 2001). The expansion of the functional niche of mesocarnivores in the absence of large carnivores is called 'mesopredator release.' Salient examples of mesopredator release include the expansion of coyote *(Canis latrans)* ranges, populations, and depredations in the absence of wolves (K. M. Berger et al., 2008; Galle et al., 2009). These changes can perpetuate through community assemblages.

Extirpations of large carnivores have had consequences that include dis-regulated prey populations and disrupted ecosystem services, to the extent that carnivore conservation has been proposed as a strategy for ecosystem restoration (J. A. Estes, 1996; Licht et al., 2010; Ritchie et al., 2012; Wallach et al., 2010). Carnivore-initiated causal chains have been termed 'trophic cascades.' The term 'trophic cascade' describes the phenomenon of influences that originate with top consumers and affect the abundance and distribution of primary production indirectly through one or more adjacent trophic levels. These interactions may be density-dependent, as in the effects of predation on herbivore abundance; or behaviorally mediated, when the presence of predation risk alters the distribution, fitness, or abundance of herbivores by creating a "landscape of fear". Trophic cascades initiated by large carnivores have been documented in terrestrial systems in North America, Europe, Australia and Africa (Atkins et al., 2019; Ripple et al., 2014). Most famously, wolf predation pressure has been identified as the cause of trophic cascades affecting primary production in the Great Lakes and Greater Yellowstone Ecosystems (J. Berger & Stacey, 2001; Callan et al., 2013), initiating changes in habitat structure, ecosystem processes (Beschta & Ripple, 2009), and geophysical processes including stream bank stability and overflow control (Ripple et al., 2014), alluvial deposition and channel braiding (Beschta & Ripple, 2012) and carbon sequestration (Ripple et al., 2014).

The studies indicating a trophic cascade in the GYE rely heavily on correlative methods and are confounded by changes in ungulate populations, density-mediated effects of predation

(Kauffman et al., 2017), climactic variables (Creel & Christianson, 2009), and the fairly recent (1960s) cessation of heavy human management actions (Clark et al., 1999). Other studies find no significant impact of elk on primary production in a manner consistent with a trophic cascade (Beyer et al., 2007; Creel et al., 2009; Kohl et al., 2018; Winnie Jr., 2012). The application of the principles of trophic cascades to manage herbivore influence on primary production predates the academic development of the concept considerably and remains one of the rationales for both predator control and reintroduction (Clark et al., 1999; Halaj & Wise, 2001).

Sheep Ranching and Carnivores in the Inter-mountain West

Strong cultural perceptions and concerns for the safety of humans and livestock and the supply of game animals have driven the persecution of large carnivores worldwide with the result of drastic reductions in their distributions and abundances (Carter & Linnell, 2016; Ripple et al., 2014; Treves & Karanth, 2003). Old-world attitudes accompanied settlers to the Americas, where bounties on large carnivores were quickly established. Human contact and conflict with large carnivores increased as the wilderness frontier moved west. Predator management was left to local communities until 1915, when the Federal government began control actions that included bounties, hunting, baiting, trapping, and poisoning of animals on federal and private lands, including within the confines of National protected areas (figure 2). By the 1930s large carnivores had been functionally extirpated from the vast majority of the conterminous United States (Bruskotter et al., 2014). Ranching was a driver of the extirpation of large carnivores, but depredation by large carnivores has not been a driver of the decline of the sheep ranching industry (K. M. Berger, 2006).

Figure 2. *USFS promotional poster c. 1930s. This poster is readily interpreted in several ways, but seems to depict both the wolf and forest fires as dangerous "outlaws." Federal wildlife and land management included extermination and control actions to ensure a low density of predator populations. These policies continued as late as the 1960s in some places. U.S. Forest Service District Office, Ketchum, Idaho*

As the fields of wildlife sciences and ecology began to develop in the 1920 and '30s, scientists and lands managers began to realize that large carnivores play significant roles in ecosystem processes and advocated for further research and policy change. Within Federal lands management, new approaches were adopted in policy earlier than they were implemented in practice (Sellers, 1997; Williams, 2005), but as environmental consciousness and conservation efforts dramatically increased in the 1960s-1980s wildlife management strategies began to focus increasingly on managing for the health of entire ecosystems rather than single species or resources.

In Idaho, wolves, black bears, and mountain lions are also managed and harvested as game animals (table 1). Carnivores may be lethally controlled (killed) in the case of molestation, or attack on domestic animals or livestock; incidents must be reported to the Idaho Department of Fish and Game. Ranchers may also request lethal control actions from

U.S. Wildlife Services (WS), a division of the United States Department of Agriculture (and distinct from the U.S. Fish and Wildlife Service) charged with the resolution of human-wildlife conflict in the U.S. Control actions are performed in the case of threats to human property and safety and can include relocation, dispersion, and lethal action by poisoning, trapping, and shooting from the ground or helicopter (table 2). The Idaho Wolf Control Board manages funds to hire WS for these services. Depredations must be verified by WS prior to a control action, which poses difficulties to ranchers when operating in remote locations or in cases when predator activity does not leave readily distinguishable marks on livestock, such as an advanced state of decomposition or suffocation caused by livestock crowding in response to predator pursuit. In 2019, $1.38 million in federal funding was approved for WS to implement non-lethal anti-depredation measures. This appropriation was advocated for in part by environmental organizations including the Defenders of Wildlife, and is not the first of its kind. Non-lethal deterrents to depredation include the use of livestock guardian dogs, fencing, alarm or scare devices, hazing predators, use of husbandry practices such as grazing larger stock or protecting lambing stock, and increasing human presence.

Compensation for verified livestock depredations by wolves is available to ranchers. Funding sources include U.S. Fish and Wildlife Service, state appropriations, funding from hunting, fishing, and trapping permits, and livestock industry groups and have previously included Defenders of Wildlife (Idaho Office of Species Conservation, 2019). Ranchers must typically document ranch input costs associated with wolves or anti-depredation efforts before receiving compensation. Compensation for damage from wildlife is available to all landowners, and financial assistance to implement damage and non-lethal depredation prevention is available.

Table 1. *Recreational carnivore harvest, Idaho. Populations of black bears, mountain lions, and grey wolves are sufficient that recreational harvests similar to those of game species are regularly allowed as part of the Idaho Department of Fish and Game's management strategy.*

Carnivore	Harvest	Year
Bears, black	2,505	2016
Mountain lions	610	2016
Wolves, grey	281	2017

Source: Idaho Department of Fish and Game. (2020). https://fishandgame.idaho.gov Retrieved 02/16/20.

Table 2. *Carnivores killed/euthanized by Wildlife Services, Idaho. Wildlife Services is the division of the Department of Agriculture tasked with managing human-wildlife conflict, and does so using both lethal and non-lethal control actions. Ranchers and non-ranchers may request the assistance of Wildlife Services.*

Carnivore	2017	2018
Badgers	18	35
Bears	6	2
Bobcats or lynx	1	0
Coyotes	3,477	2,898
Dogs	1	1
Foxes, red	22	25
Mountain lions	5	4
Wolves, grey	29	84

Intentional kills only.
Source: Animal and Plant Health Inspection Service. (2020). https://www.aphis.usda.gov. Retrieved 02/16/20.

Carnivore management is influenced and contested by a public whose perceptions of wildlife are determined by factors that include gender, economic and educational status, and place of origin (Kellert & Berry, 1987) and are increasingly polarized. There is substantial public support for some methods of predator control (Slagle et al., 2017); but American's attitudes toward large carnivores have begun to shift as urbanization, industrialization, and growing environmental awareness reduce human-wildlife conflict in many places (George et al., 2016; Manfredo et al., 2003). Efforts at public education conducted by state and Federal land and wildlife management agencies, most notably the National Park Service, have also contributed to Americans' changing perception of large carnivores (Biel, 2006). Proximity to large carnivores may negatively influence perception of them, particularly in the early stages of carnivore recovery (Houston et al., 2010) and when carnivore recovery restricts recreational and commercial use of public land (Fritts et al., 1997). In a review of 50 peer-reviewed reports between 1974 and 2000, Americans who perceived wolf reintroduction as a threat to their livelihood were not supportive of wolf reintroduction, in spite of Americans generally supporting the measure (Brown-Nunez & Taylor, 2002). Direct experience with large carnivores and rural residency are both negatively related to positive perceptions of predators (Slagle et al., 2017).

The recovery of large carnivores in the American West has returned them to the spaces in which they are most contested: grazed rangelands. Wolves, and by extension other large carnivores, have become symbols of larger and increasingly polarized movements: land sovereignty and States' rights on one side, environmental conservation on the other (Fritts et al., 1995 in Fritts et al., 1997). Although they do not cause the majority of depredations (table 3), among those who perceive them negatively the perception of wolves tends to be strongly negative as compared to other predators (Kellert et al., 1996). The transition of American carnivore management policy has involved a series of legislative struggles that carry into the present day and the tug-of-war over the protection status of the American grey wolf and is illustrative of the national debate over carnivore management and of the role that public lands, livestock herding interests, and public involvement and attitudes play in it.

Wolf Reintroduction

Wolves- charismatic megafauna steeped in complex cultural contexts- have become a symbol not only of wilderness but of wildlife conservation, and a rallying point for environmentalists. Grey wolves were functionally extirpated in the majority of the conterminous

U.S. by some estimates as early as the 1930s. Small populations remained in Minnesota (which continued to harvest them) and remote areas of the Canadian Rocky Mountains. Federally protected with the Endangered Species Act (ESA) in 1973/4, wolves were found to be colonizing Montana in 1979. Throughout the early 1990s dispersing wolves moved into Washington and Idaho and were projected to achieve sufficient numbers for recovery by 2015 (Hayden, 2017).

Table 3. *Idaho loss of sheep and lambs by predator type and year. In 2016, the value of sheep and lamb loss caused by predators was estimated at $1.36 million. While attention and tensions have focused on wolf reintroduction, coyotes are responsible for the majority of losses to predators. These figures do not include injured animals or those killed unintentionally while targeting other species.*

Carnivore	1990	1994	1999	2004	2014	2016	2018
Bears	100	-	700	1000	196	200	100
Bobcats or lynx	100	-	-	-	<20	-	-
Coyotes	8800	-	7,800	6,900	3,686	4,200	5,100
Dogs, feral	900	-	900	1400	193	600	200
Foxes, red	100	-	-	-	0	-	-
Mountain lions	300	-	600	400	49	200	-
Other and Unknown	0	-	-	800	61	700	700
Wolves, grey	-	-	57	-	277	800	800
Total loss (head)	10,300	19,000	10,057	10,500	1,750	6,700	6,900

1990-2004: National Agricultural Statistics Service. Sheep and Goat Predator Loss. United States Department of Agriculture. Washington, DC.
2014: Animal and Plant Health Inspection Service (2015). *Sheep and Lamb Predator and Non-predator Death Loss in the United States.* United States Department of Agriculture. Washington, DC.
2016-2018: National Agricultural Statistics Survey Press Release. *Idaho Sheep and Lamb Losses.* United States Department of Agriculture. Washington, D.C.

After extensive research, groups of 35 and 31 animals were released into the Frank Church Wilderness in Idaho and Yellowstone National Park in Montana in 1995 and 1996. By 2002, populations of wolves in Montana and Idaho were sufficient for reclassification of the Northern Rockies population from endangered to threatened, and management plans were written to ensure their sustained survival. The 2002 Idaho wolf conservation and management plan prepared by the Idaho Legislative Wolf Oversight Committee established population objectives and laid the groundwork to cede control of Idaho's wolf population to the Idaho Department of Fish and Game upon ESA delisting. A similar plan was drafted for Montana, with Wyoming's control of its wolf population pending an acceptable management strategy.

A lawsuit brought by a coalition of environmental organizations successfully sued the Federal government for the reversal of the reclassification in 2005. Lawsuit followed lawsuit until in 2008, Idaho gained control of its wolf population under five-year oversight of the U.S. Fish and Wildlife Service after a Federal judge remanded the decision on their status to that organization. In 2009, wolves in Idaho and parts of 4 other western states as well as the Great Lakes region were delisted as endangered, an injunction reversing this decision was denied, and a wolf harvest was taken in the fall before wolves were returned to endangered status per Federal ruling on non-compliance with the ESA. Wolves were returned to state management in 2011 via a rider on the Federal budget and in Idaho have remained thus managed since that time as a game species. The U.S. Fish and Wildlife Service proposed nationwide delisting in 2019 on the grounds that wolf populations are continuing to recover in many parts of the U.S. Wolves are dispersing from Idaho, Montana, and Wyoming into Washington, Oregon, Utah, and Colorado (Peek et al., 2012) and wolf reintroduction is on the 2020 ballot in Colorado, while a current (2019) proposal in Idaho advocates the establishment of chronic depredation zones (in which animals had been killed by wolves in four of the past five years) and wolf-free zones. In these zones, wolves could be killed year-round rather than in only in designated hunting seasons.

Carnivore Recovery

Other populations of large carnivores of the Inter-mountain West are recovering without reintroduction, through natural dispersal aided by conservation efforts and protection status. All eleven western states have viable populations of mountain lions and black bears (S. D. Miller, McLellan, & Derocher, 2015). Grizzly bears continue to disperse from the Yellowstone National Park throughout the GYE and from Canada into Washington. Their conservation story is similar to that of wolves: most recently, a planned 2018 grizzly harvest of one animal was canceled when a Federal court in Montana ruled that the U.S. Fish and Wildlife Services had not adequately considered the effects of delisting and had exceeded its authority by doing so. An appeal has been filed and is pending as of this writing. Wolverine (*Gulo gulo luscus)* and Canada Lynx *(Lynx canadensis)* numbers in the northern Rocky Mountains have been making a slow but uncertain recovery; as of 2018 the wolverine was a candidate for ESA listing as “threatened” and the lynx for delisting from the same status (U.S. Fish and Wildlife Service, 2019).

Habitat and wildlife conservation and maintenance of ecosystem services requires the protection of entire ecosystems (Defries et al., 2016); as the largest tracts of wilderness, public lands are important refuges, study areas, and population sources for wildlife and particularly for large carnivores, which require larger home territories and reproduce more slowly than other North American mammals. Habitat connectivity is critical to maintaining genetic diversity and provide routes for dispersal and migration, particularly in the face of changing patterns of climate and the ensuing changes the distribution of prey species. Connectivity is threatened by rapid development around protected areas in the American West (Davis & Hansen, 2011), a contributing factor to increased human-wildlife conflict. The BLM and USFS maintain their own classifications of threatened, endangered, and sensitive species that enhance conservation on federally managed lands.

Study Area

Blaine County describes a jurisdictional unit of 6846.87km^2 of land in central Idaho (U.S. Census Bureau, 2017). The southern area of the county is sparsely settled and sparsely vegetated lava plains, camas prairie, and semi-arid foothills at the edge of the Snake River Plain. The northern portion is described by the Idaho Batholith and Middle Rockies ecoregions, consisting of mosaics of grasslands and sagebrush-dominated shrub lands rising to alpine forests of aspen, pine, and fir in the rain shadow of the Rockies (Arno et al., 1989). Elevation is from roughly 427 to 3658 meters. Annual average precipitation at the Ketchum Ranger Station between 1981-2010 was under 46 centimeters; mean maximum and minimum temperatures during that period were 12.6 and -3.2 degrees Celsius (NWS, 2018). Winters are characterized by snow and summers are hot and dry with periodic thunderstorms (figure 3).

The Big Wood River and its tributaries carve an ecologically distinct valley through the northern portion of the county (the Wood River Valley) in which the majority of its human population resides. The 2018 population estimate of 22,601 has grown by 5.7% since 2010 estimates and is projected to grow to 23,921 in 2020 (U.S. Census Bureau, 2017). That population is predominantly of Euro-American ethnicity with the largest minority group the 22.5% of citizens of Hispanic or LatinX descent, and it is aging at a faster pace than the national average. To accommodate pulses of population growth in the 1970s-1990s, farmland and range was converted to private property and developed for residential use (Blaine County Comprehensive Plan, 2018). Of 8,190 households, 4,766 are seasonal housing units.

In their 2007 factor and spatial analysis of demographic and economic trends of Inter-mountain West communities, Winkler et. al. found that 4 of 5 of the Blaine County towns they examined have followed a trajectory of development characteristic of the "New West." This pattern of transformation is common to many Inter-mountain West communities, and is characterized by demographic and social change accompanying economic transition from dependence on extractive industries (e.g. mining, forestry, and ranching) to economies based on cultural and natural amenities, e.g. tourism and recreation. The New West transition is marked by population growth from in-migration of both seasonal and permanent residents seeking to live near to natural amenities and recreation, and the social and cultural restructuring resulting from demographic and economic shifts. Winkler et. al.'s results indicate that New West communities tend to be located near public lands with developed recreational amenities (Winkler et al., 2007).

Prior to American colonization the area of Blaine County was occupied exclusively by Shoshone, Bannock, and Paiute peoples moving in seasonal patterns. Documentation of European-American presence in Blaine County begins in 1819. The later discovery of silver, lead (c. 1865) and gold ore (1873) gave rise to mining camps, smelting infrastructure, permanent European settlement, and a rail line connection. As the value of silver decreased livestock herding became increasingly important to the regional economy. Sheep were particularly suited to the harsh winters. In Blaine County as in the rest of Idaho, the sheep industry (along with agriculture more generally) played a central economic and cultural role as it began to boom in the 1890s. Ketchum was among the largest livestock shipping centers in the U.S. Herders from Scotland and The Basque Country flocked west to become "sheepmen" (Blaine County

Comprehensive Plan, 2018). Some of these sheepmen gained influence in state, local, and national elected roles, including current governor Brad Little and the ranching and political dynasties of the Blaine County Peavey family. As elsewhere in the American West, grazing on Blaine County's public lands predates the existence of both the county (1895) and public lands. In 2011 Blaine County ranchers owned 14,600 sheep and lambs permitted to graze 62,993 AUMs on approximately 369,124 acres (Blaine County Comprehensive Plan, 2018). These sheep are owned by fewer than ten ranches. Most of the herders employed in Blaine County are Peruvian nationals working on two-to-three year contracts, living on the range for 9-10 months of the year as they tend the sheep on the transhumance grazing pattern dictated by heavy snows and the availability of water. Blaine County's sheep industry declined steeply after the Second World War, following national trends (figure 1).

Even as mining then ranching waned, Blaine County's natural resources engendered another source of livelihood for its residents. The hot springs and stunning vistas were already drawing tourists, and in 1936 a ski lift (the world's first) was built in the area known as Sun Valley (Blaine County Comprehensive Plan, 2018). While sheep ranching continues to decline tourism and outdoor recreation continue to grow. The leisure and hospitality industries accounted for roughly 25% of the jobs in 2012, whereas ranching and farming were estimated to employ 392 people (The Hailey and Wood River Valley Chamber of Commerce, 2019). By the Census Bureau's estimate there are 12,000 jobs in the county; farming, fishing, and forestry were the source of 4.9% of these jobs in 2017, from 10% of jobs in 2013. (Data USA, n.d.). In 2017-2018, tourism- including 380,000 skiers- accounted for 78% of the Hailey and Wood River valley region's $1.8 billion gross domestic product (The Hailey and Wood River Valley Chamber of Commerce, 2019). The region's agricultural heritage remains an important facet of its cultural identity with yearly rodeos, a sheep festival, a Farmer/Rancher community appreciation night, and abundant cowboy imagery on display and sale in local businesses. For the ranchers it remains a way of life as well as a livelihood to which public lands are essential. The "outdoors" culture of Blaine County is evident in the prevalence of cyclists, off-road vehicles, outfitters selling skiing, fishing, hunting, and boating equipment, and those residents and visitors who flock to camp in the warmer months- all on the same public lands that make up the majority of the county.

