Pfaeffle, T., M. A. Moore, A. E. Cravens, J. McEvoy, and A. Bamzai-Dodson. 2022. Murky waters: divergent ways scientists, practitioners, and landowners evaluate beaver mimicry. Ecology and Society 27(1):41. https://doi.org/10.5751/ES-13006-270141

Research

Murky waters: divergent ways scientists, practitioners, and landowners evaluate beaver mimicry

Tori Pfaeffle [1], Megan A. Moore [2], Amanda E. Cravens [3], Jamie McEvoy [4] and Aparna Bamzai-Dodson [1]

ABSTRACT. Beaver mimicry is a fast-growing conservation technique to restore streams and manage water that is gaining popularity within the natural resource management community because of a wide variety of claimed socio-environmental benefits. Despite a growing number of projects, many questions and concerns about beaver mimicry remain. This study draws on qualitative data from 49 interviews with scientists, practitioners, and landowners, to explore the question of how beaver mimicry projects continue to be promoted and implemented, despite the lack of comprehensive scientific studies and unclear regulatory requirements. Specifically, we investigate how these three groups differentially assess the salience, credibility, and legitimacy of evidence for beaver mimicry and analyze how those assessments affect each group's conclusions about the feasibility, desirability, and scalability of beaver mimicry. By highlighting the interaction between how someone assesses evidence and how they draw conclusions about an emerging natural resource management approach, we draw attention to the roles of experiential evidence and scientific data in debates over beaver mimicry. Our research emphasizes that understanding how different groups perceive salience, credibility, and legitimacy of scientific information is necessary for understanding how they make assessments about conservation and natural resource management strategies.

Key Words: *beaver dam analogs; credibility; legitimacy; political ecology; salience; unsettled science*

INTRODUCTION

Beaver mimicry is a fast-growing conservation technique promoted as a low-cost, nature-based strategy with many potential socio-environmental benefits, which has led to an emerging popular culture of "beaver believers" (Goldfarb 2018a). Beaver mimicry refers to the construction of instream, channel spanning structures—such as beaver dam analogues (i.e., willow branches woven through wooden posts that are pounded into the streambed; Fig. 1) or low-rise rock dams—that mimic the effects of beaver dams (Vanderhoof and Burt 2018, Charnley et al. 2020). Claimed benefits include increased surface and groundwater storage, elevated riparian water tables, increased water availability in late summer, flood attenuation, improved water quality, restoration of incised streams, increased channel stability, riparian vegetation restoration, and improved fish habitat (Holmes et al. 2017, Pilliod et al. 2018, Vanderhoof and Burt 2018, Charnley et al. 2020). Although other forms of beaver-related restoration exist, including riparian vegetation restoration and beaver translocation (Pilliod et al. 2018, Charnley et al. 2020), in this paper we focus specifically on beaver mimicry.

As snowpack declines and spring runoff shifts earlier in the season, ecological impacts of drought are receiving greater attention and there is growing recognition of the need for increased water storage as a climate change and drought resilience strategy (Crausbay et al. 2017, Brick and Woodruff 2019). Beaver mimicry has garnered attention among federal agencies (e.g., the U.S. Forest Service), state agencies (e.g., the Montana Department of Natural Resources and Conservation), non-governmental organizations (NGOs; e.g., The Nature Conservancy), and some private landowners in several western U.S. states (MT DNRC 2015, Goldfarb 2018b, Pilliod et al. 2018) as an alternative form of water storage. Recent federal legislative changes allow the U.S. Bureau of Reclamation's WaterSMART program to fund natural water storage projects, such as beaver mimicry (Trout Unlimited Staff 2020, United States Congress 2021).

Fig. 1. Beaver mimicry structure using vertical wooden posts with tree branches spanning the channel and woven between the posts in western Montana. Source: Andrew Lahr, University of Montana, used with permission.

Although there is increased interest and funding for beaver mimicry, many biophysical and socio-legal aspects of the practice remain murky, though there is a growing number of scientific studies describing the biophysical effects of beaver mimicry (e.g., Pollock et al. 2014, Majerova et al. 2015, Bouwes et al. 2016, Silverman et al. 2019, Munir and Westbrook 2021). Nash et al.

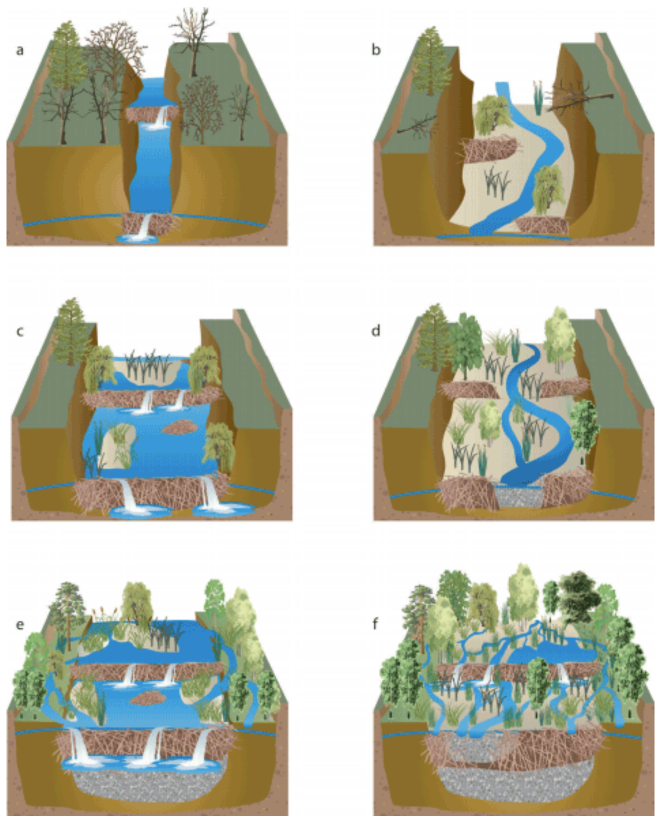
[1]U.S. Geological Survey, North Central Climate Adaptation Science Center, [2]University of Montana, Department of Society and Conservation, [3]U. S. Geological Survey, Fort Collins Science Center, [4]Montana State University, Department of Earth Sciences

