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Ranchers and Beavers: Understanding The Human Dimensions of Beaver-Related Stream Restoration on Western Rangelands[☆]

Susan Charnley[a,*], Hannah Gosnell[b], Rachael Davee[b], Jesse Abrams[c]

[a] Pacific Northwest Research Station, US Forest Service, Portland, OR 97205, USA
[b] Oregon State University, Corvallis, OR 97331, USA
[c] University of Georgia, Athens, GA 30602, USA

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ABSTRACT

The past decade has seen a rapid rise in beaver-related stream restoration (BRR) using beavers and beaver dams (real or artificial) as a tool. Potential benefits of this low-cost, nature-based restoration approach include restoring aquatic and riparian habitat and recovering of threatened species dependent on it, improving water availability and stream flow regulation, reducing erosion and stream incision, and supporting climate change adaptation. Although the ecological restoration literature acknowledges the importance of addressing the human dimensions of restoration, there is a gap regarding the human dimensions of BRR. To help fill this gap we examined six projects involving riparian revegetation or artificial beaver dams to identify central elements of a supportive social environment for BRR on western rangelands. Our research questions examined how beavers, beaver dams, and BRR affect ranching operations and how ranchers view them; the policy context for BRR; and how BRR practitioners, regulatory agencies, ranchers, and partners work together for successful BRR. We synthesized our findings across cases and identified six social factors important for BRR: 1) ranchers who perceive the benefits of beavers, beaver dams, and BRR to outweigh the drawbacks; 2) education and assistance to help landowners adopt nonlethal mitigation techniques for nuisance beavers; 3) grazing practices compatible with BRR; 4) low harvest pressure on beavers; 5) a regulatory environment that enables experimentation, flexibility, and adaptive management; and 6) proponents, ranchers, and partners willing to take risks, innovate, be flexible, and stay committed.

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Introduction

The past decade has seen the rapid rise of beaver-related stream restoration (BRR) approaches using beavers and beaver dams (real or artificial) as a tool (Pollock et al. 2014, 2017; Pilliod et al. 2018). Beavers *(Castor canadensis)* and their dams hold potential for restoring aquatic habitat conditions beneficial to fish, reducing erosion and stream incision, and improving riparian and wetland habitat (Pollock et al. 2014). As such, they may help recover threatened species dependent on healthy aquatic and riparian systems. In western rangelands, examples of sensitive species that may benefit from BRR include salmonids (*Oncorhynchus* spp.) (Bouwes et al. 2016) and Great Basin species, such as the greater sage-grouse *(Centrocercus urophasianus)* (Donnelly et al. 2016) and Columbia spotted frog *(Rana luteiventris)* (Cushman and Pearl 2007; Arkle and Pilliod 2015). Beavers and beaver dams also hold potential to improve water availability by increasing surface and groundwater storage (Williams et al. 2015; Fesenmyer et al. 2018; Nash et al. 2018). These services are particularly important in rangelands of the western United States, where climate trends and projections point to warming and drying in the southwest and warming and declining summer precipitation in the northwest, with decreasing snowpack and increasing aridity (Polley et al. 2013; Snyder et al. 2019). Biophysical research about beavers and their dams is fairly substantive (see Collen and Gibson 2001; Baker and Hill 2003; Gibson and Olden 2014 for reviews), and research about the biophysical aspects of BRR has been increasing as part of the growing interest in this restoration approach (Pollock et al. 2014; Bouwes et al. 2016; Ecke et al. 2017; Weber et al. 2017). Nevertheless, there remain gaps in knowledge about best practices for BRR and whether it can deliver its expected outcomes (Pilliod et al. 2018), and a major gap exists regarding the human dimensions of BRR.

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* Corresponding author: Susan Charnley, Pacific Northwest Research Station, US Forest Service, Portland, OR 97205, USA.
E-mail address: susan.charnley@usda.gov (S. Charnley).

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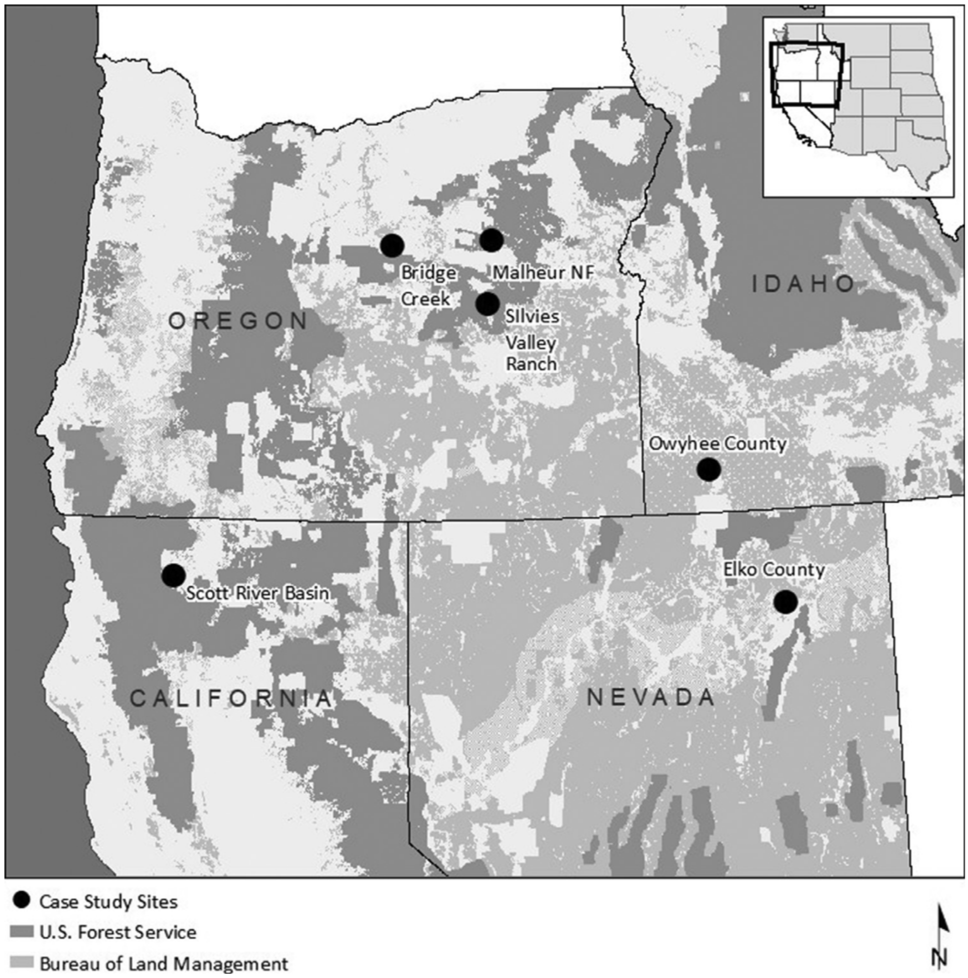

Fig. 1. Case study locations.

The ecological restoration literature increasingly acknowledges the importance of addressing the human dimensions of restoration (Gobster and Hull 2000; Egan et al. 2011a; Clewell and Aronson 2013; Martin 2017). Social and cultural values shape restoration goals and actions, and the ecosystem services that people desire inform restoration interventions (Hobbs 2004; Martin 2017). Political and economic processes influence the kinds of restoration activities that are possible (Fox et al. 2016). Ecological restoration has socioeconomic impacts that are important to consider, such as how it affects people's natural resource access, use, and management (Bliss and Fischer 2011). Traditional and local ecological knowledge, as well as public participation in ecological restoration activities, contributes to their design and implementation (Senos et al. 2006; Egan et al. 2011a). Restoration projects that are codesigned and comanaged with local stakeholders to incorporate their values and needs are more likely to garner participation and support (Egan et al. 2011b; Santos et al. 2015; Lautz et al. 2018). These same considerations are relevant for BRR.

