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Beef Production and Imperiled Species: Understanding a social-ecological system for sustained conservation

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Beef Production and Imperiled Species:
Understanding a social-ecological system for sustained conservation

By

Sheila Barry

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Abstract

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On California's Mediterranean rangelands, cattle ranching supports the conservation of threatened and endangered species; however, ranchers are generally not compensated for providing this ecological service or beneficial natural process. Instead, the provision of ecological services, including species conservation, relies on livestock production-- primarily beef cattle production-- to sustain beneficial grazing and rancher stewardship. Poor economic returns, production losses from weather, fire, or other causes, loss of access to forage, and conflict from the demands of a growing population put livestock ranching at risk in California. To understand how beef production can be sustained to provide ecological services, it must be understood as a social-ecological system (SES), where people and their activities work within and use nature.

In three research studies, I used mixed methods and qualitative research methods to examine key aspects of the social-ecological system framework that describe ranching in California and the San Francisco Bay Area. First, using document review, I studied ranching activities or the SES interactions that impact species conservation. Second, through interviews, survey, direct observation, and big data analysis of all recorded cattle movements in the state over two years, I considered the SES actors by examining the function of the production system that support ranching or rancher-livelihood requirements. In a final study, I conducted spatial analysis to document the role of grazing land in species conservation. I also examined case studies of exacted easements to assess impacts of a governance strategy for land protection increasingly impacting SESs on grazing lands.

Overall, the research revealed that land sharing, a conservation strategy for conservation in concert with agricultural production, is demonstrated on California's grazing lands. However, relationships between conservation, livestock production, and the people involved in managing grazing lands are varied and complex. A review of United States Fish and Wildlife Service's listing documents indicated that 143 species (51% of federally listed plant and animal species in California) are found in habitats with grazing. While livestock grazing is stated to threaten 73% of these species, 59% of these species positively benefit from livestock grazing, with substantial

overlap where species are both threatened by and benefit from grazing. Most threats result from overgrazing, while benefits result from grazing providing and maintaining habitat structure and ecosystem function in the management of the state's novel vegetation. Benefits to some species are provided across all of California's terrestrial habitats except alpine.

Extensive livestock grazing systems in California, providing benefits for species conservation, were found to be supported by the integration of production systems. Transportation and marketing enable ranchers, from small-scale to larger producers, to strategically move cattle to optimize production within a variable climate. Over 500,000 head, 47 percent of the state's calf crop leave extensive grazing lands in California and are moved to new pastures or feedyards over a 12-week period each year. Rancher interviews indicated that cattle are moved around and sold off grazing land in response to change in forage quality and quantity. These movements support their interest in managing for conservation objectives. Research results found that saleyards and cattle buyers drive efficiency by sorting, pricing, and moving cattle to match them to feed resources; however, transactions lack traceability to inform policy and consumer choice.

While beef production systems provide economic value for ranching and support ranchers' ability to manage grazing lands for conservation benefits, land protection strategies meant to support conservation on grazed lands can deprivilege livestock production. Exacted easements, which support development on some land through compensatory mitigation, provide for the conservation of threatened and endangered species by protecting other land. Exacted easements are increasingly viewed as a tool to conserve ranching, especially in areas like the San Francisco Bay Area, where much of the high-value conservation land is grazing land. These easements result in reterritorialization; land use is redefined, and land management activities may be restricted. However, they also create accumulation from conservation by providing new economic values from conservation services, which both challenge and support a rancher's place on the landscape and land sharing.

As revealed and described by the three research studies presented in this dissertation, cattle ranching on California's rangelands is a social-ecological system (SES), where ranchers steward land and manage grazing. Interactions in the SES, primarily livestock grazing, support ecological services like conservation of imperiled species conservation but rely on the rancher's ability to move livestock though transportation and markets to manage resources and provide economic viability. The SESs is economically viable through its contributions to beef production. Nevertheless, beef production in California and globally has a large footprint with consequences for human and animal welfare, environmental health, and nature conservation. To maintain a social license to continue producing beef, research needs to inform efficient and sustainable beef production practices, and the value of ecosystems services supported by beef production should be determined and understood.

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Chapter One

Introduction
Sustaining a social-ecological system to conserve species

In late February 2015 fourth-generation rancher, Tommy Williams brought six black Angus cows to graze the Arana Gulch, a 30-acre greenbelt neighboring the Santa Cruz Harbor in California. Cattle had not grazed the city-owned site since 1989. Prior to 1989, when it was grazed, the soils, climate, established seed bank, and grazing management on this small piece of California's coastal prairie supported the annual growth of more than 100,000 Santa Cruz tarplants (*Holocarpha macradenia*) (Clark 2015). This sticky forb is a federally listed threatened species and state listed endangered species. In 2014, there were only four individual tarplants in the greenbelt; there were none in 2015. After three years of seasonal grazing, tarplant numbers increased: 267 plants were counted in 2018 (FOAG 2021). Cattle grazing supports habitat for *H. macradenia* by reducing competition from non-native annual grasses during the growing season. It also removes plant biomass and prevents the accumulation of thatch that inhibits germination (USFWS 2014). Non-native annual grasses, which are naturalized and dominant across much of California's rangelands, compete with native plants for light, water resources, and space (Abraham et al. 2008, Beck et al. 2014).

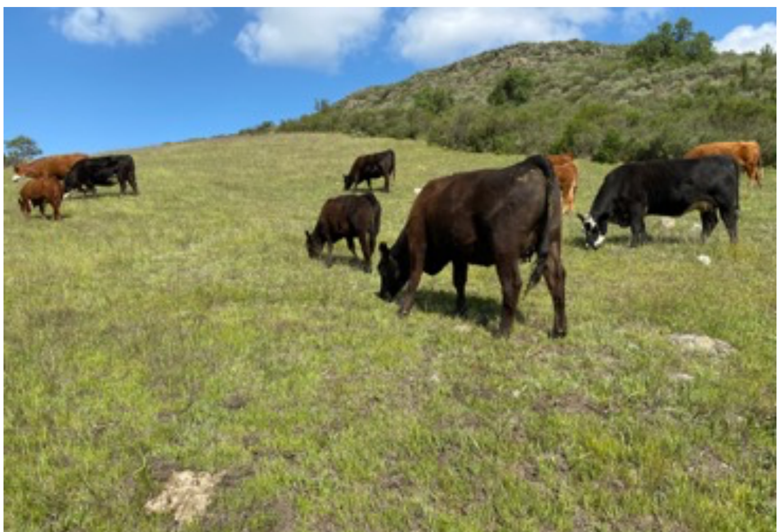

Fig. 1. Cattle grazing for Bay Checkerspot butterfly habitat at Santa Teresa County Park, San Jose, California. Photo by Sheila Barry, March 2020.

The use of livestock grazing to enhance habitat for imperiled species in California is not unique to the Arana Gulch or even the coastal prairie. In recent years, cattle have been re-introduced to serpentine grasslands in Santa Clara County's Santa Teresa Park to improve habitat for the threatened Bay checkerspot butterfly (Fig. 1) (Lyons 2017).

Livestock grazing supports vernal pool habitat for several listed species on US Fish and Wildlife lands in Alameda County (Cordell 2018) and on lands owned and managed by the University of California in Merced County (UCM 2021). In San Diego County, cattle grazing has been re-introduced to an ecological preserve managed by the California Department of Fish and Wildlife to support habitat for burrowing owls (CDFW 2018). Habitat values have also been recognized on privately owned and managed ranches in California. Landowners have accepted conservation easements which allow them to continue grazing on lands valued for habitat for several federal and state-listed species (for example, CRT 2020).

Defining the Lands that Provide Habitat and Support Beef Production

The lands providing habitat and supporting beef production may be described as grazing land or rangeland; however, neither term is a perfect fit. While grazing land may include some cultivated lands, e.g., croplands, irrigated pasture, less likely to provide substantial habitat, most grazing land in California is rangeland. Rangeland is delineated primarily by the type of vegetation. Spiegal et al. (2016) defines rangeland as: “land on which the vegetation is predominantly grasses, grass-like plants, forbs, or shrubs and which is managed as a natural ecosystem, even if the dominant plants are non-native.” This definition is particularly relevant to describe California’s rangelands which have been heavily invaded by non-native annuals. Rangeland may be grazed by livestock, but it is not synonymous with grazed land. In California, rangelands cover 23 million ha or approximately 58% of the state. While grazed land also referred to as “range” covers about 12.8 million ha or 32% of the state (FRAP 2017).

Terminology for land cover and land use notwithstanding, grazing is the most predominant land use in state, and as these previous examples show, ecological services are being provided by livestock grazing in California. However, ranchers are generally not compensated for providing these services. Instead, the provision of services like species conservation relies on rangeland livestock production-- primarily beef production-- to sustain beneficial livestock grazing.

Sustainability of beef production for species conservation, a research question

A central question driving my research is: Can beef production and ranching be sustained on California’s rangelands to support species conservation? Poor economic returns, loss of access to forage, production losses from weather, fire or other, and aging ranchers (Cameron et al. 2014, Brunson and Huntsinger 2008) put the future of livestock ranching in California at risk. Growing concerns from consumers about beef’s environmental footprint and its contributions to human health may negatively affect the future of beef markets. This public interest could also influence government policies, which allow and support grazing on both public and private land. For example, Eshel et al. 2018 showed eating less beef or eliminating beef from diets as a way to reduce environmental impacts from food production, including beef’s significant “use of pasturelands.” In addition to replacing omnivore diets with plant-based diets, cultured or synthetic meat (Post 2012) is promoted as a potential replacement for traditional protein sources, fulfilling nutritional needs while leaving a smaller environmental footprint (see New York Times, October 1, 2019). In an interview with *MIT Technology Review* in March 2021, Microsoft founder, Bill Gates said, “all rich countries should move to 100% synthetic beef” to cut greenhouse gas emissions driving climate change. He suggested regulations could be used to shift demand (Temple 2021).

Frequently, environmental concerns surrounding beef stem from a myopic consideration of its production as a mere land use for commercial purposes (see Broom 2019 and Eshel et al. 2014, 2018). From these assessments, researchers conclude that beef production “uses” more land than the production of any other food. However, there is no consideration for the ecological services provided from the management of extensive livestock grazing. While livestock ranching converts grass and other plants to food and products that support ranchers’ livelihoods, it also supports other ecological services, including those that maintain and enhance habitat for some native species (Yahdjian et al. 2015, Plieninger et al. 2012).

Ecological Services from beef production and ranching

Ecological services or benefits from natural processes have been defined from landscapes used by people including croplands, grazing lands, or forests as ecosystem services in the Millennium Ecosystem Assessment (MEA 2005). The assessment categorized ecosystem services, or the benefits people derive from ecosystems, into provisioning, regulating, supporting, and cultural services. On rangelands, beef production resulting from livestock grazing is a provisioning service. A provisioning service from rangeland also includes forage for wildlife (Havstad et al. 2007). Wildlife habitat, carbon sequestration, water quality, and pollination are supporting services provided by rangeland (Daily et al. 1997). Other ecosystems services from rangeland include open space and cultural amenities (cultural services) and fire protection (regulating services) (Campos et al. 2009, Huntsinger et al. 2010).

Ranching as a social-ecological system (SES)

I maintain that to sustain beef production to provide ecological services, it must be understood as a social-ecological system, where people and their activities use and work within nature (Berkes and Folke 1998). Developing policies and programs that support ranching viability requires understanding the ecological, social, and economic systems and the interaction thereof. Next, in this introduction, I review the framework of social-ecological systems described by McGinnis and Ostrom (2014) to show how it can apply to livestock ranching and the conservation of species in California. I close with an overview of the three studies in my dissertation that examine key variables of ranching within the social-ecological system framework to foster an understanding of how ranching can be sustained to support species conservation. These key variables include grazing's role in conservation (resource units), rancher livelihood requirements (actors and resource units), and conservation strategies (governance). In California's rangeland resource system, resource units, actors, and governance systems interact to support species conservation and livestock production, but they also affect one another (Fig. 2).

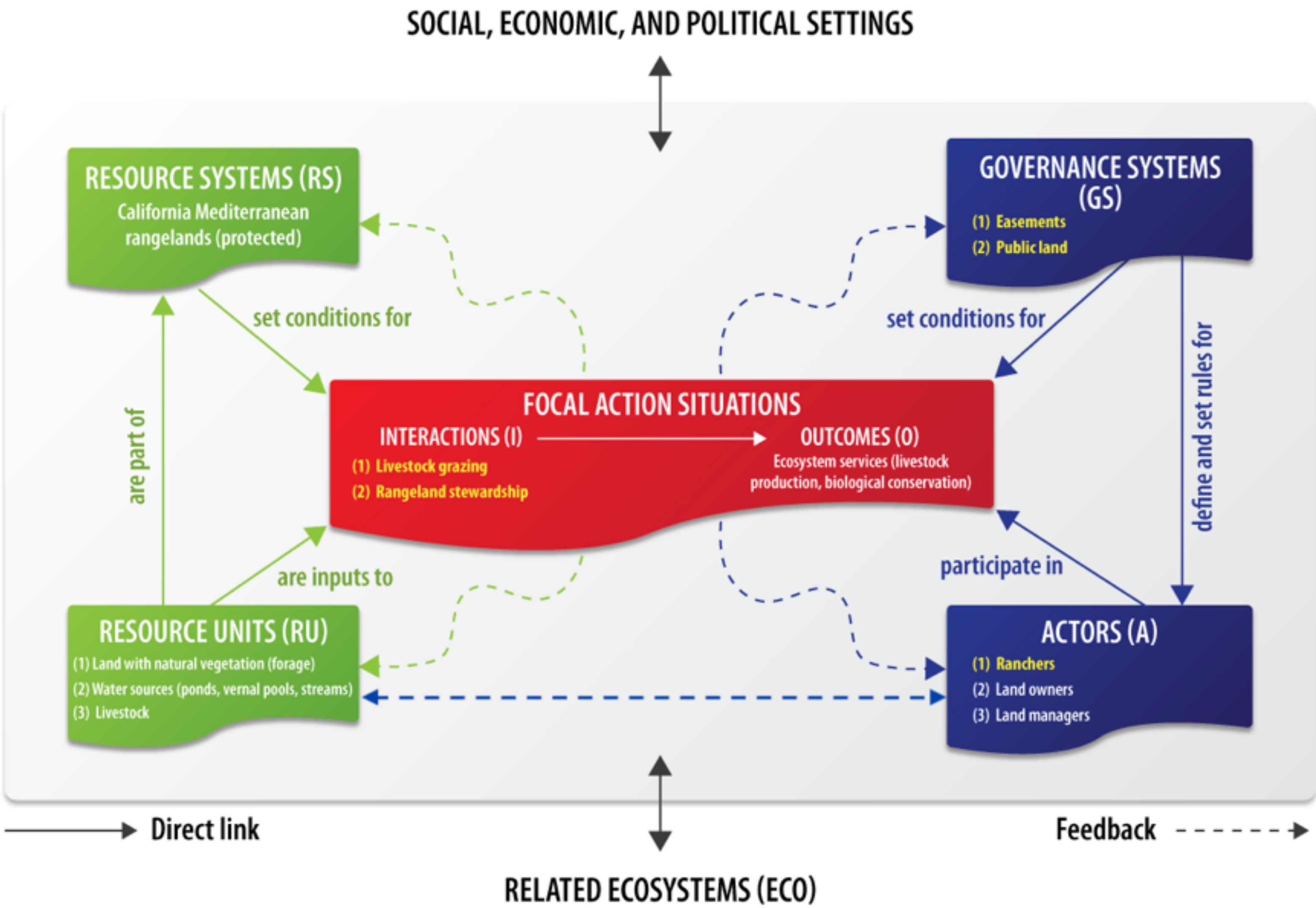

Fig. 2. Framework for the social-ecological system supporting ecosystem services provided by livestock ranching on protected Mediterranean rangelands in California. Adapted from McGinnis and Ostrom 2014.

As described by Ostrom (2009), a social-ecological system (SES) recognizes that connections between ecological and social systems are integral to conservation outcomes. The SES framework was initially developed for common-pool resources management (Ostrom 2009), where resources were considered to be extracted by users from an ecological system interacting within specific governance systems, but it has been modified to be more broadly applicable. The modified framework presented by McGinnis and Ostrom (2014) recognized that resource users may also maintain resources. The modified framework also considers that others who interact with resources may not be direct users of the resources e.g., landowners, policy makers. Hence, the term ‘users’ was generalized in the modified framework to ‘actors.’ However, the framework is not inclusive of the fact that ‘actors’ within SESs can provide ecological services. Huntsinger and Ovieda (2014) hold a view that ranching in California’s Mediterranean rangelands combines the production of commodities with the production of various ecosystem services. They conclude that ranching could be described as providing social-ecological services from social-ecological systems. Despite McGinnis and Ostrom’s (2014) focus on how SESs function to avoid environmental degradation, I found the framework to be useful to describe system variables, their connections, and the capacity of SES to provide ecosystem services.

Table 1 lists the variables of the SES framework proposed by McGinnis and Ostrom (2014) and applies them to ranching and species conservation in California. Rancher (actors) manage livestock on land with natural vegetation (resource units) on California’s Mediterranean rangelands (resource system) (Fig. 2). Controlled by governance systems, including land use and environmental regulations, conservation programs, government, and non-government entities, and marketing requirements, ranchers’ management of livestock and land stewardship (interactions) result in various conservation outcomes, including ecosystem services. Supplying ecosystem services such as food production of food and habitat maintenance may be synergistic (Bennett et al. 2009, Foley et al. 2005). However, there may be tradeoffs. Increases in provisioning services have been shown to decrease regulating, cultural, and supporting services (MEA 2005).

Management decisions reflect the balance between the supply of ecosystem services and multiple demands by actors and governance systems, each weighted by its relative social, economic, or political power. Governance systems may both ease and limit the provision of certain ecosystem services. For example, land use regulations may protect rangeland by preventing land use change. At the same time, environmental regulations or conservation strategies may even restrict infrastructure development and maintenance, such as maintaining a stock pond that supports grazing management and even acts as habitat for wildlife. Environmental (resource system) and biological factors (resource units) can also constrain rancher management and land stewardship.

Table 1. Social-ecological system (SES) variables and descriptions for rangeland livestock production and species conservation.

SES variables McGinnis and Ostrom (2014)	**Description for Rangeland Livestock Production and Conservation**
Social, economic and political setting (S)	Rancher population Government assistance programs, i.e., disaster programs Cattle and real estate markets Media coverage of beef impacts on environment and health Technology for management, production, and marketing
Resource system (RS)	California Mediterranean rangelands
Governance Systems (GS)	US & California Endangered Species Act Other environmental and agricultural regulations Conservation easements Public land and local land policy Livestock marketing requirements
Resource units (RU)	Land with natural vegetation (forage) Livestock water sources (ponds, vernal pools, streams, troughs) Livestock (number, class) Ranching infrastructure Markets and marketing infrastructure (transportation, sales yards, buyers)
Actors (A)	Ranchers Landowners, including NGOs, Government agencies Land managers, including NGOs, government agencies, and easement holders Cattle buyers
Interactions	Livestock grazing Ranching activities, including land stewardship Management activities, including regulations and monitoring
Outcomes Ecosystem Services	Livestock production Biological conservation

Three studies to understand the rangeland social-ecological system

Understanding complex social-ecological systems requires knowledge of specific variables and how they relate and interact with one another. I conducted the following three studies, presented as chapters two, three, and four, to describe the variables in ranching as an SES and develop an understanding of how livestock ranching can be sustained to deliver social-ecological services:

Chapter two. Rangeland land sharing, livestock grazing's role in the conservation of imperiled species

The first study, published in *Sustainability* in 2021, examines the role of livestock grazing on species conservation and demonstrates a role for land sharing. A land sharing conservation strategy advocates for conserving biodiversity on the same lands used for food production, like grazing lands (Kremen and Merenlender 2018). In contrast, land sparing is a strategy that segregates nature conservation from productive lands. Land sparing intends to use intensive, high-yielding agricultural production on a limited landscape while protecting other lands for nature conservation. The land sharing strategy is often presented as creating tradeoffs, where either food production yields or species conserved are sacrificed (Phalan et al. 2014). My research shows that neither agricultural production nor conservation is compromised on California's grazing lands. And in fact, species conservation and recovery in some cases increases.

Ranching and imperiled species in California often occur on the same landscape in California-both are widespread. About 40% of the state's landscape is grazed by livestock (Huntsinger et al. 2007), and – mentioned above – grazing is the most widespread land use in the state. With its varied climate, topography, and a growing population, California is a globally recognized biologically hotspot (Myers et al. 2000). In this study, I developed a database from official documents published by the USFWS for all federally listed threatened or endangered species in California as of December 1, 2017. The database covers 282 species (182 plants and 100 animals). The documents found on Environmental Conservation Online System (ECOS), and managed by the USFWS, include the final rules, recovery plans, and 5-year reviews. I compiled information on grazing's impact to listed species and habitat types, including reasons for grazing's effect on species conservation both threats and benefits.

Past assessments of impacts to listed species from ESA data have only discussed livestock grazing in terms of a threat, categorizing it as extractive (Wilcove et al. 1998), a resource use (Lawler et al. 2002), or a direct threat (Salafsky et al. 2007). However, an analysis of recovery plans for all listed species in the US found that 84% were "conservation reliant," which means they require some form of management to persist (Scott et al. 2010). Conservation reliance is considered on a continuum from captive-breeding programs to control of predators or invasive species, and maintenance of habitat (Scott et al. 2010). On California's Mediterranean rangelands, livestock ranching results in management of vegetation and habitat thereby supporting listed species (Germano et al. 2012, Marty 2005, Weiss 1999). This research documents the outcomes from grazing and rancher stewardship as an SES interaction (Fig. 2, Table 1).

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Chapter three. Livestock mobility through integrated beef production-scapes supports rangeland livestock production and conservation

While managed grazing contributes to species conservation, livestock ranchers create value from grazing by contributing to beef production. This second study, published in *Frontiers in Sustainable Food Systems* in 2020, describes the beef cattle production industry in California and how ranchers' mobility supports beef production and conservation outcomes. The US beef value chain is complex; it engages multiple producers operating in different production systems and includes various businesses and services providers. In California's beef industry, transporting and marketing animals integrate the extensive grazing system with intensive production systems, including feedyards. Within the SES framework, Table 1, this study documents the role of ranchers (actors) in managing livestock (resource units) to support beef production and conservation interest. It also describes the input and feedback from other actors (cattle buyers) and resource units (markets and market infrastructure) in supporting SES interactions and outcomes.

California's ranchers, like ranchers throughout the nation, are mostly small operators with less than 100 head and ranch income coming primarily from livestock sales rather than sales of meat (USDA 2017, Andersen et al. 2002). Due to forage resources and the current marketing system nearly all California ranchers, especially those grazing conservation lands, have a cow-calf or yearling stocker operation, and the majority do not supply a consumer end product. Instead, they rely on feedlots and processing facilities to produce a marketable product (Andersen et al. 2002). Accordingly, most beef cattle (non-dairy origin) in California are raised on operations based on rangelands and eventually shipped to a feedlot (or sometimes to grass) in or out of the state, for finishing.

My description of the beef production system from inspection data, direct observation, interviews, and surveys revealed the extent to which ranchers in California rely on saleyards to facilitate the movement of cattle and integrate their production with intensive production systems to create value. Ranchers said that their movements result from changes in forage quality and quantity, and support their desire to manage for conservation objectives, including reducing fire fuels, controlling weeds, and maintaining wildlife habitat. Saleyards and cattle buyers (SES resource units and actors, Table 1) drive beef production efficiency by sorting, pricing, and moving cattle and matching them to feed resources in more intensive production systems. For ranchers managing grazing and supporting conservation, this analysis highlights opportunities and constraints for ranching to maintain its economic viability.

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Chapter four. Land sharing on San Francisco Bay Area grazing land, implications of exacting easements on conservation values and valuing ranch work

Although ranchers and landowners capture revenue from livestock markets (provisioning services) or private consumption (provisioning and cultural services) (Campos et al. 2009), a substantial portion of the overall benefits are realized off-site by society including species conservation, carbon storage, and watershed functions (supporting and regulatory services) (Kroeger et al. 2010). Accordingly, ranchers do not often have an incentive to take the total value of ecosystem services into account when making management decisions, for example, about conversion and development. Landowners who are motivated to own rangelands and continue ranching increasingly depend on public-conservation payments, cost share programs and markets for ecosystem services (Kroeger et al. 2010, Liffmann et al. 2000, Plieninger et al. 2012). While meant to sustain land use, these governance systems, as shown in the SES framework (Fig. 2) set the conditions for conservation outcomes or ecosystem services and define how ranchers can steward lands and manage grazing.

Rangeland governance systems in California is increasingly a result of protection strategies including mitigation requirements associated with implementing the United States Endangered Species Act. With so many federally listed species in California, it is virtually impossible to conduct development or public works project without affecting a listed species or its habitat thereby triggering mitigation requirements often on grazed land. Mitigation drives funding, land use, and management; it results in land protection and new governance of grazing land and its resources through public acquisition and conservation easements. Conservation easements are a tool to protect rangeland ecosystems and listed species, but many ranchers use conservation easements to help sustain their ranching operations (Huntsinger and Oviedo 2014).

Using exacted easements to fulfill mitigation requirements is promoted as a 'win-win' solution. Environmental enhancements and long-term protection of conservation values are required on one site. For example, rangelands are often used to offset the negative impacts of a project on another site (Lippmann 2004). Rangeland owners not only receive help from the sale of their rights to develop their land, but they also extract ranching benefits. Ranching's pastoral management and stewardship often provide the conservation values that the exacted easement seeks to protect (Barry et al. 2007).

However, the promise of the 'win-win' for ranching and conservation through an exacted easement deserves a closer look. Conservation easements are prescriptive with prohibitions and not with affirmative actions. Through examining a case study of conservation easements, this third study considers how an exacted easement influences the landowner's relationship to the land, grazing and livestock management, and associated conservation values. This chapter has been submitted to *Ecology and Society.*

Conclusion

Chapter 5. Sustaining a social-ecological system for conservation and beef production

In the concluding chapter, key findings from the research presented in this dissertation are reviewed within a broader context of current discourses around the sustainability of beef production and its contribution to the global food system. New research directions to inform policy and economic opportunities that sustain social-ecological systems supporting conservation of grazing lands is also discussed.

Chapter Two

Rangeland Land-Sharing, Livestock Grazing's Role in the Conservation of Imperiled Species

The first study, published in Sustainability in 2021, examines the role of livestock grazing on species conservation and demonstrates a role for land sharing. On California's Mediterranean rangelands, livestock ranching results in management of vegetation and habitat thereby supporting listed species. This research documents the outcomes from grazing and rancher stewardship as an social-ecological system interaction.

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Abstract

Land sharing, conserving biodiversity on productive lands, is globally promoted. Much of the land highest in California's biodiversity is used for livestock production, providing an opportunity to understand land sharing and species conservation. A review of United States Fish and Wildlife Service listing documents for 282 threatened and endangered species in California reveals a complex and varied relationship between grazing and conservation. According to these documents, 51% or 143 of the federally listed animal and plant species are found in habitats with grazing. While livestock grazing is a stated threat to 73% (104) of the species sharing habitat with livestock, 59% (85) of the species are said to be positively influenced, with considerable overlap between species both threatened and benefitting from grazing. Grazing is credited with benefiting flowering plants, mammals, insects, reptiles, amphibians, fish, crustaceans, and bird species by managing the state's novel vegetation and providing and maintaining habitat structure and ecosystem functions. Benefits are noted for species across all of California's terrestrial habitats, except alpine, and for some aquatic habitats, including riparian, wetlands, and temporary pools. Managed grazing can combat anthropogenic threats, such as invasive species and nitrogen deposition, supporting conservation-reliant species as part of land sharing.

Keywords: livestock grazing; species conservation; land-sharing; invasive species; nitrogen deposition; conservation-reliant species.

Introduction

Livestock grazing is the widespread agricultural use of natural and seminatural landscapes throughout the world. Although estimates vary, as much as 50 percent of the world's land area is grazed by domestic livestock (Holechek et al. 2011). People have relied on grazing livestock as a source of high-quality protein for thousands of years, especially in ecosystems not usable for cultivation due to a lack of water, poor soils, harsh climate, rough topography, or high elevation. Throughout their history, grazing domestic livestock have generally shared grasslands with wild grazers and a host of other wild animals. Traditionally taking place on lands that are not arable, livestock producers are adapted to rearing animals on lands in a seminatural condition, sometimes with natural or anthropogenic fire, and other land management practices to keep woody vegetation in check and improve the forage for both wild and domestic grazers.

Despite technological and production shifts initiated in the twentieth century, the life cycle of commercial beef cattle in the United States still most often includes a significant period on grazing lands (Sayre et al. 2012, Galyean et al. 2011). Such lands have been promoted for conservation through land sharing under the rubric of "working landscapes" (Plieninger et al. 2012, Charnley et al. 2014). Land sharing, which encompasses wildlife-friendly farming practices, integrates biodiversity conservation with agricultural production on the same land (Green et al. 2005, Fischer et al. 2014). To better understand the relationship between livestock grazing and species conservation from land sharing, this study assesses the current impacts of livestock grazing, detrimental and beneficial, on the conservation of federally listed plant and animal species in California as stated in listing documents published in the United States Federal Register.