(2021) describe a myriad of biophysical uncertainties related to the complex and understudied process pathways that must occur for the expected ecological and hydrological goals to be achieved, e.g., increased floodplain connectivity, increased water storage, improved habitat for key species (see Figure 2). Charnley et al. (2020) describe key socio-legal questions from ranchers, agency staff, and NGO staff about beaver-related restoration (e.g., How will the projects affect ranching operations? How will downstream water rights holders be affected?). Such policy or regulatory uncertainties are well known barriers to decision making (Baker et al. 2016). Furthermore, unclear regulatory requirements and a lack of funding for monitoring make it difficult to implement scientific studies to rigorously assess outcomes. This poses a challenge to state and federal agencies that need clear scientific evidence of effectiveness to meet "best available science" standards before widely adopting new practices (Jarvis et al. 2020). Despite the lack of conclusive scientific evidence, beaver mimicry projects are being promoted and implemented at a rapid pace, with NGOs often playing a pivotal role (Goldfarb 2018b).

Previous research on the political ecology of natural resource conservation and restoration has shown how unsettled science and divergent knowledge claims can lead to disagreements that make environmental management more challenging (Robbins 2006, Lave 2012, Sayre 2017). Disagreements may exist both because "empirical uncertainties abound" and because there are a "range of controversial and contradictory scientific and lay claims" about an ecosystem and how it functions (Robbins 2006:189). Although further ecological studies may help settle some disagreements, it is also important to empirically examine how diverse stakeholders involved in environmental conservation understand an issue. These stakeholders, including scientists, natural resource managers, businesses, NGOs, landowners or other resource users, and the public (Biggs et al. 2011, Vogler et al. 2017), bring different backgrounds and worldviews to their assessment of conservation practices, such as beaver mimicry. They also assess information and evidence differently (Cook et al. 2013). To this end, Cash et al.'s (2002) framework on salience, credibility, and legitimacy is a useful heuristic for understanding what counts as valid knowledge and evidence.

Salience, credibility, and legitimacy are three evaluation criteria used when evidence is incorporated into planning or action. Following Cash et al.'s framework (2002), evidence is considered salient based on its perceived relevance to a decision context. Credible evidence is produced by sources that are perceived to be authoritative. Legitimate evidence is created through processes that are perceived as fair and unbiased (Cash et al. 2002). Salience, credibility, and legitimacy of information are independent, individually determined characteristics (Hegger et al. 2012). They not only serve as standards to understand evidence, but ultimately reflect people's knowledge and value systems related to decision making in the face of uncertainty (Cravens and Ardoin 2016). How evidence meets these three criteria must be negotiated between scientists and other groups (White et al. 2010, Cravens and Ardoin 2016, Cash and Belloy 2020). Such negotiations play out over multiple dimensions, including who is considered an expert and invited to contribute ideas, what values and perspectives are incorporated in the framing of problems and goals, and how resources are allocated to support or reward participation (Hegger et al. 2012). Locally tailored scientific information enhances salience to decision makers (Clifford et al. 2020), although targeted information may lack salience and legitimacy for the scientific community, where curiosity-driven research with rigorous experimental design is often elevated in the peer-review publication process (Cook et al. 2013).

Fig. 2. The effects of beaver mimicry on stream channels. This graphic shows phases a-f, which demonstrate the changes in a stream channel when a beaver mimicry structure is built. A structure is built during low flows (a), which may result in the structure blowing out, but this can lead to the widening of the trench near the stream and the floodplain (b). More structures are built (c) and slowly sediment aggrades and riparian vegetation establishes (d). More sediment, widening of the channel, and riparian vegetation continue until the water table is high enough and connects the stream and floodplain (e). The ponds are filled and a complex ecosystem emerges (f). (Image reprinted from and caption adapted from Pollock et al. 2014).



The purpose of this paper is to analyze the different ways that scientists, practitioners (including managers, NGO employees, and business owners), and landowners assess the evidence surrounding a new conservation practice, i.e., beaver mimicry, and how those assessments influence the conclusions each group draws about the practice. Scientists, practitioners, and landowners offer a range of claims about beaver mimicry and use these claims to draw conclusions about the desirability (i.e., projects are seen as valuable; e.g., IDF 2020), feasibility (i.e., projects are practical and likely to be implemented; e.g., Ulibarri et al. 2021), and scalability (i.e., ability to achieve goals at the individual site scale as well as the larger watershed scale; e.g., Forrest et al. 2020) of the practice. We investigate the claims made by these groups, how they differentially assess the salience, credibility, and legitimacy of information, and then analyze how those assessments affect each group's conclusions.

By highlighting the interaction between how someone assesses evidence and how they draw conclusions about an emerging natural resource management approach, we draw attention to the roles of experiential evidence and scientific data in debates over beaver mimicry. This contributes to literature in political ecology that examines knowledge claims and different epistemological views of knowledge production, i.e., positivist and constructivist approaches (Hacking 1999). As Lave (2015) observes, formal scientific knowledge increasingly carries less "clout" and many accepted knowledge claims are being produced outside of the peer-review process. As such, it is important to examine how different groups perceive salience, credibility, and legitimacy of information, which in turn influences the conclusions they draw about conservation approaches. We argue that these insights may better align science and management by revealing how different standards of evidence underlie divergent views about environmental management. Our research is also applicable to other conservation approaches and environmental governance decisions made in the face of uncertainty or without sufficient scientific data.