The Sawtooth Wilderness National Recreation Area (SNRA), which presently consists of 2.1 million acres (United States Department of Agriculture Forest Service, n.d.), was established by the U.S. Congress in 1972. It incorporated the preexisting Sawtooth Wilderness Area to the Northwest of Blaine County (1937) and became the southern outpost of the continents' largest network of contiguous protected areas (US Department of Agriculture Forest Service, n.d.). The USFS Ketchum Ranger District oversees 321,544 acres of the SNRA in Blaine County including several areas designated as wilderness and one of the SNRA's four ski areas, Bald Mountain. The BLM manages 587,103 acres of land in Blaine County, roughly 20% of Idaho's total (table 4; figure 3).

Table 4. *Acreage of land by ownership and management in Blaine County, Idaho, and in the U.S., 2009. The majority of Blaine County and of Idaho are federally managed, primarily by the BLM and USFS. This represents a larger proportion of Federal management than the U.S. total: most public lands are in the Western states. Adapted from the Economic Profile System tool,* Headwaters Economics, 2019.

	millions of acres		
	Blaine County	Idaho	United States
Total Acres	1.70	53.48	2303.09
Private Lands	0.34	15.45	1406.72
Conservation Easement	0.04	0.20	21.24
Federal Lands	1.30	33.55	632.46
Forest Service	0.49	20.45	192.65
BLM	0.59	11.78	242.86
National Park Service	0.22	0.52	78.37
Military	0.00	0.12	24.41
Other Federal	0.00	0.68	94.18
State Lands	0.06	2.70	184.97
State Trust Lands*	0.06	2.44	51.98
Other State	0.00	0.27	132.99
Tribal Lands	0.00	1.78	67.95
City, County, Other	0.00	0.01	10.99

Blaine County includes parts of the Craters of the Moon National Monument and Preserve and the Sawtooth National Forest, which forms a North-South corridor of protected wilderness lands extending through Montana and western Canada. While not considered a part of the Greater Yellowstone Ecosystem, Blaine County is adjacent to it. Patches of protected land to the northwest of the county may serve as wildlife corridors important to maintaining the genetic diversity, resource bases, and habitat of wildlife species. The most numerous wild ungulates are mule deer *(Odocoileus hemionus)*, elk, *(Cervus canadensis)*, and pronghorn antelope *(Antilocapra americanus)* with low densities of moose *(Alces alces)*. The pre-colonial terrestrial apex carnivore guild consisted of grey wolves, black and grizzly bears, Canada lynx and bobcat, wolverine, and mountain lions. Mesopredators include coyotes, red fox, American mink *(Vison vison),* American marten *(Martes americana)*, fishers *(Pekania pennanti)*, and weasels *(Mustela* *erminia,* M. *frenata)*. Populations of both ungulates and carnivores were decimated for food, fur, and the protection of crops and livestock during the period of American westward expansion. As in the rest of the US wolves, wolverines, lynx and grizzly bears were functionally extinct by the 1920s and the remaining carnivores threatened. Successful conservation and the dispersal of reintroduced grey wolves and grizzly bears to Blaine County have restored its native carnivore guild, although at lower numbers than previously.

House pets have been victims of large carnivore depredation in Blaine County, primarily by mountain lions. Elsewhere in Idaho, wildlife conflict has included attacks by brown and black bears and mountain goats. Livestock depredations are more common than depredations on either humans or house pets, though data are not available at the county level. In 2014 the city of Ketchum, Idaho, adopted a resolution supporting coexistence with wolves (Recommendation To Adopt Resolution 14-022, 2014). This proposition was a direct result of cooperative efforts by ranchers and the Wood River Wolf Project. Founded in 2008 in response to an incident in which sheep and a livestock guardian dog were killed during wolf pupping season, the rancher-founded Wood River Wolf Project brought together stakeholders to promote coexistence between sheep herders and wolves by using non-lethal depredation deterrents such as lights, presence of livestock guardian dogs and humans, fladry (flags hung from ropes), flares, and monitoring and adjusting herding and depredation deterrence activities in response to carnivore presence. These measures have successfully reduced depredation rates within the project area (Stone et al., 2017). The effects of these activities on carnivore behavior, distribution, and fitness have not been examined. IDFG has recently proposed expanding wolf hunts statewide and allowing trapping of wolves in the Wood River Valley, the only place in the state in which it is currently prohibited (Greg Moore, 2020).

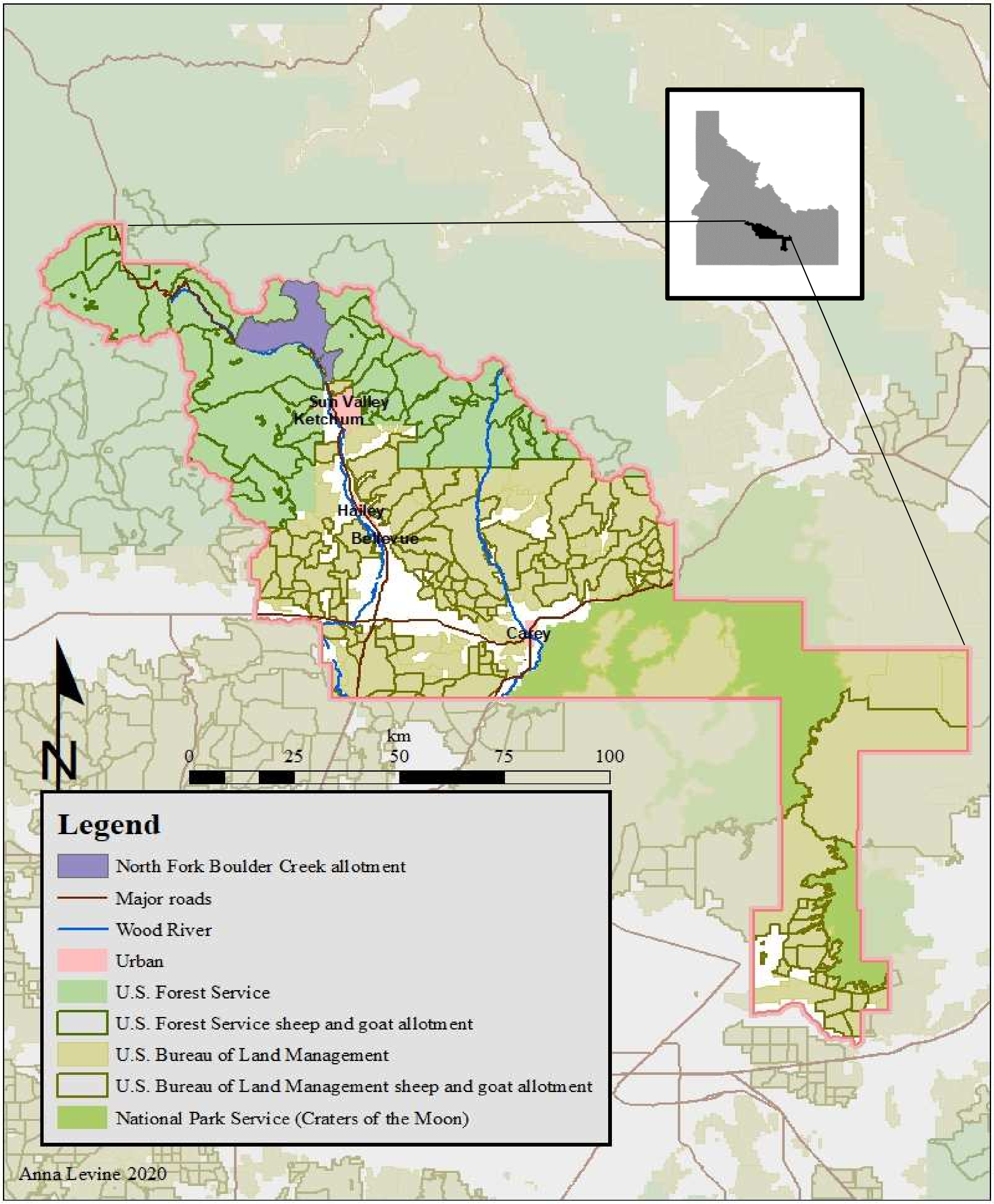

Figure 3. *Blaine County, Idaho, lands and sheep and goat allotments, by U.S. management agency. The North Fork Boulder Creek allotment, in purple, is the allotment in which predictors of sheep location were tested (see "Methods"). Approximately 63% of Blaine County lands are federally managed; uses of these federal lands include year-round recreation, camping, angling, Wilderness-designated areas, and 369,124 acres (2011) of sheep grazing. These uses often overlap both spatially and temporally. Map by Anna Levine from data sources in Appendix.*

Social-Ecological Systems Research Approach

A primary objective of this research was to determine the causal variables and process relationships of the social-ecological system of sheep ranching, large carnivores, and recreation on multiple-use public lands, and to identify interventions that may increase adaptive capacity for SES management. While academic science and European systems of resource management once dichotomized concepts of "human" and "natural" (Folke et al., 2002, 2011; Liu et al., 2007) a preponderance of evidence in social and environmental sciences, medicine, and economics supports that we are in actuality embedded in nested, linked systems of dynamic social and ecological relationships. The social-ecological systems (SES) perspective has emerged in the scientific literature of the past two decades (Colding & Barthel, 2019; Schoon et al., 2015) to describe the relationships and feedbacks between the "natural" or biogeophysical network and networks of human activities, institutions, and actors. Here I use the term SES to refer generally and collectively to the complex, adaptive systems of interactions, feedbacks, and dynamics within and between social/human sub-systems and biogeophysical (ecological, environmental) sub-systems. This definition of SES reflects the understanding that humans are "a part, not apart" from nature while recognizing and organizing the complexity and strength of anthropogenic networks and effects, and provides an effective framework with which to manage these. SES are open, complex adaptive systems and are characterized by spatial and temporal heterogeneity, nested levels of organization, cross-scale interactions, feedbacks, adaptation, non-linearity, self-organization, dynamics and emergent properties (Dorward, 2014; Folke et al., 2002, 2011; Levin, 1998; Liu et al., 2007; McGinnis & Ostrom, 2014; Pahl-Wostl, 2007; Preiser et al., 2018; Rammel et al., 2007; Schultz et al., 2011; Virapongse et al., 2016). A referenced glossary of these terms may be found in the appendix.

Managing the properties, patterns, processes, and flows of SES can foster their resilience (Olsson et al., 2004; Preiser et al., 2018), sustaining critical processes and features within and between systems. As research continues to support and embrace complex systems theory, scientific and management paradigms- including those of the USFS, National Park Service, and BLM- are shifting to address and incorporate these findings. SES frameworks have most commonly been applied to case-studies of fisheries, common-pool, and water resources. Rangelands and ranching systems are increasingly viewed as SES, though this work has generally been in the context of cattle (Abel et al., 2006; Charnley et al., 2018; Hruska et al., 2017; Wilmer & Fernández-Giménez, 2015). This is the first application of the SES framework to sheep ranching or to a multiple use system of which I am aware.

Frameworks for describing and analyzing SES emphasize the importance of social and ecological systems differently and address complexity and dynamics to varying degrees (see Binder et al. 2013). Multiple frameworks are necessary to assess disparate systems and achieve different research goals, but developing and using common terminology and variables remains the chief obstacle to comparative studies and theoretical development (Binder et al., 2013; Colding & Barthel, 2019; Herrero-Jáuregui et al., 2018). A lack of framework operationalization and the quantification of variables of actual SES hinder the implementation of theory to natural resource management (Dressel et al., 2018). I have used the language for system components proposed by the enhanced Ostrom social-ecological framework (Ostrom, 2009) presented by Hinkel et al. (Hinkel et al., 2014) because it has compiled refinements and clarified the representation of relationships and dynamics; however, I diverge from them in my visual representation of the sheep ranching SES because it more accurately captures the system's structure. Case-studies and stakeholder involvement in resource management provides an understanding of the social and ecological contexts of the resource at the appropriate scales and helps identify the relevant factors and actors affecting the resource. Individually and collectively resource users hold detailed, contextualized, often co-evolved knowledge of ecological systems that when shared contributes significantly to understanding both ecological and social phenomena. Such knowledge has been used elsewhere to study wildlife distribution (Ronnenberg et al., 2017) and characteristics of grazing areas (Fernandez-gimenez, 2010; Wario, 2015). Although often given less attention, the social knowledge of stakeholders and their understanding of SES properties are equally important (Olsson et al. 2004). Stakeholder knowledge, attitudes, behaviors and beliefs, regardless of their accuracy, are key components in this system and drive multiple social and ecological processes. I used the qualitative methods of participant observation and semi-structured interviews, discussed below, to solicit rancher knowledge and perspectives and identify causal variables in the SES of sheep ranching.

The second objective of this research was to identify the causal variables- both biogeophysical and social- that influence the location of sheep grazing, with the ultimate goal of building a predictive model to extrapolate sheep grazing locations within allotments in similar terrain. Such a model can be combined with models of other public lands uses, such as recreation and wildlife conservation, to create a geographic tool for examining the cumulative impacts of, and predicting and preventing conflict between, multiple uses.

To determine which variables to include in a potential predictive model of grazing location I first observed grazing sheep to better understand their fine-scale spatial use, attempted to solicit mental maps from ranchers, and collected qualitative information from ranchers regarding the effects of spatial heterogeneity on herding decisions. With the assistance of a herder I applied GPS tracking collars to sheep and tested the biological and anthropogenic variables previously identified for statistically significant relationships with sheep presence or absence in the recorded locations. I did so in two ways. Qualitative methods suggested that forage quality and quantity is the chief determinant of sheep location. To test the statistical significance of the relationship that ranchers indicated between sheep location and forage, I used Welch's T-tests to compare the mean NDVI values of grazing locations recorded by GPS collars and un-grazed areas in the allotment, in the same time period. To test the relationship of NDVI and additional variables with grazing location, I fit a binomial linear regression model using sheep presence or absence as the outcome variable.

Methods

I used grounded theory methods to build my own understanding of the social and ecological landscapes through participant observation and interactions with a variety of stakeholders. Grounded theory is a series of principles of qualitative data collection and interpretation methods in which the researcher simultaneously collects and analyses data to build a theoretical framework of processes and relationships from emergent patterns (Charmaz & Mitchell, 2002). It differs from other ethnographic methods in that its goal is not simply to describe but to systematically code and compile qualitative information to inform theoretical development. I used qualitative and geospatial knowledge co-created with herders and ranchers in Blaine County to formally document portions of their social and local ecological knowledge (LEK). With this I identified variables and processes important to the form and function of the social-ecological system of sheep ranching on multiple-use public lands. Through participant observation I became familiar with aspects and actors and built rapport with research participants that enabled me to have dialogues, observe events, and hear anecdotes and opinions that were neither formally encoded nor elicited in interviews (figure 4).

Prior to contacting sheep ranchers in Blaine County, I established a collaborative relationship with the Wood River Wolf Project. Associates of this project were helpful in providing contextualized background and geographic information at both local and state scales. I was advised to allow a project member to facilitate contact with ranchers and local land managers from the USFS, and used this mediated snowball sampling method to speak first to operators and owners and then, pending their permission, to ranchers in their employ. I established contacts at the Shoshone BLM independently. Communications took place in person and via email, telephone and text from June through February of 2020.

Speaking with herders posed a significant challenge due to their dispersal in large allotments outside of cell phone range. I did not have success at locating herders within allotments even when sheep were present, and met exclusively at their wagon camps (figure 5) which are by necessity accessible from the road system. Herders keep in contact with their supervisors as cell phone signal allows to arrange rendezvous for re-supply and trailering of sheep. I communicated with Spanish-speaking herders primarily with the aid of a translator proficient in Spanish and recorded interviews for future reference with audio when allowed and through note-taking when consent to record was not given. I estimated a total pool of twenty-five potential participants, roughly five per ranch grazing sheep allotments in Blaine County. I was able to locate and interview fewer than half of the herders in the employ of the three participating ranches. In the cases that herders were willing to participate but their employers were not, the herders were not interviewed. The identities of all research participants have been protected and their informed consent obtained in their primary language (see appendix).

Figure 4. *Camping with sheep to deter depredation, at the request of a rancher, when a wolf had been sighted in the area the previous night. No sheep were depredated on our watch. Participant observation built a systemic and contextualized understanding of the system and rapport with participants.*

Figure 5. *A herder's wagon camp, horse, and herding dogs. Although their camps are more easily located, herders were difficult to locate in large allotments and were often out of cellular reception.*

Semi-structured Interviews

Semi-structured interviews (see appendix) were completed in June and July of 2019 in the primary language of participants. These interviews were designed to record basic demographic information related to the participant's position, and to elicit information regarding the participant's knowledge of determinants of sheep location and habitat selection, depredation patterns, and perception and management of risk from carnivores. Following the first interview, the structure of the questions was revised based on the feedback and experience of the participant. To encourage a more natural form of dialogue and obtain spontaneous information and clarification when necessary, the wording and order of the interview questions was slightly altered depending upon the situation while conforming to the theme of the questions. Table 5 summarizes the number of stakeholders in each stakeholder category interviewed or contacted, the number of in-person meetings with these stakeholders, and the number of semi-structured interviews completed.

Table 5. *Stakeholder participation. Sample size was small, due in part to the small number of ranchers now operating in Blaine County (estimated at 7) and unwillingness to participate in a study that addressed large carnivore conflict. Many of the 13 herder meetings were repeated encounters with the same herder to arrange for the GPS collaring of sheep. Multiple participants held overlapping or multiple roles; these figures include those participants only once.*

Stakeholder Category	Contacted	Meetings	Interviews
BLM	2	0	n/a
Ranch Operators	5	4	3*
Ranch Foremen	4	2	0
Herders	5	13	2
USFS	3	2	n/a
WWWP	2	5	n/a

*This figure includes one interview that did not follow the study format, but was valuable for the contextual information it provided.

Participatory Mapping

Mental (sometimes called cognitive) maps are representations of space in the minds of individuals and encode social and historical information as well as environmental knowledge. Individual experiences of scale and perspective can be controlled for using participatory GIS to standardize spatial representation of mental models. The difficulty of linking social and ecological ontologies and scales is a significant obstacle to the operationalization of SES frameworks (Berkes et al., 2006; Jones et al., 2011): mental and other forms of participatory mapping offer a partial solution to this obstacle by associating social and ecological knowledge and flows at the appropriate spatial and temporal scales. Spatializing this information allows direct comparison with scientific ontologies (Mckenna et al., 2008; McLain et al., 2013) and the examination of nested systems, and facilitates statistical analysis.