Listing documents used to implement the US Endangered Species Act of 1973 (ESA) identify plants and animals vulnerable to extinction, designate their critical habitat, and inform their recovery, including recognizing threats to the species and their habitats. The United States Fish and Wildlife Service (USFWS) administers and enforces the ESA for terrestrial species. The USFWS is required to use scientifically valid information to describe reasons for a species' demise and recommend actions for its recovery. The descriptions as outlined in Section 4 (a)(1) of the ESA consider five factors: (A) habitat loss, (B) overutilization, (C) disease or predation, (D) inadequate regulatory mechanisms, and (E) other natural or human-made factors affecting a species' survival. The impact of livestock grazing on a listed species and its associated habitat is included in the USFWS's analysis of the five factors when livestock grazing occurs with the species or within its habitat. The information provided is the current state of knowledge and continually changing; when new information is learned about a species' needs and survival, the five-factor information is updated through 5-year reviews and recovery plans.

A previous highly cited study, Wilcove et al. (1998), used ESA listing information published in the US Federal Register to quantify threats to listed species. They found 22% of all US-listed endangered, threatened, or candidate species (n = 1207) were impacted by habitat degradation or destruction resulting from livestock grazing. This finding is similar to Czech et al. (2000), which compared Federal Register documents and World Wildlife Fund compendium data for causes of the endangerment of 877 species. They found 16.0% were threatened by livestock grazing and 20.8% of the species by ranching, respective of the data source.

Both Wilcove et al. and Czech et al. provided little explanation of livestock grazing's role in species decline. Wilcove et al. (1998) categorized grazing as an extractive land use along with logging and mining. Czech et al. (2000) found a strong relationship between grazing threats and non-native species, which they noted was at least, in part, explained by grazing's modification of plant and animal community composition. However, there is a growing body of research from grazed lands worldwide that recognize the potential of domestic animal grazing to modify or maintain habitat in ways that benefit certain species (Howell et al. 2019, Schieltz et al. 2016, Bartolome et al. 2014, Germano et al. 2012, Marty 2015, Pyke 2005, Weiss 1999). In recent reviews, for example, positive impacts from livestock grazing maintaining open habitats were found for amphibian (Howell et al. 2019) and small mammal (Schieltz et al. 2016) species.

Livestock grazing affects biota and their ecological systems in varied and complex ways. Through consumption, physical impact, and nutrient redistribution, grazing livestock can change vegetation, soils, and habitats (Heitschmidt and Stuth 1991). Although these effects of grazing are well-known, whether they have negative or positive impacts in a particular ecosystem and on a specific plant or animals species depends on the species, the ecosystem, the current environmental conditions, as well as the management of the livestock and their grazing (Koerner et al. 2018, Milchunas 2006, Augustine and McNaughton 1998). In terms of livestock's influences on ecosystems and threatened and endangered species, herbivory should not be treated as a "black box".

Despite the varied and contrasting impacts of grazing, to date, there is no assessment of threats to imperiled species that considers livestock grazing's varied impacts on specific species and their habitats, positive as well as detrimental. If nothing else, Wilcove's concerns with the importance of conservation on private lands and the need for active management (Wilcove et al. 2004) calls for such an assessment since so much land in a natural and seminatural state is owned by ranchers, who rely on grazing for income and use it as a tool of active habitat management.

California is well suited for such an assessment. First, with a varied climate and topography and a growing population, the California Floristic Province, which includes most of the state and small parts of adjacent areas in Oregon, Nevada, and Baja California, Mexico, is one of the world's most biologically rich and endangered ecoregions; it is a globally recognized biodiversity hotspot (Myers 2000). Six thousand one hundred forty-three plant species are native to the province; 42% of these species are endemic (Burge et al. 2016). California has more federally listed species (282 in 2017) than any other state in the continental United States. With so much biodiversity at risk, threats to species and recovery activities have been identified for a large number of plants and animals across many species' groups.

Second, despite California's rich biodiversity, non-native annual grasses and forbs or broad-leaved plants are widely established and dominant across most of California's rangelands. These annuals are part of a novel ecosystem with large numbers of species from Mediterranean environments worldwide, many originating in the "Fertile Crescent", a domestication hearth (Baker 1989, Mooney 1986, Zeder 2008). Biological introductions, both intentional and unintentional, are pervasive, impacting native species and ecosystems in California and throughout the world (Simberloff et al. 2013).

Third, like much of the western United States, livestock grazing across the state is extensively managed, with about 40% grazed by livestock to some extent (Huntsinger et al. 2007). While California's Mediterranean climatic zone, which includes grasslands, hardwood woodlands, and chaparral, provides most of the forage consumed by livestock, two other zones also support extensive livestock production. The cold desert steppe, which is characterized by sagebrush grassland and pinyon-juniper woodlands, and the warm desert, which includes barren lands and, at higher elevations, montane meadows and conifer forest, provide seasonal grazing, primarily for cattle (Huntsinger and Bartolome 2014).

Another reason that California is well suited for an assessment of grazing impacts on listed species and associated habitats is that it is a natural laboratory to study land sharing. Although livestock grazing in the western United States has a relatively short history (<300 years) compared to Europe and Asia, native species found on California's rangelands evolved with herbivory by now-extinct megafauna, including medium to large herbivores, such as ground sloth, bison, camel, horse, mammoth, mastodon, and ox (Edwards 1996). Like in other parts of the world, conservation efforts in California increasingly consider livestock grazing a way to maintain extensive natural landscapes and their native diversity (Maestas et al. 2002), expanding available habitat well beyond the possibility for nature reserves. Land sharing provides an income to landowners through livestock production and reduces the risk of development or land-use conversion (Huntsinger et al. 2007, Diaz et al. 2013). While land sparing strategies emphasize separating nature conservation and agriculture, relying on intensification of agriculture on smaller areas to "spare" conservation areas, land sharing strategies seek to accomplish both biodiversity conservation and agriculture within the same landscape (Kremen 2015). This strategy is often presented as requiring trade-offs, where either agricultural yields or species conserved are reduced (Phalan et al. 2014). For instance, Butsic and Kuemmerle (2015) have suggested considering land-sharing and land-sparing across a spectrum where agricultural yields and species conservation are optimized depending on the ecosystems and species. Given the limited feasibility of intensifying agricultural production on many grazing lands (Mottet et al. 2017), including California's rangelands, livestock grazing may provide a decisive land-sharing opportunity where conservation is not compromised for agricultural production and species conservation and recovery for some species is enhanced.

A quantitative assessment from USFWS listing documents for multiple species across a wide variety of habitats grazed by domestic livestock allows detection of patterns that may explain the varied and sometimes contradictory responses from livestock grazing observed and often reported in the literature. This assessment of all federally listed species in California addresses the following questions (i) What is the role of grazing in the conservation of federally listed species? (ii) Does grazing's role in species conservation differ by taxonomic groups and across different ecosystems? Moreover, (iii) What are the specific reasons that plants or animals are threatened by or benefit from grazing? These three questions allow us to understand better land sharing's potential for conservation on livestock grazing lands in California. It is important to keep in mind that "grazing" occurs on all rangelands, by everything from caterpillars to elephants depending on location. However, in this paper, the term grazing refers to the agricultural pursuit of managed livestock grazing unless otherwise stated.

Materials and Methods

Federal Register documents published by the USFWS for all federally listed threatened or endangered species (182 plants and 100 animals) in California as of 1 December 2017, were reviewed. A searchable database of ESA documents developed by the Center for Conservation Innovation of the Defenders of Wildlife (Center for Conservation Innovation 2017) was initially used to identify species associated with grazing. ESA listing documents search through the database included the final rule for listing, 5-year reviews, and recovery plans.

Federally listed species were determined to be associated with grazing if "graz*", "overgraz*", or "trampl*" appeared in the text of at least one of the listing documents associated with an imperiled species in California (Table 1). Mentions of "grazing" and "trampling" were verified as being related to domestic livestock versus wild or feral animals. The term "livestock" was searched, but it did not yield additional species affected by grazing livestock or ranching. Other terms for herbivory, "browsing" and "foraging", were also searched but were not found to be used in the USFWS documents reviewed to describe interactions with livestock.

From the search results, an Excel database was developed with the document's title, type, date, web URL, and the associated listed species, as well as statements from the text regarding grazing. The data were sorted by species and date, and the newest listing document associated with each species with a grazing interaction identified. The complete listing documents were accessed from the Environmental Conservation Online System (ECOS), managed by the USFWS (2018). The most recent listing document was typically a 5-year review, but a recovery plan or the final rule was the latest in some cases. From listing documents, species type (plant or animal), animal species group, plant guild, and date of the latest listing document were recorded for each species. Information on the species' terrestrial and aquatic habitat was obtained from NatureServe Explorer Species reports under ecological and life history (Natureserve 2019). NatureServe Explorer Species reports, a product of NatureServe in collaboration with the Natural Heritage Network, are referenced on the USFWS ECOS website as an authoritative source of additional species information. NatureServe reports terrestrial habitat for species based on US National Vegetation Classifications at the formation level (Comer et al. 2003). Some species are found in multiple terrestrial or aquatic habitats, and all habitats were recorded for each species. From the NatureServe listing, the primary terrestrial and aquatic habitats, if applicable, were recorded for each listed species and included in the Excel database.

The USFWS uses various statements to describe the effects of livestock grazing on listed species and their habitats (Table 1). Statements on grazing were coded and categorized. A category for a grazing benefit and a grazing threat was independently assigned for each listed plant and animal species. Stated threats from "grazing", "overgrazing", or "trampling" were categorized as grazing threats. The threat of "loss or cessation of grazing" was considered to indicate a benefit from grazing. In USFWS documents, this threat results from lack of grazing leading to habitat degradation because grazing is acting to maintain habitat structure or function. "Inappropriate grazing" was typically categorized as both an indication of potential threat and benefit from grazing. The USFWS generally uses inappropriate grazing to mean that grazing at the wrong time or intensity is detrimental to the species or its habitat, while grazing at the right time and intensity may be beneficial. The benefit of appropriate grazing is indicated by statements like, "too little grazing is detrimental to the species or its habitat".

For species with mentions of grazing in initial listing documents but no statement on grazing's threat or benefit in the newest listing document, the categories, "no grazing threat" and "no grazing benefit" were used. The category "no grazing threat" also includes species where the USFWS states that "grazing is not a threat". The statement "grazing is a not threat" typically reflects a change in the USFWS's understanding of grazing's effect on a listed species, where previous listing documents had mentioned grazing as a threat to the imperiled species or its habitat.

Table 1. Categorization of grazing impacts on species conservation stated in the most recent United States Fish and Wildlife Service (USFWS) listing documents (5-year reviews or recovery plans) from 2000 to 2016 for each listed species in California where grazing is mentioned.

Categories for Grazing's Mention	Impact Statements or Category Descriptions
Livestock grazing current	Livestock grazing has a current relationship with listed species
No longer a factor	"Grazing is no longer a threat" because livestock is not present, or the habitat has been protected, and livestock has been excluded.
No current threat	Grazing was listed as present or threatening in previous listing documents, but there is no current mention of grazing.
Other grazing threatens	"Wild or feral animals, including burros, deer, gophers or rabbits, are a threat". This category was used only when grazing threats were limited to feral or wild animals.
Island species	Species and their habitat on the Channel Islands have been impacted by uncontrolled grazing of non-native feral and wild species, including cattle, sheep, goats, deer, elk, bison, and pigs. Most of these animals have been removed, but historical impacts persist.
Categories of grazing's current threats	
Grazing or overgrazing threatens	"Grazing or trampling by livestock is a threat". "Overgrazing, severe, heavy, intensive, improper, inappropriate, poor or unmanaged grazing or trampling is a threat". "Goat grazing for fuels breaks is a threat".
Unknown grazing threat	The impact of grazing on the species is unknown.
No grazing threat	"Grazing is not a threat". No grazing threat is stated.
Categories of grazing's current benefit	
Grazing benefits	"Appropriate, managed, controlled, optimal, moderate or light grazing benefits, enhances, restores or maintains". "Loss of grazing or cessation of grazing is detrimental or a threat". "Inappropriate grazing (which includes too little grazing) is a threat".
Unknown grazing benefit	"Grazing's benefit is unknown".
No grazing benefit	No benefit is stated.

"No longer a factor", "other grazing threat", "no current grazing threat", and "island species" are additional categories used in this study that describe the stated relationship between grazing and a listed species in listing documents (Table 1). The USFWS states that grazing is no longer a threat when grazing no longer occurs within the species' habitat, often due to protections that restrict grazing, e.g., reserve status. "Other grazing threatens" was used when listed plants or animals are not known to be impacted by domestic livestock, but the stated threat is from wild or feral herbivores, horses, or burros. "No current grazing threat" was assigned to species where the presence of livestock grazing was noted as a threat in early listing documents, e.g., USFWS final listing rule, but in the most recent documents, e.g., five-year reviews, livestock grazing was not mentioned.

Both "no longer a factor" and "other grazing threat" describe the threat of grazing to listed species endemic to the Channel Islands off the coast of California, but because of the unique grazing history of these islands, the 21 plants and three animals found only on the islands are categorized as "island species". Grazing threats were primarily from uncontrolled grazing by feral sheep and goats, deer, bison and elk. These animals were introduced to the islands and were generally not managed; they have now been nearly entirely removed.

Although initial results identified 209 species or 74 percent of the listed species in California where grazing is mentioned, the review of most recent documents found a current livestock grazing relationship with 143 species or 51 percent of the listed species (Table 2). Further analysis of grazing threats and benefits for this assessment was only considered for species with a current livestock grazing relationship.

Table 2. Number of listed animal and plant species in California with grazing mentioned in USFWS listing documents, oldest and current.

Livestock Grazing Mentions	# Animal Species	% Listed Species	# Plant Species	% Listed Species	Total	% Listed Species
Other grazers (feral, wild)	1		7		8	3%
Island species (historic, feral)	3		21		24	9%
No Longer (historic)	2		17		13	5%
No Current	6		9		14	5%
Livestock grazing current	56	56%	87	48%	143	51%
Total grazing mentions	68	68%	141	78%	209	74%
Total listed species	100		182		282	

The association between grazing's role on listed species and species attributes, including type, i.e., animal versus plant, animal species groups, plant guilds, and habitat types within terrestrial and aquatic systems, was determined using Pearson's chi-squared tests. Calculating the chi-squared statistic and comparing it against the chi-squared distribution indicates whether the observed pattern of responses is significantly different from expected if the variables were truly independent of each other (Franke et al. 2012). In this case, Pearson's chi-squared allows us to determine if grazing's role as a threat or benefit is independent of species' type, animal group, plant guild and habitat type.

To illuminate the specific assertions about the nature of grazing impacts beyond the broad categories of threats and benefit, reasons for grazing's stated role in the newest listing documents were coded and categorized and included in the database. Multiple reasons for grazing's benefit or threat are recorded for some species. Direct threats to an individual animal or plant or its natal site were differentiated from indirect impacts to habitat or ecological processes, e.g., plant succession, impacts to soil and water quality. All benefits were identified as indirect impacts.

Results

Grazing was considered an impact in listing documents for most of California's federally listed species (74%, 209 species). However, based on the most recent listing documents, the impact of livestock grazing on federally listed species is currently considered for 143 species or 51% of federally listed species in California (Table 2). The United States Fish and Wildlife Service (USFWS) updated listing documents based on the review of new information, including research findings, expert opinion, and reports, and in some cases, the presence or absence of grazing animals. Among federally listed species with a current grazing relationship, the USFWS states threats from livestock grazing for 73% (104) species but recognizes benefits from grazing for 59% (85) of the listed species occurring in the state (Table 3). Since a grazing benefit and threat were independently assigned for each species, there is considerable overlap. Both negative and positive impacts from grazing are reported for 65 species with a current grazing mention (Fig. 1). Threats and benefits to federally listed species from livestock grazing in California are primarily attributed to cattle, although the USFWS notes impacts from sheep and goat grazing for some species' populations.

Table 3. Number of listed animal and plant species in California (2017) with current grazing mention, percent of species threatened and benefiting.

Livestock Grazing Current (Threats and Benefits)	# Animal Species n = 56	% Current Animals	# Plant Species n = 87	% Current Plants	Total	% Listed Species
Grazing threat	47	84%	57	66%	104	37%
Unknown grazing threat	2	4%	5	6%	7	2%
No grazing threat	7	13%	25	29%	32	11%
Grazing benefit	36	64%	49	56%	85	30%
Unknown grazing benefit	0		4	5%	4	1%
No grazing benefit	20	36%	34	39%	54	19%
Both grazing threat and benefit	30	53%	35	40%	65	23%

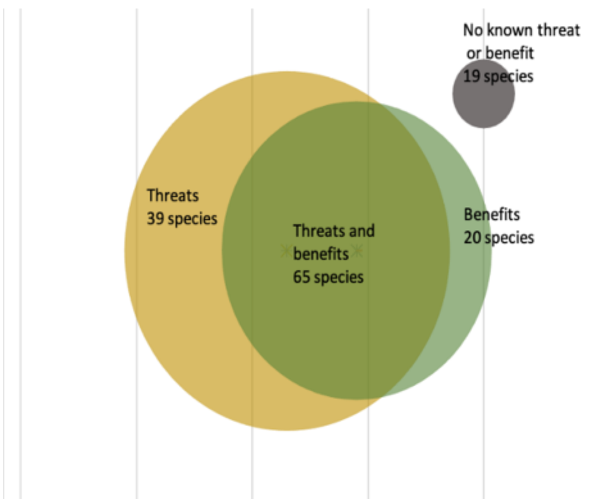

Fig. 1. Number of federally listed species with threats or benefits from grazing in most recent listing documents, including all federally listed species in California occurring with livestock grazing or in habitats grazed by livestock (n = 143 species).

Grazing's Impact by Species Type

Similar numbers of federally listed flowering plant and animal species in California occur in conjunction with livestock grazing, 56% (56) of animal and 48% (87) of flowering plant species; however, the USFWS more often states a threat to animal species from livestock grazing than to plant species. Grazing threatens 84% of the animal species and 66% of the flowering plant species with a current livestock grazing mention (Fig. 2, Table 4). In contrast, there is no relationship in grazing's stated benefits to species type, with 64% and 56% of the animal and flowering plant species benefitting, respectively (Fig. 2, Table 4).

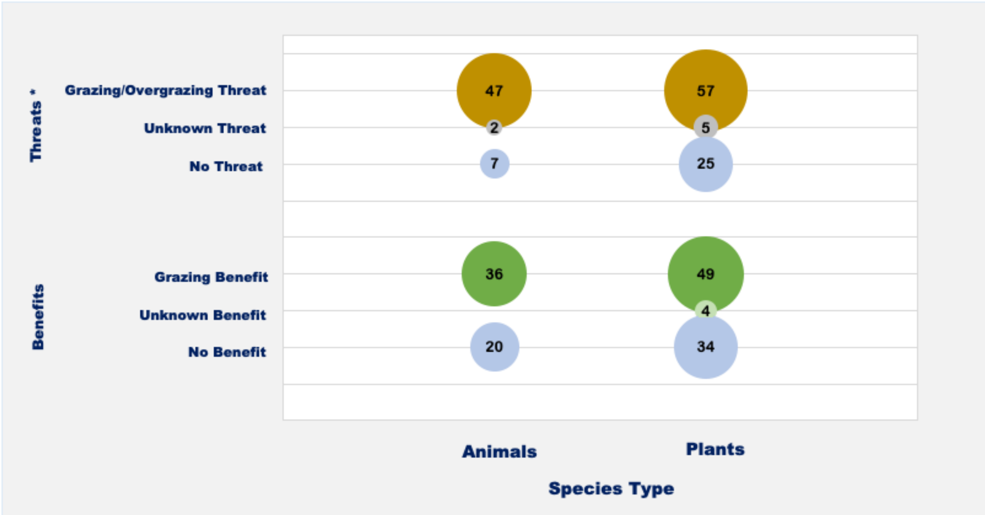

Fig. 2. Livestock grazing's impacts, threats, and benefits for federally listed species in California by species type. The size of the circle is relative to the number of species. Pearson's chi-squared test level of significance represented as * $p \leq 0.05$ for threats and no significance for benefits between species type $p > 0.05$.

Table 4. Summary of statistical analysis of differences in grazing's role as a threat and benefit concerning listed species in California. Level of significance represented as * $p \leq 0.05$ and ** $p \leq 0.01$.

		Threat				Benefit			
Difference in Grazing's Role for Each	**n**	**Pearson's X^2**	**df**	***p*-Value**		**Pearson's X^2**	**df**	***p*-Value**	
Animals vs. plants	143	5.931	2	0.05	*	3.04	2	0.22	
Animal species group	56	10.385	12	0.58		17.07	6	0.01	**
Plant guild	87	10.001	10	0.44		17.396	10	0.07	
Terrestrial habitat	105	25.835	16	0.06		29.161	16	0.02	*
Aquatic habitat	73	20.126	12	0.07		18.473	12	0.10	

Grazing's Impact by Animal Species Group and Plant Guild

All California animal and plant species groups with federally listed species have species that may be threatened or may benefit from livestock grazing except "conifers and cycads". Among animal species groups, there is no association between groups and threats from grazing (Table 4). Threats to animal species are widespread across all species groups, with at least 75% of the species within each species group being stated as threatened by grazing (Fig. 3). In contrast, the potential benefit from grazing varies by animal species group (Table 4). Amphibians, crustaceans, insects, mammals, and reptiles all have more species that benefit from grazing than species that do not benefit. Fishes and bird species are not likely to have a stated grazing benefit. Of listed California species, only one bird species (California Condor, *Gymnogyps californianus*) and one fish species (desert pupfish, *Cyprinodon macularius*) are noted to benefit from livestock grazing.

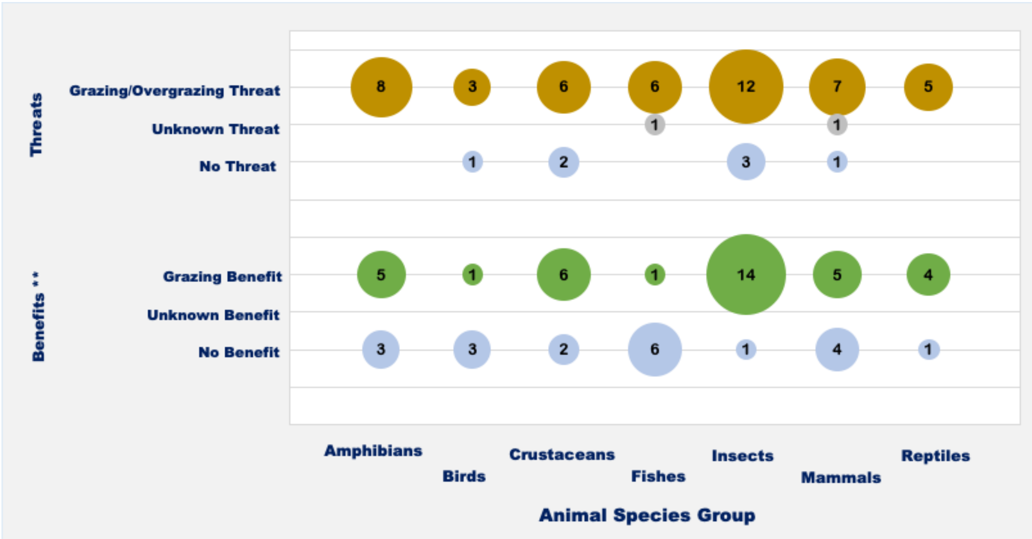

Fig. 3. Livestock grazing's impact, threat and benefit for federally listed animals in California by species group. The size of the circle is relative to the number of species. Pearson's chi-squared test no significance for threats $p > 0.05$ and level of significance represented as ** $p < 0.01$ for benefits.

Plant species with federally listed species are in the "flowering plants" and "conifers and cycads" groups. All the federally listed plant species in California impacted by livestock grazing are in the flowering plant species group. This group includes both annual and perennial species in the forb, grass, and grass-like plant guilds. However, most of the listed plant species (84%) impacted by grazing are forbs or broad-leaf plants (Fig. 4). There is no association between plant guilds and the stated likelihood of threat or benefit (Table 4).

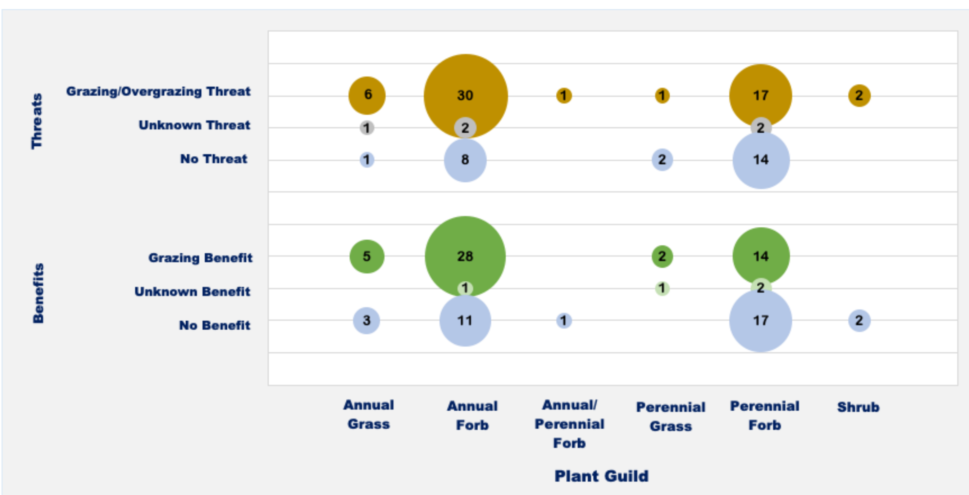

Fig. 4. Livestock grazing's impact, threat, and benefit for federally listed species in California by plant guild. The size of the circle is relative to the number of species. No significance for Pearson's chi-squared test for threats or benefits by plant guild $p > 0.05$.

Grazing's Impact by Ecosystem

Impacts from livestock grazing to listed species are found across a diversity of ecosystems in California. Plant and animal species may be found in or complete their lifecycle in multiple types of terrestrial or aquatic habitats. Of those species with a grazing relationship, 52% are found only in terrestrial habitats, 25% are found only in aquatic habitats, and the remainder, 23%, may use or spend different parts of their lifecycle in both terrestrial and aquatic habitats.

Some species are threatened, and some benefit from grazing in every terrestrial habitat type with livestock grazing in California except alpine, where Sierra Nevada bighorn sheep may contract a disease from domestic sheep (USFWS 2008), but no benefits from grazing are noted. Although 60% of the species that benefit from grazing in terrestrial habitats are found in grasslands (Fig. 5), there are more species with a stated grazing benefit than with no benefit in grasslands, barren land, and woodlands. There was no association between terrestrial habitat types and the number of species threatened by grazing (Table 4).

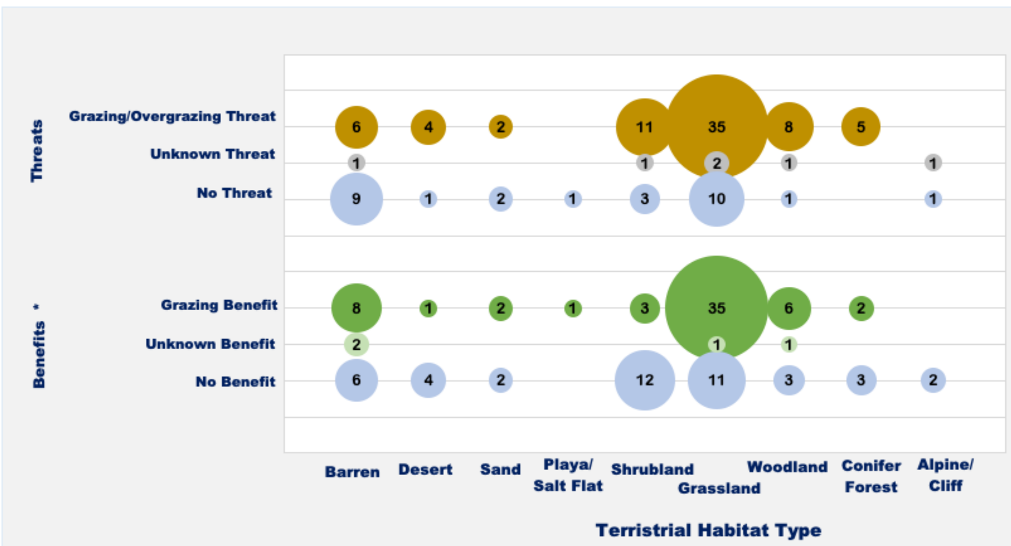

Fig. 5. Livestock grazing's impact, threat and benefit for federally listed species by terrestrial habitat type. The size of the circle is relative to the number of species. Pearson's chi-squared test no significance for threats $p > 0.05$ and level of significance represented as * $p \leq 0.05$ for benefits.

Listed species impacted by livestock grazing are also found in various aquatic habitats, but most are found in temporary or vernal pools, 62% (Figure 6). On California grasslands, federally listed species using temporary pools for all or part of their lifecycle include 21 plant species, annuals and perennials, and 12 animal species, amphibians, crustaceans, fish, and insects. While grazing threats are stated for some species in every aquatic habitat type with listed species impacted by grazing, benefits from grazing are found for some federally listed species in temporary pools (including vernal pools), wetlands, riparian, and springs (Fig. 6). There is no association between the likelihood of stated grazing benefits or threats for a particular species from grazing with aquatic habitat types.

In summary, this assessment considered the number of federally listed species in California by species type, animal species group, plant guild, terrestrial habitat, and aquatic habitat that is threatened by or benefit from livestock grazing. The number of species stated as threatened by grazing in California only differs significantly by whether they are an animal or flowering plant, not among animal species groups, plant guilds or habitat type. In contrast, the number of species found to benefit from grazing is related to animal species group and type of terrestrial habitat (Table 4).