METHODS

This study employs re-analysis as a method to integrate qualitative data from two separate datasets (Irwin et al. 2012, Davidson et al. 2019, Alexander et al. 2020). Re-analysis of qualitative data (also called re-use or secondary analysis) allows researchers to ask new questions and identify new evidence within the original data set(s) (Irwin et al. 2012, Davidson et al. 2019, Alexander et al. 2020). Integrating qualitative data sets into a new corpus allows researchers to analyze issues "beyond the foci of the constituent parts" (Davidson et al. 2019:364). Re-analysis can be conducted by researchers with or without involvement in the project(s) from which the data is drawn to gain "insight from data collected by different groups of researchers to address their own specific research aims" (Irwin et al. 2012:73). Researchers are increasingly synthesizing and reanalyzing qualitative data (Turner et al. 2019) in order to "scale up" qualitative research into larger data sets (Davidson et al. 2019) and allow for "novel cross-case and multi-level comparisons of patterns and contexts" (Alexander et al. 2020:82). In this study, we integrate two distinct datasets of 49 total interviews with individuals categorized as either scientists, practitioners, or landowners. Although the goals and specific interview questions were different for each project, conversations between researchers involved with each project indicated that compelling emergent themes were common across both datasets, warranting further re-analysis via cross-case comparison (Irwin et al. 2012).

The first dataset consisted of 26 unstructured interviews (Zhang and Wildemuth 2016) with scientists (n = 15) and practitioners (n = 11), from the western United States (including Colorado, Wyoming, Montana, Utah, Washington, and Oregon), all of whom were actively involved in the research or practical application of beaver mimicry. These individuals were classified according to their primary job function, although in some cases an individual's role included both research and practice. Practitioners were defined as individuals who were primarily involved in the design, implementation, or outreach aspects of beaver mimicry projects, e.g., restoration practitioner or conservation district employee. Practitioners worked for a variety of entities such as environmental NGOs (n = 2), state (n = 3) and federal (n = 2) agencies, or stream restoration firms (n = 4). Scientists were defined as individuals whose primary involvement with beaver mimicry stems from research. Their research foci included hydrology, soil science, restoration ecology, fluvial geomorphology, wildlife biology, or social science. Scientists primarily worked for universities (n = 6) and federal government agencies (n = 7), and occasionally for NGOs (n = 1) or private firms (n = 1). The original goal of the larger project for which this data was collected was to investigate characteristics of actionable science; beaver mimicry was one case study toward this objective. Interviewees were asked a series of open-ended questions about their professional roles, experiences with beaver-mimicry projects and research, perception of the relationship between scientific information and beaver mimicry practice, and understanding of the state of scientific literature as it relates to beaver mimicry.

The second dataset consisted of 23 semi-structured interviews with individuals categorized as landowners, all of whom lived and worked in southwest Montana and had variable levels of prior knowledge or experience with beaver mimicry. The original goal of this project was to understand how landowners experience and prepare for drought. Landowner interviewees were asked a series of broader questions related to their understanding of and experiences with drought and natural water storage, with particular questions focusing specifically on beaver mimicry as a form of natural water storage. In this paper, we only report analysis and results for the interview data relating to beaver mimicry. (For more detail about the project and full dataset, see Moore 2018).

To conduct the re-analysis, we used a modified grounded theory approach (Corbin and Strauss 2008) to identify emergent themes. Both datasets were re-coded by a single researcher (using Microsoft Excel software) who was not involved in the collection of the original data (Table 1). Key themes identified in the primary round of coding included claims related to beaver mimicry as well as information sources people relied upon and various types of evidence or knowledge used to assess beaver mimicry effectiveness. Given the diversity of claims about beaver mimicry we observed in the data and the ways that different types of evidence were used to evaluate beaver mimicry, we completed a second round of axial coding (Saldaña 2016) using Cash et al.'s (2002) salience, credibility, and legitimacy framework. Our axial coding assessed how each group's, i.e., scientists, practitioners, and landowners, understanding of evidence for beaver mimicry reflected their conceptions of what makes information salient, credible, or legitimate. We then used this analysis to examine each groups' conclusions about three aspects of implementing beaver mimicry: desirability, feasibility, and scalability (Table 1).

RESULTS

Claims about beaver mimicry

Our interviews with scientists, practitioners, and landowners highlighted three key areas of unsettled science and divergent

Table 1. Coding framework for re-analysis of two distinct datasets of 49 total interviews with individuals categorized as either scientists, practitioners, or landowners.

Code type	Category	Description	Codes
Primary code	Claims about beaver mimicry	Perceived benefits (scientific or anecdotal) of, or barriers to beaver mimicry/beaver restoration projects expressed by interviewees	Ecological effects; Socioeconomic effects; Nature-based strategy; Scientific bases for projects; Scientific uncertainty; Monitoring data; Regulatory uncertainty; Cost effective; Low tech; High cost; Lack of funding; Collaboration; Volunteer labor; Terminology
Primary code	Information Sources	Sources of information that scientists, practitioners, and landowners rely on to inform and guide their decisions and perspectives about beaver mimicry	Peer-reviewed research; Other people; Local agencies or organizations; Other information source
Primary code	Practice-based knowledge	The knowledge that people in a given community have developed over time, and continue to develop through use or practice	Experiential knowledge; Anecdotal evidence; Traditional ecological knowledge; Local knowledge; Holistic; Adapted to the local culture; Embedded in community
Primary code	Scientific knowledge	The system of knowledge that relies on certain laws that have been established through the application of the scientific method to phenomena in the world around us. The process involves experimenting and collecting data to answer specific research questions.	Scientific method; Technical knowledge; Peer review
Primary code	Conclusions about beaver mimicry	Conclusions or evaluations someone makes about beaver mimicry	Conclusions
Axial code	Salience	Relevance of information or knowledge for decision making (relevant to scale, environmental context, cultural context, etc.). Also how someone perceives or evaluates the relevance of information for decision making.	Analyzed by interviewee group and compared
Axial code	Credibility	Belief that the sources of knowledge, as well as the facts and causal explanations invoked by these sources, are considered accurate and/or believable. Credibility is influenced by how someone judges the process of generating information (e.g., methods; epistemological frame; etc.). Credibility reflects the extent to which the information matches rules of evidence in a given knowledge system.	Analyzed by interviewee group and compared
Axial code	Legitimacy	Reflects the perception that the production of information has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests.	Analyzed by interviewee group and compared
Axial code	Feasibility	Conclusions that projects are practical and likely to be implemented	Analyzed by interviewee group and compared
Axial code	Desirability	Conclusions that projects are seen as valuable	Analyzed by interviewee group and compared
Axial code	Scalability	Conclusions that describe the ability to achieve goals at the individual site scale as well as the larger watershed scale	Analyzed by interviewee group and compared

claims about beaver mimicry: debates over outcomes, confusion about regulatory requirements, and disagreement about the cost and ease of implementing beaver mimicry projects. Table 2 reports the number of interviewees in each group who mentioned a specific claim about beaver mimicry in each of these categories. The relative differences between the number of mentions by scientists compared to practitioners compared to landowners serve as a rough proxy for how important each claim was to each group.