I attempted to collect participatory spatial data in tandem with interviews to assist in understanding how herders perceive and use grazing allotments, how spatial heterogeneity affects decision-making, and what biophysical and social variables determine grazing locations and patterns. I presented participants with 11x17 color maps of the study area and the area which they were currently ranching (see appendix). These maps depicted topography, rivers, roads, populated areas, and grazing allotment boundaries for reference. I oriented participants to the map using these locations and identified additional features as we discussed the landscape. Each participant was provided with a marker and asked to draw, label, and discuss salient features on their map (see appendix).

Geospatial Analyses

The objective of the geospatial analyses was to test the biophysical and anthropogenic variables indicated by qualitative analysis for statistically significant relationships with the location of sheep. Statistically significant relationships indicate that variables may be determinants of sheep grazing location and should be included in an eventual predictive model of sheep location to aid multiple-use management. Participant observation and interviews with ranchers suggested that the quantity and quality of forage is the primary determinant of grazing location and that slope, terrain ruggedness, proximity to water, proximity to roads, and recreational activity influence the selection of grazing sites by both sheep and ranchers. Because little data is available on trail use, I used the sheep's distance to trail as a proxy for recreational activity.

It has been demonstrated elsewhere that NDVI can be an effective proxy predictor of ungulate grazing location (Pirotti et al., 2014). To map the forage quality of sheep grazing locations I used 250m NASA MODIS gridded NDVI values, extracted with the MODIStsp package in R (Busetto & Rhangetti, 2016; R Core Team, 2017). I resampled all raster layers to a resolution of thirty meters using bilinear interpolation: this spatial scale is more meaningful for fine-scale analysis of predictors of grazing location, and closely matched the original resolution of the DEM and tree cover data (see appendix). I collected GPS locations of sheep bands from July 4 through July 22, 2019 from a sheep band grazing the North Fork Boulder Creek allotment (figure 3; figure 6). The MODIS intervals that corresponded most closely to the sheep location sampling period were June 28 through July 11, and July 12 through July 27, 2019. I used a Welch's T-test assuming equal variances to confirm that the mean NDVI values of the North Fork Boulder Creek allotment differed between these intervals at a significance level of 0.01. To ensure analysis of the most appropriate NDVI sampling period for each sheep location, I divided the sheep location observations into two groups by observation date. I refer to each of these sheep location groups by the start date of the NDVI observation period to which I compared it (06/28 and 07/12). These groups share spatial overlap. For each group of observations I scored each cell in which sheep were present at the appropriate time period as a “1” and those in which they were not as a “0” to indicate presence/absence.

I geoprocessed all layers using ArcMap 10.6. A table of data, original layer resolutions, and sources may be found in the appendix. All layers were projected in Albers Conical Equal Area and a CRS of WGS 84 to preserve consistent distance measurements. I masked all layers to the extent of the boundaries of the North Fork Boulder Creek allotment after removing the north-eastern portion of the allotment (figure 6), which is pine forest, talus, and rock faces unsuitable for grazing, to reduce the sample size and minimize the over-inflation caused by the indication of sheep presence/absence by 1 and 0, respectively. I extracted cell values from raster layers of NDVI, slope and terrain ruggedness by converting each to a point, and calculated the Euclidean distance from the center of each cell to the nearest road, river, and trail to obtain “distance to” observations. All observations reflect the values of the variable in each 30m x 30m cell. Where resampling was required to obtain consistent spatial resolution I employed bilinear sampling.

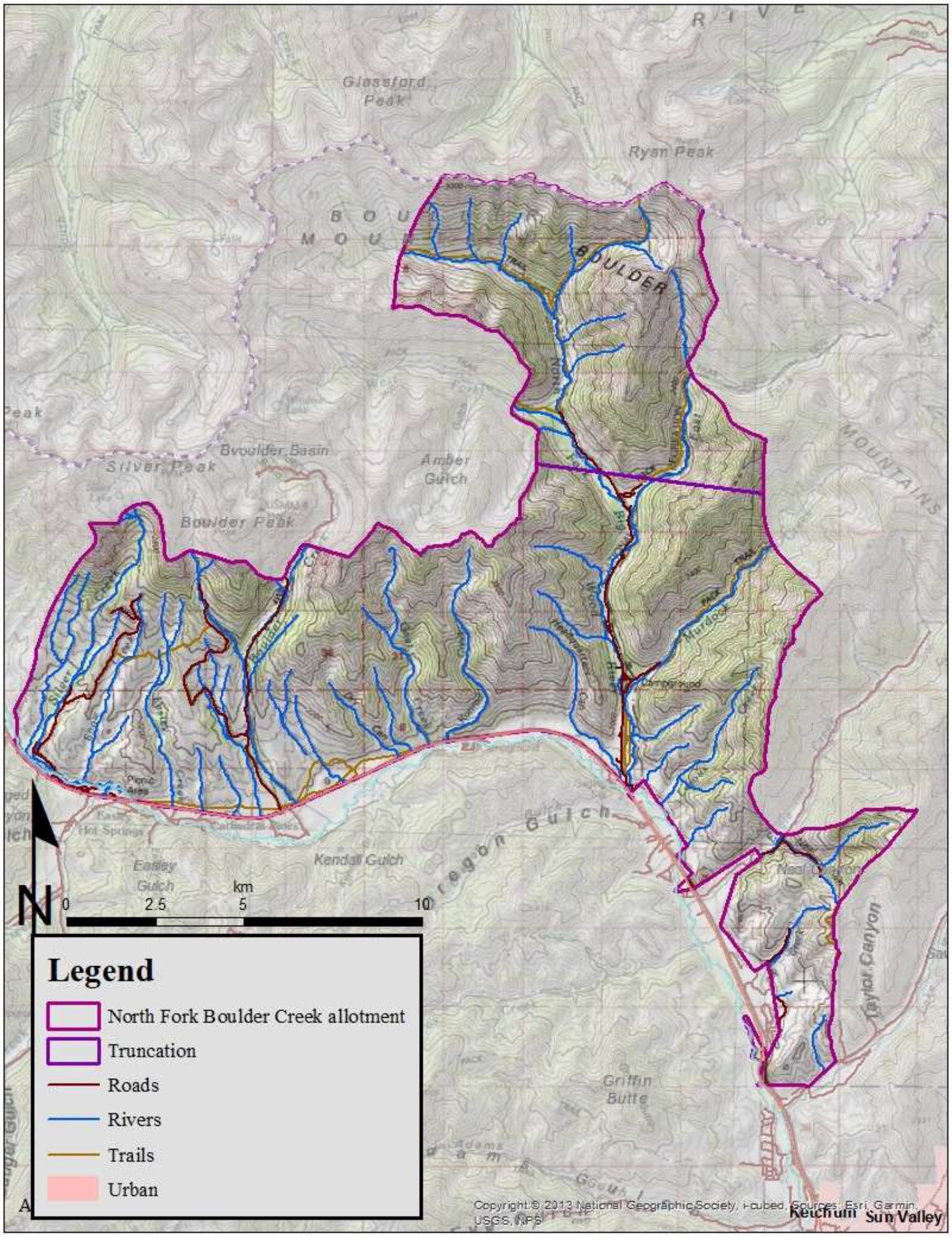

Figure 6. *The North Fork Boulder Creek grazing allotment (29,867 acres) is roughly 5 kilometers from the town of Ketchum and lies along the area's only highway. To reduce sample size and the over-inflation caused by adding a binary sheep presence attribute, I removed the north-eastern portion of the allotment from the analysis (truncation, above). This area was pine forest, talus, and rock faces unsuitable for grazing, and sheep only grazed the Western portion of the allotment. Map by Anna Levine from data sources in Appendix.*

After being informed by participants and observing that sheep typically graze only during daylight hours, I defined the period of "daytime" as the fourteen-hour period between 0630 and 2030 hours and used only sheep location points taken between these hours in my analyses to capture times at which sheep were likely grazing rather than resting. Mean sunrise and mean sunset during the collection period was 0639 and 2043 hours, respectively.

To compare forage of geolocated sheep grazing locations to all other areas in the allotment I followed methods used by Pirotti et al. to compare the NDVI at daytime sheep locations with that of an equal number of randomly assigned points within the truncated allotment (see below, for each time period. Removing no-data values resulted in unequal sample sizes. After an F-test indicated that both datasets have unequal variances, I used a t-test assuming unequal variances to test the similarity of mean NDVI values using a significance level of 0.05. These tests were performed in MS Excel.

As an alternative means of testing the relationship between NDVI and sheep grazing, I created a "grazing zone" within 300 meters of any recorded sheep location that defined the area in which the majority of the flock were likely grazing, for each time period (NDVI sampling periods beginning on June 28 and July 12). I determined the extent of this buffer by questioning ranchers, and visual analysis of tracker data and grazing bands. To test for a difference in mean NDVI of cells within the grazing zones and all cells within the allotment, I used the t.test function in R version 3.6.2 to perform a two-sided Welch's t-test for difference of means at a significance level of 0.05. The Welch's t-test assumes unequal variance and/or sample sizes. The observations of NDVI within the grazing zones are paired samples, potentially confounding the results, but there is no method to compare the means of paired samples with unequal sample sizes.

To test the statistical significance of the relationship between slope, terrain ruggedness, distance to river, distance to trail, and distance to road with sheep location I performed a linear regression of these variables with sheep presence/absence in a cell as the outcome variable. Again using R, I fitted a binomial linear regression model of the best biophysical and anthropogenic predictors of sheep presence, beginning with the biophysical factors of NDVI and slope (which was a better predictor of sheep presence than was terrain ruggedness) and progressing with a forward stepwise method based on the value of the model's likelihood ratio after adding each variable. I tested all variables for collinearity; all VIF values were under 1.2 for all variables at both temporal resolutions, indicating no significant collinearity.

GPS Collars

From July 4 2019 through July 11 2019, a herder fitted three sheep in one band grazing the North Fork Boulder Creek allotment (figure 6) with SPOT Trace GPS units affixed to collars (SPOT Trace Satellite Tracker with GPS, 2020) (figure 7). These units have an accuracy of approximately three meters. The majority of the herder meetings (table 5) relate to sheep collaring activities with this herder, whose work and improvements to the collar design were instrumental to the success of this portion of the project. The participating herder did not want collars on the guard dogs, as they already wear large spiked collars to minimize potential harm from carnivores.

The units were set to transmit GPS locations every hour and transmitted intermittently from July 4 2019 through July 22 2019. Units attempt transmission for a period of 20 minutes before resuming dormancy until the next sampling period. Both GPS fixes and transmissions can be affected by tree cover, elevation, and weather conditions. Screening data for habitat characteristics when rate of location error is known is a simple method of increasing accuracy but requires significant investment to determine the transmission error rate for each model of collar (Lewis et al., 2007). To minimize data bias resulting from transmission frequencies and I excluded from analysis those areas with greater than 20% tree cover, the threshold determined by the Multi-Resolution Land Characteristics Consortium for classification of an area as forest. Discussions with ranchers and observations of sheep indicated that sheep do not typically graze in forested areas, although they may travel through these areas and use them for shade. The data support that sheep either utilized these areas less, or that GPS transmissions were blocked in these areas by tree cover.

Figure 7. *GPS units affixed to collars first with screws and then with Gorilla tape, and secured closed with a zip tie. The herder's suggestions helped ensure the collars' durability. Collars were installed dorsally on the sheep, but slippage may have resulted in increased transmission error.*

Results

The causal variables and processes I highlight here reflect those contexts and components of the system whose values and dynamics drive its current state. Variable concepts follow Hinkel et al. 2014 and use the numbering system from that publication, depicted in the diagram keys. A benefit of the SES framework is that it facilitates the analysis of cross-scale interactions between and among nested conceptual organizations of variables, which Ostrom (Ostrom, 2009) calls “tiers” and Hinkel also refers to as “concepts,” as do I. For example: “Governance system” is a concept that contains several nested levels of detail and may be decomposed into “government organizations,” “non-government organizations,” etc.; these are themselves conceptual groupings of specific organizations.

Causal variables exist at different levels of conceptual organization and have various semantic relationships, some of them recursive, with other extra-systemic and endemic variables and processes. I present a detailed model of the flows between important variables in figure 8 but for the purposes of clarity have generalized several causal pathways that lead to the outcomes of human confrontation, ranching/recreationist conflict, and depredation at a higher conceptual level (figures 9-14). Systemic variables not included in these causal pathways but present in figure 8 are italicized below, while those that are included are bolded. The appendix includes additional systemic variables by tier and concept, and their proposed metrics; as well as a table indicating the type of data sources that I used to identify variables and the relationships between them.

The primary causal processes that result in the outcomes of human confrontation, ranching/recreationist conflict, and depredation are social and spatial. The cumulative effects of these social and spatial processes positively reinforce the outcomes and perpetuate the current system state, and the outcomes have self-perpetuating relationships with several of their causal variables. At the largest organizational scale (figure 9) non-government institutions- environmental and ranching organizations- influence government institutions and thereby indirectly influence land use and predator control regulations. Multiple-use regulations- specifically, the contexts in which these regulations are established- engender confrontation between human users. Non-government institutions also influence actors and the social norms of their interactions, and the current state of these social norms is contributing to outcomes of ranching/recreationist conflict, human confrontation, and depredation through several intermediate pathways. These outcomes are directly affected by the geospatial locations of the resources of sheep, wildlife, recreation, and forage and the ways in which these resources change location (resource mobility) in response to one another.

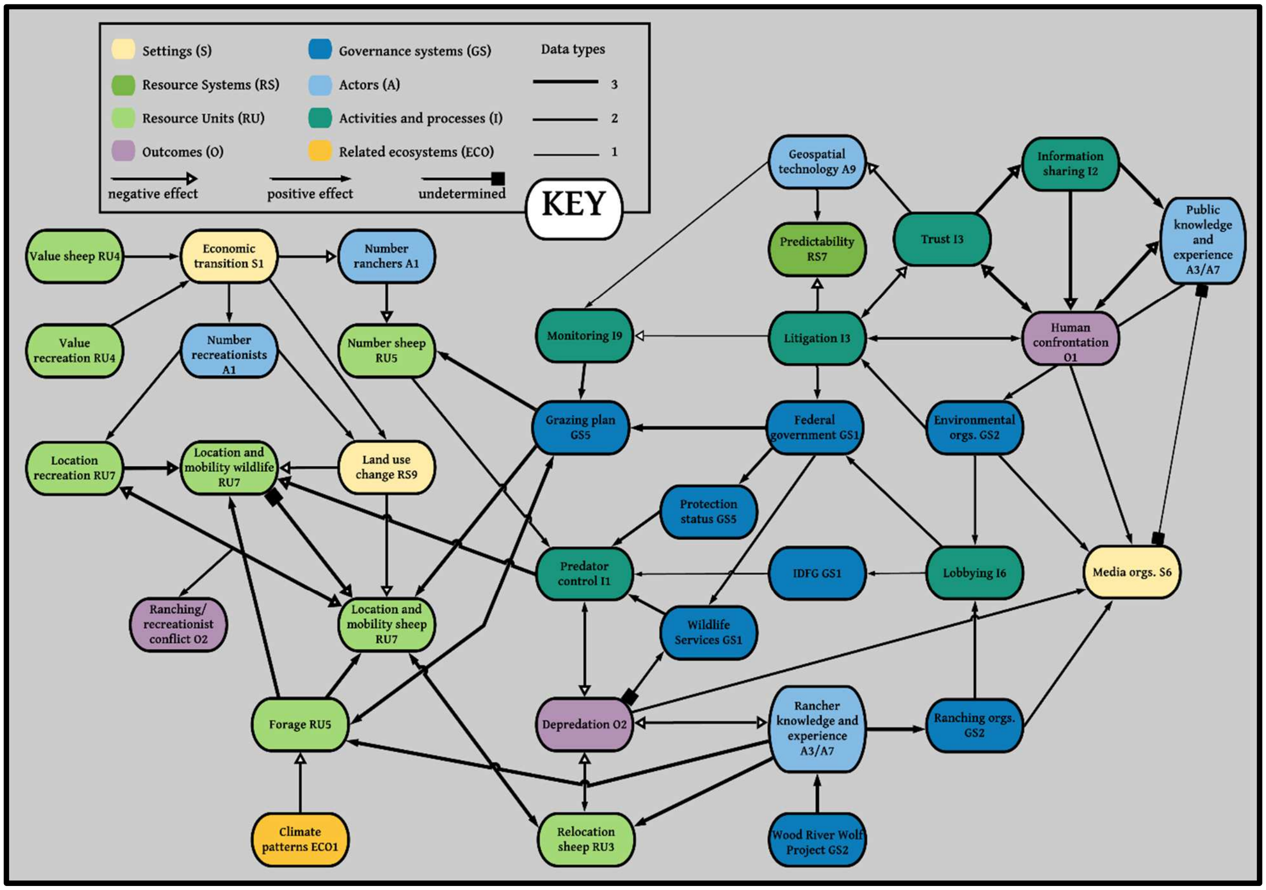

Figure 8. *SES causal variables and processes. This representation describes the current value or state of systemic variables and processes. "Positive/negative effect" describes increase/decrease in some cases, rather than the quality of the effect. The width of connecting lines indicates the total number of data types used to identify the variables and relationships between them: direct observation/s, primary source/s, and literature sources. Where linked variables were identified by a different number of data types, the lower value is shown. See "Data sources of SES variables" in the appendix for a table of data types used to identify each variable.*

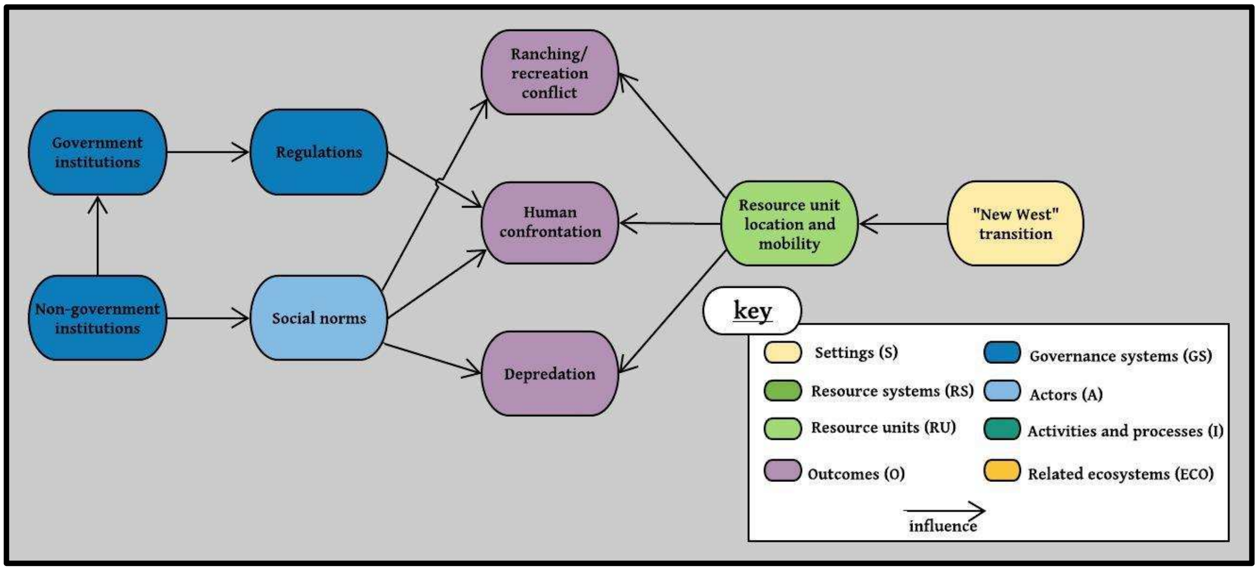

Figure 9. *Generalized causal pathways of the SES of sheep ranching, depicting how components of the system influence outcomes. This is a highly simplified version of figure 8. Non-government organizations- such as environmental and ranching organizations- influence Federal management agencies and, through them, regulations that contribute directly to outcomes. The social norms non-government institutions have helped to create also influence outcomes directly. The spatial locations of resource units- sheep, wildlife, and recreation- are the proximal cause of outcomes. The New West transition influences the distribution and, in the case of sheep and recreation, number of resource units (as do regulations).*

"New West transition" (S1) is a higher-level concept which comprises the decrease of the variables *value of sheep (RU4)*, *number of ranchers (A1)* and *number of sheep (RU5)* and the simultaneous increase in the *value of recreation (RU7)* and the *number of recreationists (A1)*, as well as describes the regional economic transition from extractive to consumptive and service industries, including the burgeoning tourism industry and the increasing number of visitors to America's public lands (Livesay, 2018). This economic transition is accompanied by a demographic transition that entails population increase, particularly of seasonal residents and those whom originate from out of state; increased property values and cost of living; and social and cultural change and its ensuing conflict (Winkler et al., 2007). This transition is contributing to land use change (RS9) (figure 10) both within and on the borders of protected areas (e.g.

abandonment of mines, construction of housing and accommodations, tourism and recreational infrastructure, conversion of agricultural land) (Blaine County Comprehensive Plan, 2018; Spadoni, 2008).