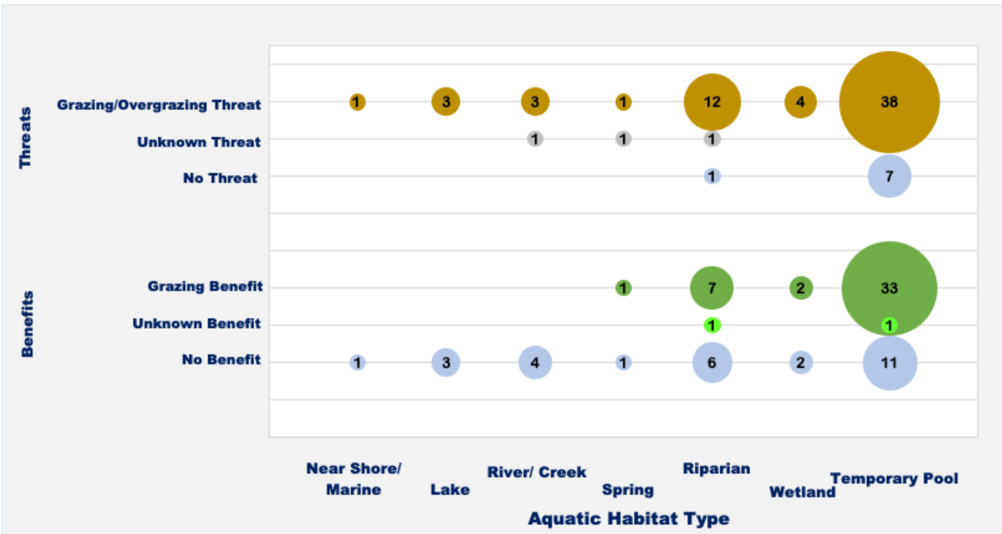

Fig. 6. Livestock grazing's impact, threat and benefit for federally listed species by aquatic habitat type. The size of the circle is relative to the number of species. No significance for Pearson's chi-squared test for threats or benefits by aquatic habitat type.

The Reasons Livestock Grazing Threatens Species

The primary reasons stated for grazing's threat differ between federally listed plant and animal species. Direct impacts, including the potential for a plant or part of a plant to be consumed or trampled by livestock, is the most frequently stated threat to plant species; 58% of the listed flowering plant species occurring in grazed habitats were reported to be threatened by direct impacts (Fig. 7). Evidence of direct impact from grazing and trampling is mostly anecdotal, although sometimes it is reported with observations, including description or data.

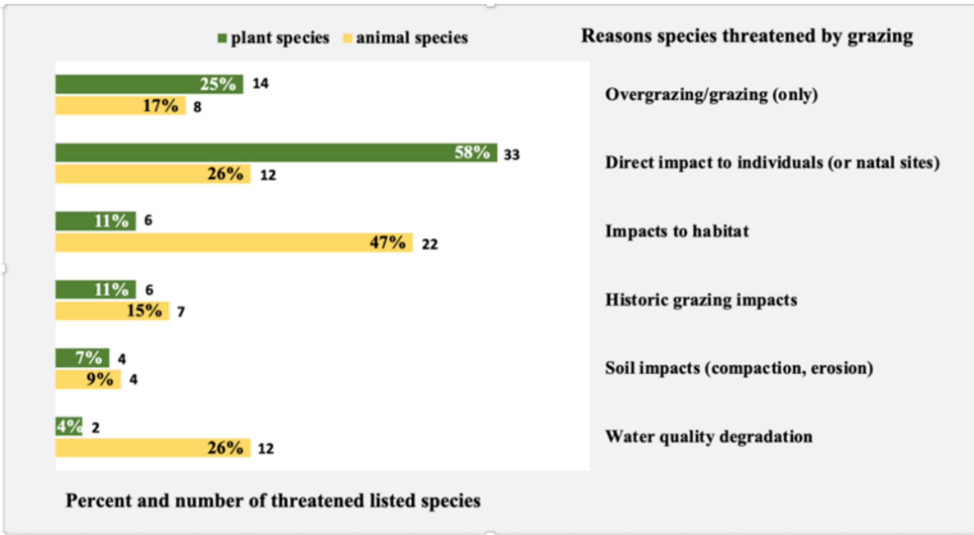

Fig. 7. Reasons for livestock grazing's threat to federally listed plant and animal species in California.

In reporting the threat from direct impact from grazing and trampling, the USFWS recognizes that grazing threats to individuals do not necessarily result in species decline or drive a plant species to extinction. For example, in describing grazing impacts on the annual forb, *Sidalcea keckii*, the USFWS reported that cattle were observed causing damage by eating the plants, but the damage was barely noticeable a week later (USFWS 2012). Similarly, the USFWS (2014) reported cattle herbivory and trampling impacts to the perennial forb, *Cirsium fontinale var. obispoense*, but cites a 1998 study where researchers determined that grazing impacts, which were to mature plants, were offset by an increase in juvenile plants.

There are, however, a couple of examples where direct impacts of grazing were reported to have facilitated extirpation in listing documents. A population of the shrub, Arctostaphylos pallida, already weakened by a root fungus and shading, was considered extirpated by goats grazing at intensities designated to reduce fuel loads (USFWS 2010). Trampling by cattle was reported to have extirpated a population of *Cordylanthus mollis spp. mollis*. This annual forb is supported by fragile underground connections, haustoria that were considered to have been damaged by trampling (USFWS 2009). The USFWS in listing documents often states that direct impacts are primarily a risk to species under situations of overgrazing or heavy grazing, and when listed, species have small or isolated populations that are vulnerable to stochastic expiration.

After threats from direct impacts, "grazing", or more often "overgrazing", with no specific explanation, is the most frequently stated reason livestock grazing threatens a flowering plant species. As described in Table 1, "overgrazing" as a threat includes severe, heavy, intensive, improper, inappropriate, poor, or unmanaged grazing or trampling. Overall, 83% of listed flowering plant species occurring in habitats with livestock are stated to be threatened by grazing or trampling's direct impact on a plant, or grazing or overgrazing (Fig. 7).

On the other hand, federally listed animal species are primarily threatened by indirect impacts from habitat loss or degradation, which is the stated reason that grazing threatens 47% of federally listed animal species (Fig. 7). Impacts to habitat from livestock grazing include introductions and increases in invasive species and loss of riparian vegetation. Water quality degradation, which includes livestock grazing causing excess sediment and nutrients or higher stream temperatures, is a stated impact on 26% of the federally listed animal species found in grazed habitats in California. In addition, 26% of the animal species are threatened by direct impacts to individuals or natal sites, e.g., burrows or nests. Other less frequently stated threats to listed species plant and animal species from grazing and trampling include other indirect impacts to hydrologic functions and soil condition, e.g., erosion and compaction (Figure 7).

While threat reasons to listed species from grazing were individually identified for analysis in this assessment, the impacts are not necessarily independent. The USFWS describes the cascading effects of livestock's impact on ecosystem processes leading to habitat degradation and diminishing survival or recovery for some species. For example, livestock impacts to water quality, stream channels, and riparian vegetation threaten the Little Kern golden trout, *Oncorhynchus mykiss whitei*, and Paiute cutthroat trout Oncorhynchus clarkii seleniris (USFWS 2011, 2013). As described in the listing documents for these fish species, livestock may concentrate in riparian areas due to water availability, green vegetation, and shade. Fish habitat is degraded by the reduction in water holding areas, shade, and cover, resulting in increased water temperatures and decreased water quality from excess sediment and nutrients. However, the USFWS listing also notes that grazing has occurred in the drainage of the Little Kern golden trout for more than 100 years, and it is known that controlling the timing and intensity of grazing can minimize impacts (USFWS 2011). Similarly, the USFWS states that grazing threats to Paiute cutthroat trout have been reduced because grazing has either been eliminated from their habitat or conservative grazing management objectives have been put in place (USFWS 2013).

The Reasons Livestock Grazing Benefits Species

Benefits from livestock grazing to the survival or recovery of federally listed species all result from indirect impacts. For plant and animal species in California, species benefit from grazing that maintains or enhances habitat by controlling non-native annual plants (biomass, cover, and height), reducing thatch (buildup of dead vegetation), maintaining hydrologic functions (inundation period), mitigating dry atmospheric nitrogen deposition, preventing land-use change, providing disturbance creating some bare ground, or preventing woody plant invasion from maintaining grassland (Fig. 8). Controlling non-native species, mostly non-native annual plants, is the most frequent reason stated that grazing benefits both federally listed flowering plant and animal species in California; 89% of species positively impacted by livestock grazing benefit from control of non-native species. For example, in the USFWS listing documents for several insects (ten butterflies and one moth), controlling non-native annual grasses is stated to favor native forb or broad-leaf plant populations supporting the conservation of these species, which rely on forbs for nectar and larvae food. Similar to grazing threats, grazing benefits were individually recognized for this assessment, but many are related to one another.

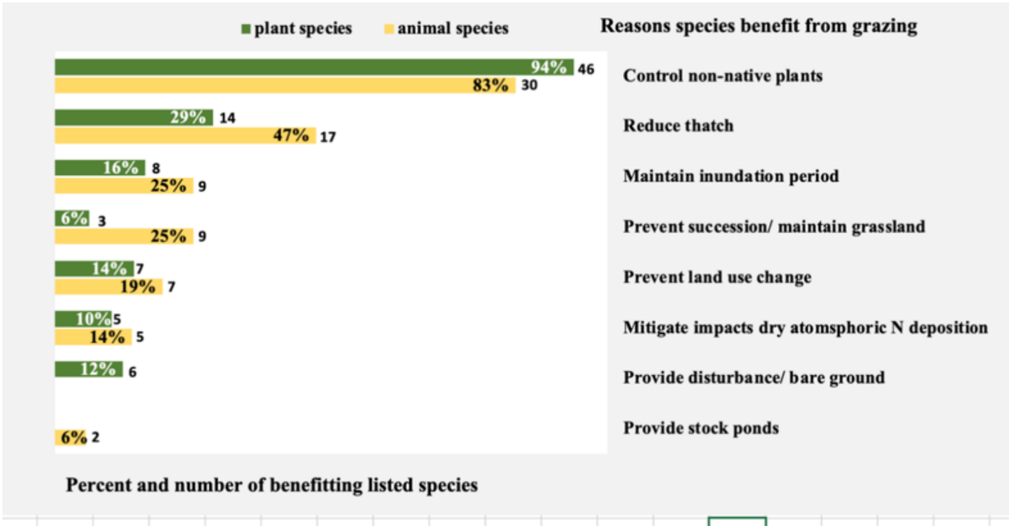

Fig. 8. Reasons for livestock grazing's benefit to federally listed plant and animal species in California.

In addition to controlling non-native plants to favor certain species, grazing is stated to benefit some listed species by controlling vegetation that alters habitat, including thatch (Figure 8). In the grasslands and shrublands of the San Joaquin Valley of California, for example, maintaining habitat with sparse vegetation supports various listed species, including Kern mallow (E*remalche parryi ssp. Kernesis*) (USFWS 2013), blunt-nosed leopard lizard (*Gambelia silus*) (USFWS 2010), giant kangaroo rat (*Diposdomys ingens*) (USFWS 2010), and San Joaquin kit fox (*Vulpes macrotis*) (USFWS 2010). For the small ground-dwelling native vertebrates, annual grass and thatch can create an impenetrable thicket (USFWS 2010). For the larger native vertebrate, San Joaquin kit fox, taller, dense vegetation can obscure their visibility of predators (USFWS 2010). Habitat with sparse vegetation is also necessary for both listed plant and animal species in coastal grasslands, including the Santa Cruz tarplant (*Holocarpha macradenia*) (USFWS 2014) and Ohlone tiger beetle (*Cicindela ohlone*) (USFWS 2009).

Some species (five plants, annual and perennial forbs; five animals, insects and a reptile, Fig. 8) benefit from grazing that controls vegetation associated with air pollution. The USFWS cites research that shows air pollution, specifically dry atmospheric nitrogen deposition, creates a fertilizer load that alters plant communities and habitat, and livestock grazing can maintain habitat by removing excess vegetation and nitrogen [Weiss 1999, USFWS 2009]. Grazing's control of vegetation is also associated with maintaining grasslands by preventing succession or invasion by brush to benefit some animal and plant species (Figure 8). For listed plants like the Western Lily, Lilium occidentale that are threatened by loss of grassland, the USFWS (2009) has stated that the benefits of grazing seem to outweigh the potential threat from these plants being grazed or trampled.

Within aquatic habitats, species benefitting from grazing, which includes flowering plants, amphibians, and invertebrates, are primarily found in temporary or vernal pools, where livestock help maintain an adequate inundation period, for example, [USFWS 2012, 2103]. Listing documents for species in temporary pools cite research by Marty (2005) and Pyke and Marty (2005) that describe increased grass cover in and around ungrazed vernal pools leading to increased evapotranspiration and decreased pond duration. Other benefits stated for listed species in aquatic habitats include a couple of animal species that benefit from the presence and maintenance of stock ponds associated with livestock grazing. Livestock grazing is also credited with maintaining a compatible land use for six animals and four plants (Fig. 8), despite development pressure—a direct link to the land-sharing concept.

Discussion

Livestock grazing is a widespread land use in California and has often been considered a threat to conservation (see Wilcove 1998, Czech et al. 2000), regardless of whether or not confirming research has been conducted (Fleischner 1994, Brown and McDonald 1995). Despite this, this assessment from the USFWS listings shows a complex and varied response to grazing among imperiled species and their habitats. Beginning in 1769 with the arrival of Spaniards in California, livestock grazing, among other things, contributed to introducing and spreading non-native species (D'antonio and Meyerson 2002, Jackson and Bartolome 2007) resulting in habitat loss and a novel ecosystem. Now, as documented in this assessment, grazing is credited with controlling non-native plants and thatch buildup and maintaining specific habitat structures and functions for many listed plant and animal species. The fact that USFWS identifies grazing as a threat and a benefit to many species indicates that how grazing is done matters. Grazing management certainly affects the conservation outcome for the listed species in California that are either negatively or positively affected by grazing (n = 65).

Value and Limitations of Best Available Science and the USFWS Listings

In fulfilling ESA requirements to identify threats that put species at risk of extinction, the USFWS documents indicate the relationship between livestock grazing for every threatened and endangered species based on the "best scientific and commercial data available". In many cases, the studies needed to understand better how species and habitat respond to grazing over time or to a particular grazing pattern have not been done. In the absence of published research for many species, applying the best available science means that threat information may be based on expert opinion, including observations and unpublished data, or may be extrapolated from research findings for similar species or ecosystems (Lowell and Kelly 2016). For example, in some cases, threats to species are based on assessments of grazing's impact on western rangelands or aquatic habitats, including Fleischner (1994) and Belsky et al. (1999). Often as not, grazing benefits are identified when grazing exclusion leads to loss of the species targeted for protection (Weiss 1999, Hayes 1998, Germano et al. 2001), and these research findings may be applied to similar species in similar habitats.

While the use of the best available science allows for thorough coverage of all listed species potentially impacted by livestock grazing or other threats, it also means that some statements of effects are amplified as findings are repeated. In this assessment, using the best available science from the USFWS listings may limit our assessment of patterns relative to grazing's impact across species types, groups, or ecosystems. It should also be recognized that the USFWS listing documents are not always up to date, and just like California ecosystem conditions, things are continually changing. The full picture of grazing impacts over time and with variation in conditions is seldom fully known (Schieltz et al. 2016, Briske et al. 2011). The analysis here adds more depth and detail to the complexities of the situation in considering the role of livestock grazing in land sharing based on the diversity of species and their habitats that are threatened by or benefit from grazing.

Proper Management to Minimize Threats

Terms, including severe, heavy, intense, improper, unmanaged, uncontrolled, or overgrazing, have all been used by the USFWS to describe grazing and trampling impacts that threaten listed species. Generally interchangeable with "overgrazing", these terms are not consistently defined or applied in listing documents or in the scientific literature (Mysterud 2006). Overgrazing implies that grazing is in excess of management goals (Coughenour et al. 1991) or has described any grazing that results in negative impacts (Mysterud 2006). Whether or not a species is at risk from "overgrazing" depends on the severity and frequency of the grazing impact, the ecosystem, and adaptations of the plant or animal to grazing or its outcomes (Schieltz 2016, Diaz et al. 2007).

In this assessment, the likelihood of threat to listed species from livestock grazing was not associated with ecosystems, plant guilds, or animal species groups (Table 4). Instead, grazing was found to threaten numerous species across all species groups and habitat types, suggesting that some grazing level, typically unmanaged or excessive, can impact any habitat and affect the survival of most species on grazed lands. There is evidence in the published literature that grazing managed inappropriately can change species composition, cause erosion and decrease productivity and fail to meet habitat conservation goals (Belsky 1999, Diaz et al. 2007, Boyd et al. 2014, Krausman et al. 2009, Jones 2000); however, grazing can also be managed so that negative impacts are mitigated and minimized. From a comprehensive review of literature on grazing systems and impacts, Briske et al. (2011) concluded that grazing intensity, a function of stocking rate and livestock distribution is the single most important management factor influencing conservation outcomes and livestock production in grazed systems. Controlling grazing intensity with proper stocking rates coupled with livestock distribution practices, including water distribution, supplement placement, herding, and fencing, have been found to reduce impacts of livestock on rangelands, including impacts in riparian areas (Briske et al. 2011, George et al. 2011, Sliwinski et al. 2015, Malan et al. 2018, O'Callaghan et al. 2019, Derose et al. 2020).

Grazing Supports Conservation Reliant Species

Managed grazing can reduce threats from grazing to listed species and meet livestock production needs (Briske et al. 2011, Holechek 1999), but it is grazing's benefit to species conservation that defines a role for land-sharing and counters arguments that suggest land-sharing requires trade-offs between species conservation and agricultural production. Ranching's benefit in protecting rangelands from development has been valued across the western US and throughout much of the world where land is at risk for development (Maestas et al. 2002, Luoto et al. 2003). Between 1984 and 2008, over 195,000 hectares of California's rangeland habitats were converted to residential development or intensive agriculture (Cameron et al. 2014). In this assessment, the benefit of maintaining ranching as compatible land use was recognized for a few listed species (seven animals, eight plants, Figure 7), but the value of grazing as a process was recognized for many more animals and plants.

Grazing has been described as a natural or even keystone process in ecosystems that have evolved with grazing (Knapp et al. 1999). The plants and animals in these systems are considered to have co-evolved with herbivores and exhibit adaptations that support their success while being grazed (Milchunas et al. 2006). In systems with ecological and evolutionary grazing histories, livestock grazing can replace some of the functions provided by native herbivores, which may be extirpated, or incompatible with current land uses. However, the benefits to listed species from grazing in California are often indifferent from local evolution and grazing history because the native flora has been largely replaced. Instead, livestock grazing is playing a pivotal role in mitigating the environmental consequences of anthropogenic-driven change, including invasive and naturalized non-native species and nitrogen deposition, and in fact, the management of a novel ecosystem comprised of plants from other places.

This value of grazing for species conservation is explained, at least in part, by the concept of “conservation reliant” species (Scott et al. 2005, Rholf et al. 2014). Due to anthropogenic activities’ impacts on a species or its habitat, many species require ongoing conservation management actions to recover or even persist, becoming conservation reliant. Scott et al. (2010) examined the management actions required by recovery plans for species listed under the ESA and found that 84% of 1136 species are conservation reliant. The most common management actions reported for conservation-reliant species were control of other species, active habitat management, and artificial recruitment.

Invasive plants are a major challenge to the conservation of native species throughout the world and a leading driver of extinction (Blackburn et al. 2019), and several researchers have concluded that California has some of the most heavily invaded ecosystems (Zavaleta et al. 2001, Kettenring and Adams 2011, D’antonio and Vitousek 1992). Non-native annual grasses are naturalized across California’s grasslands, shrublands, and woodlands (Shapero et al. 2018). They have also colonized areas in California that were once sparse with vegetation like dunes (Stark et al. 2012) and desert (Germano et al. 2011) or areas once dominated by low-growing broad-leaved plants (Minnich 2008). They are larger statured than most native broad-leaved plants, highly resilient to grazing and drought, and reproduce with vigor from high seed production and fertility. The ubiquitous presence and impact of naturalized non-native grasses underlie livestock grazing’s benefits for many species across various ecosystems. While stated benefits were more common for listed species in grasslands than in other habitats, species benefitting from grazing’s control of non-native species and habitat management, in general, are found on barren lands, desert, sand, playa or salt flats, shrublands, woodlands, and conifer forest as well as temporary pools, wetlands, and riparian zones. A decline and extirpation of native species are evident when livestock grazing is removed from ecosystems that are naturally open and barren but now crowded by invasive species and thatch (Germano et al. 2012, Marty 2015, Pyke and Marty 2005).

While this study focused on grazing’s impacts on threatened and endangered species, the effects identified are also related to species, not a risk, e.g., forage and pollinator plants for listed insects (Weiss 1999, USFWS 2009), and may apply to other species on grazed lands. The value of some level of grazing to support biodiversity in grasslands has been demonstrated in many locations worldwide (Yuan et al. 2016, Loeser et al. 2007, Rook et al. 2004, Fuhlendorf and Engle 2001, Noy-Meir 1995). When livestock are managed to prevent over utilization and habitat degradation, grazing can impact rangeland vegetation, increasing heterogeneity or patchiness and creating habitat for a greater diversity of species (Fuhlendorf and Engle 2001, Holechek et al. 2006, Davidson et al. 2017). In California, the continued and growing impact of non-native species driven by anthropogenic activities, including climate change, inadvertent species introductions, and air pollution (Weiss 1999, Chaplin-Kramer and George 2013, Fenn et al. 2010), extends the value of grazing to support listed species across all terrestrial habitats and in some aquatic habitats.

Lunt et al. (2007) proposed a framework to assess grazing’s value for achieving conservation objectives in different ecosystems in Australia. Like stated reasons for grazing’s benefit to species conservation in this assessment, they found grazing to be beneficial when it either (1) controls the biomass of potentially dominant, grazing-sensitive plants, (2) prevents encroachment by undesirable, grazing-sensitive, potential dominants, (3) provides required disturbance niches (4) maintains habitat structure or (5) enhances the diversity of species and vegetation structures across the landscape. This framework could be used to evaluate the role of grazing and rangeland livestock production in land sharing in many ecosystems.

Conclusions

This review of the USFWS listings documents concludes that many federally listed species in California are conservation reliant, requiring continued interventions to support their lifecycle or maintenance of habitat and that sharing land with livestock grazing will continue to be an important conservation strategy. Most, if not all, ecosystems on the planet have been altered by land use and other anthropogenic effects. Threats to biodiversity stemming from pervasive non-native species, climate change, and the disruption of essential ecosystem processes and disturbance regimes may not be overcome simply by preserving land, improving regulatory protections, and removing threats (Carroll et al. 2015). Livestock grazing is perhaps the only ongoing land use that can be feasibly manipulated to manage vegetation and habitats at the landscape scale.

Chapter Three

Livestock mobility through integrated beef production-scapes supports rangeland livestock production and conservation

While managed grazing contributes to species conservation, livestock ranchers create value from grazing by contributing to beef production. This second study, published in Frontiers in Sustainable Food Systems in 2020, describes the beef cattle production industry in California and how ranchers' mobility supports beef production and conservation outcomes. Within the sustainable-ecological systems (SES) framework, this study documents the role of ranchers (actors) in managing livestock (resource units) to support beef production and conservation interest. It also describes the input and feedback from other actors (cattle buyers) and resource units (markets and market infrastructure) in supporting SES interactions and outcomes.

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Abstract
Much of the world's rangelands contribute to food production through extensive grazing systems. In these systems, livestock producers, pastoralists and ranchers move grazing animals to access variable feed and water resources to create value while supporting numerous other ecosystem services. Loss of mobility due to political, social, ecological, and economic factors is documented throughout the world and poses a substantial risk to rangeland livestock production and conservation of rangeland resources.

The integration of production-scapes can facilitate livestock mobility through transportation and trade. This paper describes the beef cattle production system in California, where transporting and marketing animals integrate an extensive grazing system with intensive production systems, including feeding operations. Analysis of livestock inspection data quantifies the magnitude of livestock movements in the state and the scope of production-system integration. Over 500,000 head – 47 percent of the state's calf crop – leave California rangelands and are moved to new pastures or feedyards seasonally over a 12-week period each year. Most ranchers in California, from small-scale producers (1 to 50 head) to larger producers (more than 5000), participate in the integrated beef production system. Less than 1% of steers and heifers go from rangeland to meat processing. Like pastoralists, ranchers strategically move cattle around (and off) rangeland to optimize production within a variable climate. Ranchers indicate that their movements result from changes in forage quality and quantity and support their desire to manage for conservation objectives, including reducing fire fuels, controlling weeds, and managing for wildlife habitat. Inspection data, as well as direct observation, interviews, and surveys within the San Francisco Bay area, reveal the extent to which the region's ranchers rely on saleyards to facilitate the movement of cattle and integration of production systems. Saleyards and cattle buyers drive beef production efficiency by sorting, pricing, and moving cattle and matching them to feed resources in more intensive production systems. However, transactions lack traceability to inform policy and consumer choice. New data technologies like blockchain can provide traceability through

integrated production-scapes and facilitate market development to support grazing landscapes and consumer choice.

Keywords: pastoralism, ranching, ecosystem services, feedyards, saleyards, grazing, beef production, blockchain, conservation

Introduction

Grazed lands occupy about 60 percent of the world's agricultural land and substantially contribute to communities' social, economic, and environmental well-being (FAO 1997; FAO 2018). For millennia, the sustainable management of grazed lands has depended on pastoralists moving their animals to access enough high-quality feed to create value. Mobility allows grazing animals to opportunistically utilize highly variable plant and water resources over both time and space in response to stochastic events (Niamir-Fuller 1999). Livestock mobility is critical for livestock production and resource conservation on grazed lands.

Most of the world's grazed lands, 91 percent, can be described as rangelands (Reid et al. 2008). These are lands on which the potential natural or native vegetation is predominately grasses, grass-like plants, forbs, or shrubs. They are often characterized as marginal and managed with little to no agronomic inputs and are generally unsuitable for crop production (FAOSTAT 2016; Mottet et al. 2017; Follett and Reed 2010). Grazing by herbivores under the stewardship of pastoralists and ranchers is the primary production system on the world's rangelands, allowing these lands to contribute to the production of food and fiber (FAO 2018; Reid et al. 2008; Davies et al. 2013; Behnke 1994; Brunson and Huntsinger 2008).

In addition to providing food and fiber, rangelands provide a myriad of other ecosystem services, including supporting biodiversity, capturing and storing water, sequestering carbon, and providing for recreation (Davies and Hatfield 2007; Sala and Paruelo 1997); and there are growing expectations that these services will be protected and conserved (Brunson and Huntsinger 2008; Barry, Schohr, and Sweet 2007; Blench 2001). This paper considers how expanding the beef cattle production-scape supports livestock mobility as well as rangeland livestock production and conservation. Through a case study, I demonstrate that ranchers use transportation, trade, and markets to expand their production system boundaries and facilitate the mobility of their livestock so as to manage and benefit from the variability of California's rangelands despite the loss of more traditional or more independent forms of mobility.

The degree of mobility and, consequently, land tenure has been used to define pastoralism types, e.g., nomad, semi-nomad, transhumant, and differentiate them from livestock ranching (Ruthenburg 1980; Ingold 1980). Whereas pastoralists and their livestock are mobile and rely on communal lands, ranchers are considered to be stationary and to hold exclusive rights to property. In reality, a clear distinction between pastoralists and ranchers is difficult to draw. While ranchers, at least in the western United States, generally do not either stay or move with their livestock, they will herd animals to move them away from an area or to a new pasture, often on horseback or with dogs (Derose et al. 2020), and transhumant is also a practice (Huntsinger, Forero, and Sulak). Similarly, ranchers may not graze communal land, but they also do not always have exclusive land rights. For example, in California, ranchers may own their land, but many access a mix of private and public rangelands through grazing leases (Liffmann et al. 2000; Lubell et al. 2013), which they rely on to sustain their ranching operations (Sulak and Huntsinger 2007). Grazing rights may be exclusive on leased land, but the ranchers' tenure of this land is often insecure and shared with other uses, including recreation, hunting, and wildlife conservation (Huntsinger, Forero, and Sulak 2010; Wolf, Baldwin, and Barry 2017).

The difference between pastoralism and ranching are best understood along a continuum. However, it is the attributes that pastoralism and ranching share that are critical to understanding extensive livestock production and differentiate it from other agricultural production systems. Ranching and pastoralism are conducted in a non-equilibrium ecosystem--arid and semi-arid rangeland—characterized by the natural growth of herbaceous vegetation, which tends to be highly responsive to weather and relatively unresponsive to grazing (Jackson and Bartolome 2002; Behnke et al. 1993). Ranchers and pastoralists use livestock mobility and their knowledge of the highly variable ecosystem and the livestock's nutritional needs to support livestock production, rangeland health, and lifestyle (Huntsinger, Forero and Sulak 2010).