Evaluations of evidence about beaver mimicry

How scientists evaluate the evidence about beaver mimicry

Scientists considered information about water storage, stream water temperature changes, soil moisture, or vegetation to be salient if it was relevant to the implementation of beaver mimicry projects. For instance, one wildlife biologist described trying to address questions because "managers want to know 'what should I do here, when and why and how?'" (Scientist 15). Scientific information was characterized as providing rigorous evidence of outcomes and describing causal mechanisms, which can be used to inform practitioners, resource managers, and other decision makers of the specific inputs needed for beaver mimicry projects to achieve the desired results. One wildlife biologist explained this link: "If you do A you'll get X, if you do B you get Y ... so, laying that out for the management community" (Scientist 15).

For scientists, credibility was established when information was perceived as meeting the standards of scientific plausibility and technical adequacy. This generally implied that information was published in the scientific literature after formal peer review: "There is a good body of literature out there, peer-review[ed] literature, a lot of it coming out of a long-term study." (Scientist

Table 2. Claims made about beaver mimicry: number of interviews (and percent of interviewees within the scientist, practitioner, or landowner group) in which claim was discussed.

Claim category	Claims made about Beaver mimicry	Description of claim	Practitioners	Scientists	Landowners	All Interviewees
Outcomes of beaver mimicry	Ecological benefits	Claims that beaver mimicry can assist in the recovery of degraded ecosystems resulting in increased biodiversity and ecosystem function. Such benefits include riparian habitat restoration and expanded habitat for a variety of plant and wildlife species.	7 (64%)	11 (73%)	13 (57%)	31 (63%)
Outcomes of beaver mimicry	Hydrological benefits	Claims for benefits of beaver mimicry related to water availability, water flow, and temperature. Examples of benefits include increased surface water flows in late summer and fall, increased groundwater filtration, and decreases in stream-water temperature.	7 (64%)	6 (40%)	10 (43%)	23 (47%)
Outcomes of beaver mimicry	Socioeconomic benefits	Claims for benefits from beaver mimicry projects on the goods and services that society derives from a healthy ecosystem. Socioeconomic benefits include increased property value, benefits to livestock and/or ranching operations, and increased opportunities for wildlife tourism or recreation.	5 (45%)	4 (27%)	16 (70%)	25 (51%)
Outcomes of beaver mimicry	Lack of data and monitoring	Discussion of the lack of long-term scientific monitoring and/or data collection to verify claims made about beaver mimicry.	6 (55%)	8 (53%)	3 (13%)	17 (35%)
Outcomes of beaver mimicry	Concerns over scientific uncertainty and unknown impacts	Concerns about scientific uncertainty and the unknown impacts of beaver mimicry projects (e.g., on ecological or hydrological outcomes).	2 (18%)	6 (40%)	2 (0.09%)	10 (20%)
Regulatory uncertainty	Complex rules and regulations	Concerns about the difficulty and/or uncertainty surrounding the legal and regulatory aspects of beaver mimicry projects, including permitting and water rights.	8 (73%)	10 (67%)	15 (65%)	33 (67%)
Regulatory uncertainty	Concerns over landowner rights and autonomy	Mentions of landowner's concerns over losing autonomy over their land or property because of the implementation of beaver mimicry projects.	7 (64%)	1 (0.07%)	8 (35%)	16 (33%)
Cost and ease of projects	Cost effective	Claims about the low cost of implementing beaver mimicry projects, especially in comparison to other stream restoration techniques.	6 (55%)	4 (27%)	0	10 (20%)
Cost and ease of projects	High cost	Claims about the high cost of implementing beaver mimicry projects, particularly for private landowners in terms of the time, money, and resources required.	0	0	17 (74%)	17 (35%)
Cost and ease of projects	Lack of funding for monitoring	Claims that there is not adequate funding available for scientific monitoring or data collection for beaver mimicry.	6 (55%)	5 (33%)	0	11 (22%)
Cost and ease of projects	Low technology	Claims that beaver mimicry projects tend to require little to no heavy machinery or equipment and many of the needed materials can be found on-site.	5 (45%)	3 (20%)	1 (0.04%)	9 (18%)
Cost and ease of projects	Collaboration/ Volunteer labor	Claims that beaver mimicry projects lend themselves to collaboration with other organizations and/or allow for participation from a wide variety of actors, including volunteers, elders and youth, and local and/or tribal communities.	7 (64%)	2 (13%)	0	9 (18%)
	Total Interviewees		11	15	23	49

1). Scientists particularly emphasized the importance of reducing uncertainty through long-term monitoring and evaluation of beaver mimicry projects, thereby establishing a more credible evidence base for beaver mimicry. For instance, as a beaver ecologist described, "They're [stakeholders] doing the right thing in wanting to see scientific results from replicated studies and repeated measures and see what the possible outcomes are before they choose to put these in or not." (Scientist 10).