This paper synthesizes the results of research to investigate the human dimensions of BRR in western rangelands and identify central elements of a supportive social environment for BRR. We conducted research in six locations (Fig. 1) where BRR using different approaches was under way or soon to begin. On western rangelands, BRR typically occurs on private land where ranchers graze livestock, or on federal lands (US Forest Service, Bureau of Land Management [BLM]) with grazing allotments where ranchers operate permits to graze livestock seasonally. Thus, we focused on cases of BRR implementation in the context of livestock ranching. Our research questions were 1) How do beavers and beaver dams affect ranching operations, and how do ranchers view beavers and beaver dams? 2) How does BRR affect ranching operations, and how do ranchers view BRR? 3) What is the policy context for BRR and how does it influence implementation? and 4) How can BRR practitioners, regulatory agencies, ranchers, and their partners work together for successful BRR?

After discussing the relevant literature and describing our methods, we present our results associated with each research question. Our discussion identifies six social factors that emerged as key to successful BRR implementation across cases. We conclude by considering the implications of our findings for BRR on western rangelands, where it is desirable and appropriate, in order to enhance the potential for success of this increasingly popular stream restoration approach.

Background

Beaver-related watershed restoration: short primer

The story of beavers in the United States is well told by Goldfarb (2018), a journalist who describes how the fur trade that began in the early 1600s in the east expanded to the west by the early 1800s, decimating beaver populations over the course of the century. Added to this were changes to beaver habitat that began in the mid-1800s caused by the draining and reclamation of wetlands using dikes, canals, ditches, and levees to create land suitable for farming and grazing (Naiman et al. 1988; Müller-Schwarze 2011; Goldfarb 2018). These events brought about extensive hydrogeomorphic and ecological changes in western streams and watersheds. By the late 1800s, beavers had begun to recover with the assistance of reintroduction schemes in several western states (Müller-Schwarze 2011; Goldfarb 2018). Since then, state regulations regarding beaver management have shifted over time, often in response to waxing and waning human-beaver conflict, contributing to fluctuations in beaver populations throughout the 20th century (Tappe 1942; Jonker et al. 2006). Today, the desire to restore riparian and aquatic ecosystems in an affordable manner that leverages natural ecosystem processes has led to the rise of beavers and beaver dams as a "nature-based solution" to stream restoration (Faivre et al. 2017).

BRR consists of three main types, which are not mutually exclusive; some projects use a combination. Two—translocation and riparian revegetation—involve beavers directly, aiming to increase the number and distribution of beavers and their dams at a particular site. Beaver translocation entails trapping nuisance beavers and relocating them to areas where they and their dams are desired. Its success has been highly variable, however, because translocated beavers often do not survive or move away from their release sites (McKinstry and Anderson 2002; Petro et al. 2015). Riparian revegetation entails actively planting vegetation used by beavers and excluding livestock or other browsers from riparian areas (with fencing) or altering grazing management to promote establishment of riparian shrubs and trees used by beavers. The hope is that riparian revegetation will lead to natural colonization of streams by beavers, who will then build dams. In some cases, riparian revegetation undertaken to meet other stream restoration goals, such as fish recovery or water quality improvement, has the unplanned consequence of catalyzing beaver colonization, enhancing the restoration process (Fesenmyer et al. 2018; Charnley 2019).

The third approach to BRR involves building instream structures designed to function like beaver dams and mimic their effects. There are many types of artificial beaver damlike structures, and there are many terms used to refer to them (Pilliod et al. 2018). Artificial beaver dams have the potential to trigger stream restoration processes that support natural colonization by beavers and the construction of new beaver dams or maintenance of artificial ones by them (Bouwes et al. 2016; Pollock et al. 2017). In this article we use the term "artificial beaver dam" to refer to the suite of artificial structures designed to mimic the effects of beaver dams.

Our study focuses on BRR using riparian revegetation and two types of artificial beaver dams: beaver dam analogs (BDAs) and low-rise rock dams. BDAs consist of wooden post structures that are pounded into a stream channel bottom and then woven with vegetation and sediment. They are semiporous, span all or part of a stream channel, and are typically installed in a series along a stream reach (Pollock et al. 2017). The low-rise rock dams in our study were constructed from rock and gravel mixed with dirt, spanned the entire stream channel, rose about 15 cm above the floodplain, and were installed along stream reaches at roughly one per 0.3 m of elevation drop.

Beavers, beaver dams, and people

Although research about the human dimensions of BRR is lacking, there is a small body of research from the United States on the human dimensions of beavers and beaver dams. Most of this work is based on the premise that beavers are nuisance animals that come into conflict with people as their mutual habitats overlap and populations grow, calling for policy and management interventions to reduce negative impacts of beavers on people. The same premise is found in the international literature (e.g., Kaphegyi et al. 2015), with the addition of studies designed to inform beaver control and eradication programs where beavers are non-native and invasive and cause ecological damage (Schüttler et al. 2011; Santo et al. 2015, 2017). Much of this research aims to understand people's attitudes toward beavers, their experiences with beavers and beaver damage, and management approaches that are socially acceptable to inform wildlife management programs (Payne and Peterson 1986; Wigley and Garner 1987; Enck et al. 1992; Conover 1998; McKinstry and Anderson 1999; Jonker et al. 2006, 2009; Siemer et al. 2013; Morzillo and Needham 2015).

The most frequently reported negative impacts of beavers on people are flooding caused by beaver dams (of timber, agricultural crops, pasture, roads); damage to human-built infrastructure (levees, dams and other water control structures, fences, roads); interference with farming activities (blocking irrigation structures, burrowing below agricultural fields, eating crops); and damaging trees valued for timber or fruit production (Payne and Peterson 1986; Wigley and Garner 1987; Enck et al. 1992; McKinstry and Anderson 1999; Collen and Gibson 2001). Research indicates that people whose properties or livelihoods are affected by beaver damage are willing to tolerate it up to a point, but there is a threshold at which the amount of economic damage or nuisance causes them to desire control measures (Conover 1998; Jonker et al. 2006, 2009; Siemer et al. 2013; Morzillo and Needham 2015). In general, people favor nonlethal control measures, such as dam removal, beaver relocation, or preventive tools like fencing, but become more amenable to lethal control if the amount of economic damage or nuisance is high.

The literature also identifies positive attributes of beavers that people acknowledge. These include consumptive benefits (meat, furs, castor oil); aesthetic enjoyment; trapping opportunities (recreational and to obtain income from selling furs); tourism benefits; ecological benefits (creating habitat for fish and wildlife, combating soil erosion, improving water quality, increasing riparian vegetation); and water benefits (elevated water tables, flood prevention, increased water for livestock and irrigation) (Wigley and Garner 1987; Enck et al. 1992; McKinstry and Anderson 1999). However, the literature indicates that beavers' reputation as a nuisance animal far exceeds their reputation as an asset, suggesting the model of human-beaver interactions portrayed in Fig. 2.