Globally, livestock mobility, and pastoralists and ranchers' ability to manage rangelands and sustain their livelihoods are at risk. Pastoralists and ranchers require grazing lands that are extensive and diverse for rangeland livestock production, but access to grazing land is in many places eliminated or restricted. From Africa's drylands to China's grasslands, and to the United States' western rangelands, grazing lands are being taken over by other land uses or set aside for conservation (IIED and SOS Sahel 2009; Yeh 2005; Cameron, Marty, and Holland 2014). Growing populations and economics drive subdivision and land-use change, but the widespread misunderstanding of use and management of rangeland resources also lead to loss of use (AAC 2006, Huntsinger, Forero and Sulak 2010).

Pastoralists have historically been construed as culprits in desertification narratives that blamed them for overgrazing (Swift 1996, Davis 2016, Behnke and Mortimore 2016). Similarly, rangeland degradation in the western United States has been attributed to ranchers and their management of livestock grazing (Huntsinger, Sayre and Wulfhorst 2012). While newer paradigms have developed from understanding arid and semi-arid lands as non-equilibrium and valuing local ecological knowledge, these paradigms have yet to fully inform policy or prevent barriers to pastoral and rancher management of rangeland (Krätli 2016; Wolf, Baldwin and Barry 2017). The new pastoral paradigm acknowledges that pastoralists use livestock mobility to strategically manage and benefit from variable rangeland resources and, thus, manage grazing impacts and avoid degradation within a variable climate (Krätli and Schareika 2010, Niamir-Fuller 1999, Roe, Huntsinger and Labnow 1998). In non-equilibrium ecosystems, abiotic factors, primarily precipitation, are more significant in determining vegetation structure, function, and dynamics than grazing or other ecological processes (Westoby, Walker, and Noy-Meir 1989; Behnke and Abel 1996). This explanation does not negate the fact that grazing impacts vegetation, but it recognizes that grazing's impact is a function of climate variability.

While the current movement around ranching, "working landscapes," does not call out the role of livestock mobility, it more broadly recognizes that ranchers can manage livestock production to be compatible with the conservation of rangeland resources (Plieninger et al. 2012). However, there remains a need to fully understand the production systems that support livestock mobility and working landscapes, especially as the systems have become more complex, and system boundaries are expanded. In recognition of ecosystem services associated with rangeland livestock production that are not currently valued in trade or marketing, and maybe even obscured in the expanded production-scape, I also consider opportunities afforded by new technology (e.g., blockchain) to communicate values to buyers and consumers.

Materials and Methods

Study Area. Cattle grazing is the most extensive land use in California. Nearly 26 million ha of California (62 percent) are classified as rangeland (CDFF 2003), with about 12.8 million ha grazed by domestic livestock—mostly beef cattle (CDFF 2017). The California Department of Forestry and Fire Protection (2017) defines rangelands as lands on which existing natural vegetation is suitable for grazing domestic livestock for at least part of the year. Like most of the world's rangelands, these are marginal lands that would require substantial interventions to support other agricultural uses. Rainfall is highly variable, with a coefficient of variation greater than 30 percent for most California, suggesting non-equilibrium conditions (Dettinger et al. 2011; Ellis and Swift 1988). The predominant types of rangeland in California include Mediterranean rangelands, cold desert steppe, and warm desert (Huntsinger and Bartolome 2014, George et al. 2015) (Fig. 1).

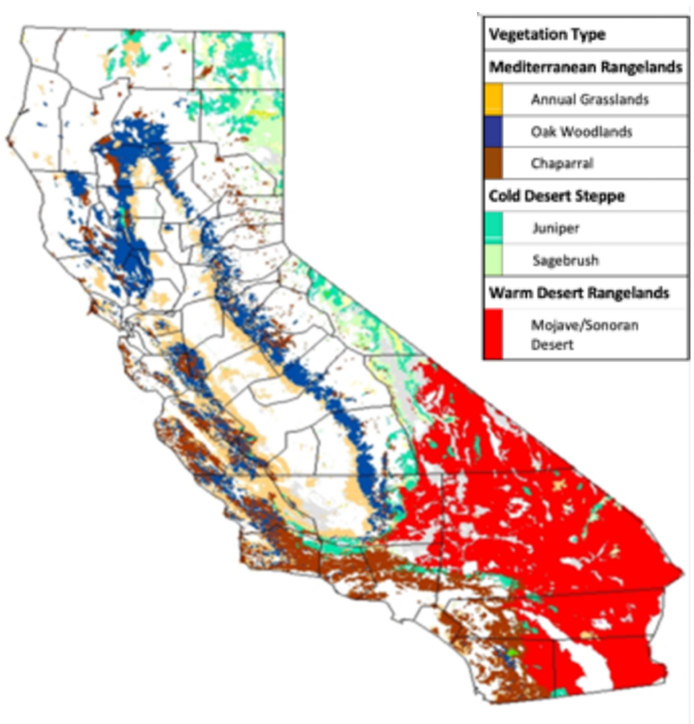

Fig. 1. Location of major California rangeland vegetation types (adopted from George et al. 2015). Lands colored white are non-range landcover types (e.g., forest, urban, more intensive agriculture).

Although California's Mediterranean annual rangelands are just over one-third of the state's rangelands (Fig. 1), they support most of the state's beef cattle grazing, providing at least 70-80 percent of the forage in the state (Huntsinger and Bartolome 2014; Salls et al. 2018). More than 80 percent of these rangelands are privately-owned (CDFF 2017). Ranging from sea level to an elevation of about 2000 m, a long, hot, dry season of 6-9 months is complemented by a wet, cool winter growing season. Many annual rangelands are grazed year-round—with only breeding animals, primarily cows, being left on rangeland through the dry season when feed quality is inadequate for a growing animal.

The Mediterranean annual rangelands are characterized by the dominance of non-native annual grasses in open grasslands and understories. They include about 10 million ha of grassland, 2 million ha of oak woodland and savannah, and nearly 3 million ha of chaparral and coastal scrub (CDFF 1988; CDFF 2003). Common grassland and understory plant species include Eurasian annual grasses (e.g., *Bromus, Avena*, and *Festuca* spp.), with a few native perennial grasses (e.g., *Stipa*, *Poa,* and *Elymus* spp.) and a great variety of forbs. Intermixed are more than 66,000 ha of valley-foothill riparian and other moister habitats that may have a higher component of perennial species (CDFF 1988; CDFF 2003). These rangelands, part of the California floristic province, are recognized as a global hotspot of plant biodiversity (Myers et al. 2000; Heady 1995; Huntsinger and Bartolome 2014).

The cold desert steppe is mostly above 1158 m elevation and includes 2 million ha of sagebrush grasslands and pinyon-juniper woodlands that are more than three fourths federally owned. Grazing on privately-owned lands is supported by transhumance. Livestock graze montane meadows in the summer, which are managed by the US Department of Agriculture, United States Forest Service (USFS), and then graze lower elevation land in the winter, which is managed by the US Department of the Interior, Bureau of Land Management (BLM) (Huntsinger and Bartolome 2014).

Over 9 million ha of arid lands, California's warm desert is primarily owned by the federal government and managed by the BLM. Low elevations, low rainfall, and warmer temperatures year-round are characteristic. With low resistance and resilience to anthropogenic disturbances (Belnap et al. 2016; Milchunas 2006), these lands are considered marginal for livestock production. Nevertheless, livestock may graze for seven months from spring to fall, utilizing pulses of forage that follow sporadic rainfall, especially in higher elevations, where perennial grasses are more abundant (Huntsinger and Bartolome 2014).

As described for the different types of rangeland in California and similar to other pastoral livestock production systems globally, livestock movements on California's rangelands occur at different scales depending on the spatial and temporal variability of the resources and other aspects of the production system (Adriansen 1999). California ranchers generally keep stock densities low (e.g., > one animal unit per four to sixteen hectares) and use large pastures (e.g., 50 to 1000+ ha), allowing livestock to graze selectively. Especially in larger fields, cattle may be periodically herded, and cows or experienced animals may be kept to guide young or naïve animals (Derose et al. 2020; Vallentine 2001:206; Launchbaugh and Howery 2005).

Grazing of domestic livestock has been a widespread use of land throughout most of California for around 200 years (Burcham 1981). Beef cow numbers representing the cowherd and the primary type of livestock grazing on California's grazing lands peaked in 1982 at nearly 1.2

million head (Saitone 2018) and today average about 730,000 beef cows and replacement heifers (USDA 2019). There are also small numbers of 307,000 ewes and 100,000 non-dairy goats (Huntsinger and Bartolome 2014).

Within California, the San Francisco Bay Area was selected as the study area to evaluate the driving factors and infrastructure facilitating cattle movement. Despite its notoriety as a hub for high-tech industries, the region's most common land use is cattle grazing (Huntsinger, Starrs and Barry 2016). Ranchers use older traditions, including moving and gathering cattle on horseback, and ecological knowledge to manage cattle grazing over 700,000 ha, 39 percent of the region's private and public lands, including regional parks, habitat conservation lands, and watersheds (Huntsinger, Starrs and Barry 2016). Cattle grazing on the region's annual rangeland promotes species diversity, including the conservation of several threatened and endangered species (Barry et al. 2015, Bartolome et al. 2014).

Livestock carrying capacity on California rangelands varies both seasonally and annually but expressed on a yearly basis ranges from 4-12 ha/animal unit/year. In addition to seasonal differences, carrying capacity and stocking rates vary by climate (annual precipitation and temperature) and site conditions such as soil and vegetation health, plant residues, topography, tree cover, water availability, and the presence of noxious weeds (Barry et al. 2016). These factors interact to influence plant growth and the length of the growing season. Livestock management, including movements and resulting rangeland health, is also a significant influence on carrying capacity (Krueger et al. 2002).

Study Methods. I used a mixed-methods approach to understand how cattle movements and production are influenced by market integration. Through data analysis, interviews, and surveys, I studied movement patterns and factors driving individual ranchers to move cattle from grazing land. I identified the infrastructure needed to support livestock movements and the information provided with livestock transactions through data analysis and direct observation of livestock sales.

Cattle Movement Data Analysis. To assess cattle movements, I used data collected by California's brand inspectors. Brand inspectors check brands on livestock when they are transported as required by state law. They also check any documents, such as shipping manifests and bills of sale, that show ownership when livestock is sold and record the description and number of animals shipped. I analyzed movement data collected in 2017 and 2018 at the following times (CDFA 2020):
1. At the time of sale or transfer of ownership
2. Prior to moving out of state
3. Prior to slaughter
4. Upon entry to registered feedyard
5. Prior to release from a saleyard

Since the California Hide and Brand Law was approved in 1917, cattle have been inspected to protect owners from loss of animals by theft, stray, or misappropriation (CDFA 2020). According to the California Bureau of Livestock Identification, 50 brand inspectors inspect 3.2 million head of cattle a year. Inspections occur in every county in the state except San Francisco, at approximately 20,000 ranch locations, 30 livestock saleyards, 31 feedyards, and four major meat processing plants. Cattle owners entirely finance the brand inspection system through brand registration and fees for the inspection service.

There is no current mandate to individually identify an animal in the US, so state brand inspectors identify cattle as individuals or in lots. They use descriptions based on the owners' hot iron brand, if available, breed or color, and class of animal (e.g., cow, bull, heifer, steer, calf). Brand inspectors also record the date of inspection and change in status, location of inspection, the reason for inspection, cattle county of origin, and owner identification. If applicable, inspectors will include information on the cattle buyer and destination and the agent who facilitated the sale.

In California, brand inspection data includes movements of cattle used for dairy, beef, breeding stock, show, and rodeo. I categorized cattle as beef or dairy using breed and color information. Cattle of beef breeds were classified as dairy if they originated from a dairy. Dairy cattle in California are primarily raised in confined feeding operations or, if pasture-based, they are raised on improved pastures. Few cattle for dairy production utilize dryland pasture or rangeland. Dairy cattle contribute a significant number of steers and heifers, and cows to beef production. These numbers are presented in the results for comparison (Table 2).

Movements of beef cattle from grazing lands to new pasture, animal feeding operations or feedyards, saleyards, or meat processing plants were identified based on inspection type, buyer, and destination information. Cattle movements associated with shows, breeding, or rodeo were excluded based on sale type, event or destination, or buyer. Buyer and destination information was not generally available for cattle sold at saleyards. If beef producers retained ownership through processing, cattle were considered as direct marketed. Data were categorized by the producer's size based on the number of head inspected by premise (owner) identification.

Saleyard Direct Observation and Interviews. I directly observed cattle buyers and sales at seven "feeder" (animals ready to be put on feed after reaching an appropriate size on forages) sales conducted at three different saleyards in California from May to July 2019. Feeder sales are held as special sale events to attract buyers and local cattle sellers during the time described by one of the saleyards as their "busy off-the-grass season." I reviewed the written, oral, and visual information presented to buyers for each sale transaction. Written information was provided in a sales catalog by one saleyard for three observed sales, but each saleyard provided information onscreen. Sales lasted 8 hours or more, and around 5000 head of cattle sold in 300-400 separate lots moved through the sale ring.

I recorded information in an electronic survey during each sale, for 679 lots of 1 to 45 head of cattle from the San Francisco Bay Area. I noted in the survey information announced and actions taken to influence price and marketability by either sale yard staff or buyers. Actions included sorting animals based on size or type. In some cases, buyers requested additional information, such as the geographical origin of the cattle. For example, in one case, a potential buyer wanted to know the distance of the cattle's origin from the coast. The auctioneer called the cattle rancher during the auction to verify. To fully describe the type of information available to livestock buyers and attributes associated with beef cattle production from the producer's perspective, I tracked four lots of cattle sold at a feeder sale from the ranch through the saleyard process. Observation and producer interviews provided a description of attributes associated with grazing management, and livestock feeding and care.

Observation is frequently used in social science to understand the actions of individuals (Clark et al. 2005). Previous research has investigated how spatial, quality, and temporal factors have impacted cattle's price in the western United States by analyzing satellite video auction data (Saitone, Forero, and Nader 2016). Observation provides some additional context to price differences that may not have been revealed in data analysis research.

In addition to observation at the saleyards, I conducted semi-structured interviews with auctioneers (n=2), cattle buyers (n=3), and bay area ranchers (n=16). Interviews were conducted within one week. Bay Area ranchers who sold cattle at the sale were randomly selected and interviewed via telephone. These ranchers sold between 15 and 161 head, with a combined total of 1,445 head of steers and heifers. Each interview was structured around two questions: (1) the reasons for selling/buying at the recent market and (2) how they felt selling impacted conservation objectives. I asked auctioneers about the buyer's interests and preparation of sellers. All responses were recorded in writing during the interview and imported into MAXQDA 2020, which was used to code and categorize responses (VERBI Software, Berlin, Germany).

Rancher Surveys. The majority of California ranchers are small, cow-calf producers—78 percent have < 50 head (USDA 2017). I mailed a questionnaire to ranchers located in four counties in the San Francisco Bay Area who sold less than 50 head during the year (2018). The four counties sampled included Alameda, Contra Costa, San Mateo, and Santa Clara counties. Producers in these counties use a mix of private and public rangelands. Access to irrigated or improved pastures is minimal, similar to the statewide availability of irrigated pasture (Table 1). The questionnaire was mailed to 465 ranchers in December and March 2019, following the Dillman Total Design Method (Dillman 2007).

Table 1. Beef cattle production in California and the San Francisco Bay region, grazing land resources and producer numbers.

	California	Bay Area [1]
Rangeland (ha) [2,4]	12,800,000	183,000
Irrigated pasture (ha)[3,4]	196,000	2400
% Total grazing land irrigated (ha)	1.5%	1.4 %
Number of beef producers[5]	10,254	458
Number of beef cows[5]	682,372	33,073
% producers with 50 head or less % of total cattle for area[5]	78 % 14%	62 % 9%
Average herd size (head)	66	72

[1] Includes Alameda, Contra Costa, Santa Clara and San Mateo Counties.
[2] State data from CDFF 2017
[3] State data from USDA NASS 2017
[4] Regional data from County Crop Reports (Alameda, Contra Costa, Santa Clara, and San Mateo 2017)
[5] USDA NASS 2017

To improve the response rate, I sent out a total of 4 mailings over two months: the full survey was sent twice, and two reminder postcards were sent. One hundred thirteen people returned the questionnaires, representing a 27 percent response rate after accounting for undeliverable questionnaires. The questionnaire was an 8-page booklet with 12 questions. Ten questions were closed-ended, with categorical or Likert scale response choices. I used categorical questions to collect information about rancher experience, ranch size, and marketing choices. Ranchers rated their agreement with a series of statements about why they graze cattle, why they sold cattle using a particular method, and how they manage grazing. Their answers ranged from "completely disagree" (1) to "completely agree" (6). I presented the resulting Likert data as median scores. Figures were developed using Tableau Desktop Professional Edition 2018.1.

Results

Cattle movement patterns. Beef cattle have an extensive footprint on the California landscape, where grazing lands contribute just over 1.1 million steers and heifers, and 150,000 beef cows to beef production in 2017 (Table 2). Beef cows were counted as contributing to beef production if they were moved to a saleyard, feedyard, or a meat processing plant; however, cows sold at saleyards during special female sales were excluded. Beef cattle from medium and small producers are found on grazing lands in every county in the state but San Francisco (Fig. 2).

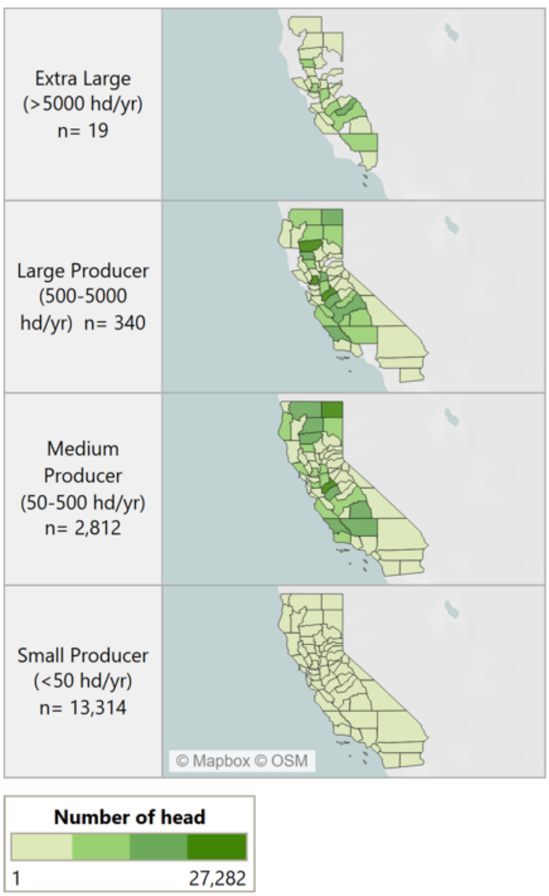

Fig. 2. Origin of all beef cattle from California (by county) moved from grazing lands by producer size (2017).

Table 2. Beef and dairy cattle contributing to beef production in California by age class for 2017 and 2018 based on movement from grazing lands and dairies.

	Cows					Steers and Heifers			
	Beef		Dairy			Beef		Dairy	
Type of Movement	2017	2018	2017	2018		2017	2018	2017	2018
Grass out of state[1]	52,345	55,003				110,856	118,544		
Grass in State (sale)						50,350	36,914		
On feed	6,536	5,937	25,633	11,982		590,215	651,110	795,075	817,994
Saleyard	118,407	136,127	492,805	509,961		352,384	402,152	228,658	233,345
Wholesale/retail meat	20,154	28,276	299,620	318,767		7,327	14,025	37,381	51,100
Direct Marketed	3,241	5,745	171	100		20,550	19,328	1,927	1,681
Grand Total	**148,338**	**176,085**	**818,229**	**840,810**		**1,128,327**	**1,238,767**	**1,063,041**	**1,104,120**

[1] Not included in grand total.

The movement of beef cattle from grazing land in California in 2017 and 2018 has a distinct seasonal pattern (Figs. 3 and 4). Forty-seven percent of beef steers and heifers (calves and yearlings) – 533,583 head that moved off California's grazing lands in 2017 – were moved in late spring to summer—May through July (Fig. 3). A smaller flush of movement occurred in the fall, October through November 2017, when 16 percent or 181,352 head of beef cattle calves were moved from grazing lands, typically but not exclusively from herds in the cold desert steppe where winters are snowy.

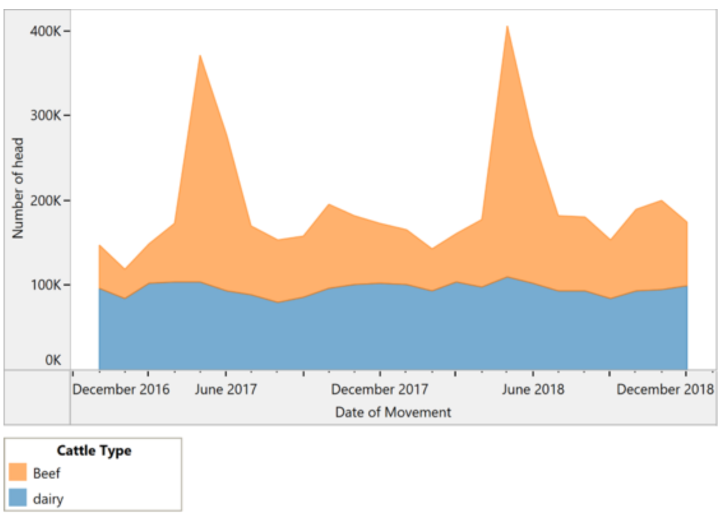

Fig. 3. Steers and heifers (number of head) moving from California grazing lands (beef) and dairies or feedyards (dairy) from January 2017 to December 2018.

The seasonal pattern is similar for beef cows in that 51 percent of beef cows moved in 2017 left California grazing lands from May through July 2017 during the dry season on California's rangelands (Fig. 4). Beef cow movement includes cows headed to grazing land out of state and those headed to saleyards, feedyards, or meat processing. Data is not readily available to accurately track the movement of cattle back on to California grazing lands. However, presumably, the beef cows leaving for grazing land out of state with no change in ownership return to California in the fall in anticipation of the Mediterranean annual rangeland's growing season. In 2017, cows leaving for grazing land out of state with no change in ownership described 96 percent of the 52,345 beef cows that left for grass out state. This movement of cows back and forth between grazing lands in California and Oregon has been previously documented by the United States Department of Agriculture, Economic Research Service (Shields and Matthews 2001).

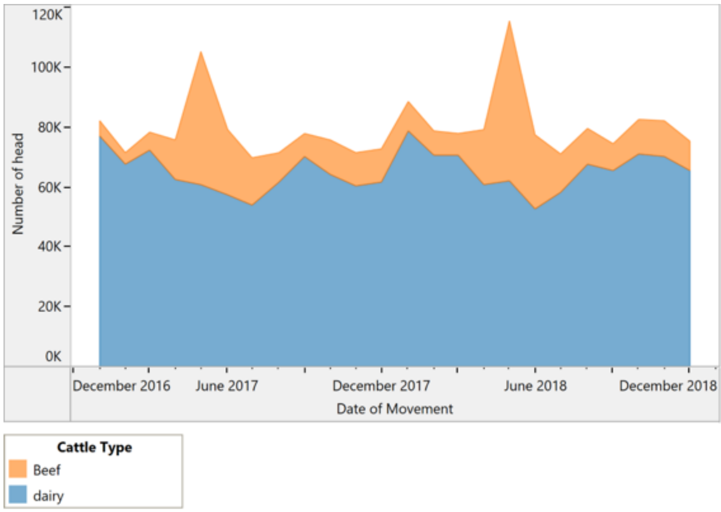

Fig. 4. Cows (number of head) moving from California grazing lands (beef) and dairies or feedyards (dairy) from January 2017 to December 2018, includes beef cows moved to grass out of state.

The seasonal movements of around 1.1 million head of beef cattle are in contrast to the nearly 2 million head of dairy cattle, which are also moved through production systems and contribute to beef production, but with little indication of any cyclical or seasonal pattern (Figs. 3 and 4).

Types of cattle movements. In California, growing cattle (steers and heifers) are generally moved from an extensive grazing system to a more intensive production system for continued growth and finishing. On the other hand, culled beef cows are sent from grazing lands directly to processing, most frequently through a saleyard (Table 2). Saleyards also facilitate the movement of many steers and heifers to more intensive production systems (Table 2), but they also may be moved off rangeland through direct sale to a buyer or another producer. Some producers will move cattle and retain ownership. Among small- and medium-scale producers, producers retain ownership of 79 percent of cattle moved to grass out of state, whereas the largest producers retain ownership of 95 percent.

In contrast, retained ownership in the feedyard is most common only among the largest producers. Small- and medium-scale producers, retain ownership in the feedyard of approximately 25 percent of their cattle, and large producers retain ownership of 49 percent. The seven extra-large producers (more than 5000 head of cattle) retain ownership of 90 percent of their cattle moved to feedyards.

Thirteen percent of all producers with beef cattle retain ownership of at least one animal all the way through processing. They may sell meat directly to consumers, known as "direct marketing," or keep it for household consumption (Fig. 5, Table 2). However, the number they process for direct marketing or household consumption is small, 23,791 head of cattle, or less than 2 percent of all beef cattle produced in 2017 (Table 2).

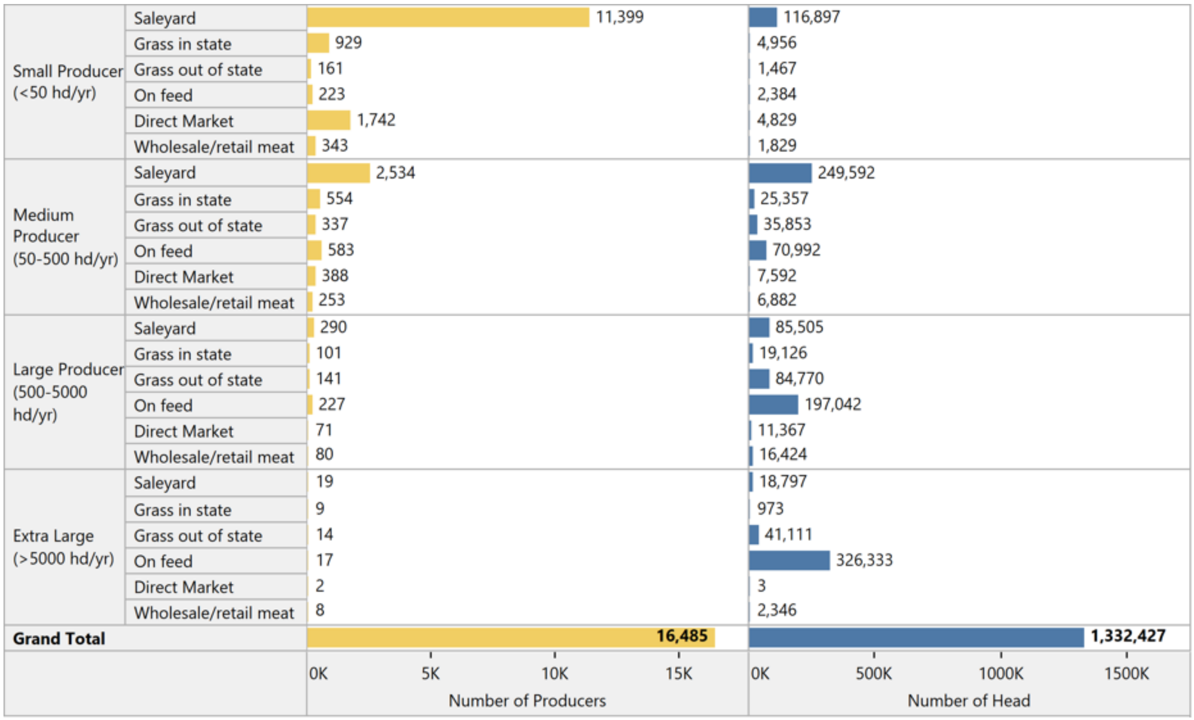

Fig. 5: Movements of beef cattle in California by size of ranch producer and destination from grazing land (2017). Size is based on total number of head but producers may use more than one type of movement.

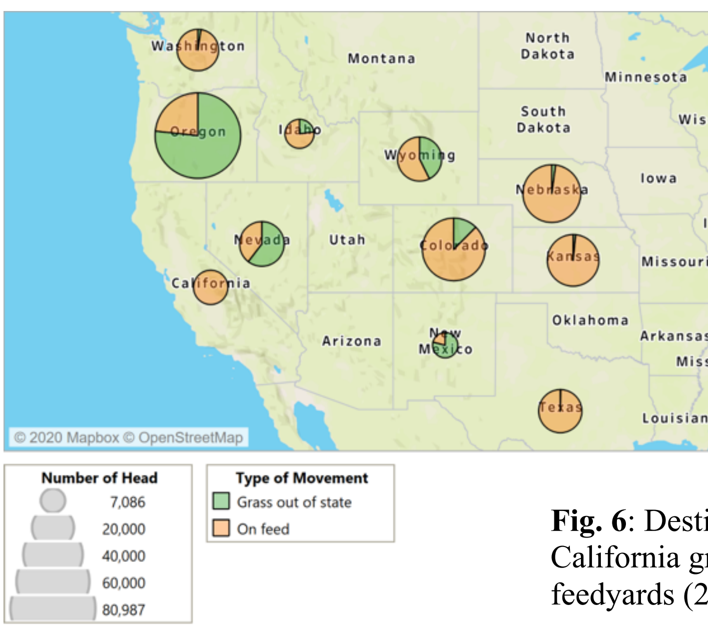

Fig. 6: Destinations of beef cattle traveling from California grazing lands to grass (out-of-state) or to feedyards (2017), excludes cattle sold at saleyards.