Scientists' descriptions revealed a strong link between credibility and legitimacy, as scientists defined information as legitimate when it is the result of structured data collection and analysis, based in the scientific method, and subject to peer review. For example, one hydrologist stressed, "We should be using a scientific approach to make decisions about what constitutes decent restoration strategies" (Scientist 5). Similarly, a social scientist argued, "Any old landowner shouldn't just go out and start sticking in a [beaver mimicry structure] ... You have to do it right ... with the right design" (Scientist 4). Scientists believed that scientific information, as a product of an unbiased scientific process, can and should be applied by decision makers to make objective decisions about beaver mimicry. As a wildlife biologist explained, "We are trying not to be a bunch of condescending, ivory tower scientists ... there's just quite a bit of enthusiasm about beaver-assisted restoration and I think when you step back it's a good tool but it's not going to get you where you need to go" (Scientist 15).

How practitioners evaluate the evidence about beaver mimicry

Practitioners drew from a range of knowledge types to answer questions about beaver mimicry, given the diversity of their professional backgrounds, as well as "[the current] state where the practice is so far ahead of the science" (Practitioner 3). Knowledge types included experiential knowledge (gained through personal experience), anecdotal evidence (successes, challenges, or strategies of other projects, gathered through observation or word of mouth), and scientific evidence (produced through peer-review).

Given practitioners' applied role in project design and implementation, information salience was a primary concern. This group defined evidence as salient when it was relevant to achieving the desired ecological, hydrological, or socioeconomic results of a given beaver mimicry project. As a stream restoration practitioner mentioned, "You really have to think about what the long term goal is, and what you want your system to look like" (Practitioner 11). Because the necessary conditions for beaver mimicry may differ based on the desired project outcome, e.g., riparian restoration, increase in fish habitat, etc., information was salient when it informed decision makers of the specific management actions that were most appropriate to meet particular goals. As one water commissioner emphasized, there was a "whole diversity" of ways projects can be designed and distinct information was needed to support "slightly different techniques in the way that they're visualizing what [a project] looks like and what they're doing" (Practitioner 7).

For practitioners, credibility occurred on a wide spectrum and was established when information was perceived as meeting the criteria within the particular type of knowledge being applied. For instance, one federal agency contractor explicitly invoked the credibility of anecdotal evidence: "We anecdotally can see this is making the landscape better than it used to be. Therefore, why do we need to do this monitoring to answer these questions?" (Practitioner 3). Other practitioners described a need for more empirical data on beaver mimicry. A stream restoration practitioner pointed out gaps in scientific evidence: "I think it would be great to have a lot more field data demonstrating what happens [as a result of beaver mimicry]" (Practitioner 1). However, this individual, like others in the practitioner group, was generally unconcerned about the risks posed by insufficient data, continuing, "I think it's pretty obvious. I don't think it takes a lot of science to really realize these massive changes that have taken place." Whereas scientists and practitioners both saw a data gap, many practitioners did not view it as a barrier, accepting that credibility could be established through experiential knowledge and anecdotal observation instead of traditional scientific standards.

Practitioners also viewed the legitimacy of information on a spectrum, acknowledging explicitly that information about beaver mimicry was influenced by social and professional values and priorities regarding natural resource management and restoration. Therefore, practitioners defined legitimacy in terms of community acceptance of beaver mimicry. In their view, legitimacy was established when decisions, information, and management actions aligned with the specific values and desired outcomes of those (e.g., tribes, landowners, NGOs, etc.) considering beaver mimicry. For instance, the owner of a restoration firm explained,

> *What did the landscape used to look like? And is that your goal? Are you trying to restore natural processes, natural function? ... We may not actually be able to recover that or return to that because of current practices, but I think it's not entirely fair to talk about where beaver based restoration is applicable and it's not. The question you should be [asking] is, "Do you want to try to recover the natural function of these watersheds or not?"* (Practitioner 6)

Practitioners reported that values and beliefs surrounding beaver mimicry influenced rules and regulations, funding availability, community buy-in, scientific data interpretation, and even definitions of project success. As a federal contractor noted, "The impact that society and social world views have on this can't be ignored ... It's substantial" (Practitioner 3). Practitioners' explicit recognition of the relevance of values to the decision-making process regarding beaver mimicry revealed a strong connection between salience, credibility, and legitimacy.

How landowners evaluate the evidence about beaver mimicry

To answer questions regarding beaver mimicry, landowners relied on local agencies or organizations, e.g., a conservation district or watershed committee, as well as anecdotal evidence gathered from community members with personal experience. In general, landowners seemed to accept information about the ecological and hydrological benefits of beaver mimicry as long as it came from trusted sources.

Landowners considered information to be salient when it provided specific information regarding the cost and benefit of implementing beaver mimicry projects on their own property. As described by one interviewee, "The primary reason for the project was fishing ... we also realized it helped the resource too ... the stream is much more healthy [now] than it was" (Landowner 15). For landowners, the balance between socioeconomic and ecological benefits and the high personal cost was key to their decision to pursue beaver mimicry. One landowner described this balance: "There's got to be an economic incentive for [a landowner] ... say cattle prices are low but he can sell permits to fish on his land, [so] he has the economic incentive to take care of those fish and that water" (Landowner 19).

For landowners, credibility and legitimacy were closely linked; only two landowners mentioned the lack of scientific data as a concern. The most common way landowners evaluated the credibility of information was by the trustworthiness, or legitimacy, of the information source. Trust in information was established through personal relationships and previous experiences with certain organizations or agencies. One landowner explained, "We have a good relationship with both of those groups ... our local people on the advisory boards and everything. I think there's a good level of trust already built in and established" (Landowner 13). When asked who they would go to for information regarding beaver mimicry, landowners expressed a strong desire to work with local individuals or known organizations. One landowner stated, "There's no use getting more agencies involved in something that's already being done ... [staff from agencies in the state capital] don't know. It's a local board. Keep it local" (Landowner 23). Personal experience and anecdotal observations provided by trusted sources were considered to be both credible and legitimate sources of information. For example, one landowner described, "The nice thing about people in our [ranching] industry is that they like to go visit the neighbors and look around. If something works and really has value, I think the word gets out" (Landowner 13).