Nevertheless, a common finding in studies of the human dimensions of beavers and beaver dams is that people's attitudes toward and experiences with beavers, as well as perspectives on beaver management, are variable depending on who and where they are. Key variables include the region of the United States, urban versus rural dweller, landowner or agency manager versus not, and livelihood strategy (farmer, rancher, timber producer). For instance, a national survey of agricultural producers found that 31.9% of respondents from the southeastern United States, but only 7.3% of respondents from the western United States, reported beaver damage to their farms or ranches (Conover 1998). McKinstry and Anderson (1999) found that most private landowners they surveyed in Wyoming wanted beaver populations to decrease or remain at current levels owing to concerns over blocked road culverts, impeded irrigation infrastructure in hayfields, and tree girdling. At the same time, most public land managers wanted to see an increase in beaver populations to promote riparian restoration on public lands.

Among landowners and rural producers who have beavers on their properties, ranchers stand out as one population for whom the benefits of beavers may outweigh the costs. A historical study by Fountain (2014) found that farmers in California in the first half of the 20th century—when beavers were being reintroduced there—viewed beavers as an extreme nuisance in need of control and eradication. Coexistence was problematic because beavers blocked irrigation infrastructure, flooded agricultural fields, and

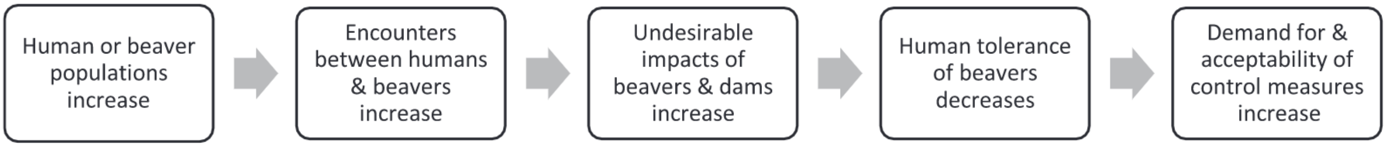

Fig. 2. Model of human-beaver interactions in which people view beavers primarily as a nuisance.

made burrows beneath fields that caused farming equipment to sink and get stuck, leading to economic losses for farmers. In contrast, California ranchers experienced economic benefits from beaver dams, including increased vegetation growth in meadows and riparian areas (increasing livestock forage); prolonging stream flows into the summer dry season, enabling livestock to make use of previously marginal upland grazing areas; and reduced demand for irrigation water to produce hay, owing to higher water tables (Fountain 2014). The finding that ranchers may view beavers as more of an asset than a nuisance suggests a model of human–beaver interactions that differs from the model portrayed in much of the literature on beavers, beaver dams, and people.

Methods

Our research employed multiple case studies and cross-case comparison (Yin 2014). We chose six cases of BRR projects (Table 1) using four selection criteria:

- location in a rangeland environment of the western United States, where livestock grazing was a historic or current land use, and ranching an important livelihood activity;
- project involved BRR techniques other than translocation (riparian revegetation in response to shifts in range management or through active planting and/or construction of artificial beaver dams);
- implementation under way for at least 2 yrs so that enough experience had been gained to inform our research questions;
- key stakeholders were supportive of having research conducted about the project.

We collaborated in an extensive survey of BRR projects in rangelands of the western United States in 2015 (reported in Pilliod et al. 2018) that provided a sample frame for our study. We found that BRR projects involving techniques other than translocation were new enough in rangeland streams that it was difficult to find cases meeting our first three criteria, limiting our sample size.

Our cases were located in California, Oregon, Idaho, and Nevada. Four (California and Oregon) involved artificial beaver dams, three of which also included active riparian revegetation. One (Nevada) entailed passive riparian revegetation triggered by changes to livestock management in riparian areas. And one (Idaho) was an exploration of rancher and stakeholder views of potential BDA installation in Owyhee County, where government agencies and nongovernmental organizations (NGOs) are considering BRR to restore and conserve wildlife species of concern and their habitat. Although this case did not fully meet our criteria, we included it to increase our sample size and inform prospective BRR, and because it included reconstruction of some natural beaver dams. Two cases illustrate BRR on private lands, two on federal lands, and two on a mix of public and private lands. Project initiation dates ranged from the early 1990s to 2016.

We used two main methods for gathering data about the cases: 1) a review of relevant literature, databases, and websites and 2) semistructured interviews (Bernard 2006) with ranchers and other landowners, agency staff, and staff working for NGOs. We conducted a broad review of published and gray literature about people, beavers, and BRR. Documents about individual cases were obtained from project websites and individuals involved in the projects. Data about beaver management, harvests, and pelt prices came from state agency websites, publications, and databases or, in some cases, from websites of organizations purchasing beaver pelts. Information about regulations relevant to BRR was gathered from federal and state agency websites and through interviews with agency employees.

We developed two interview protocols for use during semistructured interviews—one for ranchers and other landowners

Table 1
Case study characteristics.

Study site	Type of BRR	Project goal	Land ownership	Initiation date
Scott River Basin, CA	BDAs	Improve instream habitat for threatened coho salmon *(Oncorhynchus kisutch);* reduce stream incision; increase water storage and availability	Private	2014
Silvies Valley Ranch, OR	Low-rise rock dams, riparian revegetation	Restore degraded stream channels and riparian areas in a cost-effective manner to meet wildlife and ranching objectives; recover fish and beaver populations	Private	2001
Bridge Creek, OR	BDAs, riparian revegetation	Restore streams to increase Columbia River salmonid populations, especially ESA-listed Columbia River steelhead *(Oncorhynchus mykiss);* reduce stream incision	Federal (BLM Prineville District)	2007
Malheur National Forest, OR	BDAs, channel-spanning wood jams (large, coarse wood), riparian revegetation	Restore incised stream channels, reconnect streams to floodplains and side channels, create pools, and raise water table to improve riparian and aquatic habitat important for the rearing and survival of juvenile Columbia River steelhead	Federal	2016
Elko County, NV	Riparian revegetation	Restore aquatic and riparian habitat to promote recovery of Lahontan cutthroat trout *(Oncorhynchus clarkia henshawi)* by changing grazing management	Federal (BLM, Forest Service) and private	Early 1990s
Owyhee County, ID	Beaver dam reconstruction, riparian revegetation, exploration of BDAs	Increase beaver dam densities, especially in the Owyhee Uplands, where appropriate, to improve aquatic and riparian habitat for species in need of conservation and to prevent Endangered Species Act listing of Columbia Spotted Frog	Public and private	2001

BDA indicates beaver dam analog; BRR, beaver-related stream restoration.

Table 2
Number of interviewees.

Case study	Ranchers	Agency staff	NGO staff	Total interviewees
Scott River Basin, CA	9[a]	11	2	22
Silvies Valley Ranch, OR	5	3	2	10
Bridge Creek, OR	3	18	2	23
Malheur National Forest	2	2	0	4
Elko County, NV	21	6	0	27
Owyhee County, ID	13	4	2	19
Total	53	44	8	105

[a] In this case, seven ranchers and two nonranching landowners were interviewed. NGO indicates nongovernmental organization.

and one for agency and NGO staff. We used the same interview protocols at each case study location to enable cross-case comparison but adapted them slightly for the Idaho case. We chose interviewees using a purposive sampling approach (Bernard 2006), identifying the main stakeholders involved in each project and interviewing as many as possible until we reached saturation. Although we mainly interviewed project participants, we also interviewed some nonparticipating, neighboring landowners to learn how they were affected by the projects, as well as their views on beavers. Ranchers interviewed were not randomly selected, and most were involved in a BRR project; therefore they may have a more favorable perception of beavers and BRR than ranchers in general. Interviews took place between June 2016 and February 2018, and we obtained project updates from key informants through November 2018. Nearly all of the interviews were in person, but 10 were conducted by telephone because it was not possible to meet face to face for logistical reasons.