Whether through retained ownership or sale, most beef cattle leaving California's grazing lands move into more intensive production systems or move directly to slaughter in the case of beef cows. Many cattle go to feedyards in Colorado, Nebraska, Kansas, Oregon, or grazing land, mostly in Oregon, Wyoming, and Nevada (Fig. 6). Some of the beef steers and heifers from California's Mediterranean grazing lands may continue to graze extensive grazing lands or rangeland in locations with a summer growing season like Wyoming or Colorado (Fig. 6). However, there is no data readily available to determine if cattle are moved to rangeland or improved pasture. This movement data also does not include intrastate movements when cattle are moved between fields without a change in ownership; nonetheless, 1.13 million head of beef steers and heifers were tracked in these data for 2017. Based on USDA cattle inventory data, the movement data includes 79 percent of California beef steers and heifers (USDA 2017) since most are sold or moved out of state.

For all but the very largest producers (Fig. 5), saleyards support most cattle movement from grazing lands. Small and medium-sized producers marketed nearly 70 percent of their cattle through a saleyard (Fig. 5). Survey data from small-scale bay area ranchers revealed broad agreement that the saleyards (auctions) provided a fair price for their cattle (Fig. 7), even though, for some, the saleyards are not nearby. Saleyards are dispersed throughout the state, with the larger saleyards located in the Central Valley near dairy cattle production, processing, and transportation corridors (Fig. 8). The movement of cattle from the saleyards is not included in cattle movement data from California brand inspectors. However, based on the buyers' interest at feeder sales in 2019, most steers and heifers sold at the saleyard were purchased by a few large volume buyers and are moved into more intensive production systems.

Mature culled cows account for most cattle that are moved directly from California's grazing land to a meat processing facility. Culled beef cows mostly reached the meat processing facility after being sold in a saleyard (Table 2), where meat processors or their agents purchase them. Approximately 140,000 beef cows from California's grazing lands were processed for beef in 2017, representing a replacement rate of 18 percent for beef cows based on California's beef cow inventory (USDA 2017).

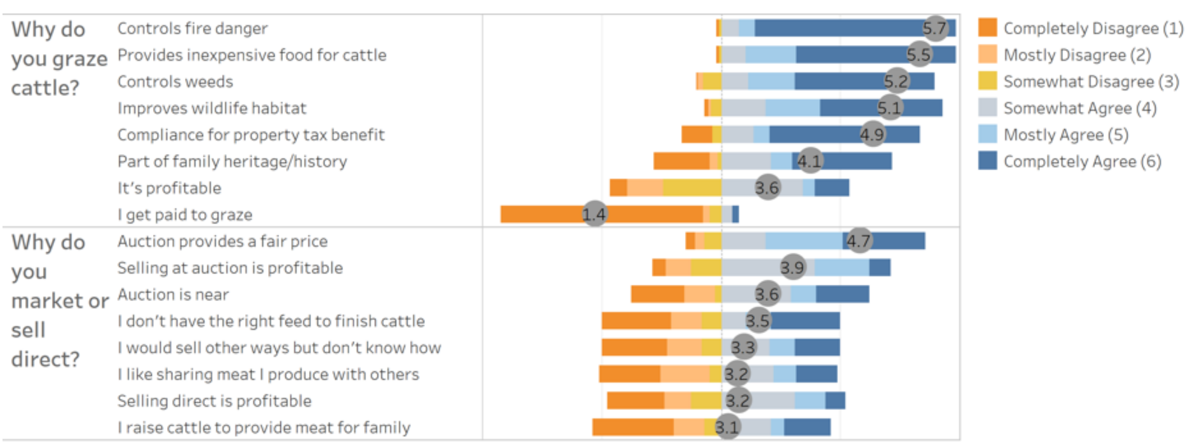

Fig. 7: Reasons small-scale beef producers in the San Francisco Bay Area, California graze cattle and sell at auctions or market directly, survey responses.

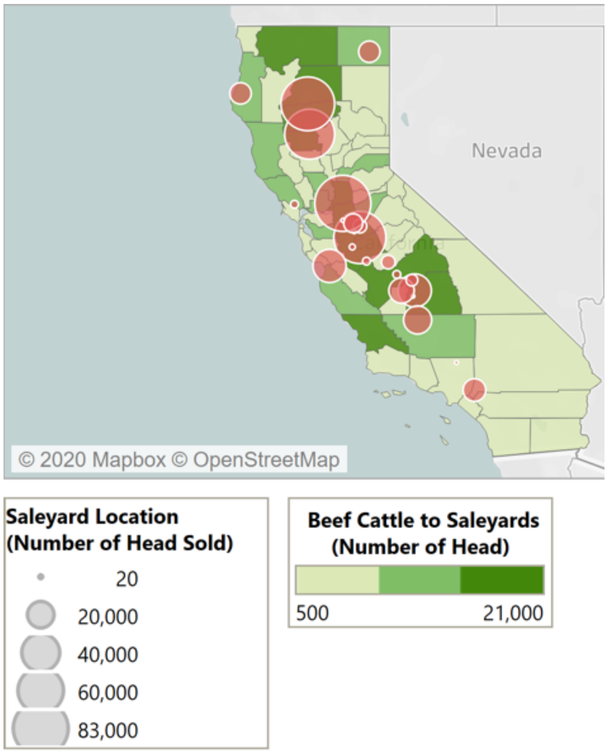

Fig. 8: Origin of all beef cattle from California (by county) sold at saleyards with location of sale yards and number of head sold in 2017.

In addition to the cows moved from grazing land to processing facilities, the cattle movement data documents transhumance, at least when it occurs across state lines. Approximately 50,000 cows, some with calves, left annual rangelands in California in the late spring for grazing lands in Oregon, where there is green summer rangeland or irrigated pasture.

Fig. 9: Reasons for time of sale of calves and yearlings from grazing lands in the San Francisco Bay Area, California and expected conservation outcomes, based on interview responses.

Factors driving cattle movements. San Francisco Bay area ranchers selling calves and yearlings at feeder sales in May, June, and July in 2019 reported forage quality and quantity as influencing the time they chose to sell their calves or yearlings (Fig. 9). Statements from Ranchers 4 and 15 acknowledged the change in feed quality and its impact on animal performance:

> *"This is the typical time of year to sell fall-born calves. You could keep them longer when feed is abundant, but calves do not grow well."*

> *"The feed turns this time of year and does not give calves what they need to grow. I retain feed [forage] for the cows."*

In terms of forage quantity, ranchers like Rancher 5 noted the importance of leaving feed (forage on the ground) through the dry season:

> *"We pull the calves and move the cows, so there is feed to come back to."*

When asked how selling at this time impacted conservation objectives, most ranchers spoke about conservation in terms of a desire to prevent overgrazing (Fig. 9). Ranchers also acknowledged how their grazing management, including livestock sales, worked to support specific conservation interests. For example, Ranchers 7 and 15 recognized the value of grazing management to provide habitat for federally-listed threatened and endangered species:

> *"I take cattle off to rest the pasture during the summer. My grazing is compatible with the California red-legged frog, fairy shrimp, and the giant garter snake. I do not overgraze."*

> *"I have no conservations restrictions, but I keep it the best I can. According to the [United States Department of Agriculture, Natural Resources Conservation Service] NRCS biologist, it remains a good habitat for red-legged frog, California tiger salamander, and San Joaquin kit fox. I sold later than usual because I had excess feed, but there was no impact [to conservation]. I don't like to graze to the ground."*

Rancher 11 described how moving cattle, including the timing of sales, reduced fire risk, and protected soils.

> *"It was good to keep calves a little longer. I graze, so it does not burn. I graze closer [to the ground] next to property boundaries since my neighbors don't graze and have grass six feet tall. I keep cows and calves out of the hills during the rainy season to avoid erosion. After the rainy season, I jump [the cow and calves are moved] back and forth between hill and flats."*

Rancher 14 also stated how grazing management (selling) could protect soils.

> *"I sold because we were short of feed [forage]. I leave feed for the following year to come back to. Leaving feed to come back to also helps us with erosion on hillsides."*

A common theme among the ranchers was a commitment to good grazing management regardless of land ownership or conservation requirements. This view was clearly articulated by Ranchers 2 and 16:

> *"I have no directive for conservation, but as all cattlemen, I convert grass to beef, so we need to manage grass…I manage it (public and private), all the same, to keep grass."*

> *"I graze all lands (public and private) similarly. If you take care of the land, it takes care of you."*

Indeed, there are straight economic considerations that influence when ranchers move (or sell) cattle from California grazing lands. However, in rancher interviews, even economic reasons for selling, like changing market conditions or the need for cash, typically were explained within the context of forage quality or availability, like Ranchers 1, 6, 13:

> *"The market was going south. I could save a little feed by selling now."*

> *"I was watching the market and needed cash. I only marketed the heavy end because I have grass [irrigated pasture] for the lighter cattle to go on."*

> *"I had feed and prices were low, but I needed cash to pay bills."*

The balance of economic and ecological goals driving ranchers' decisions around moving (selling) is further exemplified by ranchers who spoke about retained ownership as a factor in selling decisions. Having access to quality forage to support yearling growth is key to a decision to retain ownership as exemplified by Ranchers 7 and 12:

> *"We used to sell calves, and now we retain ownership because we have [irrigated] pasture."*

> *"When we had permanent [irrigated] pasture, we would sell our calves as yearlings in November, but we lost that pasture, so now we sell our calves."*

A mix of economic and ecological interests was also illustrated in survey data from small-scale producers in the San Francisco Bay area (Fig. 7). There was strong agreement with economic reasons for grazing, including it is *inexpensive feed* and it *provides tax benefits*, but also for ecological reasons such as *grazing controls fire dangers*, *improves wildlife habitat*, and *controls weeds*. However, very few of these producers regard *grazing as profitable.*

How small-scale producers in the San Francisco Bay area manage grazing also reveals information about factors driving cattle movements (Fig. 10). Responses from ranchers suggest that their livestock mobility strategies, including rotating or moving cattle between pastures, are aimed at maintaining plant cover and meeting the livestock's nutritional needs, more than reacting to lack of available forage. Early weaning and selling calves is a favored strategy in poor feed years. In response to lack of forage, destocking or selling animals is only somewhat practiced by most producers, and few producers consider feeding.

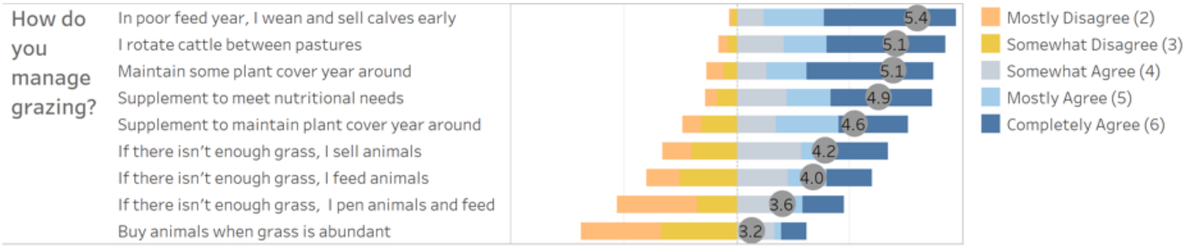

Fig. 10: Cattle grazing management by small-scale beef producers in the San Francisco Bay Area, California, survey responses.

Infrastructure supporting cattle movements. Interviewed ranchers explained that transportation, saleyards, access to additional quality feed sources, and processing capacity all support cattle movements in California. Ranchers may use a pickup and gooseneck trailer combination to haul livestock to a market or move cattle between pastures. However, most also rely on professional livestock haulers that operate semi-truck and trailer combinations specifically designed to haul livestock. Haulers may transport animals from grazing lands to saleyards, and then to grazing lands or feedyards after they are sold. At the feeder sales, semi-truck and trailers were lined up to transport purchased cattle, and after a winning bid, buyers assign lots of cattle to different groups for transport. Livestock haulers are also required for the final transport to a processing facility. The value of transportation to managing grazing lands was acknowledged in the survey of bay area ranchers. When asked about future challenges to managing their grazing lands, some ranchers noted that recently proposed federal regulations regarding hours of service by truck drivers as well as state regulations requiring newer vehicles that met emissions standards may limit the availability of livestock haulers and increase transportation costs and could impact ranching sustainability.

While transportation is required to move animals for production system integration, sale yards facilitate matching livestock with a production system. Saleyards are the primary marketing method for most small and medium-size producers (Fig. 5). They allow producers to market all classes and types of cattle. At a saleyard, buyers come together to bid on cattle providing current market price through competitive bidding. The saleyard may sort cattle from a seller into lots of similar size and kind. Buyers put together loads of similar cattle from different sellers. The sorting and grouping of cattle conducted at a sale yard can add value. For example, small groups of cattle may receive a more competitive market price when combined to make a load of cattle.

Cattle buyers utilized specialized knowledge gained through experience to choose cattle at the feeder sales to go back on grass or into a feedyard based on age, weight, breed, sex, and geographical origin. Buyers are looking for certain types of cattle to fit specific forage or feed conditions available to them, and some clear patterns can be observed. Recently weaned, lighter cattle are more likely to go back to feeding on grass, including irrigated pasture, while yearlings or heavier cattle may go directly to a feedyard. Breed type may also influence cattle destination. One buyer noted that he would no longer put black-hided cattle on feed in Colorado because of his experience with a higher incidence of a brisket disease, a genetically-transferred heart disease that impacts cattle at higher altitudes.

Buyers learn about cattle through written, visual, and oral information during the sale (Table 3). Some information such as weight, sex, breed, and vaccinations support premium prices or result in discounted prices relative to other cattle. Based on the ranch name and location, reputation may also influence the price or even a buyer's interest in bidding. A buyer may be willing to pay more if he knows that cattle from a particular producer perform well.

Table 3. Information available to cattle buyers for feeder cattle from San Francisco Bay Area ranches and impact on sale price.

Attribute	Information Available to Buyers of Feeder Cattle			Sale Price Impact	
	Written	Visual	Oral	Premium Price	Discount Price
Number of head	Onscreen	Observed	No	Truck lots	Small number
Weight, frame	Onscreen, average weight	Observed	Announced, heavy end, light end	Light weight (230-270 kg)	Heavy weights (> 385 kg) or small frame
Class (sex and age)	Sale catalog, if available	Observed	Announced sometimes	Steers	Heifers, bull calves
Color (hide), horns	Sale catalog, if available	Observed	No	Black hide	Horns
Breed	Sale catalog, if available	Observed, breed types	Announced sometimes		Dairy Bos indicus features
Shots (vaccines)	If provided, Sale catalog, if available	No	If provided, announced	Two rounds of vaccines	No vaccine information
Ranch Name	Sale catalog, if available	Observed, brand	Announced sometimes	Reputation, performance history	
Ranch Location (town)	Sale catalog, if available	No	Announced sometimes		Coastal locations
Origin (ranch-raised or bought)	Sale catalog, if available	Maybe, brands	Announced sometimes	Reputation	
Sire information	If known, Sale catalog, if available	No	If known, announced	Reputation, performance records	
Weaning status	If occurred, Sale catalog, if available	No	If occurred, announced	30-day minimum	
Program (Natural, No Implants, Source verified)	Sale catalog, if available	Observed, ear tag	If applicable, announced	Eligible for export markets	
Feed (pasture type)	Sale catalog, if available	No	No		
Grazing Management	No		No		

Buyer's decisions are not only influenced by the supply of cattle at the market but also by the available forage or feed, or processing capacity. For example, one buyer remarked that he was placing fewer cattle on grass because there were far fewer acres of irrigated pasture available in the Klamath Basin, Oregon than five or ten years ago. Instead, he was buying cattle to place in a feedyard in Washington, where by-products from processing potatoes and distillers grain keep feed costs down.

Little information is provided to buyers about managing the cattle or feed resources, including grazing management. Grazing land management that provided ecosystem services, including conservation of wildlife habitat or watershed protection, is not attributed to the cattle. Ranchers surveyed in the San Francisco Bay area overwhelmingly disagreed with the statement that "they are paid to graze" (Fig. 7). Nevertheless, bay area beef producers can identify ecosystem services that they attribute to their grazing management (Table 4). Cattle buyers moving cattle into more intensive production systems also recognize resource management practices such as feeding by-products and animal welfare practices such as low-stress livestock handling that they provide without attribution (Table 4). Unless cattle are associated with a specific-value added program (e.g., natural, organic, source-verified), information transferred through the production systems is limited to physical details that can be visually assessed or measured, such as weight, color, sex, frame size, and hot-iron brand if available (ranch origin).

Table 4. Example of production attributes, identified by producers of beef cattle originating in the San Francisco Bay area, that are not tracked or shared through the integrated production system.

Class	Head	Producer 1 (Cow-calf)		Producer 2 (Stocker)	Producer 3 (Feed yard)
		Attributes presented at sale (auction)	**Attributes not shared**	**Attributes not shared**	**Attributes not shared**
Steer	61	Natural (no implants), At Branding: vaccinations and dewormer; Booster: vaccinations. (Product names provided). Sorted off cow (not weaned).	Conservation grazing management program on public land. Grazing supports habitat for native flora and fauna, and reduces fire fuel loads.	Irrigated pasture provides hunting grounds for wintering raptors and feed for migrating birds along the Pacific Flyway.	Health program. Low-stress livestock handling. Daily ration includes food processing waste and agriculture by-products. Feedyard produces manure and bedding which fertilizes nearby field and vegetable crops.

Discussion

Beef cattle graze throughout California (Fig. 2), and most of the landscape they graze is rangeland. Like rangelands throughout the world, this land is often not suitable for cultivation, yet it supports livestock production. Arguably, extensive livestock grazing is not the most efficient production system in absolute terms of the number of head produced or livestock gains per hectare (Tichenor et al. 2017; Huntsinger, Sayre, and Wulfhorst 2012). For instance, the California dairy industry provides more cattle – a larger number of culled cows – to beef production than beef cattle producers (Table 2), and they operate on a smaller land footprint in California (without considering land used out of state to grow their feed). However, extensive livestock grazing contributes to food production on land with limited to no ability to contribute otherwise (Reid et al. 2008). Perhaps, more importantly, rangelands are high in biodiversity and ecosystem service production, which can often be enhanced or protected with ranching (Huntsinger and Oviedo 2014).

Beef cattle production on extensive lands supports conservation. Integrating extensive grazing systems with other production systems supports livestock production while maintaining extensive grazing lands in California. Integration provides alternative feeds resources to support production and allows ranchers flexibility to manage for multiple ecosystem services. Most ranchers seasonally move cattle, with many ranchers selling their growing calves or yearlings where they are finished in a more intensive production system. Ranchers surveyed overwhelmingly indicated that grazing provides inexpensive feed and serves to reduce fire fuel, control weeds, and improve wildlife habitat (Fig. 7). Roche et al. (2015) showed a similar finding in a survey of California ranchers. Nearly all (97%; n=490) agreed with the statement, "whenever possible, I try to conserve natural resources."

Conversion to other land uses, including cultivated agriculture, where feasible, has resulted in ongoing losses of rangeland in California (Cameron et al. 2014; Sulak et al. 2008), but intensification on grazing land is not a common practice. Rangeland improvement practices, including seeding, fertilization, and control of brush and trees, were tested and promoted by agricultural extension and government assistance programs beginning in the late 1800s to increase forage quality and quantity for livestock production (George and Clawson 2011). However, since the 1980s, rangeland management in California has increasingly emphasized multiple goals, including native species conservation and providing other ecosystem services (Spiegal et al. 2016). Supported by integration with other production systems, California's rangelands in public and private ownership remain as extensive grazed landscapes, covered with native or naturalized plants. Ranchers move cattle and manage grazing to support native biodiversity by reducing non-native plant species and accumulated residual dry matter, and increasing landscape-level diversity (Bartolome et al. 2014).

The value of maintaining extensive grazing lands to contribute to food production while providing multiple other ecosystem services is not unique to California (Reid et al. 2008; Curtin and Western 2007). Grazing systems on different continents function in ecologically similar ways; conserving native and wildlife grazers, and many species associated with grazing lands, requires protecting extensive natural landscapes (Niamer-Fuller et al. 2012; Harris et al. 2009; McNaughton 1985). While conversion of grazing lands to other land uses jeopardizes vast landscapes, interventions, or strategies purported to save rangeland or pastoral livestock production may also have negative consequences for conservation and ecosystem services. These strategies include ending extensive livestock grazing (e.g., Chinese grazing ban, Han et al. 2008), often along with encouraging pastoralists to settle and adopt intensive forms of agricultural production (Scoones 1995; Flintan et al. 2011). Agriculture intensification increases yield per unit area, but settlement and agricultural intensification may do little to improve the well-being of the pastoralist or the condition of degraded rangeland. Intensification can lead to both more and less intense grazing—both factors that may adversely impact ecosystem services (Angassa and Oba 2008, Niamer-Fuller 1999). The loss of native biodiversity from the intensification of agriculture on grazing lands is documented, as is the threat to biodiversity and other ecosystem services from both over- and under-grazing (Cameron et al. 2014; Metera 2010; Milchunas et al. 1998; Mcintyre 2003) resulting from lost flexibility for grazing management and the failure to understand non-equilibrium systems (Ho 2001).

With regards to agriculture intensification, pastoral management of non-equilibrium rangelands should not be confused with the management of improved pastures or pastures created by the conversion of native forested habitats to grazing land, like in the Amazon or New Zealand. On pasturelands that are developed by removing native forest, intensive management that includes rotational grazing, seeding of legumes and improved cultivars, and integration of livestock with cropping systems may be a viable strategy to spare native habitats while increasing agricultural output (Latawiec et al. 2014; Phalan et al. 2011). Intensification of rangelands, however, results in degradation and puts at risk resource values, including native biodiversity, which instead is often complimented or enhanced by the kind of managed grazing of pastoral systems that work with the natural environment (Kaufmann, Hülsebusch, and Krätli 2018; Alkemede et al. 2013; Cameron et al. 2014; Niamir-Fuller et al. 2012).

Mobility matches cattle production to forage resources. Ranchers expect and work with variability in forage quality and quantity by moving livestock across biomes and pastures and into other production systems, where forage or feed resources are available to meet livestock production needs. Moving cattle to different production systems is typical in the United States and in some other parts of the world where beef production occurs in three phases (cow-calf, stocker, finisher) (Nin et al. 2007). The three-phase system developed due to cattle's relatively long biological production cycle and the different resource and management needs for each phase of production; these same factors have been a disincentive to vertical integration (Ward 1997). The three-phase system typically includes integration of grazing systems, which support cow-calf and stocker production, with intensive systems that finish cattle in a feedyard. For California ranchers, who manage non-equilibrium systems, these movements are timed to manage variability and fit forage resources. While ranchers are able to sell their calves into the next phase of production, the timing of the sale allows cattle to "fit" the resource, which is evident from the substantial seasonal movement of cattle from California's grazing lands (Figs. 3 and 4). Based on rancher statements and similar to traditional pastoralists who move livestock to track forage resources, cattle movements are informed by livestock needs and changes in forage quality and quantity. On California's non-equilibrium rangeland, annual forage productivity varies unpredictably by a factor of three or more based on weather (George et al. 2001). Where forage quality may be predictable based on season, the weather also creates uncertainty about the timing of the seasons (George et al. 2001; George, Nader and Dunbar 2001).

The seasonal movements of cattle from grazing lands align with seasonal changes in forage quality and quantity, particularly on California's annual rangelands. Bentley and Talbot (1951) defined three seasons, inadequate green forage, adequate green forage, and inadequate dry forage nearly 70 years ago. These descriptions are still used by rangeland managers to explain the seasonal patterns of California's annual rangeland as it pertains to supporting livestock production (Becchetti et al. 2016; George et al. 2001). The onset of the inadequate dry season, which describes the summer's dry annual forage, corresponds with the movement of steers and heifers and some cows off California's annual rangelands. Although the annual dry forage provides some energy for grazing animals, it is low in protein, phosphorus, carotene, and other vital nutrients, and inadequate to support young growing animals without feed inputs or prolonging production time (George et al. 2001; George, Nader, and Dunbar 2001). Mature beef cattle can be maintained during the inadequate dry season, though ranchers expect and manage cows, knowing they will typically lose weight and body condition (Renquist et al. 2006).

The new growing season begins with the inadequate green forage season in the fall.
Seeds stored in the soil from the previous year's growth germinate with fall precipitation. This season's onset and length depend on weather conditions, which creates uncertainty in determining carrying capacity. However, as the survey responses and interviews indicate, Bay Area ranchers stock to maintain dry forage through the summer, so they have feed to come back to. Residual forage helps ranchers manage the new forage season's unpredictable start and

provides dry matter to support livestock during the "inadequate" green period. While dry residual forage is often low in protein and other vital nutrients, new green forage with its high-water content can inhibit livestock from consuming enough to meet their nutritional requirements--hence the name "inadequate green forage season" (Becchetti et al. 2016).

The final forage season, rapid spring growth, or adequate green forage begins with warmer weather in late winter or early spring, depending on precipitation. During this season, livestock performance improves, and the forage is nutritionally adequate for growth, maintenance, reproduction, and gestation. Livestock weight gains are highest during this period. Rapid spring growth continues for a short time until either plant growth is limited by a lack of soil moisture or plants mature. Peak standing crop marks the end of the rapid spring growth season (Becchetti et al. 2016). In a study at a research center in the Sierra foothills of California, Raguse et al. (1988) found that average daily gains of yearling cattle increased from December to early May and then rapidly decreased. Rancher's decisions to move growing animals off the rangeland in late spring, early summer reflects this seasonal decline in forage quality. Controlling the rapid spring growth with grazing also benefits native species conservation (Bartolome et al. 2014).

The seasonal movement of steers and heifers, and cows from grazing lands in the fall (Fig. 3 and Fig. 4) also corresponds to weather and forage changes. These movements are typically associated with forage changes in California's high elevation cold desert steppe and warm desert range. Both cold desert steppe and warm deserts, which are primarily federal land, managed in partnership with the United States Forest Service (USFS) or the Bureau of Land Management (BLM), have relatively low numbers of grazing livestock. However, movement allows ranchers to graze ephemeral forage as well as shrubs and native perennial grasses (Bartolome and Huntsinger 2014). Cattle may be herded by ranchers within the leased land, or lead cows with knowledge of the range will move cattle to good foraging locations.

Transhumance, the seasonal movement of cows, has been documented within California and between California and Oregon, Nevada, and Idaho (Huntsinger, Forero, Sulak 2010). Although the seasonal movement of cows between the cold desert steppe or warm desert range and ranches on California's annual rangelands was not captured in the inspection data, the data shows over 50,000 cows (7% of the state's cow herd) moving from summer pasture to neighboring states from California's rangeland.

Managing grazing lands by fitting livestock needs to the environment was also documented among California ranchers in Roche et al.'s (2015) study. They found that the highest-rated ranch management practice was "matching calving to the environment." Matching calving to the environment sets up ranchers to market or move weaned calves off grazing lands when the rangeland becomes insufficient in quality to meet a growing animal's needs. For example, calving near the beginning of the growing season, the period of inadequate green forage, means that a beef cow will reach peak lactation as her growing calf becomes ready to take advantage of the abundant, high-quality forage during the rapid spring growth season. Roche et al. considered this practice an aspect of economic sustainability. Moving growing cattle off rangeland by selling them is a management strategy. California's ranchers use for managing the interannual forage production cycle inherent in non-equilibrium rangeland. It should not be confused with destocking, which is selling to reduce stock numbers in response to an unexpected loss in forage production from an event such as drought (Morton and Barton 2002). Droughts and wildfire have forced some California ranchers to destock or feed (Macon et al. 2016).

Decisions regarding the movement of livestock on grazing lands by California ranchers in transhumance and through trade are not unlike decisions that pastoralists have made for centuries where livestock needs are matched with forage to take advantage of the variable climates impact on vegetation (Fernandez-Gimenez and Le Febre 2006; Krätli and Schareika 2010). Like pastoralists, ranchers use their knowledge of their environments to manage resource use (Fernandez-Gimenez 2000; Niamir 1995). Whether within ranges or between biomes, seasonal weather patterns, forage growth, and livestock nutrition and production requirements typically guide livestock movement—although increasingly pastoralists and ranchers may be required to move animals in response to societal influences, such as landowner requirements, political boundaries, land-use changes or designation. Ranchers' ability to either move or sell livestock into another production system might, in some part, compensate for required movements or loss of access to some grazing lands.

As with many tools used for pastoral development (Krätli 2016), equilibrium thinking misinforms some rangeland management policies and practices on California non-equilibrium rangelands. For example, some public agencies and NGOs have removed livestock grazing from lands they manage (Fried and Huntsinger 1998), and now with conservation values, including native species habitat loss, they struggle to put grazing back (McGarrahan 1997; Barry et al. 2015). Moreover, most public grazing contracts often set fixed stocking terms and charge ranchers a set price per animal unit month (AUM), each of which fails to account for inter- and intra-annual variability in forage quantity and quality. This pricing creates a problem when a public landowner wants a rancher to extend grazing time or increase stocking rates on low-quality forage and continue to pay the set AUM rate for forage that does not meet livestock production needs (Becchetti, T. email message to author October 5, 2019).