Landowners were more concerned about the legitimacy of the decision-making processes for beaver mimicry than the specific evidence used. Landowners considered beaver mimicry projects to be legitimate if they promoted landowners' autonomy over their land, rather than advancing others' interests. For instance, one landowner explained their decision-making process: "It's a profit motive, a selfish motive, a self-serving motive but it's my ground, it's something I want to do, rather than you wanting to come on my ground and do the hidden agenda you haven't really told me about" (Landowner 12). Landowners deemed the decision-making processes legitimate if they were consulted or given the opportunity to participate in how projects affected their land. When referring to agencies or other organizations that wanted to implement beaver mimicry projects on their land, most landowners agreed with the landowner quoted above, who emphasized that "The absolute best thing they could do is not have an agenda" (Landowner 12).

Perceptions of beaver mimicry implementation

Scientists', practitioners', and landowners' different understandings of evidence translated into divergent conclusions about beaver mimicry. We analyzed each group's perceptions of implementation, specifically coding for how they understood the desirability, feasibility, and scalability of this approach (Table 1).

Desirability of beaver mimicry

Across all groups, most interviewees claimed that beaver mimicry provided myriad ecological (mentioned by 63%) and hydrological (mentioned by 47%) benefits that contributed to its desirability. Scientists and practitioners asserted that beaver mimicry could enhance riparian vegetation and wetland habitat, reconnect the stream channel with the floodplain, improve fish habitat, provide wildlife habitat, increase ecosystem biodiversity, and raise the water table. Landowners mentioned higher water tables, improved water quality, increased bank stability, and improved fish and wildlife habitat as the most important benefits, though they typically focused on how benefits could enhance their existing ranch operations.

Although interviewees agreed that there were many potential benefits, scientists in particular (40%) expressed uncertainty about some common claimed benefits. For example, some questioned how beaver mimicry affected fish passage. Others mentioned the uncertainty around hydrological benefits, such as cooler stream temperatures, water storage, and late season streamflows. As one ecohydrologist said, "Those [goals] that are related to streamflow end up being a lot murkier and a lot less likely to happen" (Scientist 9). Scientists suggested that the desirability of beaver mimicry projects was best evaluated with robust peer-reviewed scientific evidence and thus were particularly concerned about moving forward given the current lack of data about certain benefits and long-term studies. Many acknowledged, however, that beaver mimicry likely has ecological or hydrological benefits that have not yet been proven scientifically. As one wildlife biologist expressed, "There's enough science indicating there should be some significant changes occurring ... but we just don't know the impacts of those yet" (Scientist 11).

Some practitioners (18%) also expressed uncertainty about the scientific basis for some of the outcomes of beaver mimicry, but as a group, practitioners were less concerned about this issue than the scientists (Table 2). Practitioners considered beaver mimicry projects to be desirable because of the range of benefits anecdotally observed on the ground, including improved habitat for fish and wildlife, enhancement of riparian vegetation, greater vegetation and crop productivity, and additional water storage. Less desirable aspects of beaver mimicry and possible barriers to implementation identified by this group included potential negative downstream effects, e.g., structure failures ("blowouts") or willows blocking a culvert, and uncertainty about how projects may affect water storage, stream temperature, fish passage, and invasive species.

Interestingly, practitioners described a complex relationship between values held by resource managers, landowners, and others in the conservation community and stream restoration goals, which in turn influenced the desirability of beaver mimicry. Practitioners considered that decisions regarding beaver mimicry, including the setting of project goals and expectations, reflected the values held by those involved. Some practitioners noted the negative connotations associated with the terms "beaver" and "dam" among some stakeholders. As one interviewee said, "As soon as you say 'dam' that triggers a vision in our [state water rights agency] of something that's impounding water ... which would trigger a water right" (Practitioner 7). Other practitioners noted divergent visions of what people want a river to look like and what the role of beaver ought to be. As one practitioner stated, "We are talking about trying to get people to go through a cultural change. That culture is really just the community or socially constructed perception of what the stream looks like. The beavers have been gone so long that we have our value system ... our vision of what a stream looks like and what it should look like and how streams function and the role that this rodent plays in all that" (Practitioner 6). For some practitioners, beaver mimicry was so desirable, they prioritized advancing implementation over conducting basic science and monitoring, putting practice ahead of both the state of the science and the current regulatory frameworks.

Landowners considered beaver mimicry desirable when the perceived benefits of a project outweighed the high personal costs in terms of the time, money, and resources required and if they could minimize the significant personal risks to their rights and autonomy. They linked ecological outcomes to economic benefits such as increasing forage capacity for their operations, providing additional stock water, improved resilience to drought, charging tourism or recreation fees for fishery access and wildlife habitat, and enhancing their property value. As a result, landowners were primarily interested in ensuring socioeconomic benefits: "For a rancher, first, he's got to see that it will not be detrimental to him. Second, he's going to have to see some economic benefit from it" (Landowner 3). Several landowners noted that despite the costs associated with beaver mimicry projects, they were willing to implement these projects if they saw evidence that the project would provide commensurate benefits. One landowner summarized: "I think we're just like our neighbors ... We all know areas on our ranch that could use some restoration work. I would say 99% of us in agriculture believe in restoration ... and would like to be better. I think that in itself could be enough incentive if there was a way to get it done" (Landowner 13).

Feasibility of beaver mimicry

The majority (67%) of interviewees across all three groups viewed the lack of clarity about the rules and regulations surrounding beaver mimicry as a significant barrier to feasibility. The regulatory uncertainty of most concern across groups was if, or how, beaver mimicry structures affected water rights under the prior appropriation doctrine (Thompson et al. 2018). Landowners in particular expressed concern for impacts to their operations or their neighbors' through water losses. One landowner explained: "As long as it doesn't impinge on somebody's water rights ... You know ranchers, if somebody starts doing something like this, they're going to say 'they're taking my water'" (Landowner 2). Another regulatory concern was whether beaver mimicry structures required additional permits, e.g., 310 or 404 permits under the Clean Water Act (United States Congress 1972). Many interviewees considered the permitting process complex and unwieldy, especially because landowners often must complete the necessary permits, even when another organization is involved in project design or funding. As a social scientist pointed out, "If you are a landowner who wants to do this, there [are] a lot of hoops that you have to jump through in order to get all the permission" (Scientist 1). Some interviewees commented that different regulatory agencies or officials within the same agency disagreed about the necessary permits, causing further confusion during implementation. One stream restoration practitioner stated: "Different water commissioners have given me totally different answers" (Practitioner 1). Scientists noted that acquiring permits for data collection was difficult. An ecohydrologist said: "One of the things that ... continues to be really sticky is that there's not a really clear way to [obtain a] permit for experimentation" (Scientist 9). Many scientists and practitioners reported they try to "fly under the radar" (Scientist 8) in order to avoid the complex and unclear regulatory environment.