We interviewed a total of 105 people (Table 2). Agency interviewees included staff from federal agencies (e.g., US Forest Service, BLM, Natural Resources Conservation Service, National Oceanic and Atmospheric Administration [NOAA], US Army Corps of Engineers); state agencies (e.g., state fish and wildlife departments and agencies regulating water use and management); and local government (e.g., soil and water conservation districts). The NGO interviewees included staff from local watershed councils and scientists from consulting firms that helped implement the projects. Ranchers in our sample were cattle ranchers, though a few also kept small herds of sheep or goats.

We recorded, transcribed, and coded the interviews. Interview codes were analyzed and the information synthesized by topic area (see Miles and Huberman 1994). We supplemented and cross-checked the interview results with information derived from project documents, relevant publications and gray literature, project websites, and agency databases. We developed individual case reports for five of the case studies (Davee et al. 2017, 2019; Charnley 2018, 2019; Abrams et al. 2019); the exception is the Malheur National Forest, Oregon, a more recent project that we gathered information about in 2018. We then analyzed the cases to draw cross-case comparisons and conclusions (Yin 2014).

Results

1) How Do Beavers and Beaver Dams Affect Ranching Operations, and How Do Ranchers View Beavers and Beaver Dams?

Individual ranchers interviewed for our case studies identified both benefits and drawbacks of beavers (Table 3). Despite acknowledging both, the prevailing sentiment was that the benefits of beavers outweigh their drawbacks and that it is usually worth putting up with the drawbacks to receive the benefits. For example, a rancher from Owyhee County, Idaho said:

"Well, we were thrilled to see the beaver come in … My brother was like, 'Oh, no, they're gonna clog up all the irrigation.' We just worked with it. We just worked with it, and they did. They did clog things up here and there. You know, I hate to lose trees. [But] it was strictly about improving our waterways and our wetlands" (Owyhee 4).

A number of ranchers also said that "beavers in the right place" are an asset (e.g., on federal lands or private lands away from hayfields) and beavers in the wrong place, such as irrigated hayfields, are a nuisance.

The finding that most ranchers interviewed perceived the benefits of beavers to outweigh their drawbacks is primarily based on their observation that beavers increase water and forage availability for livestock. In arid and semiarid western rangelands, water is limited in summer months, forage dries out as summer progresses, and drought years are common. As one rancher from Nevada put it, "In my vote, a beaver equals water storage, and water storage equals better everything. You can't argue water storage in the desert" (Elko 16). But not all ranchers have always held such positive views of beavers. Several ranchers interviewed in Elko County, Nevada spoke of using dynamite or heavy equipment to remove beaver dams in the past because beavers were nuisance animals that blocked irrigation canals and flooded hay fields. They changed their attitudes once beavers colonized streams on their ranches where they had long been absent and observed benefits. Thus, ranchers' views of beavers are influenced by where those beavers are and how they affect streams, forage, hay fields, infrastructure, and livestock.

Nonlethal mitigation techniques that reduce the undesirable effects of beavers and their dams on ranching operations are available. Devices we observed or learned about in our cases were fencing or wrapping wire around the base of trees or riparian plantings to protect them from being gnawed or felled by beavers and several types of flow devices. Flow devices included pond levelers that reduce the risk of flooding from overflowing beaver ponds by lowering water levels; wire mesh fencing installed in streams (in various configurations) that block beavers from plugging culverts and irrigation headgates and canals; and combination wire fencing and piping installed in streams to keep water flowing through culverts and prevent beavers from blocking them and causing flooding. Another nonlethal solution to nuisance beavers that ranchers in our study reported using entailed mechanically removing beaver dams using a backhoe, tractor, or dynamite. However, this was a temporary solution; ranchers said that beavers generally returned within a few days and started building dams again.

Only a few of the ranchers we interviewed had adopted the mitigation techniques described above, not including dam removal, but efforts were under way to encourage broader adoption. In the Nevada case, training on tools for reducing human-beaver conflict sponsored by the Seventh Generation Institute (based in New Mexico) occurred on a local ranch in Elko County in 2015 to teach ranchers about the devices, and a demonstration project was developed there that other ranchers can learn from. In the California case, the local office of the California Department of Fish and Wildlife referred people who came into the office to obtain beaver depredation permits to the Scott River Watershed Council, responsible for implementing BRR in the Scott River Basin, to learn more about alternative, nonlethal mitigation measures.

2) How Does BRR Affect Ranching Operations, and How Do Ranchers View BRR?

BRR and Grazing Management.

All of our BRR case studies occurred in places where livestock grazing was a current land use. Ranchers interviewed in all but the Scott River Basin, California case typically maintain livestock on private lands from late fall through spring and then move them to grazing allotments on Forest Service or BLM lands from roughly June through September (livestock graze year-round on private ranches in our sample in the Scott River Basin). An impor-

Table 3
Benefits and drawbacks of beavers and beaver dams commonly perceived by ranchers and landowners interviewed.[a]

Benefits
For livestock and ranching operations
Raise groundwater levels and increase surface water storage, making more water available for livestock to drink from streams and ponds later into the summer and during drought years
By backing up water and raising water tables, they contribute to the creation and expansion of riparian pastures and wet meadows, increase forage production there, and cause more green forage to be available later into the summer, improving livestock health and weight gains
More green forage is available later into the summer at higher elevations, enabling cattle to graze there longer and providing more options for movement
Beaver dams raise groundwater levels, creating subirrigation for hayfields; and water from beaver ponds may overflow onto hay fields, providing natural irrigation
Financial benefits: cattle gain more weight from increased forage production; cattle eat less hay; ranchers haul or pump less water for livestock and irrigation systems
Other
Beavers are fun to watch
Beaver dams create fish and wildlife habitat and increase biodiversity
Dams reduce erosion and help reconnect incised stream channels to floodplains
Expansion of riparian areas, vegetation, and water storage deters wildfire spread and intensity
Drawbacks
For livestock and ranching operations
Beavers plug irrigation infrastructure in hay fields, disrupting water flows
Beaver dams are an impediment to livestock crossing creeks, making it necessary to find alternate crossings, creating more work for herders
Beaver dams sometimes cause riparian pastures to become muddy or flooded, making them inaccessible to livestock, making it difficult to move livestock out of them, or causing animals to get stuck in the mud
Beaver dams can stimulate the growth of dense riparian vegetation, making it difficult to find and gather cattle from riparian areas
Some beavers burrow into stream banks and underneath pastures or hay fields, causing them to cave in and wash away through erosion, or causing livestock to get stuck in sinkholes
Beavers sometimes chew fence posts or flood and knock down fencing, causing livestock to enter pastures where they shouldn't be and making it difficult to repair fencing
Other
When beavers plug culverts or beaver dams overflow, flooding can result and roads and trails may wash out
Beavers cut down trees such as quaking aspen and cottonwood that people value for aesthetics, shade, emotional attachment, and ecosystem benefits; felling trees "makes a mess" on the ground
When beaver dams wash out, they may create problems with streambank erosion and sedimentation downstream
Some ranchers who plant riparian vegetation such as willows and aspen for stream restoration have lost young plantings to beavers, hindering their restoration efforts

[a] For other, less commonly mentioned benefits and drawbacks, see (Davee et al. 2017, 2019; Charnley 2018, 2019; Abrams et al. 2019).

Table 4
Grazing management approaches used in our BRR cases.