Equilibrium assumptions also influence ideas about improving ranching's economic viability. Like in most pastoral societies, ranching is an economically marginal activity (Wetzel et al. 2012). Marketing a ranch-raised product at a higher price has been promoted as a strategy to increase returns from grazing lands (Forero et al. 2014; Huntsinger, Forero, and Sulak 2010). Based on retail sales of labeled grass-fed beef, which grew in the US from $17 million in 2012 to $272 million in 2016, there is a growing market for direct sales from ranch-to-fork (Cheung et al. 2017). While California ranchers could market ground beef from ranch cows, a type of animal the grass-fed industry describes as "default grass-fed," accessing enough quality forage year-round to grass finish steers and heifers on California's rangeland is a challenge because of the seasonality of both forage abundance and forage quality on California rangelands. Ranchers like pastoralists specialize in taking advantage of the environmental variability- this management allows them to improve productivity (Krätli 2019). It is also difficult for producers to compete with cheaper imported grass-fed beef or beef from grass-feeding operations. In other words, working within California's non-equilibrium rangeland system to find forage on other grazing lands, or feed in another production system to finish growing animals, best provides for livestock production and rangeland management.

Integrated production systems facilitate mobility. Livestock grazing systems have been classified in ways that describe both the management of livestock and the social structures of the people that own and manage them, including pastoralism, transhumance, and ranching. In each of these cases, the system is based on some form of matching seasonal and annual forage availability to livestock production needs within the context of the forage resources available to producers and the producers' social needs. The integration of extensive grazing systems through transportation, and through trade with intensive production systems, effectively expands the capacity of the beef production system without sacrificing livestock grazing systems and their associated benefits.

In the literature, grazing and confined animal feeding are often considered independent types of production systems, as in Tilman et al. (2002: 675), "Pastoral livestock production makes extensive use of ecosystem services and eliminates many of the problems of confinement production." Also, the introduction of feedyards and processing plants and other capital infrastructure is considered to "commercialize livestock production" (Fratkin and Mearns 2006) as well as require all producers, including small-scale to standardize production (Lundström 2019). However, as illustrated by the beef cattle production system in California and practiced in many other parts of the world (Krätli, Dirani, and Young 2013), grazing and confined animal feeding are not mutually exclusive. By selling an animal at a saleyard, even a rancher in California raising one head on grazing lands can participate in the integrated production systems, with little to no standardization of production. Market integration allows even small-scale ranchers with extensive livestock production systems to produce a marketable product.

Most ranchers in California, from the small producers (less than 50 head) to the extra-large producers (more than 5000), participate in the integrated beef production system. Less than 1% of steers and heifers go from rangeland to meat processing, and less than 2% are direct marketed. While the largest ranchers are more likely to retain ownership through finishing, small- and medium-scale producers can also retain ownership. Retained ownership has been promoted to cow-calf producers by agricultural economists because of its potential to increase returns; however, producer's aversion to risk has been shown to limit retained ownership among cow-calf producers (Pope et al. 2011). Backgrounding or preparing calves for feedyards by weaning and introducing cattle to feed is a practice that leads to increased retained ownership (White et al. 2007), but most California ranchers manage extensive rangeland with no such facilities. As noted in the premiums paid for California calves (Table 3), buyers are willing to pay a premium for calves weaned for 30-days as many show up to the saleyard having just been removed from the cow.

While the beef production system is not generally vertically integrated and the supply chain phases operate independently, the integrated system transfers beef production decisions and opportunities from extensive grazing systems to more buyers and producers operating more intensive production systems. These producers also determine the final product produced for meat processing. However, besides supporting grazing management, selling calves can transfer the market risk of owning stockers or feeders, allowing ranchers to focus production on calf production, where market prices are relatively more stable (Brownsey et al. 2013). Larger producers may be better able to weather the risk of owning stockers and feeders but do not necessarily increase their profits from retaining ownership through these phases of production (Langemeier 2019).

Small- and medium-scale producers in California almost exclusively rely on trade (selling at the saleyards) to support livestock moving off rangelands. However, even among all the largest producers (more than 5000 head, n=19), saleyards are used to sell at least some cattle. When large producers do not retain ownership, they often market their cattle in large lots directly to a buyer. The importance of saleyards and the buyers, who match cattle with other grazing or feed resources, cannot be overstated. The ability of saleyards to market all classes, quality, and types of cattle provides an opportunity for ranchers to effectively utilize forage for livestock production and meet other resource management objectives. Ranchers indicated that selling cattle from grazing lands helped prevent overgrazing, manage for habitat, and in some cases, reduce fire fuel loads, prevent erosion, and support oak regeneration (Fig. 9). Mobility provided by the saleyards and integration of production systems optimizes the use of forage on rangelands beyond the boundaries of discrete operations. Ranchers use the saleyards and buyers to create value from rangeland by contributing to the production of a marketable product.

While saleyards are used by ranchers to facilitate livestock mobility, the saleyards and cattle buyers also drive production efficiency by sorting cattle and matching them to feed resources. Most of the attributes of interest to cattle buyers at feeder sales relate to potential efficiency in terms of rate and cost of weight gain (Table 3). Discounting heifers, small frames, and exotic crosses (*Bos indicus* features) is a penalty for less efficient animals. These cattle generally grow slower and yield less than a medium, crossbred steer (NRC 1996). They are also less likely to produce a high-quality carcass. Premiums or higher prices for vaccinated cattle from reputable producers reflect the expectation of higher performance. Buyers want cattle that can get off to a better start with fewer health problems. Improved efficiency can reduce the cost for producers growing and finishing cattle and minimize resource use and greenhouse gas emissions (Herrero et al. 2013; Becona et al. 2014; Capper 2007). No premiums are provided for conservation values provided by grazing management and rancher stewardship but, by default, discounts on market prices related to efficiency serve as an environmental impact fee to the producer.

A drive to maximize production efficiency in the beef production system can go too far and negatively impact livestock production communities and environments. As previously noted, extensive grazing systems that support natural plant communities are not inherently the most productive. Forcing these systems to maximize production or failing to recognize non-production values of managed livestock grazing will put high-value natural ecosystem services at risk. For example, China has been promoting a "sustainable livestock industry" by intensifying all phases of livestock production. In 2002, the Chinese government required the removal of 30 million head of livestock from 92 million hectares of grazing land. The "grazing ban" was implemented to restore degraded rangeland and support sustainable intensification. To compensate pastoralists who lost grazing lands, the Chinese government provided them grain and feedyards to raise their livestock. Meanwhile, researchers in China are working to identify and develop livestock genetics that will yield more meat under an intensive production system. The grazing ban has changed ethnic pastoralists' lifestyles, who have been stewarding the grasslands for generations. Ecological impacts from the grazing ban to the grassland ecosystem, which has evolved over thousands of years with pastoralist and livestock grazing, are uncertain (Han et al. 2008; Cheng et al. 2011; Li and Huntsinger 2011). Balancing production efficiency with ecological interest requires a comprehensive understanding of production systems, including their integration with other production systems and policies that recognize non-production values, including many ecosystems services.

Even though ranchers surveyed in this study mostly agreed that saleyards provided a fair price, it is evident that ranchers continue to be price takers. Furthermore, conservation values and ecosystem services ranchers provide with managed grazing are not generally recognized and not easily reflected in prices. Landowners, including public agencies that lease rangelands to ranchers, may directly benefit from these ecosystem services and, therefore, may be willing to accept lower fees from ranchers. However, in practice, the market for rangelands for grazing in California is tight enough that lease rates are often still high (CASFMRA 2019). Some consumers may be willing to pay more for products associated with grazing for conservation benefits; in practice, the certification process and marketing can be expensive. The production system is also not well set up to otherwise label final products with the origin or production practices (Woodward 2014). Since ranchers primarily produce calves and yearling and, as a by-product, mature cows and bulls, it is difficult for them to connect their production and management efforts with beef consumers. High rent, low margins, and competition in beef calf production from both other rangeland-based producers and the dairy industry tend to lead ranchers to subsidize their ranch with off-ranch income (Smith and Martin 1972; Torrell and Bailey 2000).

While income from rangeland livestock production may not be the primary driver for many beef cattle producers, their economic sustainability is considered critical to conservation. There is growing interest in valuing ecosystem services from rangelands and from pastoralism and pastoral livestock (Plieninger et al. 2012; Hoffmann, From and Boerma 2014; Silvestri et al. 2012), and incentivizing or paying pastoralists and ranchers to provide them (Davies and Hatfield 2007; Sayre et al. 2012). The integrated production system that currently creates value for livestock products for California ranchers fails to capture the value of these services and obscures them as their ranch-raised cattle are feedyard finished and mixed with beef from other production systems, including dairy beef. Current value-added programs for meat products like natural, organic, or grass-fed are limited in beef production attributes that are accounted for and promoted. Marketing beef with specific credence attributes requires transferring verifiable information (Caswell and Mojduszda 1996; Umberger and Feuz 2004).

Blockchain to support integrated markets. New data technologies promise to support the transfer of information through an integrated production system, which could allow ranchers to document different attributes of their cattle's care and health and their stewardship of resources (Table 4). Tracking beef through the entire production system (e.g., from ranch to fork) is possible when individual animal ID is coupled with new data technologies. Blockchain, developed as a ledger for bitcoin, connects transactions with timestamps and transaction data to keep data linked. Its creation of a time-data chain allows for information like where and when an animal was born, how it was fed or grazed, what vaccines it received, and where and when it was transported to be tracked with the animal.

At least four beef production projects have been conducted demonstrating this technology's ability to provide transparency and transfer information through beef's integrated production systems. McDonalds conducted the first test of blockchain to track and verify cattle management through the supply chain in 2016 (McDonalds 2017). They demonstrated proof of concept by tracking 8967 head of Canadian cattle produced with sustainable practices—this pilot project represented one day's supply to McDonalds restaurants in Canada. Sustainability practices verified included maintaining well-managed grazing systems, implementing management plans to protect water and waterways, adhering to animal welfare practices, and supporting local rural economies.

Another pilot project was conducted by JD.com, a major Chinese e-commerce site. This project was focused on restoring consumer confidence in food safety and providing transparency about the origin of meat products. In May 2017, JD.com used blockchain to track meat from beef producers in Inner Mongolia to consumers in Beijing, Shanghai, and Guangzhou. Consumers were provided with information, such as the cow's breed, slaughter date, and what bacteria testing it went through. Then in March 2018, JD.com began tracking the production of Angus-beef sourced from farms in Australia. Blockchain data assures customers that only Angus beef from Australia is sold under a specific label (Zhao 2018).

Other aspects of livestock production are also being tracked and shared with consumers with blockchain. In Fall 2019, Wong, a supermarket chain in Peru, partnered with SUKU, a Silicon Valley, California-based company, to use blockchain to cover all meat products sold in 20 stores. The products are stamped with SUKU, meaning that the product has been tracked from pasture to shelf; the blockchain platform allows customers to view the animal and meat's history, including animal health treatments (Ashgar 2019).

In 2019, BeefChain, the first blockchain company to receive certification from the United States Department of Agriculture (USDA) as a Process Verified Program (PVP), began selling products. The USDA certification allows BeefChain to audit ranches and feedyards for compliance with value-added programs. Their PVP programs include standard USDA programs like age and source verified and natural (not treated with any hormones or antibiotics). BeefChain also has a program that identifies and tracks calves born on Wyoming grazing lands through an integrated production system. A Wyoming-born calf born can be finished in a feedyard in Washington or Nebraska and remain in the program. BeefChain's goal is to increase the value of cattle for ranchers by providing a digital identity (RFID tag or label) and traceability (blockchain) from the grazing lands to consumers (Pirus 2019). While blockchain can connect consumers to beef raised on ranches and produced through an integrated production system, it is unclear if consumers will be willing to pay more.

Conclusion

Ranchers' decisions to move cattle around and off California's grazing lands are similar to decisions that pastoralists have made for millennia where livestock's needs are matched with variable forage resources. Livestock mobility, which is critical to livestock production and the management of resources on non-equilibrium rangeland systems, is supported by the integration of beef production systems. Ranchers move animals across biomes and pastures, and they move cattle to other production systems, typically to more intensive systems. Intensive production systems, including other grazing land and feedyards, provide feed resources for improving the efficiency of growing and finishing cattle. Integrating the beef production-scape through transportation and trade (saleyards and markets) expands system boundaries beyond local resources, even when non-market-based forms of livestock mobility or expanding the production-scape have been hindered. This integration supports finishing cattle for markets, the maintenance of extensive rangeland, and grazing management.

Extensive rangelands maintained with native and naturalized plants, and managed grazing can support natural diversity, including providing habitat for wildlife. Developing the whole value chain has supported California's ranchers in managing grazing and providing multiple ecosystem services from rangelands, including beef production. Communication and data technologies, like blockchain, may help transfer production information through integrated production systems to improve livestock performance and inform markets and consumers.

Chapter Four

Land sharing on San Francisco Bay Area grazing land, implications of exacting easements on conservation values and valuing ranch work

Although ranchers and landowners capture revenue from livestock markets (provisioning services) or private consumption (provisioning and cultural services), a substantial portion of the overall benefits are realized off-site by society including species conservation, carbon storage, and watershed functions (supporting and regulatory services). Accordingly, ranchers do not often have an incentive to take the total value of ecosystem services into account when making management decisions, for example, about conversion and development. Landowners who are motivated to own rangelands and continue ranching increasingly depend on public-conservation payments, cost share programs and markets for ecosystem services. While meant to sustain land use, these governance systems, as shown in the social-ecological system framework set the conditions for conservation outcomes or ecosystem services and define how ranchers can steward lands and manage grazing. Through examining a case study of conservation easements, this third study considers how an exacted easement influences the landowner's relationship to the land, grazing and livestock management, and associated conservation values.

Abstract

Grazing lands providing forage for livestock production can support habitat for threatened and endangered species, exemplifying their good fit to a conservation strategy described as land sharing. However, nature conservation strategies often rely on acquisition to ensure protection. In the San Francisco Bay Area, a biological hotspot, over 29% of the land, approximately 0.5 million ha, is owned by public agencies, or is under easement, where development rights are held by a conservation entity. Grazing lands are 43% of this protected land. A majority of private grazing landowners support this form of land sharing when it does not conflict with livestock production. An emerging state scheme to support economic development on some land requires compensatory conservation of habitat on other land by partial title acquisition with an exacted easement. A spatial analysis approach and case study were used to evaluate the role of grazing lands in meeting conservation objectives in the Bay Area and determine what conservation activities are valued and who gets benefits from these activities. Spatial analysis reveals that based on species occurrence, grazing lands, regardless of protection status, provide the majority of habitat for many threatened and endangered species. Furthermore, over 65% of the land described as essential or important to conservation by a regional planning network is grazed land. The case study of exacted easements on cattle ranches reveals how reterritorialization alters the perceived purpose of the land and its ecosystem services and creates new opportunities for capital accumulation from conservation services that both challenge and support land sharing and a rancher's place on the landscape. Exacted conservation easements illustrate the ongoing differences and misunderstandings between conservation interests and those who steward grazing lands over how best to conserve, a disjunct that puts the production activities that support habitat at risk.

Key words: capital accumulation: conservation easements; endangered species; grazing; land sharing; land trust; livestock production; protected areas; rangeland; reterritorialization; San Francisco Bay Area; working lands

Introduction

Like pastoral landscapes around the globe, rangelands in California are at risk from land use change (White et al. 2000, Lambin et al. 2004, Cameron et al. 2014, Reid et al. 2014). Suburban and exurban development, public works, renewable power infrastructure, and where feasible, more intensive agriculture all have much greater economic value than pastoral livestock production; however, these land-use changes diminish or extinguish many of the land's resource values and ecosystem services (Brunson 2014, Cameron et al. 2014). These values and services are increasingly being recognized (Huntsinger and Oviedo 2014, Farley et al. 2017, Coffin et al. 2021). Working rangelands characterized by naturally growing herbaceous plants provide livestock forage supply food and fiber, but also water, open space, habitat, and carbon storage (Booker et al. 2013, Sayre et al. 2013, Yahdjian et al. 2015). In addition, the management of grazing itself can supply and enrich habitat for native species by managing vegetation and maintaining habitat structure and ecosystem functions in California's heavily invaded grasslands (Barry and Huntsinger 2021). Rangeland livestock production, in part, has both created and maintained current landscapes and habitats while supporting livelihoods and rural communities (Huntsinger and Oviedo 2014). Here we use spatial analysis and a review of case studies to examine the reliance on grazing lands to meet conservation objectives, and how partial title acquisitions through a type of easement may undermine the species conservation benefits, they seek to conserve.

Nature conservation strategies often rely on ownership of properties to be conserved. Despite the high costs of acquisition and management, conservation through protection by state ownership is still the most broadly familiar and supported mode of conservation in the United States (Fairfax et al. 2005). In fact, since the late 1800s, the focus of nature conservation in much of the world has been on creating protected areas (Adams et al. 2014). The creation of protected spaces, initially by states and now, additionally, by NGOs, is meant to protect threatened ecosystems, endangered plants and animals, and unique landscape features from human degradation and land-use change (Adams 2004, Brockington et al. 2008) through a land sparing strategy that for the most part excludes development and human use of the land, segregating agricultural production and conservation (Phalan et al. 2014).

Globally, a protected areas approach has often resulted in the displacement of natural resource-based activities and livelihoods. Apart from this, such an approach is predicated on the assumption that human activity, at least related to natural resource use, is antithetical to conservation and that removing these activities restores nature (Peluso 1993, Brockington 2002, Neumann 2002, Adams 2004, Robbins 2011). Countering this assumption, Cronon (1995), Watt (2002), and others provide evidence of how preservation overlooks the benefits of cultural histories as well as human activities, including stewardship, use, and management of land. Cronon (1995:88) describes how "the myth of wilderness" led to Native Americans being forced out of national parks to provide a pristine landscape for tourists. Watt (2002:100) notes that overlooking ranching history to create the Point Reyes National Seashore in California supports the appearance of natural purity, a goal in wilderness management. As a conservation approach, removing people and their livelihood from land has been described by Brockington (2002) as fortress conservation. While fortress conservation has been applied to landscapes across the globe, research findings indicate that setting aside an ecosystem to let nature run its course does not necessarily support the conservation values society expects (Huntsinger and Oviedo 2014). For these and other reasons, although acquisition may prevent human degradation associated with some types of land-use change, state or conservation ownership alone can neither ensure land management nor provide protection for various ecosystem services. In describing the limits of acquisition as a conservation strategy, Fairfax et al. (2005: 257) identified a fundamental problem: "ownership does not ensure control." They recognized that private landowners might control their properties more successfully than governments. Many places protected for endangered species require active management (Scott et al. 2010), more characteristic of private owners to maintain habitat suitability. For example, typical rancher activities such as removing invasive plants and animals, managing livestock grazing to maintain grasslands or minimize thatch, controlling pests that threaten rare species, or setting prescribed burns to support fire-adapted plants are recognized as essential activities to maintain biodiversity (Weiss 1999, Marty 2005, Maret et al. 2006, Germano et al. 2012, Adamidis et al. 2019). Various climate change scenarios suggest an even more prominent role for vegetation management to achieve desired resource conservation outcomes in the future on some landscapes (Chaplin-Kramer and George 2013).

An alternative to fortress conservation or land sparing is a land sharing conservation approach (Kremen 2015). A common land sharing approach is to use land jointly for conservation and agriculture. One prominent form of this approach in California is partial title acquisition by agencies or NGOs via conservation easements. Development rights are held by a conservation entity on private or public lands, preventing land use change and fragmentation. A type of easement, the exacted easement, is a result of mitigation of land development. An emerging state scheme to support economic development on some land requires compensatory conservation of habitat on other land through the purchase or provision of an easement by the developer. Ranch lands, much of the remaining private open land in the Bay Area, are often sought out for this purpose. Most rangeland livestock producers support and carry out wildlife management on their land, as long as it does not interfere with livestock production, and they enjoy the presence of wildlife (Ferranto et al. 2013). They do not see it as a conflicting use in most cases. Ranchers participate voluntarily in easements, a market-based approach. In addition, livestock grazing has been identified as a biophysical tool that might mitigate the impacts of climate change to conserve some native species associated with rangeland ecosystems (Pyke and Marty 2005, Marty 2015). On grazing lands, land sharing through landowner initiatives and conservation easements can provide habitat for threatened and endangered species and pollinators while providing forage to support livestock production (Shapira et al. 2020, Barry 2021, Barry and Huntsinger 2021).

In analyses of agricultural production and nature conservation informing the debate about land sharing versus land sparing, pastoral livestock production is often missing (see Balmford et al. 2018, Adams 2020). Some of the 95% of federally listed threatened and endangered species in the United States have their habitat on private land (Wilcove et al. 1996). Moreover, the habitat for approximately 50% of all federally-listed species is found only on private land (Clark and

Downes 1996). With the recognition that land conservation and rangeland management are essential to protecting a significant portion of California's wildlife and ecosystems, the social-ecological impact of easements on the stewards of ranch lands, and the potential for strategies based on taking better advantage of the land-sharing possibilities, need consideration. This study focuses on exacted easements to explore some of the advantages and pitfalls of this conservation strategy.

Conservation easements on working rangelands for nature conservation

In California, where land use change from exurban sprawl and conversion to intensive agriculture has been intense, there has been a substantial growth in the use of conservation easements to protect land. Over 830,000 ha or about 2% of the land in the state has been protected, with 11,250 different conservation easements held by 225 different non-profits or government agencies (Cameron et al. 2014, CCED 2018). A conservation easement is a three-party voluntary agreement between a landowner, government, and land trust or other conservation organization or agency to restrict future land uses. The restrictions, a partial relinquishment of property rights meant to protect specific conservation values, are accepted by the landowner in exchange for tax benefits via donation or payment with funding provided by the public or NGOs (Lippmann 2004). Restrictions are recorded deed restrictions that run with the land title, typically for perpetuity.

On rangelands, conservation easements are not only considered a tool to protect ecosystems, but many ranchers also consider them critical to sustaining their ranching operation in the face of development pressure and poor economic returns from livestock production (Huntsinger and Oviedo 2014, Huntsinger and Bartolome 2014). The demand for easements among California ranch landowners is so strong that the California Rangeland Trust has 177,250 ha of privately-owned rangeland awaiting funding for permanent conservation through easements (CRT 2017). This demand, coupled with an unprecedented need for mitigation sites by public agencies and business entities to meet local, state, and federal permit requirements for development projects, has resulted in the growing use of exacted or mitigation easements throughout California (ICF 2010, 2012, Jones and Stokes 2006, Lippmann 2006).

Like donated and other purchased easements, exacted easements provide for land protection but are focused on mitigating environmental impacts on other lands, typically a loss of habitat. Since California has thousands of unique and endemic plant and animal species-- hundreds of which are state and federally listed as threatened or endangered--it is nearly impossible to undertake a project on undeveloped land without being required to mitigate for impacts to listed species. Projects benefiting from exacted easements include exurban projects like subdivisions, schools, parks, shopping centers, and golf courses, as well as public work projects such as reservoir expansion, road improvements, high-speed rail, and green energy projects. Exacted easements, paid for by the developer, are well-funded. In addition to purchasing land use rights, the proponents fund a non-wasting endowment to underwrite conservation activities required on the easement in perpetuity. This provision of an exacted easement provides a record of what conservation activities were valued and who receives benefits from these activities.

Study objectives

Hosting 33% of California's natural communities on only five percent of the state's land, the San Francisco Bay Area is a biological hot spot (Bay Area Open Space Council 2012). Among metropolitan areas, the Bay Area leads the nation in protecting its lands and waters. Within the eight-county region, over 29% of the land--approximately 0.5 million ha—is protected by fee-simple title ownership often based on land sparing, or by land sharing conservation easements. In this study, two main approaches are used to examine the role of working lands in Bay Area land conservation strategies, and the impact of these strategies on social relationships and the environment. First, the extent of high conservation value lands provided by working lands, e.g., grazing lands, in a region with rich biodiversity and extensive land protection activity is assessed using spatial analysis. Four questions about acquisition, via fee-simple or partial title, of lands for conservation in the Bay Area are addressed as follows:

1. What is the extent of grazing lands acquired for conservation?
2. What vegetation cover types have been acquired for conservation?
3. What land use types are providing habitat for threatened and endangered species?
4. What land uses are associated with priority lands for conservation?

Second, through a review of exacted easements as a case study, we engage political ecology theory to understand the impact of acquisition through review of exacted conservation easements on working rangelands. The field of political ecology examines the relations between society and nature, considering who benefits from the land and resources (Robbins 2012). Several political ecology studies have documented how narratives about degradation justify removing people from land and natural resources to facilitate resource conservation through land sparing (Corson 2011, Kelly 2011, Fairhead et al. 2012). Applied to the creation of protected areas, they have demonstrated impacts of state territorialization, enclosure, and capital accumulation resulting in displacing resource users and enabling others to benefit from new economic values developed for nature. These studies challenge the notion that all nature protection and conservation work are meritorious, and human activity and resource use are incompatible with nature conservation. A review of exacted easements as part of a case study approach, highlighting the Golden Hills Ecological Preserve, is used to understand if conservation acquisition in the Bay Area through land sharing has similar impacts.

Methods

Methods for the spatial data analysis and case study approaches that were used to assess land conservation activity and some of its implications in the Bay Area are described.

Study area

The San Francisco Bay Area (Bay Area) encompasses nine counties (Fig. 1), totaling approximately 2 million ha. For this project, the city and county of San Francisco, which is predominantly urban, was excluded. The Bay Area has a Mediterranean climate, characterized by mild temperatures and rain in the winter months, and a long dry period from late spring often until late fall; it is within the California Floristic Province, one of the world's top biodiversity hot spots (Meyers 1990, Bartolome et al. 2014). There are over 100 federal- or state-listed threatened or endangered species and several unique ecosystems. Thorne et al. (2014) estimated that 30 to

43 alone could be impacted by proposed road and railroad projects and will require mitigation due to impacts to endangered species habitat. While rapid land-use change driven by a growing population has led to habitat loss, public support for land protection is very high (Thorne, Santos, and Bjorkman 2013), providing funding for open space and supporting numerous land trusts and acquisition campaigns. Park, open space, wildlife agencies, water districts, and land trusts have created a system of protected lands that includes parks, preserves, watersheds, as well as farms and ranches. In addition, land development is controlled through general plan and zone restrictions, urban growth boundaries, and tax breaks for agricultural land, though these are notoriously vulnerable to development pressure (Rissman and Merenlender 2008).

Fig.1. Study Area: Agricultural lands in the San Francisco Bay Area, California.

Motivated by preserving biodiversity and ecosystem functions, the Conservation Lands Network is a regional planning effort that has developed a framework to prioritize protection, including connecting ecosystems such as creeks, forests, woodlands, brushlands, and grasslands. The effort includes ambitious conservation targets--protecting 1 million ha, or 50% of the region's land by 2050 (Bay Area Green Network 2012). Regional planning and the information accumulated in support of it has been integral to the historic and continuing creation of protected lands or open space, which is widely recognized to contribute to the high quality of life in the region (Santos et al. 2014).

Spatial data analysis
To assess the role of working lands in providing habitat for threatened and endangered species and the current role of protected lands, we conducted spatial analysis across five different data layers: protected lands, agricultural use, vegetation cover type, habitat suitability, and conservation network priority lands. These data layers are available within the Conservation Lands Network 2.0, but the analysis tools do not evaluate grazing land, the primary agricultural land use in the region, relative to conservation interests.

Protected lands
For the purposes of this study, "protected land" is land where the title includes permanent conservation or public status. Spatial data on lands protected either by fee-simple title or easement was obtained for the Bay Area from the California Protected Areas Database and the California Conservation Easement Database, published by GreenInfo Network (2020). Whether they are protected through fee-simple title or easement, these lands are considered open space, protected from development (Greeninfo Network 2013). Depending on the entity's mission and land management requirements, fee-simple title lands may be grazed or ungrazed parks, nature reserves, or open space. A few are farmed. Lands with conservation easements may also be grazed or farmed, depending on the easement's stipulations. Easement lands, including donated, purchased, and exacted easements, are typically private property, although some overlay public land.

Agricultural land use
To find out the extent of grazing and farming on lands acquired for conservation in the Bay Area, grazing land and farmland were identified by designations from the most recent data of the California Farmland Mapping and Monitoring Program (FMMP) for each county (FMMP 2016, 2018). The FMMP has a 4-ha minimum mapping unit for farmland. Prime farmland, farmland of statewide importance, and unique farmland were aggregated as farmland. The designation of these farmland types requires that land was in cultivated agricultural use within the past four years. Farmland of local importance is a separate designation of farmland defined by the county; it may include grazing land, unirrigated croplands, small orchards, and vineyards. Grazing land, almost exclusively rangeland, includes lands with vegetation suitable for livestock grazing of a minimum of 40 acres (16.2 ha), mostly grassland and oak woodland. FMMP category "other" includes all undeveloped land that is not farmland or is not farmed, including forested land as well as state parks and other government properties that restrict agricultural use. We calculated the proportion of land acquired by fee-simple title and conservation easement in each land use category.

Vegetation cover type
Vegetation community maps developed by the Conservation Lands Network (CLN) (Bay Area Open Space Council 2019) were used to determine which vegetation cover types have been acquired for conservation. Vegetation mapping classifications were aggregated based on type to include annual grassland, oak woodland, agriculture (cultivated), chaparral and scrub, redwood forest, conifer forest, water, urban, and other. We calculated the proportion of land acquired by fee-simple title and conservation easement by each vegetation cover type.

Habitat suitability
In order to determine what land use types are providing habitat for threatened and endangered species, suitable habitat for threatened and endangered species in the Bay Area was established from a web-based decision-support tool, Mitigation Wizard (Bay Area Green Print 2021). The Nature Conservancy developed this tool with a technical advisory committee to support regional planning by identifying potential mitigation habitat on protected and unprotected lands. We used the tool to identify suitable habitat for every species (67 plant species, 34 animal species) potentially requiring mitigation in the Bay Area. The tool models habitat based on the California Wildlife Habitat Relationship model for terrestrial vertebrate species and Calfora listed land cover types for plant species within 2 miles (3.2 km) of verified occurrences as reported in the California Natural Diversity Database (CNDD). We calculated the percentage of potential habitat by land use for each species. We also measured which land uses provided 50% or more of the potential habitat for plant and animal species on protected versus unprotected lands.