All interview participants cited conflict with recreationists as a primary concern. Increasing recreational use brings recreationists (location of recreation RU7) into the same space as sheep (location and mobility of sheep (RU7), resulting in ranching/recreationist conflict (O1) (figure 10). Livestock guardian dogs at times chase or show aggression toward recreationists, particularly those on bicycles. Although some recreationists are drawn to the spectacle of sheep bands, recreationist concerns include the condition of trails, the smell of the sheep, sheep droppings on and near trails, interruption of the scenery, and the trampling and consumption of vegetation and wildflowers. Recreationists may startle or crowd the sheep, causing the band to move unintentionally (figure 11). Conflict is typically reported by recreationists to the appropriate land management agency and these concerns relayed to the relevant operator and then to the herder. Increasing the knowledge and experience (A3/A7) of both ranchers and particularly of recreationists likely alters their spatial distribution and reduces the intensity of these conflicts (figure 10). Ranchers manage conflict with recreationists by changing the location of sheep when they see recreationists coming; keeping sheep away from roads, trails, and populated areas; replacing rocks the sheep have kicked into trails; and leaving their campsites (which are typically dispersed sites available to the public and managed by Federal agency) tidy. Ranchers are also making efforts to train their dogs to be friendly toward recreationists.

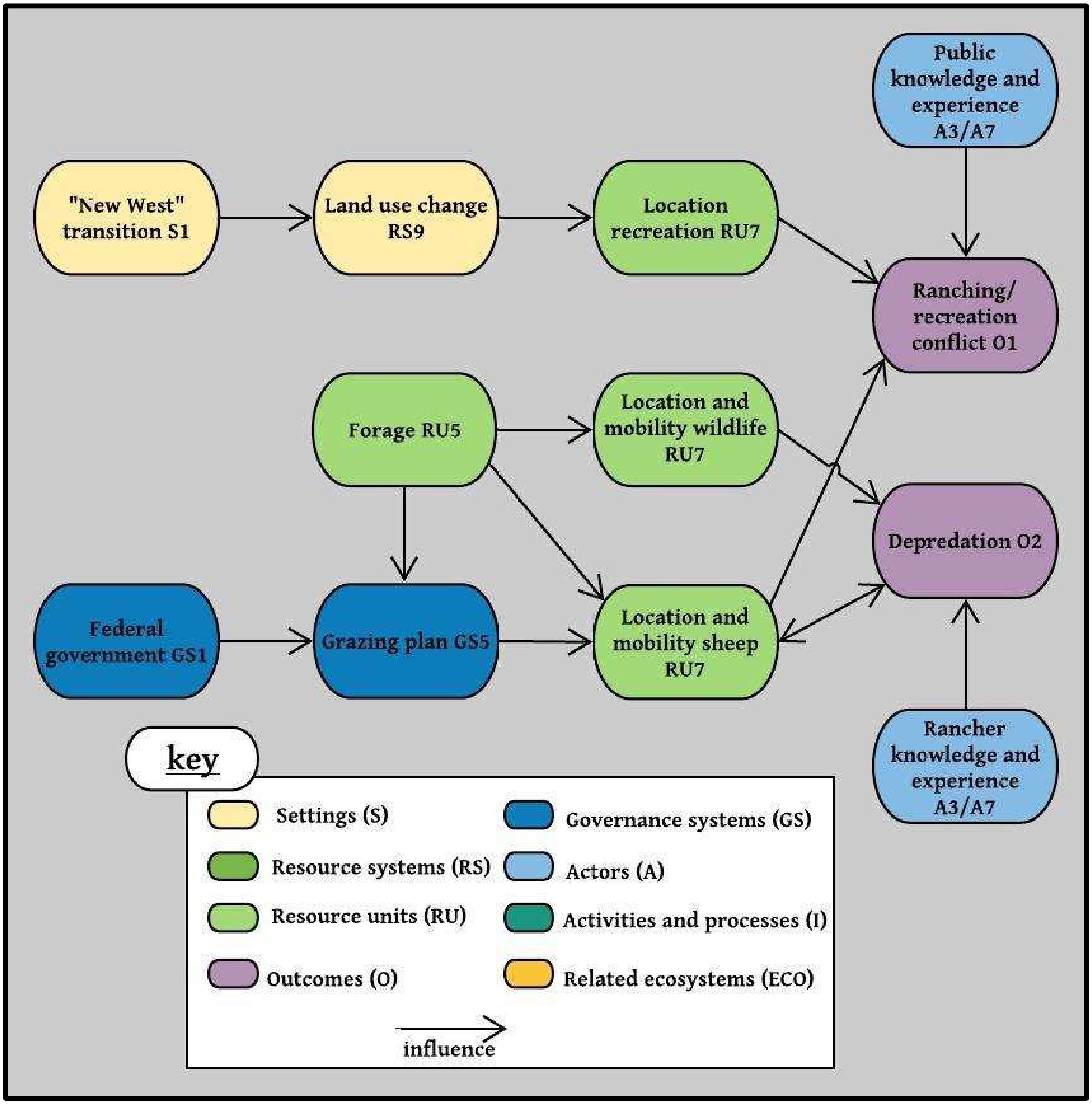

Figure 10. *Generalized causal pathways of ranching/recreationist conflict and depredation. The New West transition leads to land use change that influences the location and mobility of resource units. Forage influences the location and mobility of sheep and wildlife as animals follow forage and prey. Forage conditions and Federal government regulations are among the elements considered in the formation of the grazing plan, which partially determines the location and mobility of sheep. Shared locations of resource units, and actor knowledge and experience, both directly influence outcomes.*

Figure 11. *A member of the public stops for a photo as a herder tries to move the band away from a road. The herder did not speak to the photographer but told me that the photographer's actions were interfering with his efforts to herd by scaring sheep.*

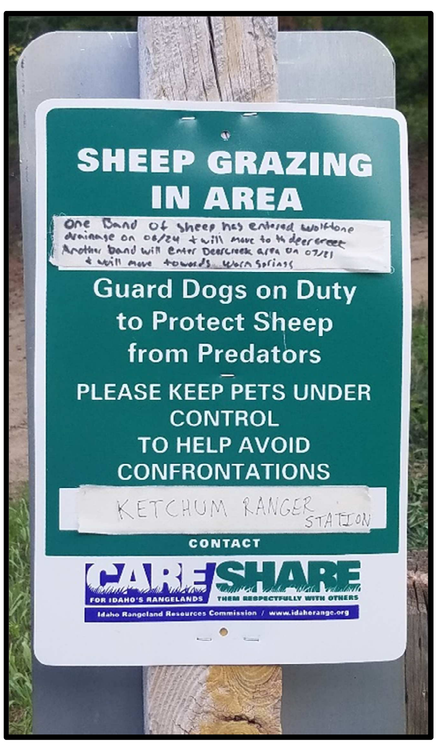

Figure 12. *A sign at a trailhead, placed by the USFS, warns recreationists of sheep grazing in the area. Such signs, accompanied by online "sheep advisories" published with trail condition updates on the Blaine County Recreation District website, have anecdotally helped to reduce ranching/recreation conflict on grazed public lands.*

Non-participatory Non-mapping

I was unable to obtain meaningful results from the participatory mapping portion of the study (see maps and questions in the appendix). Of three herders asked to participate in mapping, two were not able to transfer their spatial knowledge of allotments to our map and one was unwilling to share detailed geospatial knowledge, particularly of depredations, because of the tensions surrounding ranching and predator control. This was the case regardless of how long they had spent herding in the area. Herders reported that they do not commonly use maps to navigate within the allotments. Areas of least and greatest grazing preference are determined primarily from landscape features and on-the-ground conditions by the herder. One operator completed the participatory mapping exercise and had a more generalizable spatial knowledge.

NDVI as a Predictor of Grazing Location

All of the participants identified forage (RU5) quantity and quality as the primary determinant of location and mobility of sheep (RU7). Within the areas and dates specified by the grazing plans (GS5) and following the general instructions of the ranch operators, herders make the fine-scale decisions on where sheep graze based primarily on the availability of forage (figure 10). The sheep often select where they feed as well as the pace at which they move through an area. In the words of once rancher, "*The sheep herder is more of a guide…he watches over them [the sheep].*" One operator mentioned that he and his herders (whom I was unable to interview) used the principle of "take half, leave half;" that is, when approximately half the grass in an area is depleted, they move the sheep to a new location. None of the participants interviewed expressed concern for overgrazing in particular areas, though one mentioned that they move sheep to avoid excessive damage of riparian vegetation.

While moderate slope is not a particular obstacle for sheep, ranchers reported that better forage tends to grow in "pampas" (a South American Spanish word directly translated as 'flat expanses bounded by hills'), flatter areas, and in areas free of rocks. Because of a similar negative correlation with forage, forested areas- particularly pine forests- are not suitable grazing locations for sheep, though they will at times use trees for shade. Once a day, typically between 1300 and 1500 hours, the herder leads his flock to water. Watering locations must be accessible to sheep, i.e. of a moderate slope and free from obstructive debris. In locations where water is scarce it may be trucked in. Snowpack and moisture, as determinants of forage quality and quantity and a restrictor of movement, were also cited as a determinant of sheep location and should be included in future models.

NDVI had a statistically significant relationship with grazing location in both time periods. Sheep locations and grazing zones at each time period had mean NDVI values above 0.55 while the mean NDVI of random points and the truncated allotment was between 0.499 and 0.534. Mean NDVI at sheep locations and at random points within the allotment was dissimilar at a significance level of 0.01 at both time periods, indicating that the mean NDVI of grazing locations is significantly higher than could be expected by chance (table 6).

Table 6. *Mean NDVI and significance of t-tests at sheep locations and random points within the allotment are statistically dissimilar at a 0.01 significance level, suggesting that sheep do not graze randomly.*

	06/28		07/12	
	Sheep locations	Random points	Sheep locations	Random points
Mean NDVI	0.558	0.534	0.581	0.507
n (points)	201	225	385	412
p	0.0032		1.89e-23	

Mean NDVI of all cells within the allotment and all cells within the grazing zones at both time periods was also dissimilar at a significance level of 0.05. This indicates that the mean

NDVI in sheep grazing zones is significantly different than the mean NDVI outside of them, sup porting the hypothesis that NDVI can predict grazing location (table 7; figures 13a and 13b).

The mean NDVI within grazing zones for each time period (0.55 and 0.551) is not statistically similar at a 0.01 significance level (p= 0.0001371, Welch's t-test), indicating that the similarity in means of the grazing zones is not statistically significant.

Table 7. *Mean NDVI of cells in both grazing zones compared to the truncated allotment using a Welch's t-test are statistically dissimilar at a 0.01 significance level, suggesting that sheep select grazing areas with a specific range of NDVI.*

	06/28		07/12	
	Grazing zone	Allotment	Grazing zone	Allotment
Mean NDVI	0.555	0.502	0.551	0.499
n (cells)	5750	66693	9462	66693

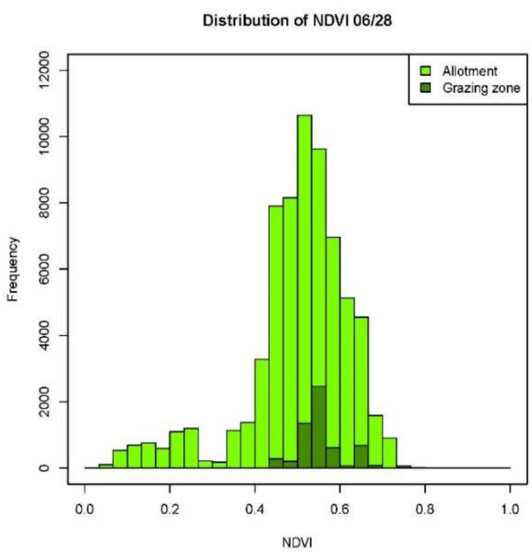

Figure 13a. Distributions of NDVI in allotment and in the grazing zone for the period between 06/28 and 07/11.

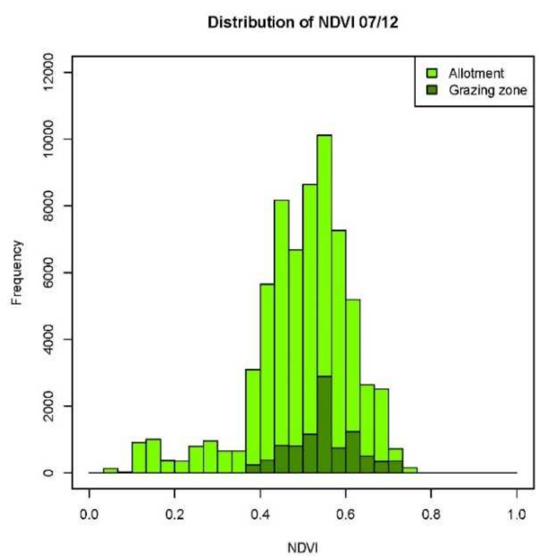

Figure 13b. Distributions of NDVI in allotment and in the grazing zone for the period between 07/12 and 07/27.

The linear regression of sheep presence with NDVI, slope, and distance to nearest river, road, and trail indicated the coefficients and log odds in table 8. With the exception of distance to river for 06/28, the p-values for all predictor variables were <0.01. Coefficients are small because n (number of cells in the truncated allotment) is large and because NDVI is normalized.

Table 8. *Coefficient and odds ratio values for a linear regression of sheep presence with NDVI, slope, and distance to nearest road, river, and trail. For all values, $p<0.01$. Coefficients are small because n (number of cells in the truncated allotment) is large and because NDVI is normalized. NDVI is the strongest predictor of grazing location. Predictors that are not NDVI have an approximately 1:1 relationship of increased or decreased odds of sheep presence; for every 1 unit of increase or decrease in the predictor variables, the odds of sheep presence increases or decreases by a factor of 1.*

	06/28		07/12	
	Coefficient	Odds ratio	Coefficient	Odds ratio
NDVI	5.4200	225.8791	1.5180	4.5631
Slope	-0.0370	0.9640	0.0206	1.0208
Distance to road	-0.0007	0.9992	-0.0004	0.9996
Distance to river	0.0002	1.0002	-0.0020	0.9985
Distance to trail	0.0003	1.0003	-0.0018	0.9982

Slope and distance to the nearest road, river, and trail are significant predictors of grazing area. Ranchers report these among the factors they consider in their herding decisions. Distance to road is negatively correlated with sheep grazing location, although this result is affected not only by the rancher's decision-making but also by the number of roads on and near the allotment. Slope, distance to river, and distance to trail were negatively correlated with sheep grazing location in one time period (07/12) and showed slight positive correlation in the other (06/28). Per 1 unit, slope and distance to road, river, and trail increased or decreased the odds of sheep presence in a pixel by a factor of approximately one, while NDVI increased the odds of sheep presence by factors of approximately 226 and 5 in the 06/28 and 07/12 time periods, respectively.

Wildlife tends to avoid humans in space, time, or both. While beyond the scope of this work, the effects of recreation on wildlife appear to be largely negative (Larson et al., 2016). The location of recreation (RU7) restricts the location and mobility of wildlife (RU7) directly on fine spatial and temporal scales through the presence of recreationists; and indirectly through the associated land use change (RS9) as discussed above (figure 10). Land use change may also have positive effects on the location and mobility of wildlife when formerly cultivated, mined, or ranched lands are converted to lower-intensity uses or new habitat is created through anthropogenic alterations such as water diversion or the propagation of edge environments. The net effect of land use change on wildlife is largely negative, however, as restricting the mobility of populations interferes with dispersal, migration, and genetic exchange. The location and mobility of wildlife (RU7) is also determined by forage for both herbivores and large carnivores, for where the prey go the predators follow. There is a significant research gap in documenting the effects of the location and mobility of sheep (RU7) on the location and mobility of wildlife, and wildlife response to the presence of humans (both recreationists and herders), predators, and dogs can depend on spatial, temporal, and behavioral configurations which require additional empirical investigation. Conflict with wildlife that are not large carnivores is not apparent. Ranchers reported that they have seldom seen bighorn sheep either in grazed allotments or in areas that are closed to grazing for their protection. There are some reports of elk removing themselves from the presence of domestic ungulates. Participants believed that certain species and individual predators follow or seek livestock, while others encounter livestock at random. *Relocation of sheep (RU3)* occurs as a strategy to prevent the occurrence or reoccurrence of depredation (O2), and is discussed in greater detail below.

Depredation: Conflict with Large Carnivores

When asked to rank risks or dangers to grazing sheep, participants cited availability of nutritious forage (in the top two for two participants), depredation (O2), and miscellaneous hazards (e.g. lambing, natural disaster) as the greatest risks. All participants cited depredation within the top two ranked risks to grazing sheep. All participants reported that they had observed no spatial patterns in depredation or in the location of predators with regard to specific areas. Predators may ambush sheep and are likely to den in forested areas, and the proclivity for sheep bands to spend the night on hilltops is encouraged as it is strategically advantageous for predator detection. All participants reported the same temporal pattern to depredation events: depredation is more likely to occur at night, and predators are crepuscular (i.e., most active in twilight).