Case study (ownership)	Grazing management
Scott River Basin, CA (private)	Fencing to exclude cattle from riparian areas was installed on private ranchlands in the 1990s as part of a federally-funded restoration program designed to recover and maintain threatened salmonid populations. Federal funding also helped pay for developing alternative water sources for livestock (e.g., water tanks). Some landowners also participate in the U.S. Department of Agriculture's Conservation Reserve Program, which provides an annual rental payment in exchange for not grazing in riparian pastures. Thus livestock were already excluded from BRR sites when the project began.
Silvies Valley Ranch, OR (private)	The landowner fenced riparian pastures in places where artificial beaver dams were constructed, and controlled grazing there. Off-channel water troughs were installed to provide year-round water for livestock away from BRR sites. Fenced enclosures were built around aspen trees planted to provide food for beavers to prevent livestock from browsing them before becoming established.
Bridge Creek, OR (federal)	Grazing was discontinued in 1994, after BLM acquired the land where the BRR project occurred in a land exchange with a private owner. BLM fenced riparian areas to exclude livestock and planted riparian vegetation to initiate stream restoration to help recover ESA-listed Columbia River steelhead. Grazing was reinstated in one allotment in 2014.
Malheur National Forest, OR (federal)	BRR took place in 2 creeks that traverse 2 separate grazing allotments having designated critical habitat for ESA-listed salmonids in riparian pastures. Grazing in critical fish habitat is strictly regulated according to a biological opinion issued by NOAA. On 1 allotment, riparian pastures at the BRR site are holding pastures used to gather livestock for 24 h at most, in between pasture moves. At the second allotment, grazing in riparian pastures occurs on a rest-rotation schedule allowing pastures to be rested every other year. Permittees comply with regulations, riparian pastures are healthy, and no changes in grazing management were required to accommodate BRR.
Elko County, NV (federal & private)	In the 1990s, ranchers began adopting a variety of conservation-oriented grazing management practices (described in Swanson et al. 2015) to reduce the frequency and duration of hot-season grazing (roughly mid-June to late September) in riparian areas, and promote riparian restoration to recover Lahontan cutthroat trout. Extensive beaver colonization was 1 outcome.
Owyhee County, ID (public & private)	Some interviewed ranchers were concerned about changes to grazing management that might be required to obtain funding for BRR on their properties, such as fencing riparian areas to keep cattle out and revising grazing management plans. However, BRR had not yet begun.

tant consideration for BRR on rangelands is how to make it compatible with livestock grazing, especially in riparian areas where projects are located. Our case studies illustrate a diverse set of grazing management strategies used on private and public rangelands (Table 4). Livestock impacts on riparian ecosystems were minimized through exclusion using riparian fencing, minimal or nonuse of riparian pastures, or a variety of conservation-oriented grazing practices that interviewees in all cases said were compatible with BRR. These strategies were either instituted to support other ecological restoration goals, with the cobenefit of supporting BRR or for the express purpose of BRR.

Ranchers' views of BRR

Landowner permission is necessary to carry out BRR on private lands; ranchers who participate do so by choice. BRR on private lands in our case studies took place at the initiative of, and by, either the landowner (Silvies Valley Ranch, Oregon) or a third party that approached landowners to request permission to implement it on their property (Scott River Basin, California). In the former case, the landowner designed, implemented, and funded the project independently, installing 640 low-rise rock dams along 30 km of river running through the ranch. This landowner was mo-

Table 5
Positive outcomes of BRR projects observed by ranchers and landowners at 2 or more case study sites.[a].

Outcome observed	Cases
Ecological	
Improved aquatic habitat for fish	CA, NV, OR (Silvies)
Increased growth and expansion of riparian vegetation and wet meadows	CA, NV, OR (Silvies, Bridge Creek)
Improved wildlife habitat	NV, OR (Silvies)
Increased biodiversity	CA, NV
Increased beaver activity and/or presence at or near restoration sites	CA, NV, OR (Silvies)
Larger and better-watered riparian areas serve as fuelbreaks to help prevent wildfire spread	NV, OR (Silvies)
Hydrogeomorphic	
Longer seasonal duration of stream flows and water ponding, increasing water availability in streams during dry summer months	CA, NV, OR (Silvies)
Higher groundwater levels/increased groundwater storage	CA, NV, OR (Silvies, Bridge Creek)
Increased soil deposition behind dams	CA, NV
Reduced streambank incision and erosion	CA, NV, OR (Silvies)
Improved floodplain connectivity	NV, OR (Silvies)
Socioeconomic	
Relationship building among agencies and landowners	CA, NV
Learning and experience to provide a foundation for improving the regulatory process for permitting artificial beaver dams	CA, OR (Silvies)
Relatively low-cost stream restoration approach	CA, OR (Silvies)
Greater community involvement in restoration and stewardship	CA, OR (Bridge Creek)
Improved livestock health and weight gain	NV, OR (Silvies)
Reduced need to provide inputs such as hay, water developments owing to increased forage and water availability	NV, OR (Silvies)

[a] Scientific research and monitoring has also occurred at most sites to document ecological and hydrogeomorphic outcomes.

tivated by a desire to restore beaver habitat and its benefits for fish, wildlife, and livestock. In the latter case, most landowners had little project involvement, with the third party—the Scott River Watershed Council—taking full responsibility for design and implementation. The most common reasons these landowners, and others interviewed in Idaho, gave for supporting BRR were a desire to restore incised streams, riparian areas, and wet meadows on their properties; raise groundwater levels and improve surface water flows (perceived as beneficial for ranching); restore habitat to promote recovery of threatened and endangered fish; and improve wildlife habitat, including for sensitive species in need of conservation. This quote from an Idaho rancher who had rehabilitated abandoned beaver dams on his property is illustrative:

> "It worked well for everything because, one, it provided water, year-round water all the time, which is a godsend for wildlife, for my cattle, everything. Two, it enhanced the wet meadows that were there, so you had better forage production for cattle, wildlife, everything else. Three, it helped with spotted frogs …." (Owyhee 2).

The issue of threatened species both galvanized support from, and trepidation among, potential participants in BRR. In the Scott River Basin, there has been conflict over allocating water for Endangered Species Act (ESA)-listed coho salmon versus farming since the 1980s. Ranchers and other landowners interviewed believed that increasing water availability and restoring aquatic and riparian habitat would be good for both salmon and agriculture, reducing struggles over water. This belief contributed to their positive views of beavers and support for BRR; 18 BDAs had been installed at 6 different sites on private lands as of late 2018. In contrast, ranchers interviewed in Owyhee County, Idaho expressed concern over BRR because of its potential to increase habitat for sensitive wildlife species such as greater sage-grouse, Columbia spotted frog, and Western toad *(Anaxyrus boreas)* on their properties. Some did not want sensitive species on their lands because they feared their presence could trigger land use restrictions including restrictions on grazing, especially if they eventually became listed as threatened or endangered under the ESA. Numerous interviewees felt that such a listing could provide leverage for environmental organizations to effectively halt ranching across much of the landscape. Although several policy tools exist to protect landowners from liability should a listing occur (e.g., Safe Harbor Agreements, Habitat Conservation Plans), concern over loss of property and livelihood options in the face of actual or potential federal regulation was a common theme in interviews. Nevertheless, some landowners in the Owyhee case believed they could prevent such listings by increasing habitat, as well as sensitive species populations, through BRR.

Three of our case studies occurred on federal lands. The Bridge Creek, Oregon project was implemented on land recently acquired via a land exchange from a private owner and therefore lacked a grazing permittee for most of its development. The Malheur National Forest, Oregon project took place on two grazing allotments. Agency staff met with permittees in advance of project implementation to explain it. Permittees were generally supportive because they believed they could benefit from resultant increases in forage and water on their allotments. Grazing permittees on Forest Service and BLM lands in Elko County, Nevada worked closely with agency staff to alter grazing management and promote riparian revegetation, and they had mostly positive experiences with BRR.