Priority conservation lands
To address the question of what land uses are associated with priority lands for conservation, priority conservation lands identified from CLN 2.0 (Bay Area Open Space Council 2019), a regional vision for land and habitat conservation were mapped by county and land use type. CLN 2.0 uses Marxan, conservation planning software (Ball et al. 2009) to categorize lands that meet specific conservation targets for minimum cost. The specific conservation targets were developed from ranked coarse- and fine-filter habitats and species occurrences (CNDD). Cost considered the inverse of suitability is defined via scores from distance to roads, population density, and parcelization. Categories based on Marxan included "Areas essential to conservation" (16 or more times out of 20 Marxan model runs), "Areas important to conservation" (11 to 15 times out of 20 runs), "Connecting lands that ensure network connectivity," and "Contributing lands," lands that were not selected but still important to conservation goals. We calculated the proportion of land in the four conservation priority categories by each land use type.

Table 1. Case study participatory observation activity for exacted conservation easements on three ranches in Alameda County, California.

Easement ID	Easement Ha	Year created	Participatory Observation Activity
MN1	12.3	2002	2007 to 2020, conducted annual monitoring with landowner for easement holder
MN2	43.3	2005	2007 to 2020, conducted annual monitoring with landowner for the easement holder
CR1	39.6	2009	2011 to 2020, participated in resource management for easement holder including weed abatement, fence and water system repair, debris removal, and road maintenance
KL1	48.6	2011	2010, reviewed draft management plan with easement holder and recommended changes
MN3	34.5	2015	2014, worked with easement holder to develop baseline resource information, conducted annual monitoring with landowner from 2015 to 2020
CR2	146.8	2019	2018, reviewed draft management plan with easement holder, consultants, and landowner and recommended changes

Case study: exacted conservation easements on working rangeland and the Golden Hills Ecological Preserve

To understand the social-ecological impact of acquisition on conservation, we engaged in participatory observation and reviewed documents for five mitigation easements on three cattle ranches in Alameda County, California (Table 1). The properties have similar habitat and land use history and were selected because the land trust and landowner invited us to participate in easement development or monitoring, which provided access to data. Subject easements were placed on the three ranches from 2002 to 2019 and ranged in size from 12.3 ha to 146.8 ha. Four of the easements are held by the same easement holder, a rancher-oriented land trust. One easement is currently held by a public agency requiring mitigation credit. Participatory observation occurred between 2007 and 2020 and has varied by easement, landowner, and age of easement, as detailed in Table 1. The consideration of five easements initiated over 16 years shows some evolution in easement agreements and funding for management over time; the most recent easement, CR2 (listed in Table 1), is fully described and highlighted in this study.

Documents reviewed for each easement included easements, management plans, monitoring reports, and the Property Analysis Report (PAR), used to calculate annual funding required for stewardship and management. During our fieldwork from 2019-2020, we conducted semi-structured interviews in person and by phone with 12 individuals, including three from wildlife regulatory agencies, three consultants, three rancher landowners, and three from entities that hold easements. Interview questions focused on

1. conservation values protected by mitigation easements,
2. the impact of easements on ranching and conservation practices, and
3. conservation easement monitoring and management and its funding.

Based on a grounded theory approach used in political ecology (Corbin and Strauss 1990), we analyzed and coded field notes, easement documents, and interview transcripts to identify social processes and relations and funding flows occurring in the development and management of the subject exacted easements. Following Clarke (2005), we developed a situational map to situate the case studies and determine the relationship between social and ecological factors impacting stewardship, management, and economic opportunity on grazed land pre-and-post an exacted easement. The most recent exacted easement, the Golden Hills Ecological Preserve, is highlighted in this review; it conserves similar values to the other easements reviewed but includes maintenance and creation of habitat. It was chosen to highlight because it provides the most up-to-date listing of conservation activities, their value, and who will be paid for conducting them.

Results and Discussion

Spatial analysis and a case study approach were used to answer the questions from our objectives about the types of land in conservation status and the influence of exacted easements on social relationships and the environment.

Spatial analysis of grazing, protection, and conservation activities

What is the extent of grazing lands acquired for conservation?

Lands protected for conservation cover 492,709 ha or 29% of the Bay Area. Grazing land describes 41% of land in the Bay Area and 43% of the protected land. It is the most common land use protected by conservation easements, such that 63% of the area's conservation easements are on grazing land, or 53,143 ha. Grazing land protected by public ownership or fee-simple title accounts for 39% (157,522 ha) of the land protected by fee-title in the Bay Area (Fig. 2). Working lands, both grazed land and farmland, have higher percentages of land protected by conservation easements than their percent cover in the Bay Area.

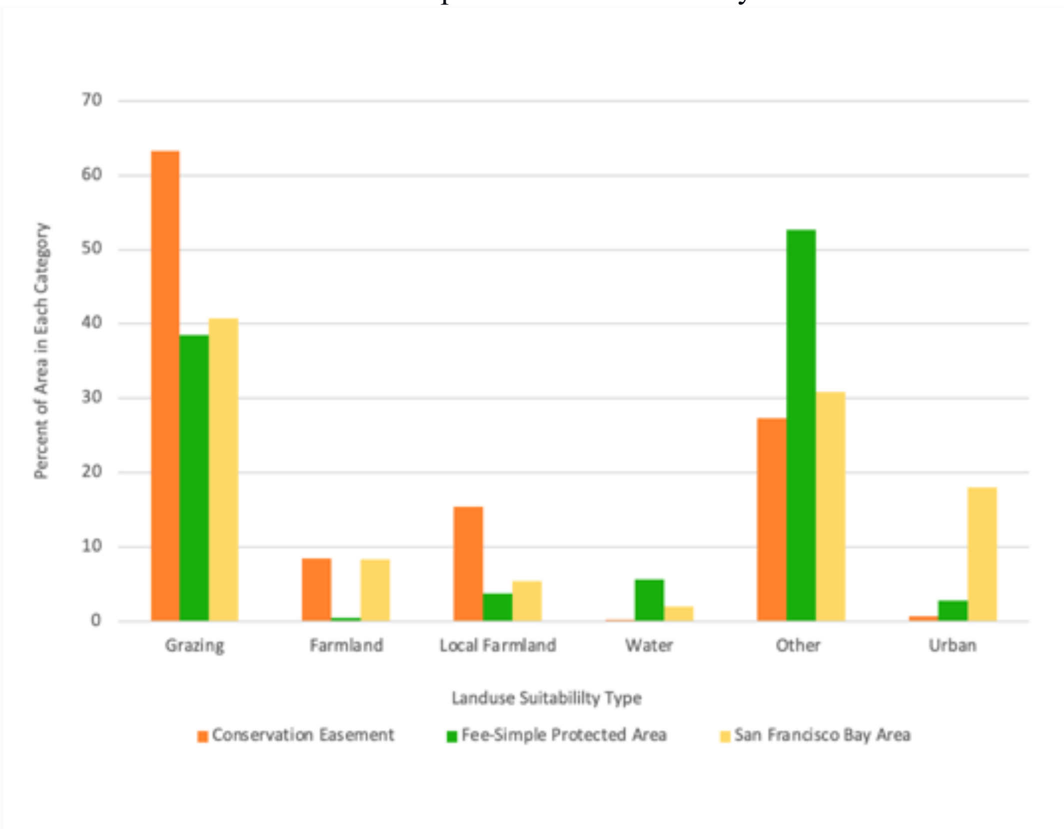

Fig. 2. Land use suitability types that occur in conservation easements, fee-simple properties, and all land in the eight-county San Francisco Bay Area.

What vegetation cover types have been acquired for conservation?

Grasslands and oak woodlands are the dominant land-cover types in the Bay Area and are commonly associated with grazing land. They cover 854,942 ha or 47% of the Bay Area and account for 52% of the protected land (272,479 ha). Grasslands and oak woodlands, followed by cultivated agricultural land and chaparral, are the most commonly protected vegetation cover types. Grasslands and oak woodlands account for 61% of the land protected by conservation easement (58,838 ha) and 50% of the land protected by fee title (213,641 ha) (Fig. 3). Only cultivated and urban land have a lower proportion of land protected by fee-simple title than percent cover in the region.

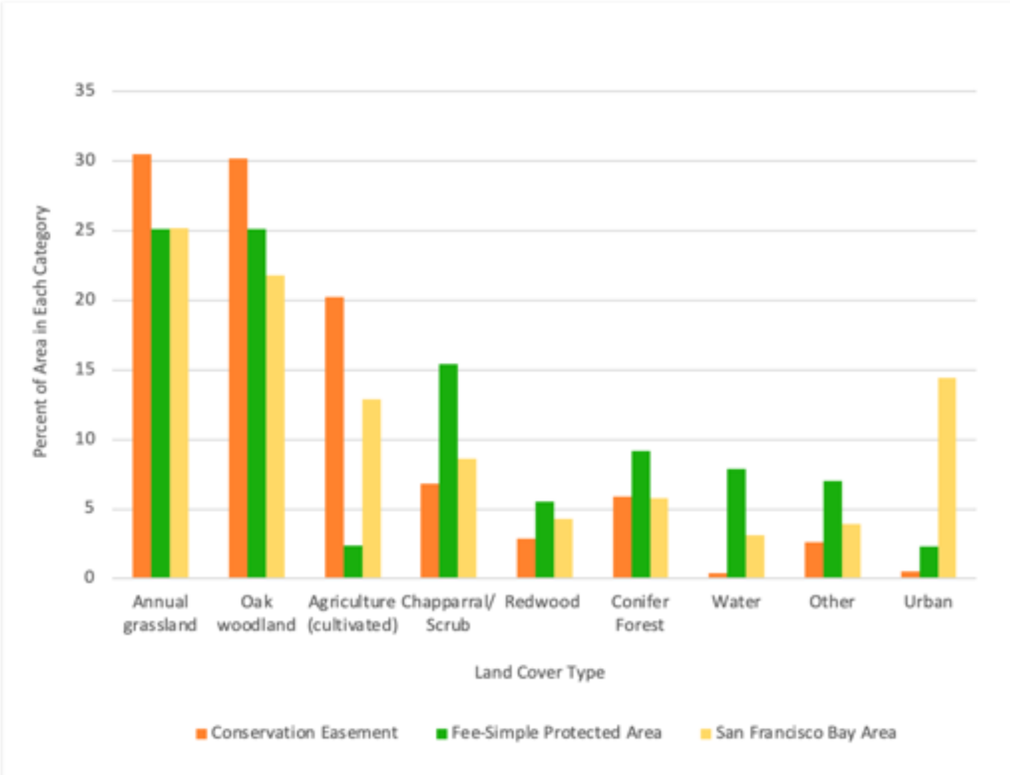

Fig. 3. Vegetation cover types that occur in conservation easements, fee-simple properties, and all land in the eight-county San Francisco Bay Area

Table 2. Number and percent of threatened and endangered plant and animal species with at least 10% of potential habitat on unprotected[1] and protected lands by land use type.

	Number and percent of plant species with >10% of potential habitat (n=65)		Number and percent of animal species with >10% of potential habitat (n=33)	
Land use type	Unprotected	Protected	Unprotected	Protected
Grazing land	40 (62%)	39 (60%)	24 (73%)	22 (67%)
Farmland	19 (29%)	15 (10%)	8 (24%)	6 (18%)
Farmland of local importance	32 (21%)	13 (20%)	6 (18%)	9 (27%)
Water	8 (5%)	4 (6%)	7 (21%)	7 (21%)
Urban	31 (48%)	24 (37%)	12 (36%)	1 (3%)
Other	53 (82%)	46 (71%)	28 (85%)	23 (70%)

[†]In this study "protected" is used to mean the land title includes permanent conservation or public status.

What land use types are providing habitat for threatened and endangered species?
All land use types provide potential habitat for some threatened and endangered species within 3.2 km of known occurrences. Both grazing land and other land types provide potential habitat, at least 10%, for most of the species likely to require mitigation (Table 2). However, among land use types, grazing lands provide over 50% of the habitat for the greatest number of plant and animals species on both protected or non-protected lands (Fig. 4).

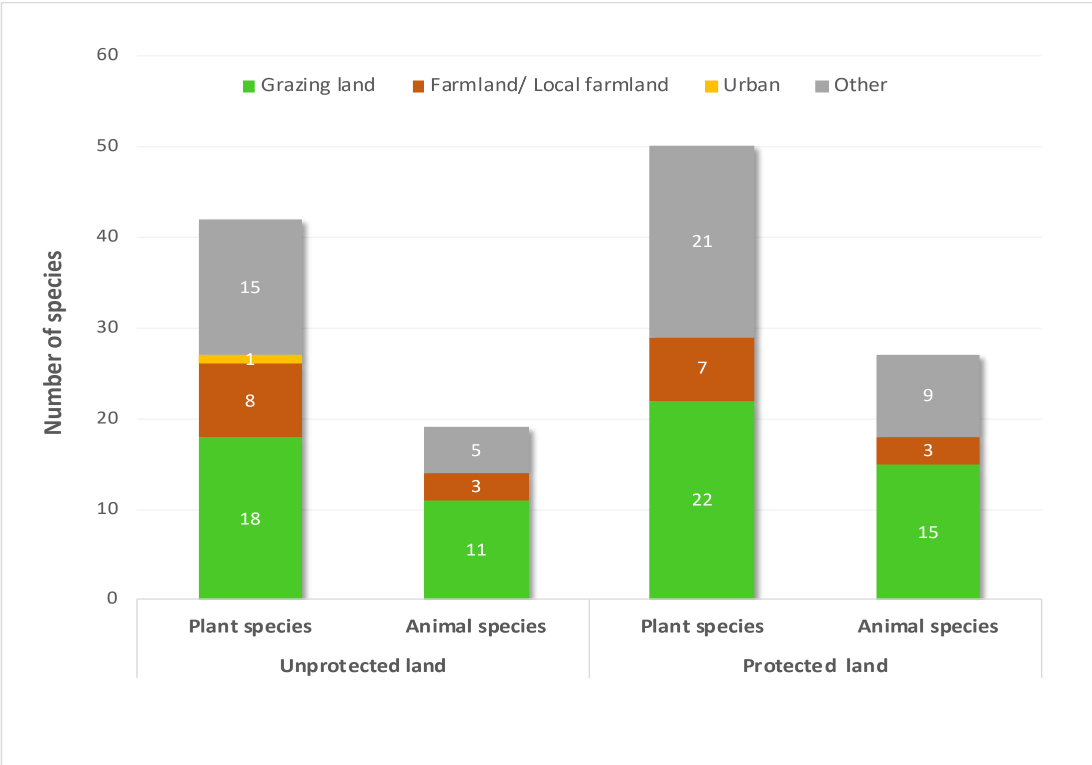

Fig. 4. Number of species with greater than 50% of their potential habitat provided by a single type of agriculture land use on unprotected and protected lands in the San Francisco Bay Area.

What land uses are associated with priority lands for conservation?
Grazing land represents over half of the land essential for conservation and 65% of the land categorized as important for conservation. The majority of contributing and connecting lands are grazing land (Table 3).

Table 3: Percent of unprotected[1] conservation priority land as defined in the regional conservation strategy, Conservation Lands Network 2.0, by agricultural land use in the Bay Area.

Conservation Priority Category	Grazing land	Farm-land	Farmland of local importance	Water	Other	Urban
Essential for conservation	51%		6%	3%	40%	
Important for conservation	65%		3%	1%	31%	
Connecting land for conservation	73%		6%	1%	19%	
Contributing land for conservation	68%		6%	1%	25%	
Not priority for conservation	4%	30%	2%		8%	58%

[1]In this study "protected" is used to mean the land title includes permanent conservation or public status.

Spatial analysis of Bay Area protected lands over a decade ago (Rissman and Merenlender 2008) found very similar results comparing the contributions of conservation easements and fee-simple title protected lands by vegetation type and agricultural land use. They found that conservation easements were more likely to conserve working lands including grazing land and farmland, whereas chaparral, scrub, redwoods, and other lands were more often conserved by fee-simple title ownership. The researchers did not consider the relation of agricultural land uses, e.g., grazing land or farmland, to species conservation or priority conservation areas; however, they concluded that including conservation easements in spatial databases is necessary for conservation planning.

In this analysis, agricultural lands, mostly represented by grazing land, have substantial overlap with lands identified as having high value for conservation. This reflects the need to specifically include grazing lands in conservation planning. Whether protected or not, grazing land in the Bay Area provides habitat to similar numbers of threatened and endangered plant and animal species, and grazing land is a primary habitat provider in the region. Beyond preventing land use change, there is no evidence that current land protection strategies, primarily focused on acquisition, improve conservation outcomes for threatened and endangered species. The case study considers the impact of land protection by exacted easements on livestock grazing and ranch stewardship in supporting species and habitat conservation.

Case Study: Exacted easements on grazing land and the Golden Hills Ecological Preserve
The exacted conservation easements reviewed in the case study were created to fulfill compensatory mitigation requirements for a variety of development projects (Table 4). Despite the difference in development projects and project proponents, the process of establishing an exacted easements and the resulting change in social-environmental relationships are similar among the easements and are exemplified by a description of the Golden Hills Ecological Preserve's creation. The Golden Hills Ecological Preserve (CR2, Table 4) was created by an exacted easement on a privately owned working cattle ranch in eastern Alameda County, California, to provide compensatory mitigation for a wind energy project on neighboring land. The wind energy project decommissioned and removed 775 obsolete wind turbines and replaced them with 48 larger, new-generation turbines. The project, completed in 2016, generates green energy for a major high-tech company and medical facility in the region. Since construction activities to remove and replace the wind turbines had the potential to impact state- and federally-listed threatened and endangered species, the United States Fish and Wildlife Service and the California Department of Fish and Wildlife required mitigation. A neighboring cattle ranch, which is grazed by livestock and has been stewarded by a ranching family for the past 150 years, was found by federal and state wildlife management regulators to support quality habitat for three threatened and endangered species requiring mitigation, San Joaquin kit fox (*Vulpes macrotis mutica*)(SJKF), California red-legged frog (*Rana draytonii*) (CRLF), and California tiger salamander (*Ambystoma californiense*)(CTS), and one species of special concern, western burrowing owl (*Athene cunicularia*). The project proponent, a wind-energy developer, was able to compensate for the loss of habitat from their project by committing to

1. purchasing from the ranch landowner a conservation easement that restricts land use for perpetuity on 147 ha,
2. creating additional breeding habitat on the ranch for CRLF and CTS by expanding a stock pond,

3. purchasing another easement on 65 ha of adjoining grazed public land managed by a municipal utility agency, and
4. establishing a non-wasting endowment to fund conservation needs, including annual monitoring and reporting.

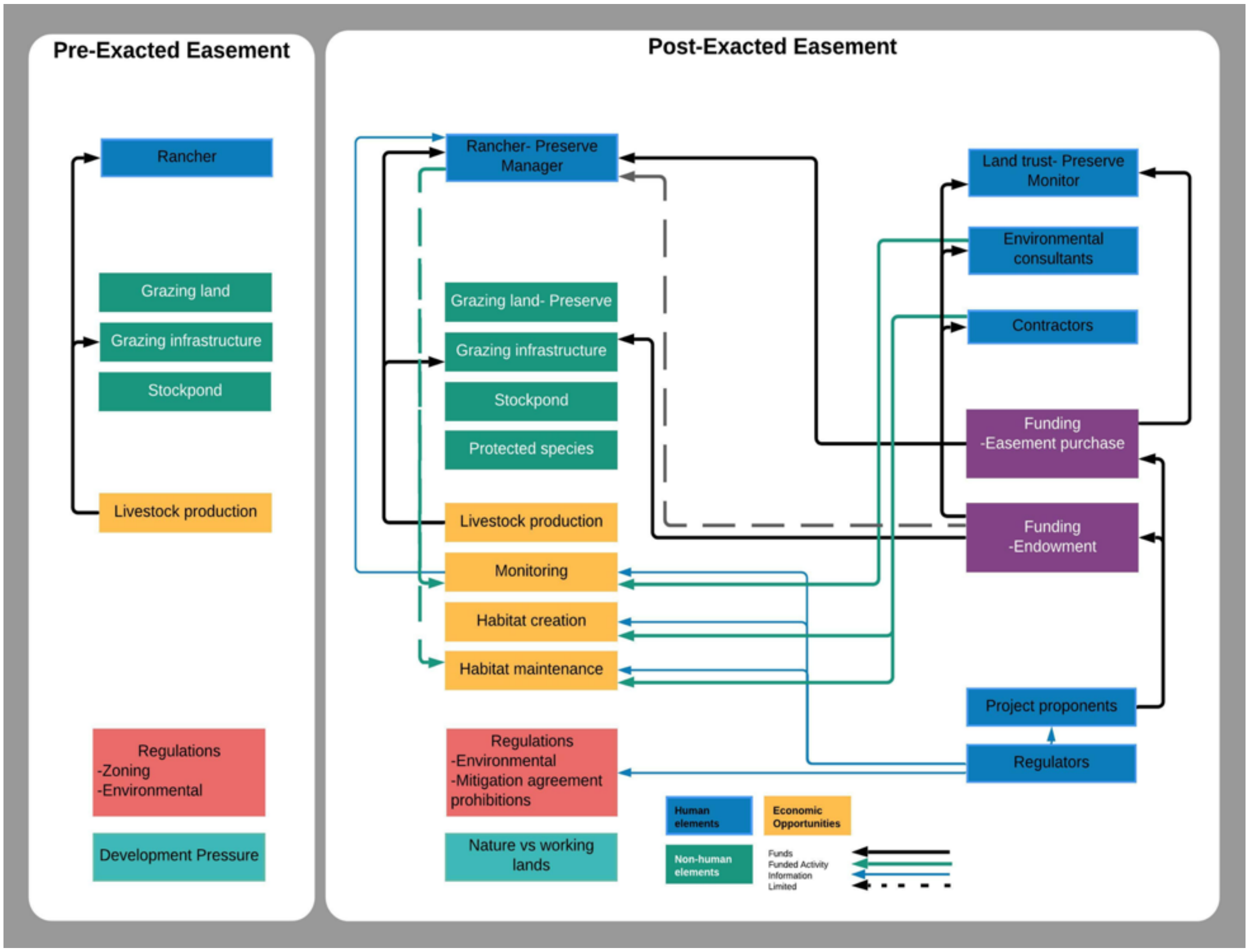

Fig. 5. Case study situational map of social-ecological system on grazing land pre- and post-exacted easement

The ranching family, interested in accessing funds to secure their ranch land for future generations, voluntarily agreed to the terms of a conservation easement agreement; they considered the easement to be compatible with rangeland livestock production. They attribute the creating and sustaining of the desired conservation values to their ranch work and past land stewardship practices and regard livestock production as fundamental to conserving the species found on their land. For example, two stock ponds within the easement area were created to provide livestock water and habitat for CTS and CRLF. Livestock grazing practices have maintained upland habitat with favorable vegetation structure for CLRF, CTS, SJFK, and western burrowing owls. With agreements from corporations to buy green energy, the wind-energy developer funded the exacted conservation easements, new habitat construction, and an endowment. The family chose a non-profit, agriculture-based land trust, approved by the wildlife regulatory agencies, to hold and enforce the easement. While the family may sell the ranch land, the easement, including its deed restrictions and conservation management requirements, remains with the property forever.

The other easements reviewed in this study provide habitat for similar listed species on grazed rangeland (Table 4), although enhancement, e.g., creation of habitat, is not always required. The situational map illustrates relationships between human and non-human elements of the easement and the flow of funds and information supporting conservation activities pre- and post-exacted easement implementation (Fig. 5). The exacted easements reviewed in this case study have resulted in reterritorialization, which redefines the purpose of the land and land use, determines which activities are appropriate, and shapes who will benefit from permitted uses.

Table 4: Case study: exacted easements reviewed on working ranches in Alameda County. The Golden Hills Ecological Preserve is CR2.

Easement ID by Ranch	Year created	Project Mitigated	Enhancements	Conservation Values
MN1	2002	Residential development	None	Habitat for California tiger salamander
MN2	2005	Municipal golf course	None	Habitat for California tiger salamander, California red-legged frog
CR1	2009	Highway road widening	Riparian planting; wetland creation	Habitat for California tiger salamander, California red-legged frog, San Joaquin kit fox
KL1	2011	Water treatment plant construction and pipeline	None	Habitat for California tiger salamander, California red-legged frog, San Joaquin kit fox
MN3	2015	Electric switching station	None	Habitat for California tiger salamander
CR2	2018	Windmill repowering	Breeding pond expansion	Habitat for California tiger salamander, California red-legged frog, San Joaquin kit fox, and burrowing owl

Reterritorialization: redefining a ranch as an ecological preserve

Creating a preserve from a working ranch through an exacted conservation easement establishes new control over a rancher's use of rangeland resources and diminishes the capacity for land sharing. Brogden and Greenberg (2003: 291) term this reterritorialization and describe it as occurring "when an interest group redefines commodity values and achieves power to rearrange rights to a natural resource system so that earlier commodity values become obsolete and disprivileged." The concept of reterritorialization builds from theories of 'internal territorialization' developed by Vandergeest and Peluso (1995: 385), which describe a process, where within a defined area, a state institution establishes control over people's activities and use of natural resources. Since as private property, the ranch was already territorialized for ranching, the creation of the Golden Hills Ecological Preserve led to a new kind of state territorialization or reterritorialization.

In the case of an exacted easement, control over ranch resources is acquired through purchase and assigned to a third-party non-government agent, often a land trust. The land trust is required to uphold easement requirements, which were developed by environmental consultants on behalf of project proponents to satisfy requirements from wildlife regulatory agencies (Fig. 5). The mitigation and purchase agreement renames the ranch as a preserve and defines the ranch landowner as a preserve manager, which communicates the shift in the purpose of the property from ranching and livestock production entirely to nature conservation. In drafting the easement agreement and conservation management plan for the Golden Hills Ecological Preserve, the ranch landowner questioned the use of the term "preserve manager:"

"I am not sure why the term 'rancher or landowner' is being replaced by 'preserve manager,' except 'preserve manager' does not acknowledge the rancher or a ranching operation."

Conservation values do not include grazing or ranching for exacted easements

This shift of purpose through reterritorialization of the ranch land is also illustrated in the conservation values specifically defined for the Golden Hills Ecological Preserve (CR2). Conservation values are part of the easement agreement, and they determine the management and preservation goals for the property. Stated as follows, the conservation values for this easement are limited to habitat values for specific threatened and endangered species:

"The Easement Area provides high quality natural, restored and/or enhanced habitat for the San Joaquin kit fox (Vulpes macrotis mutica), California red-legged frog (Rana draytonii), California tiger salamander (Ambystoma californiense), and western burrowing owl (Athene cunicularia), and contains breeding, non-breeding, foraging and dispersal habitats for these species. Individually and collectively, these wildlife and habitat values comprise the 'Conservation Values.'"

Among conservation easements on rangeland, this lack of recognition of grazing or ranching as a conservation value is specific to exacted easements. Conservation easements that are donated or purchased for conservation of rangeland typically acknowledge ranching as a value. For example, the standard easement language, used on easements that are not exacted, provided by the California Rangeland Trust recognizes grazing and agriculture as conservation values (CRT 2017):

"Landowner desires to convey for valuable consideration [make a charitable gift of] the Conservation Easement to Rangeland Trust to assure that the rangeland environment, agricultural productivity, open space created by working landscapes, the plant, [fish], and wildlife habitat and watersheds will be conserved and sustained forever through managed grazing and as otherwise provided herein (referred to herein as the "Conservation Values"), and that uses of the land that are inconsistent with these Conservation Values will be prevented or corrected."

When asked, representatives of the California Rangeland Trust commented that excluding grazing or ranching as a conservation value in an exacted easement is not ideal for sustaining livestock production; however, they noted that grazing is permitted by referencing the conservation management plan in the recorded easement. In fact, though not listed as a conservation value, the conservation management plans for the exacted easements reviewed in this study all include requirements for grazing management, and when applicable, include plans to maintain grazing infrastructure such as fences and watering systems. Support for grazing as a permitted land use is also provided by federal and state wildlife regulators and managers that acknowledge that agency and scientific understanding of livestock grazing impacts has shifted in recent years to recognize benefits from grazing in certain ecosystems. A USFWS federal regulator articulated this shift during an interview: *"For a long time, the conservation movement was based on natural environmental systems, now we work on reconciliation ecology, encouraging grazing that is beneficial to species."*

During interviews, biologists for the California Department of Fish and Wildlife also acknowledged the value of livestock grazing and a change in the department's perspective regarding grazing:

"Leaving properties ungrazed is not good. Grazing habitat does well ecologically, and grazing can reduce fuel loads."

"We are seeing grazing more positively. It is another tool like mowing or burning."