The *Wood River Wolf Project (I7)* (WRWP) is a collaboration between ranchers and conservationists with the goal of promoting the coexistence of livestock and wolves by educating and enabling ranchers to use non-lethal depredation deterrents, thereby enhancing rancher knowledge and experience (GS2) (figure 10). All participants were current or former participants of the WRWP and had worked with the WRWP to learn about and utilize non-lethal strategies when they deemed it appropriate. Employees of ranch operators adhere to instructions from their supervisors to manage depredation (O2). Several stakeholders cited generational differences in attitudes toward predators and in the management strategies used to control depredation: younger ranchers are more favorably disposed and more likely to use non-lethal deterrent strategies. The most common and effective strategy participants reported using to reduce depredation was human presence near the sheep. Ranchers used human presence to varying degrees, from presence only when there was relatively high risk of depredation (recent depredations or predator sightings near sheep) to nightly herder presence near the band. Employment of livestock guardian dogs (LGDs) was the second most commonly engaged strategy to manage depredation. LGDs, also known as “white dogs” for their characteristic color, are large dogs typically of one or a mix of several breeds created explicitly for the purpose. They are exposed to sheep at a young age and encouraged to protect them and remain with their assigned sheep band the majority of time. Herders also employ herding dogs, but these dogs are not explicitly for depredation protection. Relocating sheep when carnivore presence is known, shooting bullets with the intention to scare predators, herder experience, shooting flare guns, fladry (deterrent flagging), sirens, and varying the use of a combination of methods were also mentioned. Only one participant mentioned the use of night corrals as a strategy to reduce depredation, but reported that building corrals was prohibitively expensive.

Ranchers receive information (rancher knowledge (A7) of large carnivore activity from other ranchers, members of the WRWP, the USFS, and the BLM as well as recreationists and members of the public (figure 10). Ranchers responded adaptively to the location and mobility of wildlife (RU7) (predators) by changing the location of sheep (RU7), that is, with the *relocation of sheep (RU3)* as needed, working with the appropriate management agency to alter the grazing route or change the allotment previously outlined in the grazing plan (GS5) to avoid areas in which depredations have occurred or predators were sighted. While this is a common-sense strategy to minimize depredation, controlled trials have not verified its efficacy. When relocation is not feasible increased human presence and vigilance is the most common response to the threat of depredation, in part because it a precursor of the use of many other anti-depredation tools. Opinions varied greatly among participants on what would help them manage wildlife conflict more effectively. One operator mentioned the difficulties of depredation prediction and of communication in the backcountry; he does not know of the occurrence of conflict until after the fact. No participants mentioned the use of predictive tools to manage large carnivore conflict.

One herder cited killing (typically termed "control" when performed by *Wildlife Services (GS1)* at the request of ranchers) as the most effective method of predator control and did not believe that nonlethal methods were effective; notably, the operator by whom he was employed reported using lethal control only if other methods were ineffective, *"but I won't like it."* The removal of problem animals seemed to be a final and decisive move reserved for when others had been ineffective, although both the effectiveness and efficiency of lethal predator control is questionable and may in cases increase depredation (Treves et al., 2016). Lethal and non-lethal *predator control (I1)* has a negative effect on their location and mobility (RU7) by altering their distribution and abundance, disrupting or altering social and community ecological structures, stressing animals, and effecting behavioral changes.

In the 2019 grazing season between roughly April-October, two bears killed two sheep in separate incidents in separate locations; approximately 7 sheep were killed by a wolf late in June one to two sheep were depredated in a separate incident, although there is some uncertainty about the species of canine that caused the damage. According to personal communications with ranchers and land managers, there were "a few" other incidents with both bears and wolves and wolves were taken by wildlife services this year within Blaine County. Of diverse participants questioned, none cited a change in depredation management strategies or in the abundance of large carnivores as a casual factor in the 2019 depredation rate but expressed the belief that "it was a good year." One participant cited the incident of bear depredation of 7 sheep over 3-4 days as a small conflict, and the prevailing attitude toward depredation was that *"We're okay, losing a few, it comes with the territory."* "A few" sheep seems to be a sustainable, acceptable loss; it is when a rancher loses a large number of sheep at one time that he feels an acute impact to his livelihood, which already depends on other unpredictable elements that include the wool and meat markets and weather. It is unclear what number of sheep per season is an acceptable loss.

Human Confrontation and Depredation

Rancher knowledge and experience (A3/A7) (which variable here includes beliefs and mental models) is both influenced by and influences their attitude toward depredation (O2) (figure 14), with depredation events likely to impart negative feelings toward large carnivores. Ranchers with greater knowledge and experience may be better prepared to manage depredation, decreasing its occurrence. Knowledge and experience of large carnivores and the threat they pose to sheep varied slightly among participants. Two participants cited wolves and coyotes as the predators that pose the greatest risk to sheep; both of these participants ranked bears third, while a fourth- following a discussion of recent depredations by bears- ranked them as the greatest threat to sheep. The perception of risk from wolves was influenced by the magnitude of depredation events: wolves have been known to kill or partially kill numbers of animals (10-40 by one estimate) in one depredation incident, and to leave these animals rather than to consume them (this information has been independently verified). Wolves may also scare sheep into unsafe territory or crowding conditions, where they perish or suffocate: such losses are not typically compensated because there are no marks on the animals to verify that the loss was caused by wildlife. Participants reported that wolves were less likely than other large carnivores to be deterred by human presence, LGDs, and nonlethal methods- that they don't "scare" as easily as the rest of the guild.

Depredation of livestock is more than an economic loss for ranchers: it has an emotional significance that extends beyond livelihood. One participant described wolf depredation as a "massacre" and wolves as "intimidating" while another shared a graphic story of a wolf attack on a LGD with which he had bonded, and explained his feelings of sorrow and frustration at seeing his maimed animals. Participants often camp near their sheep, particularly when the threat of depredation is high, coming into close contact with large carnivores alone in isolated territory at night. As one participant remarked, *"Prevention is dangerous. The bear can kill you too."* Carnivores were not demonized; all of the participants acknowledged that carnivores were animals that searched opportunistically for food. Ranchers, too, are recreationists of sorts, and stewards: they enjoy and care for the land they use, as well as the animals they tend.

The extirpation of large carnivores in most of the U.S. and the transition of a large portion of the population from a rural extraction/production economy to an urban, service-based one means that many Americans have little direct experience with large carnivores. This shift is partially driving gradual changes in attitudes about large carnivores and coincides with a continued increase in environmental awareness. Depredation affects public knowledge and experience (A3/A7) through the reporting and portrayal of depredation, predator control, and conflict by media organizations (S6); this portrayal is also affected by *environmental (GS2)* and *ranching organizations (GS2)*, typically in a polarized manner. The current net effect of media organizations on the public, and the effect of personal perspectives on selective exposure to and integration of media, requires continued research. These effects vary spatially and with shifting ecological and socio-demographic qualities (Houston et al., 2010) as well as cultural and historical contexts.

Ranchers mentioned the dependence of their continued access to public lands and a market for sheep products on public opinion, and public perception influences their decisions about predator control (I1) and its indirect role in human confrontation (O1) (figure 14). Ranchers who participated expressed concerns that they would be subject to legal penalties, lose their jobs, or draw criticism if the information they shared was distributed. One rancher reported that he had received a threat of death warning against the use of lethal predator control.

Lack of Trust and Public Trust Resources

The current system state is affected by a significant and self-reinforcing lack of trust (I3) that contributes to human confrontation (O1) and weakens effective monitoring and management of multiple uses (figure 15). Environmental organizations (GS2) and ranching organizations (GS2) advocate for their respective interests and beliefs by lobbying (I6) both state and the Federal government (GS1) for favorable protection status (GS5) and predator control (I1) policies. Although these organizations have some ideological overlap- the stewardship of rangelands- and actor membership in them is not mutually exclusive, prolonged debate has resulted in their polarization at an institutional level. As compared to the previous 100 years, the last 50 years have seen decreased Federally-sponsored predator control (I1) and the adoption of ecosystem-based management as described in the background section of this study; however, as predators recover a recent pattern of increased control is likely to continue. Frequent policy changes have decreased systemic *predictability (RS7).*

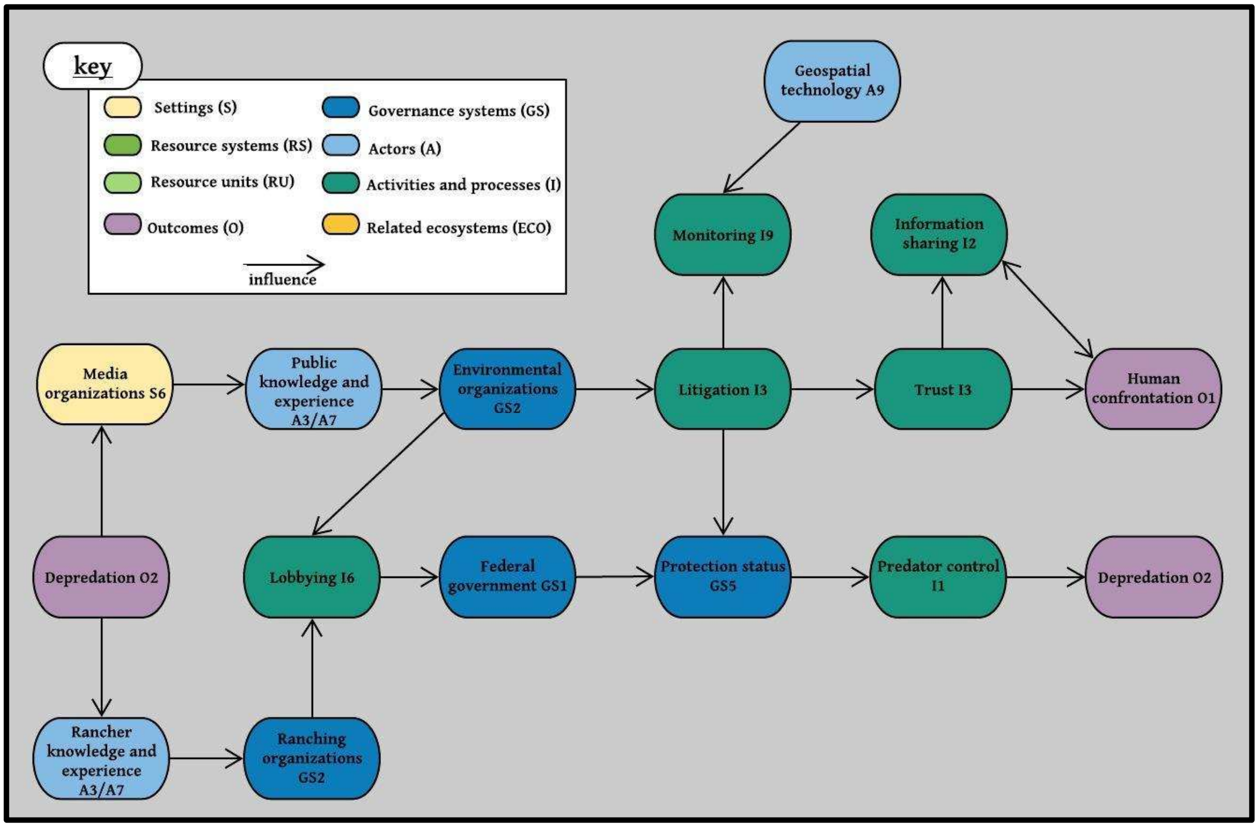

Figure 14. Social *causal pathways of human confrontation and depredation. Rancher knowledge and experience of large carnivore conflict is gained directly, while the knowledge and experience of the public may be gained directly but is likely from media or second-hand sources; more studies of media influence on knowledge and experience are needed. These experiences affect the formation and support of organizations that lobby and influence large carnivore protections. Litigation by environmental organizations to increase large carnivore protections affects resource monitoring by using the fiscal and human resources of federal management and other organizations to address legal concerns, and by discouraging ranchers from sharing or co-generating information; and contributes to a lack of trust and increasing polarization between ranchers and environmental organizations. The lack of trust decreases information sharing and increases human confrontation both directly and indirectly, since information sharing decreases confrontation and depredation. This positive feedback loop perpetuates human confrontation.*

Environmental organizations have repeatedly used litigation (I3) (figure 14) to sue the Federal Government for federal protection status for large carnivores, particularly wolves, at times reversing previous decisions; and have done so after population goals established in previous conditions for de-listing were met. The determination of protection status has at times been deferred by Federal District courts to *wildlife services (GS1).* In the words of a participant, these actions "…undermined the agreement with ranchers [who were] people who were willing to cooperate, and then the whole thing dragged out longer and longer. [These lawsuits] destroy the integrity of the ESA. [Litigation] took discontent from a grumble to a boil; that boil has continued." While only one respondent explicitly cited this lack of trust caused by litigation, all participants expressed reluctance to share information, particularly with those they perceived as environmentalists, and evinced an apparent attitude of wariness and at times frustration toward both environmental organizations and management agencies. Other studies in the Inter-mountain West and Western states have also found that litigation has damaged stakeholder trust and (S. B. Clark & Rutherford, 2014; Madden, 2015). Repeated litigation is a cause of damaged trust (I3) between stakeholders, which damage has promoted the polarization of ranchers and environmentalists and increased human confrontation (O1) to the extent described. Confrontation over carnivore conservation likely reinforces a lack of trust and promotes further litigation. Litigation is also used to sue Federal management agencies over NEPA noncompliance on allotments, the effects of which actions are reportedly similar.

In addition to damaging trust, addressing litigation and requires the use of Federal funds that may otherwise be available for monitoring (I9) in agencies already suffering from recent funding cuts (Livesay, 2018). Both ranchers and management professionals reported under-monitoring of forage, recreation use, and range conditions due to staffing and budgetary constraints. Compounding this problem, this lack of trust (I3) and the prevalence of human confrontation (O1) create a barrier to effective and efficient information sharing (I2), which has been demonstrated to reduce conflict between multiple uses and is instrumental to developing strategies for coexistence. Geospatial technology (A9) is underutilized in the monitoring and management of this SES for the same reasons. In discussing the possibility of collaring sheep, stakeholders in every category acknowledged the benefits of geospatial technology but cited instances in the past in which it had been used as a tool for confrontation and litigation as reasons for their doubt and hesitance regarding its application.

I was unable to obtain spatial information on the locations of depredations and large carnivore sightings, and it is unclear if such a record exists. Information regarding the approximate locations of depredation and predator sightings is shared among networks of stakeholders only with caution: participants were shy about identifying locations of human-wildlife conflict. "*We keep our cards close to our chest when it comes to these things*," reported a participant working toward carnivore conservation. Sharing the locations of depredations and carnivore sightings can jeopardize the safety of the carnivores by making them susceptible to hunting or control efforts. This information can also cause human confrontation (O1) between members of environmental organizations and ranchers. One participant agreed to share information on locations of his sheep and knowledge of predators/predator sightings with the caveat that that it not be shared with others, because "*we don't want environmentalists up on the hilltops."* For these and other participants, information sharing is perceived as high-risk in the current conditions of mistrust, and withholding information has become a strategy to avoid conflict. Sensitivity to the social tension surrounding the issue of livestock depredation and predator control was evident in every interaction both with stakeholders and members of the general public.

Discussion

In the 200+ years since their designation, the management of U.S. public lands has continuously evolved in attempt to fill the tall order of the multiple use mandate. This evolution and its ecological outcomes remain closely coupled with national social and cultural dynamics. U.S. public lands management must now evolve to face the challenges of balancing wildlife conservation and increased demands for recreational access with sheep ranching and extractive use, on a backdrop of climactic changes that are already decreasing systemic stability. This case-study illustrates the importance and utility of an approach to wildlife management and conservation that explicitly considers the social as well as the ecological relationships and contexts of a resource, its uses, and users. Using an SES perspective to study human-wildlife interactions reduces conflict, increases resilience, and improves outcomes for both social and ecological systems (Treves et al. 2006).

"Command and control" models of managing individual components or single processes of resource systems treated as isolated and static are grounded in flawed theory that largely ignores the features of complexity in linked systems (Pahl-Wostl 2007, Rammel et al. 2007, Armitage et al. 2008, Folke et al. 2010, Preiser et al. 2018). By assuming and seeking to conceptually organize and understand complexity, the SES framework allows the discovery and management of complex, linked, and emergent properties (Olsson et al. 2004a, Preiser et al. 2018) including indirect, contextually situated, nonlinear, and dynamic relationships. An SES is typically greater than the sum of its parts, and the SES framework recognizes that outcomes are created in a non-linear fashion. In this study the SES framework enabled a multi-dimensional and cross-scale understanding of the direct and indirect spatial, ecological, and social drivers of rancher/recreationist conflict, depredation, and human confrontation within the contexts in which these outcomes co-evolved. The interactions and cumulative effects of multiple use have been underestimated and under-studied. The SES framework provides an effective format to examine and manage linked, dynamic, and contextual- in short, complex- multiple-use systems. As SES paradigms gain continued popularity with natural resource managers continued efforts to thoroughly and methodically frame SES, and to operationalize these frameworks in real systems, are crucial to increasing and applying generalizable knowledge of common interactions and outcomes.

I have contributed to this need with the research described here by operationalizing the SES framework to identify variables and processes that drive the current system state of multiple-use public lands in Blaine County, Idaho. The broad historical, social, and economic contexts of sheep ranching, recreational use, carnivore extirpation and recovery, and the "New West" transition in Blaine County and Idaho are common to other areas of the Inter-mountain West. Across this region, human/carnivore conflict and recreation on public lands are increasing (Livesay, 2018), the successful recoveries of large carnivores are jeopardized by high rates of land-use change surrounding protected areas (Defries et al., 2016) and nuanced public attitudes toward coexistence (Houston et al., 2010), and depredation continues to damage ranching livelihoods and influence large carnivore management strategies. The generalized variables, processes, and causal pathways I have identified may be regionally extensible to the Inter-mountain West, though care should be taken to frame and re-examine their validity at a local scale and in a local context when applied to communities that are not Blaine County. I have further operationalized this framework by identifying spatialized ecological and anthropogenic predictors of sheep grazing locations. This model requires additional data and refinement before it may be used to extrapolate sheep locations.

The conclusions of this study are supported by a series of diverse but related literatures, primary sources and direct observations in Blaine County. While the majority of research participants were key informants, the small sample size and short duration of this study limits the level of significance and extensibility of the results. My interpretation of the knowledge and perceptions of those I spoke with may not represent that of others, and a larger sample size that checks this understanding would be necessary to improve confidence in these results. I have used the information I was able to obtain to infer some of the reasons that others did not share information, and this extrapolation reduces the confidence level of these inferences. Behavioral motivation and knowledge, attitudes, and beliefs are complexly and contextually generated and vary individually. Such a limited sample size as this is can only hope to capture a small fraction of the collective knowledge and perceptions of stakeholder groups, and cannot claim thorough representation. This SES causal map and proposed spatial model provide the foundations for hypothesis testing, quantification of causal variables, and spatially explicit cost/benefit analyses of land use planning and conflict prevention strategies.