Ranchers' views of BRR were grounded in their observations of project outcomes, many of which were positive (Table 5). The most commonly reported were 1) higher water tables near BRR sites, valued by ranchers for increasing the productivity and extent of riparian vegetation, creating better forage for livestock; and 2) greater water availability in streams and depressions, especially in dry summer months and drought years, for livestock to drink, increasing drought resilience. Negative outcomes were largely the same as those associated with beavers and beaver dams (see Table 3) and were perceived by all but one interviewee as being heavily outweighed by the positive. One rancher interviewed put the tradeoffs this way: "There are places that have turned back to wetlands and we can't graze them. [So] we have given up an acre that is now swamp; but we've gained 6 acres that are good pasture that weren't before." (Silvies 1).

3) What Is the Policy Context for BRR, and How Does It Influence Implementation?

We found that the policies most relevant for BRR implementation were state regulations regarding beaver management and federal and state regulations pertaining to construction of instream structures and species listed as threatened or endangered. Poten-

Table 6
Beaver harvest regulations at case study sites (excluding removals for depredation purposes).

State/Case study site	Harvest regulations
California/Scott River Basin	Siskiyou County, where the project is located, is open to beaver harvesting following state regulations. Beaver can be hunted or trapped during the open season with a trapping license, no bag limit (CFGC 2018).
Oregon/Silvies Valley Ranch	Private landowners put a moratorium on beaver trapping and shooting on their ranch (40 000 deeded acres) to help beaver numbers increase there.
Oregon/Bridge Creek	A moratorium on beaver trapping on BLM Prineville District lands within the 710 km^2 Bridge Creek watershed has been in effect since 1991 to promote riparian restoration. A moratorium on beaver trapping on the entire Ochoco National Forest, adjacent to the Prineville District, has been in place since 1992 to promote beaver population recovery and riparian restoration.
Oregon/Malheur National Forest	Open to beaver harvesting following state regulations. Seasonal trapping and hunting are allowed with a furtaker's license, no bag limits (ODFW 2018a).
Nevada/Elko County	Nevada statewide harvest regulations apply. Beaver can be hunted or trapped with a trapping license during the open season, no bag limits (NDOW 2019).
Idaho/Owyhee County	Idaho state regulations apply; no areas are closed to beaver trapping, except private lands unless landowner gives permission. Beavers can be trapped during open season with a trapping license, no bag limit (IDFG 2018).

Table 7
Changes in statewide licensed beaver harvest, 1990s–present.

State	Statewide trends in licensed beaver harvest[a]
California	Beaver take, 1990–1991: 250 (Grenfell 1992) Beaver take, 2017–2018: 6 (Meshriy 2018)
Oregon	Beaver take, 1997: 5 539 Beaver take, 2016: 1 231 (ODFW 2018b)
Nevada	Beaver take, 1990–1991: 421 Beaver take, 2017–2018: 208 (NDOW 2018)
Idaho	Beaver take, 1993–1994: 2 581 (Will 1994) Beaver take, 2016–2017: 1 302 (Crea et al. 2017)

[a] All data are from the earliest, and most recent, reports we were able to obtain. Does not include number of nuisance beavers removed under depredation permits.

tial impacts on the water rights of downstream residents are an issue that may call for policy action in the future.

Beaver management

In the four western states where we conducted research, beavers are classified as furbearers and are subject to trapping, and in some states, hunting, following regulations set out by state agencies that manage fish and wildlife. These agencies do not monitor beaver populations but do require individuals with trapping licenses to report beaver harvest numbers at the end of each season. In all four states, there is a separate process by which landowners can request depredation permits to rid themselves of nuisance beavers. Harvest reporting is not generally required, although depredation permits specify the number that can be removed. Numbers removed through this permit system appeared to be low at our study sites.

Harvest pressure on beavers was addressed in different ways at our case study sites (Table 6).

In Oregon, beaver harvest was not allowed at two of three sites. At our sites in California, Idaho, Nevada, and the Malheur National Forest in Oregon, beaver harvesting occurred during the open season with no bag limits. Harvest pressure was reportedly low enough; however, it was not a deterrent to BRR, except on the Malheur, where Forest Service staff interviewed believed it may have reduced beaver presence at BDA sites. Statewide beaver harvests have declined substantially over the past few decades in each state (Table 7). Interviewees who commented on this trend believed the decline was largely due to low prices for beaver pelts, which averaged between about $10 and $16 per pelt, depending on the state, in the most recent years for which we were able to obtain data (2014–2018) (CDFW n.d., b; Nevada Trappers Association Fallon Fur Sale; Crea et al. 2017; ODFW 2018b). Nevertheless, some interviewees felt that investments in BRR could be undermined by localized trapping pressure.

Regulations associated with BRR activities

Riparian revegetation does not involve installing artificial structures in streams; hence there are few if any regulatory requirements associated with it, depending on whether planting is involved and species planted. On federal lands, requirements may include compliance with the National Environmental Policy Act and direction contained in a biological opinion if ESA-listed species are present. On private lands, it may include compliance with state or federal environmental regulations, depending on project type or conditions associated with cost-share program funding.

By contrast, interviewees at case study sites having artificial beaver dams said that the regulatory process was the biggest barrier to project implementation. They attributed this to several factors. Artificial beaver dams are relatively new and uncommon, meaning regulatory agency personnel may not have prior experience with them, and existing regulations may be vague or inappropriate when applied to them. BRR is often motivated by the need to restore habitat for ESA-listed fish or other sensitive species, meaning regulatory agencies are wary of actions that might further threaten these species and therefore proceed conservatively. Additionally, research and monitoring data regarding project impacts may be considered insufficient to quell concerns among regulatory agencies or public stakeholders.

Federal regulatory requirements apply in all states, for instance Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, which the Army Corps of Engineers is responsible for implementing on private and public lands. State regulatory requirements vary by state. Agencies have been adapting regulatory approaches to BRR using artificial beaver dams over time as they gain experience with them.

For example, in Oregon, federal regulatory requirements have become more streamlined over time, while state requirements have become increasingly stringent. One federal example was inclusion of BDAs in a 2013 NOAA programmatic biological opinion on aquatic restoration in Oregon and Washington, stating that they do not have a significant adverse impact on several ESA-listed species, including salmonids, or their critical habitat, streamlining the consultation process (USDC 2013). At the state level, however, the Oregon Department of Fish and Wildlife (responsible for regulating fish passage) and Department of State Lands (responsible for regulating the dredging and filling of aquatic habitat) have recently applied stricter permitting standards for artificial beaver dams owing mainly to concerns about fish passage. The Silvies Valley Ranch, Bridge Creek, and first Malheur National Forest (Camp Creek) projects—implemented between 2001 and 2016—proceeded with minimal regulatory hurdles. However, the permitting process for the second BDA project on the Malheur National Forest (East Fork Beech Creek, 2017) was so onerous that the Malheur abandoned a third project (Bear Creek) planned for 2018. To address state permitting issues, in 2015, Oregon established a multistakeholder Rules Advisory Committee charged with developing a new administrative rule for permitting artificial beaver dam projects meeting certain criteria under a general statewide permit. A separate bill was introduced to the Oregon legislature during the 2019 session that would exempt artificial beaver dams from certain state regulatory and permitting requirements. Neither effort had come to fruition as of early 2020. Important to the debate is how artificial beaver dams are defined and which types should be included.