Scientists viewed the lack of peer-reviewed evidence proving benefits as the most significant barrier to the feasibility of beaver mimicry. Scientists expressed a need for more scientific evidence regarding the specific outcomes of beaver mimicry and believed the lack of such evidence could negatively impact the overall success of current and future projects. One beaver ecologist struck a cautious note typical of this group: "We might find out later that by not doing the research first, we actually caused more problems than we [produced] benefits" (Scientist 10). An ecohydrologist expressed the importance of accurate information to establish trust and ensure the success of beaver mimicry projects:

> *If we promise people something ... and it doesn't come to pass because we haven't tested it well enough or we haven't placed careful error bars around what to expect, people will lose their trust in us. We will lose the faith of people who did what we said, invested money into what we said, invested hope into what we said* (Scientist 9).

In this scientist's view, the feasibility of beaver mimicry overall could be threatened by unfulfilled promises, made based upon incomplete or uncertain scientific information.

Practitioners and landowners both mentioned that perceptions of beavers themselves affected the feasibility of beaver mimicry projects. A federal contractor explained, "The resistance is strong, and that inertia that it has ... I think goes back to that whole negative connotation that the beaver carries" (Practitioner 3). Although beaver mimicry does not in fact involve the translocation or reintroduction of beavers, practitioners described interacting with landowners and citizens who frequently linked projects to actual beavers, creating a barrier to project acceptance. A landowner interviewed in this study illustrated this negative connotation poignantly when asked about beaver mimicry: "Honestly, if beavers build in the wrong spot, they're kind of a pest ... Obviously you can't eliminate all of them, but they can be a problem. If they're not bothering anything, we don't care. But if they build in my pipe, they're a problem" (Landowner 6).

Different perceptions about the relative cost and ease of beaver mimicry projects also influenced feasibility. Many practitioners (55%) and some scientists (27%) considered beaver mimicry cost-effective, comparing it to traditional stream restoration or water storage techniques. They highlighted that the use of local resources offered design flexibility and allowed for more structures. These interviewees emphasized that beaver mimicry projects did not require heavy machinery, opening up areas previously inaccessible to large equipment. Additionally, beaver mimicry projects lent themselves to volunteer participation or in-kind partner contributions, lowering labor costs. As a state natural resource manager explained, "It's not terribly hard to get a group of volunteers together ... cutting willows is not terribly hard work" (Practitioner 5). Beaver mimicry was also seen as more feasible than building new, large dams: "There isn't really the political will to build large storage reservoirs [and because of] how much evaporative loss we have on those large reservoirs, people are saying, 'what are some smaller projects or other ideas that we can do?'" (Practitioner 7).

In contrast, landowners assessed feasibility based on personally paying for and maintaining structures, requiring money, time, labor, and often taking land out of production. One landowner concluded, "I think it would be a nice hobby ..., but I don't have time and money to even think about it" (Landowner 10). Other landowners stated that they found the projects feasible when they could obtain funding from nonprofits or other organizations. Some ranches were willing to implement projects with their own money when there were clear future ecological and economic benefits, e.g., improved fisheries allow them to charge a rod fee for recreation. Additionally, some landowners were concerned about a potential loss of autonomy, especially if there were "strings attached" to the funding they received or if the projects would restrict their ability to use their land. The landowner quoted above continued: "[It's] more difficult for us to operate because [if] you do stream restoration then pretty soon [regulators or project funders] will come along and say your cattle must be fenced off from this and that would divide our ground into [an] unusual, strange looking piece" (Landowner 10).

Scalability of beaver mimicry

Practitioners (55%) and scientists (27%) agreed that the relative low cost and ease of beaver mimicry projects were key characteristics that could allow for large-scale implementation. One ecologist described the relationship between project funding and the scalability of beaver mimicry projects: "The low tech, low cost thing is appealing ... it is more likely to be able to scale up and affect larger landscapes and not be cost prohibitive" (Scientist 10). However, both groups noted lack of scientific information could be a barrier to scalability. Practitioners also discussed that wide-spread adoption would require addressing regulatory uncertainty and a shift in societal values around restoration and beavers' place in ecosystems.

Scientists expressed concern that decisions to implement beaver mimicry projects were currently "aspirational rather than science driven" (Scientist 5), meaning that projects were funded and built across the landscape without adequate scientific evidence to support the claims being made. Scientists pointed out that current project designs had not yet allowed for investigation of the interaction between topographical, geological, and hydrological characteristics and project function that would be necessary to site projects across the landscape:

> *It's been really difficult to tease out what's the immediate effect of the restoration practice itself and what's something that was sort of a happy circumstance of combining both geographically specific conditions, especially related to ground water or tributary inputs ... versus the restoration practice. So it's really hard to disentangle the two of those* (Scientist 9).

Scientists posited that one reason for this dearth of evidence resulted from the nature of beaver mimicry projects. These projects are viewed as low-budget, pilot projects, with funds designated for implementation rather than monitoring. Similarly, a water commissioner described the need for a better understanding of water storage: "One of the questions that we have is how much water are we really storing ... what's the capacity of a system to store that water? Before we can scale that up to a larger scale you may want to have an understanding of what's happening locally in order to understand the effects of larger scale projects" (Practitioner 7). This was noted as being particularly challenging because hydrological systems are dynamic and context dependent, which made it hard to standardize beaver mimicry projects.