The role that ranching plays in provisioning food and fiber has decreased as previously discussed, but its costs and benefits too must be weighed against those of the mainstream fiber and agricultural industries. In what ways is rangeland ranching more or less sustainable than intensive agricultural operations and synthetic fiber production? The polarization of environmentalists and ranchers over predator control has resulted in hyper-focus on managing and regulating ranching, while the effects of recreation go largely unmonitored. Recreation is now the primary use of U.S. public lands and generates significant revenue for their management (although the dearth of monitoring is due in large part to financial constraints (personal communications with Federal lands managers)). As recreational use of public lands continues to increase, the use of spatial tools for recreation planning and to manage conflict between recreationists (e.g. effects of crowding, coexistence of motorized and non-motorized recreation) is becoming more common. Usually viewed as a low-impact activity, the environmental effects of recreation are in fact not well documented. This is particularly true regarding indirect environmental effects of recreation, which include land-use change. The dependence of the effects of recreation on ecological assembly, landscape features, social norms and visitor behavior make the generalization of knowledge difficult. In public lands of the West there is a pressing need to collect and examine site-specific effects of recreation use on vegetation and wildlife. Both recreationists and wildlife may displace and be displaced by sheep ranching, shifting grazing and recreation pressure and redistributing wildlife populations to create unanticipated outcomes such as overgrazing, increased human-wildlife conflict, increased stress or altered behavior of both wildlife populations and sheep, and off-trail recreation.

Although fundamentally a geographical question of shared space, there is a lack of geospatial tools to resolve ranching/recreationist and human-wildlife conflict. Spatial and temporal niche partitioning- the separation of humans and wildlife in space and time- is a mechanism for human-wildlife coexistence at fine spatial scales and has reduced ranching/recreationist conflict on Western public lands via the BCRD's "sheep advisories" mentioned above, as elsewhere (Anderson, 1998). Combined with recreation data and large carnivore occupancy models, models of sheep grazing can be used to predict and prevent ranching/recreationist and depredation conflict by facilitating their spatial and temporal segregation. The preliminary model of sheep grazing I have presented here indicates that sheep and ranchers select grazing areas within allotments based primarily on forage quality and quantity, for which NDVI is an effective metric. Further development of a predictive model of sheep location requires a greater volume of data collected from multiple allotments, and continued participant observation to understand the circumstances and conditions under which ranchers and recreationists influence the selection of grazing areas. Future models should examine snowpack as a determinant of sheep location, and incorporate uncertainty, as should models of recreational and large carnivore use. Depredation risk and habitat use models must be species-specific, because behavioral ecology plays a significant role in habitat use and attack and avoidance behavior. They must also be tailored to address the social landscape and anthropogenic variables such as soundscape, human presence, and land use (Treves et al., 2004). Continued development of methods in GIS and geospatial statistics need to explicitly consider the inherent needs and challenges of social-ecological analysis, particularly comparing continuous and discrete data, conditional correlation, and modeling uncertainty.

Risk maps are easily shared with and understood by stakeholders, though more research efforts are required regarding the implementation of spatial tools and their integration with policymaking. When implemented, risk-based geospatial tools have successfully reduced attacks by >90% (J. R. B. Miller, 2015), and elsewhere successfully reduced human conflict with elephants by identifying spatial predictors of conflict type and intensity to target mitigation efforts (Sitati, Walpole, Smith, & Leader-Williams, 2003). Geospatial tools have focused on risk-mapping and hotspot analysis of livestock depredation because of its role in large carnivore conservation and the relative ease of modelling depredation compared to the considerable expense of obtaining datasets on large carnivore movements. Thus, most models focus on actualized rather than fundamental predation risk (i.e., the effects of attempted attacks and predator presence on the condition and movement of livestock). Ranchers to whom I spoke expressed an interest in models of fundamental predation risk, and this is a potential path to increase cooperation between ranchers and land managers in developing geospatial tools. Interactive and participatory mapping offer low-cost, real-time data collection and prevention of human-wildlife and ranching/recreationist conflict but reliability of reporting, trust among stakeholders, and the potential for misuse present significant obstacles that must be addressed cautiously (the IDFG currently uses web-based reporting and mapping tools to document wildlife observations (Idaho Department of Fish and Game, n.d.)). Lack of trust and collaboration among stakeholders- particularly between ranchers and environmentalists- is a substantial barrier to collecting vital geospatial information and managing multiple uses on grazed public lands.

Trust is one of several linked processes operating between individual actors, actor networks, and governance systems within contextualized socio-political, economic, and historical settings that create current outcomes. These results are best understood within these contexts: this is the environment in which components of the SES interact and evolve. Natural resource management is often a matter of managing people's use and interaction with a resource. Multiple-use lands in the West currently rely on contentious exclusion and regulation of land and resource use (e.g. grazing plans, recreation access, carnivore conflict management regulations) and strategies of user and stakeholder participation (e.g. predator control strategies, decisions to stay on-trail). Trust is important in natural resource management because it modifies stakeholder's interactions with governing entities, policies, resources, and with one another. Other social norms, and larger social tensions, contribute to both a lack of trust and to human confrontation. Land sovereignty, insider/outsider status, and conflicting cultural values are linked processes that contribute to conflict and confrontation on public lands.

The right of the Federal government to manage U.S. public lands was debated and opposed early in their history by those (among them, ranchers) who were already living on or near and using these lands, and believed that the right to their use and development should be locally determined (land sovereignty). These sentiments remerged in the Sagebrush Rebellion movement of the 1970s-80s, when several western states responded to new environmental regulations including FLPMA by passing bills approving the state control of Federal lands; and again with the 2016 armed occupation of Oregon's Malheur National Wildlife Refuge led by extremist land-sovereignty leader and cattle rancher Ammon Bundy. Contentions of land sovereignty have fueled confrontation over wolf reintroduction and control, and large carnivore recovery has in many ways become a proxy issue for land sovereignty. At the same time wolves have become a symbol for wilderness, its inherent value, its prioritization over commercial interests, and the "rewilding" of human-dominated landscapes. Such complex individual and collective "symbolic burdens" of large carnivores play a central role in their management (Mattson et al., 2006).

The cultural, economic, and social transitions from the "old" to "new West" bring into question the "belonging" of wildlife, ranchers and recreationists on the western landscape and create new challenges for the coexistence of multiple uses and of multiple users in the same spaces and the same communities (J. V. Martin, 2015). Whom and what "belongs" or is "out-of-place" on public lands is a matter of perspective and experience. Wildlife and public lands are public trust resources, but it is not the entirety of "the public" who must coexist with wildlife on a daily basis, nor does it directly affect their interests or livelihoods, and this results in local stakeholders that are likely to be less supportive of conservation actions than non-locals (Young et al., 2015). In workshops and interviews conducted with forty-nine ranching (sheep and cattle) and non-ranching community members in 4 rural American West communities (including Ketchum in Blaine County, n=7) in 2011, both ranching and non-ranching participants identified “conservationists” and “city people” as primary influencers of large carnivore policy. They largely viewed these “outsiders” or “others” negatively, and did not feel that these policymakers understood their local perspectives (Young et al., 2015). In my own research the ranchers referred to recreationists as newcomers and non-locals, suggesting a similar perception of this demographic. While the collective creation of rules is an element of successful self-organized resource regimes, in-migration of new users with different values and social norms and no history of established mutual trust with one another threatens collective action and collaboration because of the obstacles posed to mutual understanding and agreement. Successful collective-use rules must be contextually sensitive to local conditions (Ostrom, 2000); in-migration and management at national scales are an obstacle to this as well. A question we must continue to investigate is at what social and ecological scales it makes sense to manage public-trust resources when both national and local stakeholders’ use of, dependence on, investment in, proximity, and contributions to a resource and its management vary widely?

Trust is not the only element affecting collaboration and information-sharing, but Ostrom found that, in simulated zero-sum games, “those who believe others will cooperate in social dilemmas are more likely to cooperate themselves” and that if trust in another’s cooperation is undermined, contribution toward collective action decreases. Using a social evolutionary approach Ostrom points out that trust and trustworthiness put positive selective pressure on those willing to collaborate by a) sanctioning rule violations and limiting risk and b) establishing social norms of cooperation. The absence of trust selects for the opposite: acting in rational self-interest, which typically involves significantly less cooperation and encourages less cooperation in others. When others can be relied upon to act for the mutually perceived common good, and bad actors are limited, it is also beneficial to act for sustained common good. Trust and collaboration for the public good engender more of the same, just as conflict and dis-trust are self-reinforcing. If ranchers view litigation as a harmful breach of social norms or previously agreed-upon rules, then the perception that they cannot trust environmentalists to act for their mutual benefit would rationally prevent them from collaboration in the future. How do we create conditions that reward and select for trust, trustworthiness, and cooperation, in a system of users who perceive and incur their costs and benefits differently? In both experimental and field conditions Ostrom (2000) observes that external regulation and incentives can encourage cooperation but that it is not sustained once these mechanisms are removed, particularly if these mechanisms do not establish social norms that foster it. That is, self-organization formed around social norms is more durable than "top-down" approaches of external regulation. How, then, do we encourage self-organization and self-regulation in diverse stakeholder groups with disparate objectives and values? Is this a realistic goal?

Ostrom's studies focus on common-pool resources, but the resource that is "public lands" is many linked resources and is additionally a symbolic and cultural resource. Stakeholders in the ranching-recreation-large carnivore SES value resources and view rewards differently, and so have differing objectives and motivations. While we lack information on collaboration in managing multiple-use resources it is rational to believe that in this system, too, approaches that incentivize collaboration, cooperation, and trustworthiness will select for more of the same. In the current system state, we are applying selective pressure that provides little incentive to develop strategies for coexistence and has in the past exposed those who invest in their development to increased sanctioning. If shared social norms promote trust, can creating trust promote sharing and agreement on social norms and rules of use?

The process of trust is historically, socially, and personally constructed (Gray et al., 2012) and neither easily quantified nor composed. While public involvement does not guarantee trust nor opportunity guarantee public involvement, stakeholder participation in natural resource management has been successful partly because it builds relationships of trust and collaboration toward shared goals (Davenport, Leahy, Anderson, & Jakes, 2007). Rancher's willingness to co-exist with carnivores and recreationists can be negatively influenced by the perception that their input has not been considered in decision-making and that the resulting policies disadvantage them. Collaborative problem-solving improves and legitimizes regulation by sharing power and responsibility (Berkes et al., 2006; Virapongse et al., 2016) and can distribute and buffer negative effects of management tradeoffs. Even when the outcome of stakeholder participation is not satisfactory to all stakeholders, the process of public involvement adheres to societal norms and to stakeholders' ideas of fairness: they need to feel heard (Jacobsen & Linnell, 2016). In the case of public lands ranchers, there is the perception that ranching perspectives have not been given due consideration and that distant environmentalists have steamrolled the interests and opinions of local ranchers in spite of prior compromise. Young et al. (2015) identified 4 main categories of participant perceptions of large carnivores: fear, vulnerability, illegitimacy, and questionable authority. Participants' attitudes were determined by their perceptions regardless of the accuracy of these perceptions, leading the authors to conclude, as I have, that enhancing the quantity and quality of communication, information-sharing, and co-generation of knowledge could bridge the epistemological gulf between diverse stakeholders with conflicting viewpoints and contextual perspectives and increase the legitimacy and authority of regulation (Young et al., 2015).

Stakeholder involvement needs to be in-person (Ostrom, 2000), inclusive and non-confrontational, soliciting perceptions and behavior patterns from diverse groups reflecting the spectrum of vulnerability to conflict (Treves & Karanth, 2003). Understanding and communicating diverse stakeholder perspectives, experiences, knowledge, perceptions and attitudes-their mental models- is a first step in managing the adaptive cycles to which they contribute (Elsawah et al., 2015; Jones et al., 2011). There is little research concerning ranching/recreationist conflict, but the processes of stakeholder involvement and collaboration are easily extensible and may be easier to implement, as this type of conflict has not reached the same level of contention and lacks the same history as that between ranchers and large carnivores. Organizations of recreationists, with an interest in sustainable access and use of public lands, have already been established and can be valuable resources and allies for examining the impacts of recreation and developing strategies of coexistence- and indeed have already made headway in doing so. Although addressed in less detail here because of their emergent role in this research, they are likely to play a larger role in future, particularly if the sale of public lands continue to increase. Even in the absence of ranching the recreational opportunities provided by public lands are at risk if we continue to lack an understanding of their impacts and our options to preserve equitable and sustainable access for a growing number of users.

Coproduction, collaboration, and formal documentation of knowledge is time-consuming and often costly and requires significant investment by both scientists and stakeholders. When perspectives and objectives differ participatory processes can slow decision-making (Lemos et al., 2018). However, compared to the risks of unilateral management- a fatal lack of information, relevance, and support- and the current state of conflict between multiple uses and users, stakeholder participation in documenting and managing the cumulative effects of multiple uses on public lands and developing strategies for their coexistence is not only worth the cost but essential to the preservation of U.S. public lands and natural resources. If stakeholders can be enlisted, they can contribute significantly to the co-generation of knowledge including research and monitoring efforts, which activity itself builds trust and mutual understanding. Geospatial information can help communicate, integrate, and analyze diverse ontological perspectives among stakeholders, but this case-study indicates that trust-building is a prerequisite of further development and implementation of strategies for coexistence. Continued collaboration of Federal land-management agencies with self-organized environmental, ranching, and recreation organizations is essential to creating sustained multiple-use resource management. Federal land managers should investigate strategies to facilitate trust-building and collaboration, and ensure that coexistence efforts are rewarded rather than dis-incentivized. Environmental organizations using both litigation and collaboration with ranchers to promote carnivore conservation must carefully consider the costs and benefits of each of these strategies in building sustainable resource management regimes.

To establish whether a strategy works, one requires a definition of success. What, collectively, is our definition of successful management of multiple-use public lands, our larger goal? FLPMA does not presume that all uses are appropriate on all lands, but provides no guidelines for the prioritization of uses when conflict exists. This encapsulates the debate that has recently drawn public interest and always surrounded America's public lands: for what purpose shall they be used or conserved, and by whom- and who decides this? For multiple use to be successful or uses to be prioritized, we first need to be aware of the individual and cumulative effects of policy and practice on resources and resource users. Only then can we make informed decisions that weigh the costs and benefits of management strategies.

Conclusions

Our public lands were set aside in part to continue the provision of ecosystem services, and our ignorance of the cumulative impacts of multiple uses on public lands jeopardizes this essential purpose. The operationalization of the SES framework provides an analytical tool with which to examine this system in its full complexity and context at multiple spatial and temporal scales, and aids in the theoretical systemic understanding necessary to understand the causes and consequences of outcomes. Geospatial modeling of resource units and resource users can help land managers quantify and spatialize the individual and cumulative impacts of multiple uses, but the history of conflict over public-lands ranching and the lack of trust created by litigation over the protection status of large carnivores is a significant barrier to collecting geospatial information on ranching use, and securing the knowledge and cooperation of ranchers to develop strategies for coexistence with large carnivores. In addition to thus indirectly increasing depredation, this conflict contributes to a lack of monitoring on public lands and outcomes that increase human confrontation. There is an urgent need to collect information on the ecological impacts of recreational uses, particularly in regard to large carnivores and species of conservation concern; and to get out ahead of potential recreationist/carnivore conflict by understanding the social implications of living in close proximity to large carnivores. To accomplish these goals and decrease the frequency of outcomes of depredation, ranching/recreationist conflict, and human confrontation, trust-building between polarized environmental and ranching organizations needs to be prioritized. Stakeholder involvement that provides the opportunity for constructive dialogue, compromise, and the co-generation of knowledge from diverse stakeholders in both local and national contexts are essential to increase adaptive capacity in the social sub-system of the multiple-use SES of sheep ranching on U.S. public lands.

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Appendix

"Human-environment interactions of sheep herders in Blaine County, Idaho"
Herder and operator guided interview data recording form

Interacciones entre humanos y medio ambiente de pastores de ovejas en el condado de Blaine, Idaho

Registro de datos de la entrevista guiada por el pastor y el operador

Date/fecha:___________
Researcher note-taker/Investigador tomador de notas :

Participant ID letter/Letra de identificación del participante:
Job/trabajo:
Years on job/ años en el trabajo:
City of origin/Ciudad de origen:

I know you have to follow the operating instructions, but within them, who decides where to move the sheep band?
Sé que tiene que seguir las instrucciones de funcionamiento, pero dentro de ellas, ¿quién decide dónde mover el rebaño de ovejas?

What cues the decision to move the sheep?
¿Qué indica la decisión de mover las ovejas?

What characteristics make a place favorable for sheep?
¿Qué características hacen que un lugar sea favorable para las ovejas?
What characteristics make a place unfavorable for sheep?
¿Qué características hacen que un lugar sea desfavorable para las ovejas?

Do the favorable and disfavorable places ever change? Why?
¿Cambian los lugares favorables y desfavorables alguna vez? ¿Por qué?

What are the biggest risks to sheep when they are grazing (ranked greatest to least)?
-if "depredation" is listed- which predators, ranked greatest to least on a scale of 1-5, are the biggest threats?

¿Cuáles son los mayores riesgos para las ovejas cuando están pastando (clasificadas de mayor a menor)?

-Si se enumera la "depredación"- ¿Qué depredadores (clasificados de mayor a menor en una escala de 1 a 5), son las mayores amenazas?

What actions do you take to minimize these risks?
¿Qué acciones toma para minimizar estos riesgos?

Which actions are most effective?
¿Cuáles son las acciones más efectivas?

What would help you manage wildlife conflict more effectively?
¿Qué le ayudaría a manejar los conflictos de vida salvaje de manera más efectiva?

"Human-environment interactions of sheep herders in Blaine county, Idaho"
Herder and operator participatory mapping data recording form

Interacciones entre humanos y medio ambiente de pastores de ovejas en el condado de Blaine, Idaho

Formulario de registro participativo de datos de mapeo participativo del pastor

Date/fecha:___________
Researcher note-taker/Investigador tomador de notas :
Participant ID letter/Letra de identificación del participante:

As part of the interview, participants will be presented with a map of the project area, labeled with their participant ID letter. Researchers will orient the participant to the map using these locations and ensure that they are oriented by asking them to identify additional features.

Each participant will be provided with a marker and asked to draw, label, and discuss salient features on their map. Follow-up questions will be asked as needed for clarification.