In California, the state regulatory process has eased over time. The BDA project in the Scott River Basin was the first of its kind in California. Therefore, state regulatory agencies proceeded cautiously and conservatively as they learned to work with project implementers and became more comfortable with the approach. Although there were a number of regulatory hurdles at the outset, since 2017, BDAs have been permitted by the California Department of Fish and Wildlife and North Coast Regional Water Quality Control Board under the 2014 California Habitat Restoration and Enhancement Act. This act expedites the process for permitting small-scale, voluntary projects that improve habitat, water quality, and watershed health and benefit fish and wildlife, and it allows for more adaptive management. Additionally, in 2016, federal and state agencies involved in BRR in the Scott River Basin formed a BDA technical team to improve coordination and communication about permitting and find ways to make the process easier.

Water rights

The potential for BRR to impact water rights downstream of BRR projects is another area of possible regulatory concern. We asked interviewees at our case study sites whether water rights issues had arisen in association with BRR. In the Silvies case, some NGOs and the Oregon Water Resources Department raised water rights concerns relating to low-rise rock dams. Elsewhere, none were reported. One rancher's response captured the sentiment expressed by most interviewees: " … nobody's complaining. We've increased the water flows, which has been measured … There's nothing to complain about, unless they don't want more water" (Elko 20).

4) How Can BRR Practitioners, Regulatory Agencies, Ranchers, and Their Partners Work Together for Successful BRR?

In our cases, BRR was initiated by individual landowners (Silvies Valley Ranch), scientists (Bridge Creek), agency personnel (Malheur National Forest, Elko County, Stoneman Creek in Owyhee County), and a local NGO (Scott River Basin). Each case called for practitioners, regulatory agencies, ranchers, and their partners to work together to implement BRR. For example, scientists were key in providing technical support for project design and construction of BDAs. Project funding came from diverse federal and state sources, private companies, NGOs, and individual landowners. Federal and state agency personnel were critical for working through the regulatory process and developing alternative grazing strategies compatible with BRR.

In California, ranchers and local Scott River Watershed Council members interviewed shared several lessons learned about working together to implement BRR on private lands. Important for maintaining good relationships were notifying landowners when going to their property and acting respectfully; keeping them informed of project activities; sticking to agreements; mitigating negative project impacts and protecting landowners from liability for unwanted project outcomes; and understanding and addressing landowner concerns when they arise. One interviewee from the watershed council noted: "I think my number one recommendation would be to make sure you understand [landowner] concerns … To try to eliminate or brush their concerns to the side I think is a huge mistake … it'll boil up later when there are issues" (Scott Valley 4). Also important is ensuring landowners understand the risks and uncertainty associated with BRR to help them anticipate potential undesirable outcomes before deciding to participate.

> "The landowner really has to understand … that you're working with a dynamic process, and they have to buy into this … If you're trying to build these structures in a reach where some side-channel erosion is not acceptable to the landowner, or increased frequency of water inundation on the floodplain is not acceptable to the landowner, or an increase in meander [is unacceptable]—then that is probably not the correct location to be doing this style of restoration. Find a different site." (Scott Valley 4).

Ranchers and agency personnel in the Nevada case provided insights into how to work together successfully on federal lands. These included willingness among permittees to change grazing practices to promote riparian restoration and agency flexibility in letting permittees try new grazing management approaches for reducing livestock impacts in riparian pastures. Also important were good relationships between agency employees—who had remained in their jobs for years—and permittees, creating an opportunity to develop strong working relationships and mutual trust while collaborating to develop restoration strategies. As one agency interviewee stated:

> "It works a lot better if we can sit down with the permittee and say, 'you know what? We have to change things. What can you do? This is what we're looking for, in the end. What can you do that can ensure we get there?' Versus BLM coming in and saying, 'this is what you're going to do'. The buy-off is a lot better." (Elko 8).

A permittee agreed: "Really, really good people I'm fortunate to work with … didn't come at me with a bat, came at me with a handshake and said, 'Hey, can we do something different here? What can you do here to make this better?' " (Elko 6).

Discussion

Although the human dimensions of ecological restoration have received greater attention over the past 2 decades, the growing BRR literature has overlooked this aspect. Moreover, recent overviews of climate change adaptation strategies in western rangelands to reduce negative impacts on livestock production and rangeland health (Joyce et al. 2013; Gowda et al. 2018; Snyder et al. 2019) make no mention of stream restoration as an adaptation strategy, much less BRR. To help fill these gaps, we carried out six case studies of BRR projects involving riparian revegetation or artificial beaver dams to investigate their human dimensions and identify central elements of a supportive social environment for BRR. Here we highlight six social factors important for enabling BRR on western rangelands, public and private, based on a synthesis of findings across cases.

1) Ranchers Are More Likely to Support and Participate in BRR When They Perceive That the Benefits of Beavers, Beaver Dams, and BRR Outweigh the Drawbacks

People's attitudes and values are key in determining whether there is social license for ecological restoration. These attitudes and values are influenced by people's experiences and perceptions of how their interests will be affected by restoration actions. Not all ranchers we interviewed had favorable attitudes toward beavers, beaver dams (natural or artificial), and BRR. Additionally, research from other parts of the United States and places where ranching is not a dominant land use finds that beavers are more often viewed as a nuisance than an asset. Nevertheless, the majority of ranchers interviewed for our study perceived the benefits of beavers and their dams, as well as BRR, to outweigh the drawbacks, es-

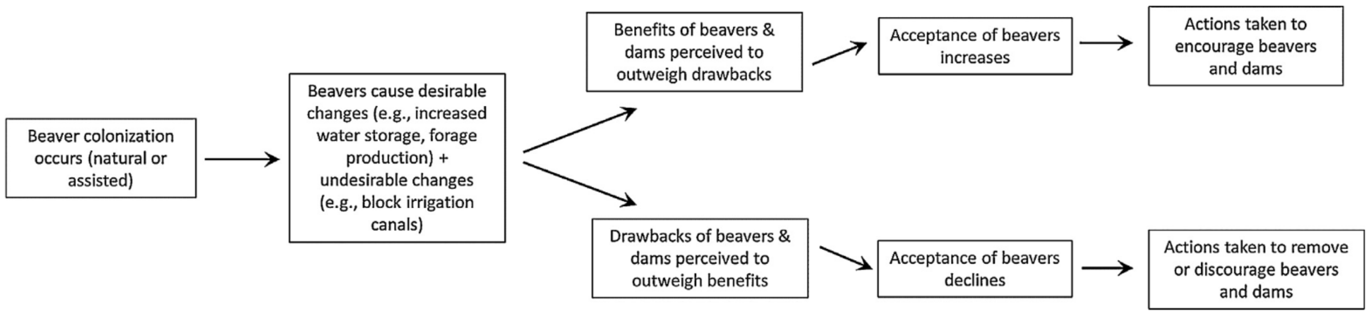

Fig. 3. Model of human-beaver interactions in which ranchers may view beavers as an asset.

pecially because they observed increases in water availability and sometimes forage where they occur. Additionally, ranchers in our study had already adapted grazing management in riparian areas in a manner compatible with BRR owing to earlier changes needed to support recovery of ESA-listed fish or promote beaver establishment. Consequently, the vast majority supported it.

These findings point to the potential for a model of human–beaver interactions that is more positive than that which prevails in much of the literature (Fig. 3). This model acknowledges that both positive and negative interactions may occur, but that ranchers are one group for whom this positive pathway could be more common. If actions to encourage and reinforce positive rancher-beaver interactions are taken, there is optimism for the prospect of BRR on western rangelands.