Although the wildlife management agencies may recognize a positive role for grazing, as one rancher landowner put it, "*They (wildlife management agencies) assume grazing will pay its way,"* said a ranch landowner, *"but who will graze and provide habitat when it doesn't work (pay its way)."* In discussing with a USFWS federal regulator how an exacted easement will maintain ranch viability, it was made clear that exacted easements for habitat conservation have a specific purpose. Exacted easements meet permit requirements for the preservation, restoration, and enhancement of an area, for covered species and their habitat, where covered species are the legally protected species requiring mitigation because of development elsewhere. The easement may accommodate other protections such as agricultural land preservation or watershed protection, but that is not its purpose. The regulations are decisive in protecting nature with little consideration for protecting the activities that have created and maintained the conditions for the covered species. During the development of easement documents for the Golden Hills Ecological Preserve, when the ranch landowner inquired about impacts to ranching viability, he was repeatedly informed by consultants drafting the long-term management plan that *"the conservation easement's primary function is covered species."* While there is some appreciation that livestock grazing may be compatible and even beneficial, active efforts to keep production viable are not valued. Yet, the loss of production would change the habitat in perhaps undesirable ways and undermine the livelihood of the landowner responsible for stewarding the land.

Enclosures: prohibited land uses and activities
Exacted easements tend to deprivilege livestock production, putting livestock grazing, an ecological process that most stakeholders and wildlife agencies agree is beneficial for most of the targeted species, at risk. In addition to defining conservation values that do not include livestock grazing, an exacted conservation easement prohibits certain uses and activities because they are deemed incompatible with the conservation of covered species. These restrictions required by the federal and state wildlife management agencies are monitored and enforced by the easement holder for perpetuity; they illustrate the effects of reterritorializing a ranch to a nature preserve creating enclosures that limit a rancher's use and management of ranch resources. Ranchers in accepting a conservation easement expect restrictions on land use change; after all, the

landowner is paid for or donates in exchange for tax benefits all future rights to develop the land. However, given that their management has created and maintained desired habitat values, they also expect to be able to maintain a viable ranching operation. They do not expect easement requirements to conflict.

The ranch landowner for MN1 described an unexpected conflict. He sold an exacted easement to protect a stockpond providing breeding habitat for California tiger salamanders. The pond, a sag pond, naturally occurred; it formed shortly after the 1906 earthquake and has been maintained by the ranch family for livestock water ever since. Just after the easement was established, a representative from the wildlife agency came to see the pond. He said, 'well, let's talk about where to put a fence to keep the cattle out.' The rancher had to convince him that a fence was not necessary given that the cattle had been accessing the pond for decades and the salamanders were abundant. An easement holder shared that other ranch landowners have been less successful in negotiations to protect livestock access to stock water. Some ponds have been fenced, although the resulting declines in habitat eventually led to gates deliberately left open, with the easement holder's consent, to aid the species. While fencing may be an appropriate tool to manage livestock grazing for livestock production and conservation, it is not fencing per se but management time that results in positive resource outcomes (Derose et al. 2020).

Physical enclosure by fencing may restrict the use, but enclosure of use or values also results from restriction of activities. In describing the mechanism of land control, Peluso and Lund (2011) recognize that enclosures restricting resource use or protecting species can impact users similar to physically fencing out the space. In the case study, concepts of nature preservation trump historical use and management, resulting in enclosures, and the need for prohibited activities in order to conserve species is not always apparent. For example, prohibitions on recreation, recreational horseback riding, or hunting have little to do with conserving the protected species and their habitat and more to do with restricting human activity. The rancher landowner for the Golden Hills Ecological Preserve asked, "so when do I know if I am recreationally horseback riding or riding for ranch work?" Another questioned why hunting is prohibited on his exacted easement when the conservation value is habitat for CTS, a salamander not likely to be affected.

Any agricultural activity other than grazing, such as planting, disking, or using pesticides and rodenticides, are common prohibitions in exacted conservation agreements reviewed in this case study. In some cases, exceptions may apply if the practice will benefit conservation values based on the easement agreement and approval from the wildlife regulatory agency and the easement holder. Even so, approval is not guaranteed, and obtaining permission may prevent timely management. These practices on a ranch may be used infrequently or just periodically but have supported livestock production on grazed land in the region for well over a century. For example, since the late 1800s, millions of acres of land in California have been treated with various toxicants to suppress ground squirrel populations (Grinnell and Dixon 1918, Schitoskey and Woodmansee 1978). Ground squirrels are native and make burrows used by CTS, burrowing owls, and SJKF, but they are also a serious agricultural pest. Historically ranchers have judiciously poisoned squirrel colonies that degrade infrastructure or have the potential to cause significant erosion. Resource protection and livestock production may also be restricted by the inability to plant. The periodic planting of non-native plants for either forage or erosion control also has an extensive history on California's rangelands (Murphy et al. 1973) and can reduce invasive species and improve forage production (Davy et al. 2017). Prohibiting historical management practices for perpetuity restricts the ability of ranchers to adapt to change, including climate change, and puts sustaining livestock production and its benefits on the conserved lands at risk.

Accumulation from conservation of protected species
While reterritorialization through an exacted easement deprivileges livestock and applies enclosures restricting certain activities needed to support livestock production, new economic values from actions to conserve protected species are created. Prior to the exacted easement, threatened and endangered wildlife species and their habitat on the ranch had no economic value. Livestock production was the sole source of income derived from grazing (Fig. 5). Both creating new habitat and protecting habitat to fulfill permit requirements resulting from environmental regulations demand ongoing services, i.e., conservation activities. These activities are funded into perpetuity at Golden Hills, as they are paid from annual income generated by the endowment established for the easement (Fig. 5). Non-wasting endowments are currently required by wildlife management agencies to be established for every exacted easement to cover future management and compliance costs. Only the oldest easement from the case study, established in 2002, does not have an endowment, although the developer paid a fee to the land trust to cover future monitoring activities.

Corson (2011: 706) examined 'state' territorialization in the creation of protected areas in Madagascar and found that protection or conservation enclosures can "create commodities from a variety of things previously isolated" from markets. This variety of things includes ecotourism, amenity values, and wildlife (McAfee 1999, Brogden and Greenberg 2003, Buscher 2009), and can be applied here to conservation services for wildlife protection for which there was no market value prior to the exacted easement. From Harvey's (2003) reframing of Marx's concept of primitive accumulation, capitalism continually seeks resources that can be converted to providing profit. Corson argued that ongoing accumulation resulting from conservation enclosures benefits third-party non-state agents. Creating a need for services for plants and animals that previously had no economic value primarily benefits the individuals and companies providing the environmental services. The easement needs result in ceding some authority of the ranch landowner and the government over the ranch resources to this environmental service industry. Questions arise about the sustainability of this conservation strategy, given the motives of both the non-profit land trust and the for-profit environmental service providers (Fairfax et al. 2005). Corson (2011) argued that the future ability of both the land and its stewards to support conservation might be compromised by the accumulation that results from the conservation enclosure and the incentives it creates.

In the exacted easements reviewed for this case study, funded conservation activities include resource management, infrastructure maintenance, monitoring, reporting, and easement administration (Table 5). Some activities can only be provided by qualified resource management professionals and solely benefit habitat, such as the required removal of bullfrogs, which are predators of the protected species. However, some tasks support land sharing by livestock production and conservation, including maintenance of stock ponds, management of invasive species, or adaptive management. Several tasks, including biological surveys or monitoring, provide little benefit to either habitat or production but serve the administration of the easement or provide assurance that conservation values are being upheld.

Table 5. Conservation tasks funded by annual endowment revenue, and their purpose, beneficiary, and value to habitat, livestock production or both (sharing) for the Golden Hills Ecological Preserve.

Funded Conservation Activities	**Purpose**	**Economic beneficiary from task**	**Value**
Aquatic resource / rare plant assessment	Monitoring	Consultant	Habitat
Den/ burrow monitoring and mapping	Monitoring	Consultant	Habitat
Protected species monitoring, CA red legged frog, CA salamander- Migration barrier	Monitoring	Consultant	Habitat
Protected species monitoring, CA red legged frog, CA salamander- Predator Monitoring	Monitoring	Consultant	Habitat
Residual Dry Matter monitoring	Monitoring	Consultant	Sharing
Photo monitoring	Monitoring	Consultant	Administration
Easement monitoring	Monitoring	Easement Holder or Consultant	Administration
Fence and gate replacement	Infrastructure	Landowner or Contractor	Sharing
Water system replacement (pump, water tank, pipeline, trough)	Infrastructure	Landowner or Contractor	Sharing
Signage, preserve boundary and no trespass	Infrastructure	Landowner or Contractor	Sharing
Pond maintenance/ repair (dredging)	Infrastructure	Contractor	Sharing
Grazing infrastructure maintenance	Infrastructure	Landowner or Contractor	Sharing
Access road maintenance	Infrastructure	Landowner or Contractor	Sharing
Trash removal	Management	Rancher	Sharing
Weed management	Management	Rancher or Easement Holder	Sharing
Wildlife management (non-native species removal)	Management	Contractor	Habitat
Adaptive grazing management	Management	Landowner	Sharing
Temporary livestock exclusion fencing	Management	Landowner	Habitat
Livestock pond fencing	Management	Landowner	Sharing
Biological monitoring report	Reporting	Easement Holder or Consultant	Administration
Residual dry matter monitoring report	Reporting	Easement Holder or Consultant	Administration
Annual monitoring report	Reporting	Easement Holder or Consultant	Administration
Annual management meeting	Reporting	Rancher	Administration
Accounting	Reporting	Easement Holder	Sharing

Easements developed more than a decade ago only established funding for easement monitoring, biological surveys, reporting, and replacement of grazing infrastructure where applicable. Except for funding for infrastructure replacement, e.g., replacing fencing every 40 years, third-party agents entirely conduct funded activities in these older agreements. The land trust must hire a qualified environmental consultant to monitor the easement and provide the rancher with information to support adaptive management. Based on monitoring reports and rancher interviews from the case study, while the ranchers conduct adaptive management, i.e., adjusting stocking rates, timing grazing to impact invasive species, or minimize impact in riparian areas, they do not rely on information from consultants to make adaptive management decisions.

However, both the land trust and environmental consultants see a critical role in the services they provide. The California Rangeland Trust, which holds all the easements in this case study except one, which the developer, a public agency, still holds, was founded by ranchers and works closely and cooperatively with ranch landowners to develop workable easement agreements that can keep livestock ranching viable while meeting regulatory needs required for species protection. Consultants interviewed recognized that conservation arrangements need to be compatible with livestock production to be sustainable, and they see their role as valuable in translating information between ranchers and regulators for easements to be successful in providing species conservation. One environmental consultant shared that "ranchers often do not have skills or knowledge to present information that (regulatory) agencies require." While biological surveys and monitoring may not provide conservation outcomes, interviewed consultants and easement holders saw value in monitoring being able to assure compliance and defend grazing practices. As an easement holder noted, "monitoring provides defense against dogma." Still, the consultants and easement holders had concerns that monitoring was "overdone," "overthought," or "overmonitored." One noted that "it's really good for consultants."

Endowments created to serve and uphold easements certainly provide long-term benefits for conservation service providers such as environmental consultants. However, the newest agreements include funds for management, which may be conducted by the landowner, allowing them to benefit from ongoing accumulation, new economic values resulting from conservation. Funded management activities often benefit habitat management and livestock production, contributing to sustaining land sharing (Table 5). For example, the ranch landowner, for MN3, is receiving annual payments for thatch management that results from managed grazing and conducting photo monitoring. The ranch landowner for CR1 was paid for mowing invasive weeds and removing debris left from illegal dumping. These new opportunities are varied, but easement landowners have shown that they are willing to conduct management activities to meet conservation objectives.

Landowner willingness to reorient the use of land or activities to take advantage of reterritorialization and resulting new economic opportunities has been observed on various landscapes. Timber companies shifted to preserve making and residential development (Olson 2016, Watson and Skaggs, 2016). On agricultural lands, farmers adjusted operations to benefit from new capital and labor resulting from in migration and amenity-based opportunities (McKinnon, 2016). However, the new economic opportunities provided from exacted easements differ in that they are prescribed by the easement agreements, managed by third-party NGOs with set funding, which may limit opportunities for landowners to benefit and sustain management activities. The ranch landowner for Golden Hills Ecological Reserve questioned the funding available for conducting adaptive management for species conservation on his easement (Table 5): "The PAR (endowment budget) only supports 8 hours per year for rancher management. The management plan is not written to support or sustain ranching but rather written as if the ranch is a preserve and the preserve manager is largely a volunteer." Ultimately, how well this new economic activity supports land sharing will depend on how funds are distributed and who gets paid to perform the conservation tasks, especially since easement restrictions may reduce landowner income from production.

Conclusion

Grazing lands supporting livestock production are often overlooked as places supporting nature conservation, yet grazing lands are the most commonly conserved lands in the Bay Area, harboring numerous threatened and endangered species. The fact that these species are found most commonly on unprotected grazing lands is an indicator of the compatibility of livestock grazing and wildlife conservation today, and the stewardship of landowners, as livestock grazing in California has surpassed its 200th year. Grazing lands exemplify an opportunity to meet high priority conservation objectives in the Bay Area, including protecting habitat for threatened and endangered species through land sharing.

The exacted easement, a current land protection strategy focused on acquisition of land rights for conservation, perhaps inadvertently or simply thoughtlessly, challenges the sustainability of livestock production and its ability to contribute to habitat management and species protection. The easement deprivileges livestock production, which puts grazing, an ecological process that most stakeholders and wildlife agencies agree is beneficial for most of the targeted species, at risk. Used to fulfill permit requirements resulting from environmental laws like the state and federal Endangered Species Act, exacted easements result in reterritorialization, which redefines land use, determines which activities are appropriate, and shapes who can benefit from permitted uses. Exacted easements demand ongoing conservation services that provide new economic opportunities resulting in capital accumulation by those able to take advantage of the opportunities. While third-party non-government agents have been the primary beneficiaries of capital accumulation, conservation activities have been identified that could benefit ranch landowners, livestock production, and land sharing. In short, the exacted easements in these cases have resulted in reterritorialization, which changed the purpose of the land, redefined land use, and created new direct beneficiaries from the land.

Chapter Five

Sustaining a social-ecological system for conservation and beef production

At the end of the grazing season, rancher Tommy Williams sells cattle that were grazing the 30-acre greenbelt next to the Santa Cruz Harbor at a nearby auction yard. Selling at the auction yard allows him to realize income from the gain his cattle made while grazing to improve habitat for the Santa Cruz tarplant (*Holocarpha macradenia*), a federally-listed threatened species. While Tommy provides 'supporting' ecosystem services from managing livestock grazing to create habitat, the value he creates from beef production economically sustains his ranching operation, a social-ecological system (SES).

The three research studies presented in the proceeding chapters consider key variables, e.g., resource units, actors, and governance systems, and how they contribute to and interact in an SES that produces beef and supports the conservation of imperiled species (Fig. 1). Although these studies are California-centric and focus on species conservation, the implications for livestock grazing and pastoral stewardship to provide provisioning, supporting, regulating, and cultural services for society are broader, if not global. In this concluding chapter, I situate these studies into a larger context and within the current discourses about the inclusion of beef in our diet and the environmental impact of cattle production. I consider how these discourses influence the sustainability of beef production and its ability to continue to provide other ecosystem services by land sharing. The value of understanding the SESs to evaluate the environmental impacts of food production is also discussed.

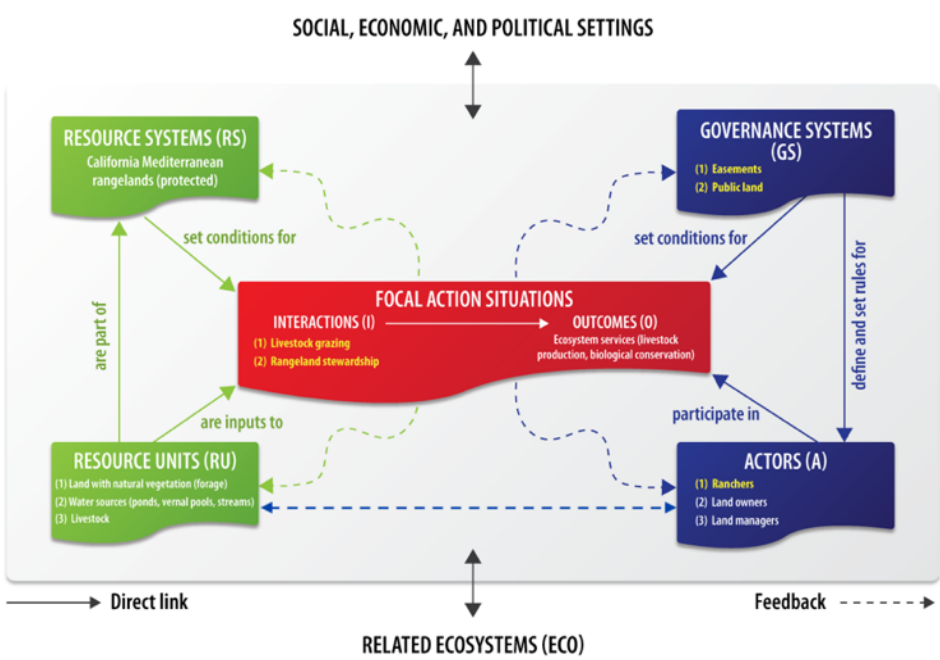

Fig. 1. Framework for the social-ecological system (SES) supporting ecological services provided by livestock ranching on Mediterranean rangelands. Adapted from McGinnis and Ostrom 2014.

The significance of beef and associated social-ecological systems

Land sharing, a conservation strategy that contributes to beef production and livelihoods (Chapter 3) and supports the conservation of imperiled species (Chapter 2 and Chapter 4) in California, substantiates a significant role for cattle grazing and rancher stewardship, a social-ecological system (SES). Globally, in terms of land and resource use, economic opportunity, social equity, and contribution to human nutrition, beef production, including cattle grazing, is significant. Grazing is the world's most prominent land use, with estimates of 26% to 40% of the planet's frost-free surface being grazed by domestic cattle, sheep, and goats[1] (Steinfield et al. 2006, FAO 2012). Much of the grazed land is characterized as marginal lands not suitable for crop production (Garnett 2009), and this land often retains natural values such as habitat for native flora and fauna, watershed function, carbon sequestration, and pollination services. In addition, 34% of the beef produced in the world is raised in a mixed livestock-crop system, where cattle graze crop residues and provide manure for crop production (Herrero et al. 2009). In several developing countries, oxen and water buffalo supply most of the draft power to grow rice and other cereal grains for human consumption (FAO 2011). In terms of livelihoods, at least 1 billion of the world's poor, of which 70% are women own livestock, including cattle (FAO 2012). An additional 1.3 billion people are employed in livestock production (FAO 2012). Livestock products contribute one-third of the protein consumed by humans and 17% of calorie consumption, although there is a wide disparity in consumption across the globe (Rosegrant et al. 2009). Livestock grazing provides ecological, economic, and social functions, but the production of livestock products, primarily beef, creates the most significant economic value to sustain SESs on rangeland.

Despite the range of ecological services provided by livestock grazing, there is mounting concern that the environmental impact of livestock production needs to be minimized, especially considering a growing world population and higher levels of wealth, which are both driving increased demand for meat (Steinfeld et al. 2006). Beef production is both a threat to and threatened by scarce natural resources, such as land and water, and by climate change. The complexity and diversity of livestock production systems worldwide, the demands and expectations placed on these systems, and the disconnect in public knowledge about the food system contribute to the difficulty of developing effective strategies and public policy to address environmental impacts. These factors advance different viewpoints among scientists, NGOs, and industry about how livestock can best provide high-value food and other products while conserving the planet's natural resources and supporting livelihoods.

Garnett (2013) and Roos et al. (2017) frame three perspectives on the issues associated with livestock production in the global food system. Reviewing these perspectives "too much greed," "not enough food," and "too much inequality" (Garnett 2015) sheds light on current challenges facing SES that contribute to beef production. Their review also demonstrates the value of understanding SESs described in the preceding chapters for sustainable global food security and conservation solutions.

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[1] Although globally, the total number of cattle is roughly equivalent to the combined total number of sheep and goats, the amount of grazing land used by cattle is substantially larger since cattle's feed requirements based on size are roughly 5x greater than sheep and goats.

Sustainability perspectives

Too much greed. Eating less beef or eliminating beef from diets is identified as a way to reduce resource use and greenhouse gas (GHG) emissions from food production (Eshel et al. 2018, Popp et al. 2010, Stehfest et al. 2009, Wirsenius et al. 2010). In addition to replacing omnivore diets with plant-based diets, cultured or synthetic meat (Post 2012) is suggested as a meat replacement to meet nutritional needs with a smaller environmental footprint. Replacing beef and other meats with cultured meat products—meat created without a live animal—assuages some people's concerns about animal welfare or rights. Both environmental and animal welfare interests are behind promoting an eat less beef approach (Garnett 2013).

In addressing environmental issues associated with food production, 'eat less beef or eat no beef' considers cattle in a singular dimension, i.e., only producing beef; it does not consider the myriad of ecological services provided by different production systems, nor does it consider differences between production systems. The general premise of this perspective is based on Life Cycle Assessment (LCA) findings that beef production 'uses' lots of land and produces large quantities of GHG emissions relative to the production of other types of food (Eshel et al. 2014, Wirsenius et al. 2010). In these LCAs, all land used for food production is considered similar, and all cows and beef production systems are considered to have similar environmental impacts.

Although the 'eat less beef or eat no beef' approach is meant to shift demand (Temple 2021), which could impact the economic viability of SESs providing beef, to date, significant increases in the sales of alternative meat products have not led to declines in meat sales. Beef sales have continued to increase in the U.S. (Simon 2021), including record exports forecasted for 2021 (USDA 2021). Nonetheless, the less meat or no meat approach will impact land sharing and sustainability of SESs if the perspective's mantra 'beef is bad for the environment' influences public policy, like grazing land use. For example, in 2020, public concerns associating grazing on public lands in the Bay Area with greenhouse gas emissions, deforestation, and species endangerment led to community members challenging the continuation of a conservation-oriented grazing program on the local open space district's land. In this case, the district commissioned a science advisory panel to conduct an extensive scientific literature review on the effects of conservation grazing on native ecosystems, its greenhouse gas emissions and carbon sequestration potential, and its use in managing vegetation for wildfire safety (Vaughn, L. et al. 2020). The review supported the grazing program, which will continue with some modifications that address public concerns about beef production.

In California and throughout much of the world, the most extensive use of land supporting beef production is grazed land in an extensive production system. As shown in Chapter 2 and Chapter 4, grazed land contributing to beef production supports natural vegetation and wildlife; and these lands are frequently associated with high conservation values. Whereas poorly managed grazing land or the conversion of forest or wetlands to pasture has negative ecological outcomes, managed cattle grazing on natural and semi-natural landscapes sustains or enhances vital ecosystem services, including biodiversity (Chapter 2, Steinfeld and Gerber 2010). Grazing's contribution to the management of habitat for imperiled species in California, presented in Chapter 2 and Chapter 4, suggests that whether beef is produced or not, grazing may be needed to provide the supporting ecological service of habitat conservation for some species. Thus, more important than the extent of land use is consideration of appropriate land-use types within SESs when evaluating the environmental impacts of food production.

Not enough food. In contrast to the eat less meat standpoint, the perspective of increasing the food supply leads researchers and policy makers to consider sustainable intensification to meet the nutritional demands of a growing population. Sustainable intensification is defined as an increase in efficiency, where production increases relative to a unit of input, including labor, land, fertilizer, seed, feed, or funds, in a sustainable way. Sustainable intensification is also promoted as a conservation strategy in contrast to land sharing, as land sparing, where yields are maximized on some land while other land is saved for conservation (Phalan et al. 2014). For beef production, sustainable intensification occurs at two scales: land-use intensification and improved animal efficiency. Like the 'eat less beef or eat no beef' perspective, sustainable intensification is narrowly focused on producing food with little regard for the SES and other ecological services it provides.

While land use intensification, such as developing improved pastures or confined feeding of cattle, provides more efficient beef production, land use efficiency is also facilitated by integrating production systems. As described in Chapter 3, in California, extensive grazing systems are integrated with intensive production through transportation and trade, which effectively expands the capacity of the beef production system. Integration provides alternative feed resources to meet production needs, allowing ranchers of all sizes to manage grazing to provide multiple ecological services through vegetation management, weed control, fire fuels reduction, and management of water resources (Chapter 3, Chapter 4). Furthermore, integrating extensive and intensive production systems or products from different production systems can increase both systems' efficiencies and social and ecological benefits.

At the scale of an individual animal, sustainable intensification of livestock production can result from new technologies and improved production practices that reduce an individual animal's environmental impacts (Capper and Bauman 2013, Garnett et al. 2013). Efficiency in terms of beef production per cow increases by raising birth rates, increasing weaning and market weights, reducing cow and calf mortality, and reducing the time required to reach market weight. In the United States, genetic selection, growth-enhancement technologies (GET), improved animal fertility and health, reduced mortality, better nutrition, and forage management have all contributed to improved efficiency over the past 50 years (Marsh 2001). This improved efficiency has significantly reduced environmental impacts through a "reduction and dilution of maintenance effect" (Capper 2011). Living animals have an ongoing daily maintenance requirement, whether they are productive or not. Increasing productivity by decreasing time to market reduces and increasing yield, i.e., dressing percent dilutes livestock's daily resources use and greenhouse gas (GHG) emissions. This impact on maintenance explains why increased efficiency in beef production has resulted in a contraction of resource use and GHG emissions in the U.S. rather than an expansion as observed in other production systems (Soper 2017). Comparing U.S. beef production systems in 1977 to 2007 showed that producing the same amount of beef required 19% less feed, 33% less land, 12% less water, 9% less fossil fuel, and 16% less GHG emission per kg of beef (Capper 2011).

Most beef production practices that improve an individual animal's efficiency or increase production per cow can be implemented in extensive production systems supporting the SES. As documented in Chapter 3, saleyards and cattle buyers drive animal efficiency in grazing systems by sorting, pricing, moving, and matching cattle to feed resources. There are penalties (lower market prices) for inefficient animals, which serve as an environmental impact fee to cattle producers (Chapter 3). On the other hand, restrictions that result from land protection strategies, i.e., prohibitions on range improvement, may limit a producer's ability to increase productivity or production efficiency (Chapter 4). When these prohibitions have little to do with protecting conservation values, there should be some consideration for impact to production and its efficiency.

Too much inequality. The third perspective, "too much inequality," focuses on the need to restore ecological systems or 'rebalance' livestock within the natural and social environment. Livestock are viewed as integral to agricultural production systems, providing manure to fertilize crops and utilizing by-products and marginal lands for feed (Garnett 2015). This perspective acknowledges livestock's role in providing food and economic security for much of the world's rural poor. Rebalance also focuses on restoring ecological systems and aligns with the conservation strategy, land sharing. Research informing 'rebalance" has evaluated the benefits of beef production systems in terms of resource use and greenhouse gas emissions and promotes livestock numbers balanced to what the local resource base can maintain. However, focused on local production and meeting local needs, researchers and advocates of "too much inequality' set system boundaries that impact the sustainability of SESs by failing to production to local resources.

While the need to increase production in some regions is recognized, 'rebalance' based on this perspective requires production levels to be in line with the region's resources and consumption needs. Some broader geographical perspectives address "too much inequality," but these focus on the imbalance of trade relations between countries and world regions. At all geographical scopes, a primary focus of 'rebalancing' should move to change socio-economic governance to promote more equitable relations between and among producers and consumers, communities, and countries. This approach should consider a full array of strategies necessary, including government interventions with fiscal instruments and regulations as well as industry agreements and standards and public education.

To support SESs contributing to beef production and conservation, the unequal distribution of natural resources across and within regions, and the benefit of division of production and sharing of resources should be considered. As documented in Chapter 3, integrating extensive and intensive beef production systems increases the opportunity to match production with a local resource base. On the conservation side, from Chapter 4, where nature conservation strategies redefine land use and restrict activities that support conservation, economic opportunities from conservations services can provide support SESs on grazed land.

New data technologies that could support rebalance were discussed in Chapter 3. Blockchain, for example, may support beef production systems to be integrated, achieving 'balance' at different scales by providing options for different sizes of producers to contribute to beef production or a phase of production in an extensive or intensive system that fit their resources, and supports their livelihood. Technologies could also connect producers with buyers or even directly with consumers worldwide, improving producer welfare. Otherwise, constraining production and consumption to local resources would not effectively resolve social inequities resulting from the uneven distribution of resources. An integrated beef production system with effective governance could enhance sustainability efforts by promoting efficiencies through technology transfer and market standards.

Since it is the production of beef that provides value to ranchers like Tommy Williams, allowing him to manage cattle grazing to support the conservation of imperiled species like the Santa Cruz tarplant, beef production must be sustainable, i.e., economically viable, ecologically sound, and socially acceptable. All three perspectives, 'too much greed,' 'not enough food,' and 'too much inequality,' contribute strategies for sustainable beef production, but they tend to be narrowly focused in one way or another. Neither eating less meat nor increasing efficiency considers livestock's role in sustaining livelihoods and communities and cattle's contribution to crop production and natural lands management and conservation. In addition, eating less meat ignores the significant reductions in resource use and GHG emissions that can be achieved by producing meat with fewer animals and fewer resources through improved efficiencies.

While 'rebalance' considers efficiency and protecting SES associated with beef production through governance, it sets up system boundaries such as constraining production to local resources, which may stifle efforts to achieve social, economic, and ecological sustainability. System boundaries to support sustainable beef production should be examined, given the availability of changing social values, looming consequences of climate change, and new technologies.

The systems that contribute to beef production are incredibly complex, involving relations between humans and natural resources. Nevertheless, beef production creates a large footprint globally with significant consequences for human and animal welfare health, environmental health, and nature conservation. To maintain a social license to continue producing beef, the social-ecological systems that produce it must be efficient, promote sustainability, and be understood.

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Chapter One: Introduction

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