Participants will be asked to identify on the map any locations that meet the following criteria:

1. Places that are favorable for sheep
   Lugares que son favorables para las ovejas

   1.1. Why area is favorable: what type of benefit exists in the area
   Por qué el área es favorable: qué tipo de beneficio existe en el área

   1.2. Favorability rating on a scale from 1 to 5, with 1 being the least and 5 being most favorable
   Calificación de favorabilidad en una escala del 1 al 5, siendo 1 la menor y 5 la más favorable

   1.3. Factors that contribute to favorable conditions
   Factores que contribuyen a condiciones favorables

2. Places that are unfavorable for sheep
   Lugares que son desfavorables para las ovejas

   2.1. Why area is unfavorable: what type of unfavorable conditions exist in the area
        Por qué el área es desfavorable: qué tipo de condiciones desfavorables existen en el área

   2.2. Unfavorability rating on a scale from 1 to 5, with 1 being the least and 5 being most unfavorable
        Calificación de desfavorabilidad en una escala del 1 al 5, siendo 1 el menor y 5 el más desfavorable

   2.3. Factors that contribute to unfavorable conditions
        Factores que contribuyen a condiciones desfavorables.

3. Areas where conflicts with wildlife have occurred
   Áreas donde han ocurrido conflictos con la vida salvaje

   3.1. What type of wildlife Qué tipo de vida salvaje

   3.2. What type of conflict Qué tipo de conflicto

   3.3. Factors that contributed to conflict
        Factores que contribuyeron al conflicto

   3.4. Severity of conflict on a scale from 1-5, 1 being the least and 5 being the most severe Gravedad del conflicto en una escala del 1 al 5, siendo 1 el menor y 5 el más grave

4. Areas where camps are typically located
   Áreas donde normalmente se ubican los campamentos

5. Areas where sheep are watered
   Áreas donde se dan de beber a las ovejas

6. Areas of environmental concern
   Áreas de preocupación ambiental.

   6.1. What is the concern?
   ¿Cuál es la preocupación?

   6.2. Why is this a concern?
   ¿Por qué es una preocupación?

   6.3. Severity of concern on a scale from 1-5, 1 being the least and 5 being the most concerning
   Gravedad de la preocupación en una escala del 1 al 5, siendo 1 la menor y 5 la más preocupante

7. Additional areas of importance Áreas adicionales de importancia

   7.1. Why is this area important?
   ¿Por qué es importante esta área?

Additional notes and comments:

AAHRPP DOCUMENT # 113

UNIVERSITY OF ALABAMA

HUMAN RESEARCH PROTECTION PROGRAM

FORM: TRANSLATOR'S DECLARATION

NOTE: *If more than one person works on a translation, each person shall sign this form but only one copy of the source and the translated document need be attached.*

IRB Study #:

PI: Dr. Nicholas Magliocca

To the University of Alabama Institutional Review Board:

I, Derek J Eby , declare that I am fluent in and

understand the English language and the Spanish language. To the best of my knowledge and belief, the attached translation(s) is true, accurate, and correct.

This is a word-for-word translation, OR

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The original (source) English document and the translated version are attached.

Other than my role as translator:

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I am the partner of investigator Anna Levine, but have no

involvement in the research or this proposal outside the scope
of translating.

- X I will be serving as an interpreter/interviewer as well as a translator.*

- _ X_ I will be consulting about the findings.

Translator's Printed Name:

Derek J. Eby Address:

3600 25th Street Apartment 207 Northport, Alabama 35476

Phone:_(907)-209-4332 FA_N/A

E-mail:______derek.j.eby@gmail.com____

*_Complete investigator training and forward certificate or have PI do so._

Informed Consent

Please read this informed consent carefully before you decide to participate in the study.

Consent Form Key Information:

- Participate in an interview about your knowledge of sheep herding
- Identify locations important to sheep herding on a map
- No information shared that will connect identity with responses
- Participation is completely voluntary and is uncompensated

Purpose of the research study: The purpose of the study is to collect information about how wildlife effects sheep herding, and how sheep ranchers and herders make decisions during the grazing season, in Blaine County, Idaho.

What you will do in the study: If you decide to participate in this research study you will be asked to respond to interview questions about your knowledge, perceptions and experiences of herding sheep and managing wildlife conflict. You will be asked to allow these interviews to be audio taped. You will be asked to identify features of your allotment (such as camping locations, areas of conflict with wildlife, and preferred grazing areas) on a map. You may be asked to allow a technician to place a GPS collar on sheep in your band, and to assist in placing and removing it. You may be asked to review the information for accuracy after it has been collected.

You may participate in whichever portions of the study you choose. You can skip any questions or portions of the study you are uncomfortable with, and you may stop the interview and/or withdraw from the study at any time.

Time required: The interview and mapping portion of the study will take 1-1.5 hours of your time. If applicable, placing a GPS collar on a sheep in your flock will take a total of 2 hours. Reviewing information will take 30 minutes of your time.

Risks: The risks associated with participating in this study are minimal. Your name will not be associated with the information you provide, and every effort will be made to protect your anonymity, but there is a slight risk that the information you provide can be attributed to you. The data will be associated with individual allotments. Because a limited number of herders and ranchers operate in each allotment, there is a small risk that you can be identified indirectly by those aware of which allotment/s you operate on.

Benefits: There are no direct benefits to you for participating in this research study. The study may help us understand the impacts of wildlife on sheep herding and of sheep herding on wildlife and may help to improve sheep safety and the management of natural resources. At the end of this study the results will be made available to you, and you will be given a map of your herding area with the information gathered during the study.

Confidentiality: The information that you give in the study will be handled confidentially. Your information will be assigned a code number. The list connecting your name to this code will be stored in a secure file on UA Box, a secure cloud-based system for file and data storage on which all data are encrypted both in transit and storage and are maintained on domestic servers. When the study is completed and the data have been analyzed, this list will be destroyed. Your name will not be used in any report. If you allow your interview to be audio taped, the audio tape will be destroyed once it has been transcribed.

The information collected will be associated with individual allotments. Because a limited number of herders and ranchers operate in each allotment, there is a small risk that you can be identified indirectly by those aware of which allotment/s you operate on.

Voluntary participation: Your participation in the study is completely voluntary.

Right to withdraw from the study: You have the right to withdraw from the study at any time without penalty. If you have consented to be audio taped and choose to withdraw from the study, the audio tape will be destroyed.

How to withdraw from the study: If you want to stop participating in the study while it is being conducted, tell the interviewer or any member of the research team that you would like to stop. If you would like to withdraw from the study after it has been completed, please contact Anna Holland-Levine at (907)-209-3550 or achollandlevine@crimson.ua.edu. If you withdraw your information from the study, it will be destroyed. Please note that we are unable to withdraw your information once the list connecting your name to your code number has been destroyed. There is no penalty for withdrawing.

Compensation/Reimbursement: You will receive no payment for participating in the study.

Using data beyond this study: The researcher may like to make the information collected in this study available to other researchers after the study is completed. Your information will be stored, used and shared for future research studies, including but not limited to studies on wildlife conflict and coexistence and assessments of grazing patterns and rangeland health. Researchers of future studies will not ask your permission for each new study. However, the information you provide will be combined with the information provided by others to create a larger data set. Your name and other information that could potentially identify you will not be connected to the information shared with other researchers nor will they attempt to identify you.

Dr. Nicholas Magliocca
Principal Investigator
Department of Geography, University of Alabama
Telephone: (205)-348-4198
Email address: nrmagliocca@ua.edu

Anna Holland-Levine
Graduate Student Researcher
Department of Geography, University of Alabama
Telephone: (907)-500-3550
Email address: achollandlevine@crimson.ua.edu

If you have questions about your rights as a participant in a research study, or would like to make suggestions or file complaints and concerns about the research study, please contact:
Ms. Tanta Myles, the University of Alabama Research Compliance Officer at (205)-348-8461 or

toll-free at 1-877-820-3066. You may also ask questions, make suggestions, or file complaints and concerns through the IRB Outreach Website at http://ovpred.ua.edu/research-compliance/prco/. You may email the Office for Research Compliance at rscompliance@research.ua.edu.

Agreement:

□ I agree to participate in the research study described above.

□ I do not agree to participate in the research study described above.

□ I agree to video (audio, photograph) in the research study described above.

□ I do not agree to video (audio, photograph) in the research study described above.

____

Signature of Research Participant   Date

____

Print Name of Research Participant

____

Signature of Investigator or other Person Obtaining Consent
Date

_Anna Holland-Levine________________________________

Print Name of Investigator or other Person Obtaining Consent

Consentimiento Informado

Por favor lea con cuidado este consentimiento informado antes de decidir participar en la investigación.

Información Clave del Formulario de Consentimiento:

- Participar en una entrevista sobre su conocimiento del pastoreo de ovejas
- Identificar ubicaciones importantes para el pastoreo de ovejas en un mapa
- No se comparte información que conecte la identidad con las respuestas.
- La participación es completamente voluntaria y no compensada

Propósito de la investigación: El propósito de la investigación es recopilar información sobre cómo la vida salvaje afecta el pastoreo y cómo los rancheros y pastores toman decisiones durante la temporada de pastoreo en el condado de Blaine, Idaho.

Qué hace usted en la investigación: Si decide participar en esta investigación, se le pide que responda a las preguntas de la entrevista sobre sus conocimientos, percepciones y experiencias de pastoreo y manejo de conflictos de vida salvaje. Se le pide que permita que estas entrevistas sean grabadas en audio. Se le pide que identifique las características de su asignación (como lugares para acampar, áreas de conflicto con la vida salvaje y áreas de pasto preferido) en un mapa. Es posible que se le solicite que permita que un técnico coloque un collar de GPS en la oveja en su rebaño y que lo ayude a colocarlo y retirarlo. Es posible que se le pida que revise la información para verificar su exactitud después de que se haya recopilado.

Puede participar en cualquier parte de la investigación que elija. Puede omitir cualquier pregunta o parte de la investigación con el que se sienta incómodo, y puede detener la entrevista y / o retirarse de la investigación en cualquier momento.

Tiempo requerido: la parte de la entrevista y el mapeo de la investigación toma 1-1.5 horas de su tiempo. Si corresponde, colocar un collar GPS en una oveja en su rebaño toma un total de 20-30 minutos. Revisar la información toma 30 minutos de su tiempo.

Riesgos: Los riesgos asociados con la participación en esta investigación son mínimos. Su nombre no se asocia con la información que proporcione, y se hacen todos los esfuerzos para proteger su anonimato, pero existe un ligero riesgo de que la información que proporcione se le pueda atribuir. Los datos están asociados a asignaciones individuales. Debido a que un número limitado de pastores y rancheros operan en cada asignación, existe un pequeño riesgo de que usted pueda ser identificado de manera indirecta por aquellos que saben en qué asignación / s opera.

Beneficios: No hay beneficios directos para usted por participar en esta investigación. La investigación puede ayudarnos a comprender los impactos de la vida salvaje en el pastoreo y del pastoreo en la vida salvaje y puede ayudar a mejorar la seguridad de las ovejas y la administración de los recursos naturales. Al final de esta investigación, los resultados se ponen a su disposición, y se le entrega un mapa de su área de pastoreo con la información recopilada durante la investigación.

Confidencialidad: La información que proporcione en la investigación se maneja de manera confidencial. A su información se le asigna un número de código. La lista que conecta su nombre con este código se guarda en un archivo seguro en UA Box, un sistema seguro basado en la nube para el almacenamiento de archivos y datos en el que todos los datos se cifran tanto en tránsito como en almacenamiento y se mantienen en servidores domésticos.

Cuando se complete la investigación y se hayan analizado los datos, esta lista se destruye. Su nombre no es utilizado en ningún informe. Si permite que su entrevista sea grabada en audio, la cinta de audio se destruye una vez que se haya transcrito.

La información recopilada se asocia con asignaciones individuales. Debido a que un número limitado de pastores y rancheros operan en cada asignación, existe un pequeño riesgo de que usted pueda ser identificado de manera indirecta por aquellos que saben en qué asignación / s opera.

Participación voluntaria: Su participación en la investigación es completamente voluntaria.

Derecho a retirarse de la investigación: Usted tiene derecho a retirarse de la investigación en cualquier momento sin penalización. Si ha aceptado que se le grabe el audio y opta por retirarse de la investigación, la cinta de audio se destruye.

Cómo retirarse de la investigación: Si desea dejar de participar en la investigación mientras se está llevando a cabo, informe al entrevistador o a cualquier miembro del equipo de investigación que le gustaría detener. Si desea retirarse de la investigación después de que se haya completado, comuníquese con Anna Holland-Levine al (907) -209-3550 o achollandlevine@crimson.ua.edu. Si retira su información de la investigación, es destruida. Tenga en cuenta que no podemos retirar su información una vez que se haya destruido la lista que conecta su nombre con su número de código. No hay penalidad por retirarse.

Compensación / Reembolso: No recibe ningún pago por participar en la investigación. Si elige recopilar datos de GPS con su teléfono celular, se le proporciona un cargador portátil que puede conservar.

Uso de datos más allá de esta investigación: El investigador desea que la información recopilada en esta investigación esté disponible para otros investigadores una vez que se complete la investigación. Su información se almacena, utiliza y comparte para investigaciones futuras, incluidos, entre otros, investigaciones sobre conflictos y coexistencia de la vida salvaje y evaluaciones de patrones de pastoreo y la salud de los pastizales. Los investigadores de investigaciones futuras no pedirán su permiso para cada nueva investigación. Sin embargo, la información que proporcione se combinará con la información proporcionada por otros para crear un gran conjunto de datos. Su nombre y otra información que podría identificarlo no se conectarán a la información compartida con otros investigadores ni intentarán identificarlo.

Si tiene preguntas sobre la investigación o necesita informar un problema relacionado con la investigación, comuníquese con:

Dr. Nicholas Magliocca
Investigador Principal
Departamento de Geografía, Universidad de Alabama
Teléfono: (205) -348-4198

Dirección de correo electrónico: nrmagliocca@ua.edu

Anna Holland-Levine
Investigadora Estudiante Graduado
Departamento de Geografía, Universidad de Alabama
Teléfono: (907) 500-3550
Dirección de correo electrónico: achollandlevine@crimson.ua.edu

Si tiene preguntas sobre sus derechos como participante en una investigación, o si desea hacer sugerencias o presentar quejas e inquietudes sobre la investigación, comuníquese con:
Sra. Tanta Myles, Oficial de cumplimiento de investigaciones de la Universidad de Alabama al (205) 348-8461 o al número gratuito 1-877-820-3066. También puede hacer preguntas, hacer sugerencias o presentar quejas e inquietudes a través del sitio web de IRB Outreach en http://ovpred.ua.edu/research-compliance/prco/. Puede enviar un correo electrónico a la Oficina de Cumplimiento de Investigaciones a rscompliance@research.ua.edu.

Acuerdo:

□ Estoy de acuerdo en participar en la investigación descrita anteriormente.

□ No estoy de acuerdo en participar en la investigación descrita anteriormente.

□ Estoy de acuerdo con el video (audio, fotografía) en la investigación descrita anteriormente.

□ No estoy de acuerdo con el video (audio, fotografía) en la investigación descrita anteriormente.

____ __________
Firma del participante en la investigacion Fecha

____
Escriba el nombre del participante en la investigación

____ __________
Firma del investigador u otra persona que obtiene consentimiento Fecha

_Anna Holland-Levine______________________________
Escriba el nombre del investigador u otra persona que obtiene consentimiento

AAHRPP DOCUMENT # 113

UNIVERSITY OF ALABAMA

HUMAN RESEARCH PROTECTION PROGRAM

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_Derek J. Eby_________________________________

Address:

3600 25th Street Apartment 207 Northport, Alabama 35476_____

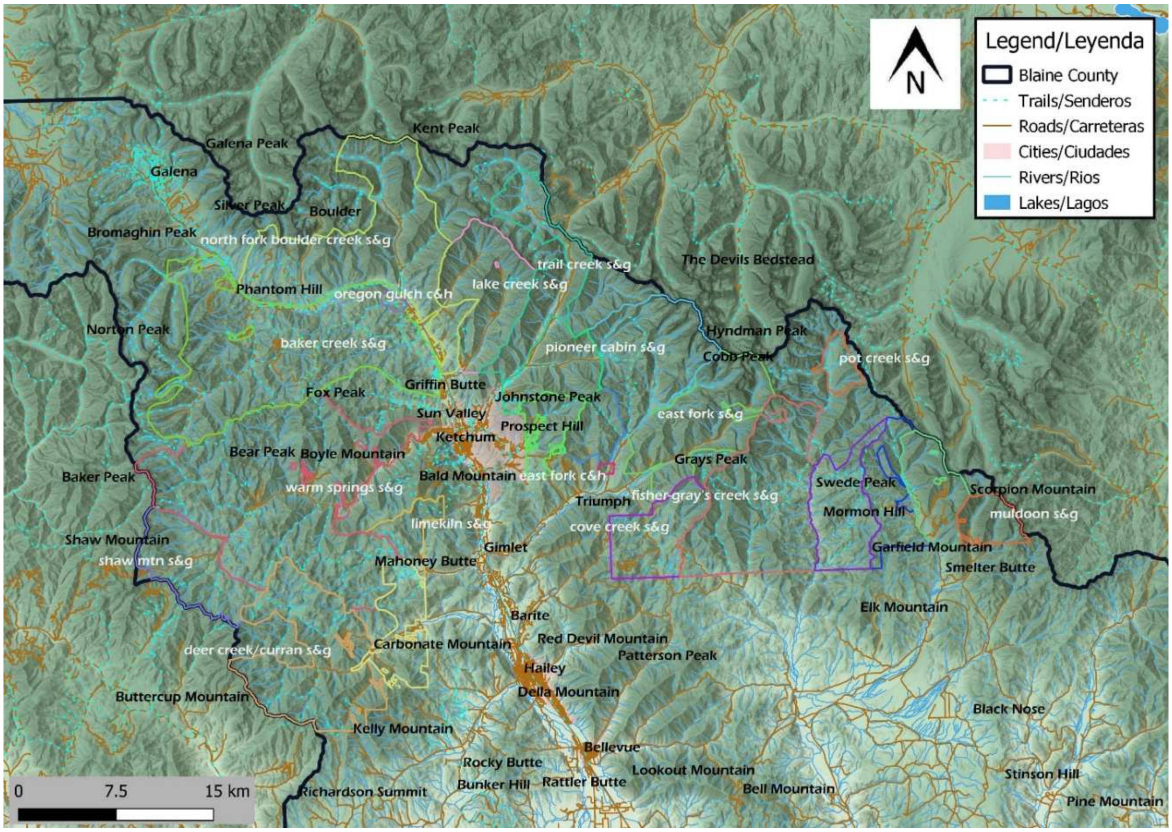
Phone:_(907)-209-4332__________   FA_N/A___________________________

E-mail:______derek.j.eby@gmail.com_______________________________________

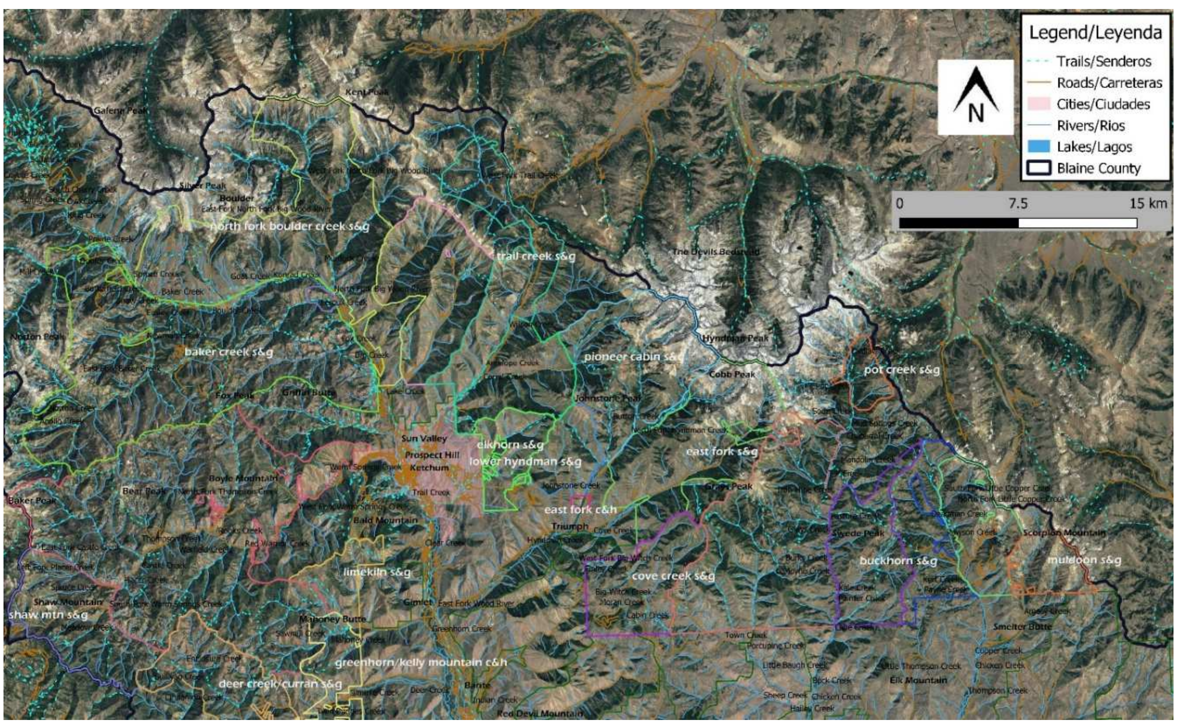
Complete investigator training and forward certificate or have PI do so.