2) Education and Technical and Financial Assistance for Landowners to Encourage Adoption of Nonlethal Mitigation Techniques Can Reduce Undesirable Effects of Beavers Without Compromising BRR

One way to improve the benefit-cost ratio of BRR to ranchers is to reduce the negative impacts of beavers and beaver dams on their ranching operations. Nonlethal mitigation techniques can be used on private or public lands where beavers pose a nuisance to landowners and managers. Such techniques help people live with beavers while maintaining the benefits of beaver dams. Written guides that describe them are available (e.g., Taylor et al. 2017). Although there are short-term costs for adopting nonlethal mitigation techniques, upfront investment is likely to save on future costs associated with beaver damage. State agencies and local NGOs can play an important role in educating landowners about, and providing technical and financial assistance for, these measures.

3) Grazing Practices Compatible with BRR Are Important for Success; Ranchers May Need to Adapt Grazing Management on Public and Private Rangelands Where BRR Takes Place

Regardless of BRR approach, if livestock grazing is a land use at the restoration site, it should be compatible with restoration goals. Cattle use riparian areas for water, shade, and nutritious forage. Unmanaged grazing affects the amount, composition, and structure of riparian vegetation, which can negatively impact stream morphology and beaver habitat (Baker 2003; Fesenmyer et al. 2018). Loss of riparian vegetation, particularly vegetation that beavers depend on for forage (e.g., willows, *Salix* spp.), can prevent beavers from colonizing streams or cause them to abandon a site (Baker 2003; Gibson and Olden 2014; Small et al. 2016; Fesenmyer et al. 2018). In contrast, livestock exclosures or conservation-oriented grazing can facilitate vegetation recovery and establishment of beaver colonies (Swanson et al. 2015; Small et al. 2016; Fesenmyer et al. 2018). It can be challenging for ranchers to change customary range management practices to accommodate BRR, making the benefit-cost ratio of BRR less favorable for them. On federal lands, regulatory flexibility to implement different management strategies may be needed. Collaborative approaches in which agency staff and permittees work together to develop alternatives are likely to have better outcomes than top-down mandates. Financial assistance can also help, for example, by paying for new infrastructure (fencing, water tanks) needed or range riders during the transition.

4) Low Harvest Pressure on Beavers Will Help Populations Colonize Areas Undergoing BRR

A desired outcome of BRR is that beaver populations increase at the restoration site and build dams, or take over, maintain, or expand on artificial beaver dams. It is difficult for beaver to colonize BRR sites and build dams if they are subject to high harvest pressure, which adds to other sources of mortality such as carnivore predation and disease (Baker and Hill 2003). State agencies responsible for beaver management can play a role in helping ensure that beaver trapping and hunting do not adversely affect beaver populations at restoration sites; localized closures may be warranted.

5) BRR Calls for a Regulatory Environment That Enables Experimentation, Flexibility, and Adaptive Management

BRR is relatively new, relies on natural ecosystem processes for restoration (Pollock et al. 2014), occurs in dynamic stream environments, and involves an animal whose colonization behavior is difficult to predict. BRR project design must also take into account social-ecological conditions in the particular place where it occurs, which can change over time. Thus its outcomes are uncertain, and approaches may need to be adapted in response to social and ecological feedbacks as the restoration process unfolds. These characteristics mean that BRR calls for experimentation to develop best practices in particular places, adaptive management, and regulatory flexibility that enables project design to adjust as impacts materialize. In three of our cases involving artificial beaver dams, existing regulations pertaining to construction of instream structures were an impediment and led to new rules being developed and debated or alternative authorities being used for permitting.

There are risks associated with making the regulatory process for BRR using artificial beaver dams either too burdensome or too lenient. If too burdensome, people may not do it, limiting its use and benefits. Alternatively, people will proceed without the required permits, meaning projects will be unregulated and perhaps more likely to have negative impacts. If too lenient, BRR may take place without a full understanding of its potential hydrogeomorphic, ecological, and socioeconomic impacts. These risks point to the importance of research and monitoring. The more data available about the short- and long-term effects of BRR, the more likely that appropriate regulations will be developed.

6) Proponents, Landowners, Grazing Permittees, and Partners Willing to Take Risks, Innovate, Be Flexible, and Stay Committed Are Critical

The ecological restoration literature emphasizes the value of involving local stakeholders in projects. We found that committed leadership and effective partnerships were critical for successful BRR. Equally important were landowners willing to participate in

BRR on their properties, and grazing permittees willing to be flexible, as needed, to accommodate BRR on federal lands. Maintaining good relations with landowners and permittees throughout the projects contributed to their success. Each case-study project happened because a core group of proponents took the initiative and stuck with it, ranchers supported it, and partners contributed capacity, resources, technical expertise, and creative problem-solving skills. In short, BRR requires passionate, dedicated proponents to spearhead and implement it, land owners and users willing to participate in it and adjust their behavior as needed, and partners to support it. It also takes people who are willing to take risks and experiment, innovate, adapt the approach as needed, and problem solve as challenges arise. Staying committed over time as the BRR process unfolds, despite challenges, is also important because BRR is a multiyear process—not a one-time intervention.

Implications

Climate change in western rangelands is predicted to increase aridity and reduce net primary productivity—decreasing the quality and quantity of forage for livestock and productivity of riparian systems (Polley et al. 2013; Snyder et al. 2019). An important finding from our research is that ranchers observed beavers, beaver dams, and BRR can increase water and forage availability for livestock. Thus BRR not only holds potential for aquatic and riparian restoration to benefit threatened fish and wildlife, but also holds potential as a climate change adaptation strategy for ranchers.

Nevertheless, ranchers in our study and the literature on human-beaver interactions report both positive and negative impacts of beavers, beaver dams, and BRR on their properties and livelihoods. If these are overly negative, they can reduce tolerance for beavers and lead to control measures that inhibit BRR. The finding that ranchers in our study largely viewed the benefits of beavers to outweigh their drawbacks holds promise for implementing BRR on western rangelands. A number of steps to improve the benefit-cost ratio of BRR could be taken. One would be to raise awareness of, and provide support for, nonlethal mitigation measures that reduce the negative impacts of beavers, such as flow devices. Another would be working with ranchers to find mutually agreeable adjustments to grazing practices, if needed, to make them compatible with BRR, and providing financial and technical support for adopting alternative practices. Reducing regulatory barriers to BRR based on research and monitoring information could also help. Finally, taking advantage of policy tools that protect landowner options if BRR increases habitat for rare and sensitive species on their properties could help allay this concern.

We urge managers, practitioners, and others involved in BRR to consider seriously the human—not just biophysical—dimensions of BRR when making decisions about how and where to implement it. Doing so will not ensure that BRR projects deliver their desired outcomes. However, creating a supportive social environment for BRR should help improve project design and increase the likelihood of successful implementation, which, in turn, increases the potential for BRR to achieve its environmental and social goals.

Our research on BRR underscores the importance of considering the human dimensions of rangeland restoration more broadly. As is apparent from this study, assessing potential social and economic impacts of rangeland restoration on ranchers' natural resource use and management practices, as well as livelihoods, is critical. Doing so will make it easier to mitigate potential negative impacts and design restoration projects compatible with these practices, especially if affected ranchers help codesign such projects. Additionally, restoration actions that increase ecosystem services beneficial to ranchers are more likely to elicit support from them. BRR and other nature-based approaches to restoration on rangelands are an ongoing process. Innovation, flexibility, adaptive management, and commitment to the process among partners are important for success.

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Declaration of Competing Interest

Please note, Susan Charnley, Hannah Gosnell, Rachael Davee, and Jesse Abrams have no conflicts of interest to declare.

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