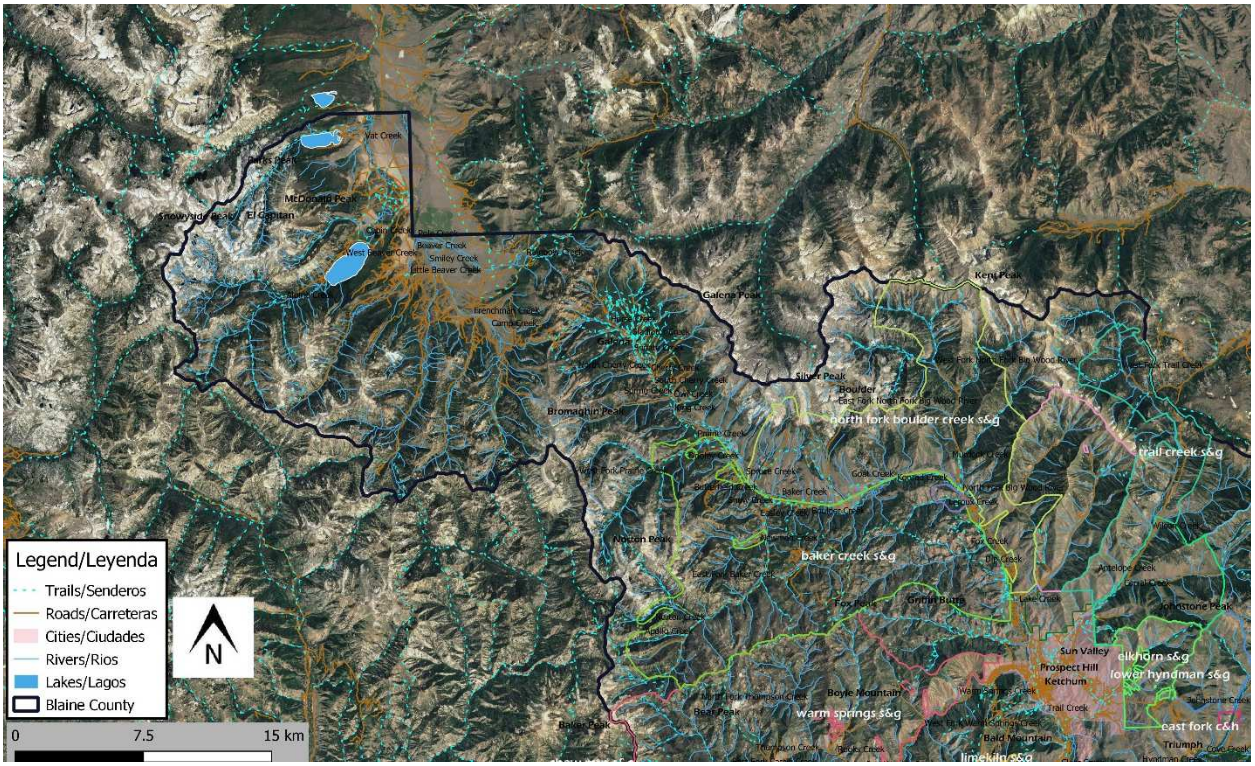
Derek J Eby

Participatory Maps of Allotments.

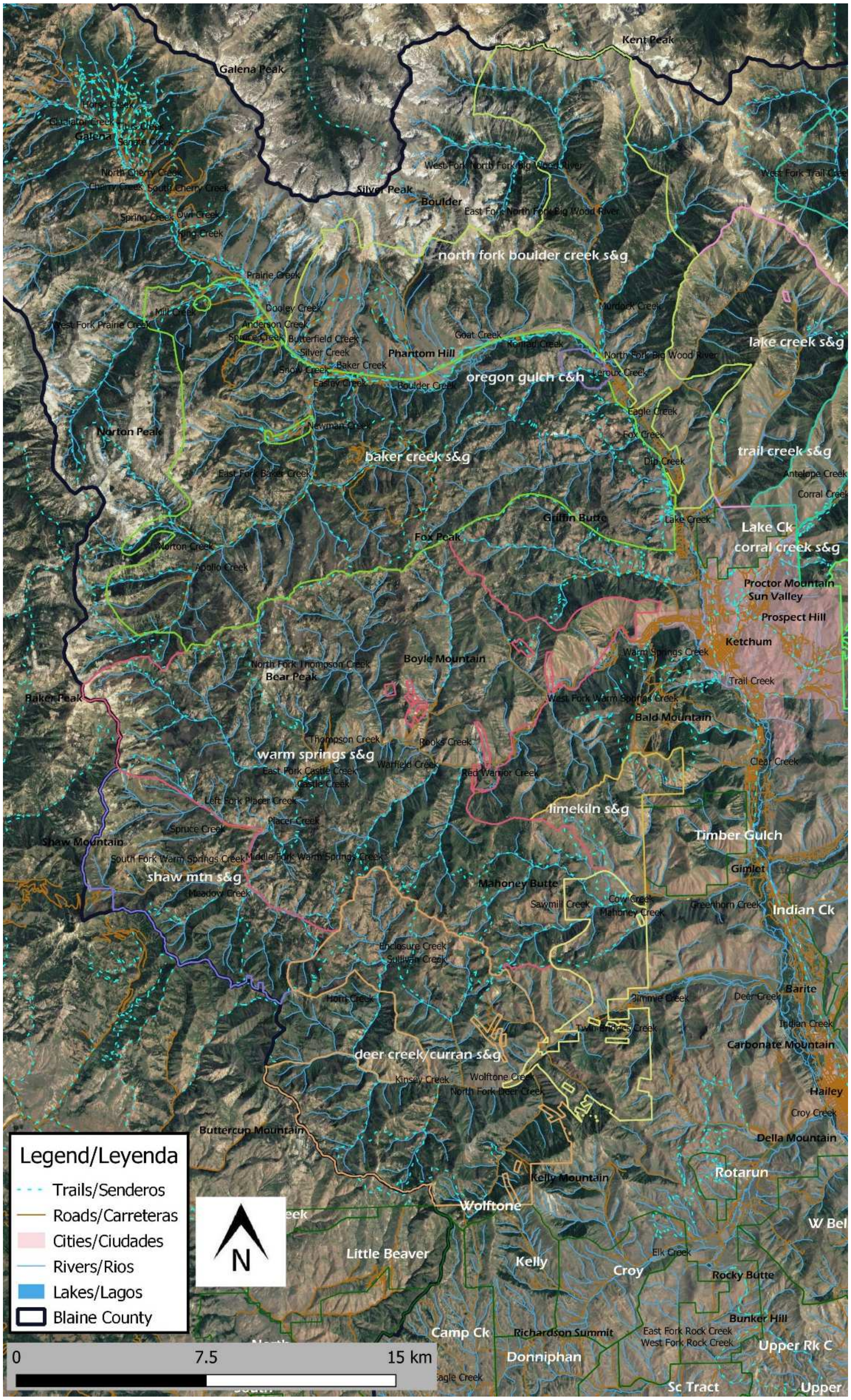


Ketchum Ranger District, all allotments (top); Ketchum Ranger District, Northern allotments (bottom).





Ketchum Ranger District, Northwestern allotments.



Ketchum Ranger District, Western allotments.

Glossary of SES Terms.

Term	Definition	Sensu
Adaptability	The key component of resilience. "The capacity to adjust responses to changing external drivers and internal processes."	Folke et. al, 2010
Dynamics	Changes in SES over time, e.g., how and to what extent social structures change, how and to what extent learning in the social system plays a role, or what patterns of growth or change occur within the ecological system.	Binder et. al, 2013
Flows	The ways in which components of a system are connected	Levine, 1998
Nonlinearity	The dynamic selective processes inherent in CAS result in the potential for multiple configurations of components but are constrained at any given moment by the history of past pathways.	Levine, 1998
Panarchy	Collectively, nested adaptive cycles across scales.	Holling, 2001
Process	A natural phenomenon marked by gradual changes that lead toward a particular result; a continuing activity or function.	Merriam-Webster Dictionary 2019 https://www.merriam-webster.com/dictionary/process
Resilience	The capacity of a SES to adapt and change in response to disturbance while retaining the essential structure, function, feedbacks, and critical limits of its state.	Folke et. al, 2010
Self-organization	The patterns of behavior produced over time as a result of the connections between system components.	Meadows, 2008 in Preiser et. al 2018
Social-ecological system (SES)	The complex adaptive system of interactions, feedbacks, and dynamics within and between social/human sub-systems and biogeophysical (ecological, environmental) sub-systems.	
Sustainability	Resilience over time.	
Threshold/critical transition	The point at which a controlling variable or set of variables and their feedbacks cause a system to take a different trajectory (toward a different attractor or state).	Folke et. al, 2010

Resolution and Source of Geospatial Datasets.

Dataset	Spatial Resolution	Temporal Resolution	Source
Blaine County boundaries	-	2018	United States Census Bureau
DEM	1 arc second	2013	U.S. Geological Survey
National Park Boundaries	-	2018	U.S. Bureau of Land Management
NDVI	250m SIN Grid	16-day intervals, 2019	NASA EarthData
Rivers	Idaho	2016	U.S. Census Bureau TIGER/Line
Roads	Idaho	2018	U.S. Census Bureau TIGER/Line
Slope	1 arc second	N/A	Derived from DEM
Terrain Ruggedness Index (TRI)	1 arc second	N/A	Derived from DEM
Trails	-	2018	U.S. Department of Transportation
Tree Cover Canopy	30m pixel	2016	Derived from land cover, MULTI-Resolution Land Characteristics Consortium
U.S. Bureau of Land Management Allotment Boundaries	-	2018	U.S. Bureau of Land Management
U.S. Forest Service Allotment Boundaries	-	2020	U.S. Forest Service
Urban area	-	2019	U.S. Census Bureau TIGER/Line

Data Sources of SES Variables.
Numbers in columns 3-5 represent the binary presence (1) or absence (0) of a source type, not the number of sources.

Variable	Total number of data types	Direct observation/s	Primary source/s	Literature source/s
Climate patterns	2	0	1	1
Depredation	2	0	1	1
Economic transition	2	0	1	1
Environmental organizations	2	0	1	1
Federal government	3	1	1	1
Forage	3	1	1	1
Geospatial technology	2	1	1	0
Grazing plan	3	1	1	1
Human confrontation	3	1	1	1
Idaho Dept. of Fish and Game	1	0	0	1
Information sharing	3	1	1	1
Land use change	2	0	1	1
Litigation	2	0	1	1
Lobbying	2	0	1	1
Location and mobility sheep	3	1	1	1
Location and mobility wildlife	2	0	1	1
Location recreation	3	1	1	1
Media organizations	2	1	0	1
Monitoring	1	0	1	0
Number ranchers	2	0	1	1
Number recreationists	2	0	1	1
Number sheep	2	0	1	1
Predator control	3	1	1	1
Predictability	2	0	1	1
Protection status	2	0	1	1
Public knowledge and experience	3	1	1	1
Rancher knowledge and experience	3	1	1	1
Ranching organizations	3	1	1	1
Ranching/recreationist conflict	2	0	1	1
Relocation sheep	3	1	1	1
Trust	3	1	1	1
Value recreation	2	0	1	1
Value sheep	2	0	1	1
Wildlife Services	2	0	1	1
Wood River Wolf Project	3	1	1	1

Systemic Variables of SES Systems (columns 1 and 2) and the public lands ranching-recreation-wildlife SES (column 3) and possible metrics to quantify them (column 4).

Tier 1	Tier 2 (Hinkel et al.)	Tier 2	Metric
Social, Economic, and Political Settings (S)	S1- Economic development	'New West' Transition	Land use change
	S2- Demographic trends	Population increase	Population increase
		Seasonality human residents	Percent permanent, percent non-permanent residents
		Median income	Median income
	S3- Political stability	Predator policy changes	Number of policy reversals
	S5- Markets	Wool market	Wool price trends
		Mutton market	Mutton price trends
		Tourism industry	Value of tourism (sub-divide into sheep-generated torusim)
		Value land	Land value trends
	S6- Media organizations	Media coverage	
	S7- Technology	Geospatial technology	Number of geospatial tools available
Resource Systems (RS)	RS1- Sector	Ranching	Hectares of grazed allotments
		Tourism	Total tourism revenue
		Ecosystem services	Economic value; social dependence
	RS2- Clarity of system boundaries	Allotments	
	RS3- Size of resource systems	Total grazed area	Hectares of grazed lands
		Federal lands	Hectares Federal lands
		Greater Yellowstone Ecosystem	Hectares of grazed lands in GYE
	RS4- Human-constructed facilities	Roads	Miles of roads
		Campsites	Number and location of campsites
		Trails	Miles and location of trails
	RS5- Productivity of system	Forage	NDVI
		Productivity sheep	Number of sheep on-number of sheep shipped
		Productivity ungulates	Average yearly population change

		Productivity predators	Average yearly population change
	RS6- Equilibrium properties	Trophic cascades	Effect strengths under differential conditions
	RS7- Predictability of system dynamics	Predictability	
	RS8- Storage characteristics	Predator population source	Dispersers to area
	RS9- Location		
Resource Units (RU)	RU1- Resource unit mobility	Mobility sheep	Area covered; impediments to mobility
		Mobility wildlife	Area covered; impediments to mobility
	RU2- Growth or replacement rate	Replacement/growt h forage	NDVI
		Replacement/growt h ungulates	Population growth/year
		Replacement/growt h predators	Population growth/year
		Growth recreation	Land area accessible to recreation
	RU3- Interaction among resource units		
	RU4- Economic value	Value sheep	Dollar value per animal
		Value wildlife	Ecosystem services and social value
		Value recreation	Dollar value revenue from recreation
		Value forage	Animal unit month
		Value ecosystem services	
	RU5- Number of units	Number sheep	Number of sheep
		Number predators	Predator population by species
		Number ungulates	Ungulate population by species
	RU6- Distinctive characteristics	Behavior predators	
		Behavior sheep	
	RU7- Spatial and temporal distribution	Location sheep	
		Location predators	
		Location forage	
		Location ungulates	
		Location recreationists	

Governance Systems (GS)	GS1- Government organizations	U.S. Federal government	U.S. District courts
			U.S. Forest Service
			U.S. Bureau of Land Management
			U.S. Wildlife Services
		State government	Idaho Department of Fish and Game
			Idaho Wolf Control Board
	GS2- Non-government organizations	Environmental	Defenders of Wildlife
			National Wildlife Federation
			Western Watersheds Project
		Bridging	Wood River Wolf Project
			Trailing of the Sheep
		Recreation	Blaine County Recreation District
		Ranching	Central Idaho Rangeland Network
		Other	Foundation for Wildlife Management
	GS3-Network structure	Personal	
		Professional	
	GS4-Property-rights systems	Public lands policies	Multiple use
	GS5-Operational Rules	Grazing plans	Annual Operating Instructions
			Annual Management Plans
	GS6- Collective-choice rules	Public lands policies	
	GS7- Constitutional rules	Multiple uses	
	GS8- Monitoring and sanctioning process	Monitoring	Range visits/year
		Sanctioning	Sanctions/year
Actors (A)	A1- Number of relevant actors	Ranchers	Active permits/year. Jobs as ranchers.
		Scientists	Scientists/managers per organization
		Recreationists	Users, by trail and recreation type
		Public	
	A2- Socioeconomic attributes of users	Age	
		Education	
	A3- History or past experiences	Experience ranchers	Years on job; measures of attitudes and perspective

		Experience recreationists	measures of attitudes and perspective
		Experience public	measures of attitudes and perspective
	A4- Location	Local	Residence
		Extra-local	Residence
		Tourist	Residence
	A5- Leadership	Leadership	
	A7- Knowledge of SES/mental models	Knowledge ranchers	
		Knowledge scientists	
		Knowledge recreationists	
		Knowledge public	
	A8- Importance of resource (dependence)	Ranching livelihoods	Jobs created by ranching
		Service livelihoods	Jobs created directly and indirectly by natural-resource tourism
	A9- Technologies available	Geospatial technology	Users of geospatial tech.
Action Situations: Interactions (I) Outcomes (O)	I1- Harvesting levels	Harvest ungulates	Hunting tags; documented kills
		Harvest predators	Trapping licenses; kills
	I2- Information sharing	Information sharing	Frequency of information sharing
	I3- Deliberation processes	Litigation	Number and cost of lawsuits
	I4- Conflicts		
	I6- Lobbying activities	Lobbying	Number of environmental and ranching lobbyists, and value of lobby influence
	I7- Self-organizing activities		
	I8- Networking activities	Actor networks	
	I9- Monitoring activities	Range assessments	Assessments/year. Financial allocation. Employees/hectare.
	I10- Evaluative activities		
		Human confrontation	Number of lawsuits; qualitative

	O1- Social performance measures	Rancher/recreationist conflict	Number of complaints; number and nature of encounters
	O2- Ecological performance measures	Wildlife conservation	
		Ecosystem services	
	O3- Externalities to other SESs	Depredation displacement	Animals depredated
Related Ecosystems (ECO)	ECO1- Climate patterns	Climate patterns	
	ECO 3- Flows into and out of focal SES	Meta-populations of wildlife	
		Tourism flows	Out-of-state or region visitors

IRB Certification

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

September 19, 2019

Nicholas Magliocca, PhD
Geography
College of Arts & Sciences
Box 870322

Re: IRB # EX-19-CM-200: "Human-environment Interactions of Sheep Herders in Blaine County, Idaho"

Dear Dr. Magliocca:

The University of Alabama Institutional Review Board has granted approval for your proposed research. Your application has been given exempt approval according to 45 CFR part 46. Approval has been given under exempt review category 2 as outlined below:

(2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

(ii) The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by §46.111(a)(7).

The approval for your application will lapse on September 18, 2020. If your research will continue beyond this date, please submit the annual report to the IRB as required by University policy before the lapse. Please note, any modifications made in research design, methodology, or procedures must be submitted to and approved by the IRB before implementation. Please submit a final report form when the study is complete.

Please use reproductions of the IRB approved informed consent form to obtain consent from your participants.

Sincerely,

Carpantato T. Myles, MSM, CIM, CIP
Director & Research Compliance Officer

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