Landowners made few comments about scalability because they were primarily focused on beaver mimicry at the individual scale. Some landowners mentioned their willingness to work across networks of trusted neighbors and partners to learn from each other and implement projects together. Others, however, emphasized their desire to keep to themselves and avoid judgments that neighbors may make regarding their management priorities. One landowner summarized the view that beaver mimicry decisions on private ranches will likely remain personal decisions: "Stream restoration below us or above us, yeah I think it would be neat if we could all get on the same page and do it, the whole stream. But, [it] probably isn't going to happen. Not everybody feels the same [about prioritizing it] ... And we all have to make a living" (Landowner 1).

DISCUSSION AND LIMITATIONS

Beaver mimicry is an example of a fast-growing conservation and water management strategy where practice is ahead of the relevant science and policy. Our re-analysis of 49 interviews provides insight into the divergent claims made by scientists, practitioners, and landowners about beaver mimicry. Our analysis of how each group differentially evaluated the salience, credibility, and legitimacy of evidence related to beaver mimicry projects illustrates the different standards for these criteria (Hegger et al. 2012, Cook et al. 2013).

For scientists, the credibility of information was key. This group emphasized that information is credible only when it meets objective standards as defined by the scientific method and not when it is anecdotal or experiential. They considered the lack of peer-reviewed publications establishing outcomes and causality to be the biggest barrier to credibility, and therefore to widespread implementation of beaver mimicry. Nash et al.'s (2021) process-expectation framework provides a starting point for increasing scientific understanding of causal mechanisms in the way the scientists suggested. Scientists expressed concern that implementing projects without sufficient scientific data could cause more problems than it solves. Perhaps unsurprisingly, scientists favored an evidence-based approach to decision making, reflecting a technocratic view of expertise and emphasizing the role of experts in resource management (Hatanaka 2020). Scientists acknowledged the likely desirable ecological and hydrological benefits of beaver mimicry, but they viewed the lack of clear scientific evidence as a reason not to proceed without further research for fear of losing stakeholders' trust. Additionally, they reported the difficulty in obtaining permits and funding for monitoring made it challenging to implement experiments.

In contrast, practitioners tended to value experience more than experiments. Although some practitioners agreed there was a lack of scientific data, they did not see this as a major barrier because they recognized a wider spectrum of information and knowledge systems as credible, i.e., experiential knowledge and anecdotal evidence, as well as scientific information. In general, this group saw little risk in proceeding with beaver mimicry projects in the absence of conclusive scientific evidence. The greatest concern for practitioners was the salience of the information, especially its relevance for supporting the desired outcomes of beaver mimicry projects, e.g., ecological benefits, increased water storage, or socioeconomic benefits. Practitioners were the most enthusiastic group in terms of their conclusions about the desirability of beaver mimicry projects and the promise of pilot projects. Practitioners were also generally optimistic that the relative cost and ease of beaver mimicry projects could allow for projects to be scaled up to achieve wider benefits in a watershed. However, practitioners considered the uncertain policy or regulatory environment to be a significant barrier to the feasibility and scalability of these projects.

Like practitioners, landowners considered experiential knowledge and anecdotal evidence to be credible. For landowners, however, credibility and legitimacy were closely linked; they were as concerned about the sources of information, e.g., familiar agencies or a trusted neighbor, as its content. Unlike scientists or practitioners, only two landowners mentioned the lack of scientific data for beaver mimicry. The legitimacy of information, i.e., trusted, unbiased sources, was most important to landowners. Like practitioners, landowners were also concerned about salience. However, landowners deemed information salient when it provided insight into the costs and benefits of implementing beaver mimicry at the scale of their individual property. For individual landowners, evaluating the desirability and feasibility of beaver mimicry and decisions to implement beaver mimicry projects on their own property were made based on a personal calculus, including socioeconomic costs and benefits, desire to keep autonomy over one's land, and perception of legitimate motives on the part of project partners.

Finally, we note that combining two datasets through re-analysis has potential limitations. The interviews for each dataset were conducted by researchers with overlapping but not identical research goals and interview guides. It is possible that additional interview questions would have provided more clarity into or evidence for beaver mimicry practices. Further, although the scientists and practitioner interviews were drawn from a broad region, the landowners all lived and worked in southwest Montana, and their experiences may differ from other landowners in the rest of the western United States. Southwest Montana is a region currently undergoing demographic change, including increasing amenity migration and purchases of ranch properties by owners who do not rely on the ranches for their primary income (Epstein et al. 2021). The Montana State Water Plan specifically encourages the exploration of natural storage as a water management strategy (MT DNRC 2015) and NGOs in the region have been actively promoting and funding beaver mimicry (Podolak et al. 2016).

Despite these distinctive characteristics, we believe the results from the landowner interviews offer broader insights. Our participants had varied socioeconomic backgrounds and included both amenity ranchers as well as traditional ranchers (see Moore 2018). Although the state might be broadly interested in nature-based strategies and more funding may be available in Montana, e.g., through various nonprofit organizations, than in other regions, this does not necessarily translate into widespread support for beaver mimicry among landowners as it is mediated by the sources of information that landowners rely upon and the organizations they consider trustworthy. Indeed, our results suggest that even in a place where there seems to be widespread support for beaver mimicry among natural resource managers and NGO employees, landowners evaluated projects based on an assessment of personal costs and benefits. We would expect to find a similar result in other locations with or without NGO and manager support.

CONCLUSIONS

This comparison of how three groups evaluate beaver mimicry emphasizes how different stakeholder groups use different criteria to assess conservation actions. Beaver mimicry, like other controversial conservation techniques (e.g., Lave 2012, Sayre 2017), thus represents not only a case of scientific and regulatory uncertainty, but also a meeting point between different communities holding different values about evidence, science, and resource management. At such a meeting point, understandings of salience, credibility, and legitimacy are negotiated in the process of determining which evidence will be accepted as authoritative (Cravens and Ardoin 2016). At the same time, negotiations over evidence in the face of unsettled science ultimately represent deeper negotiations over the validity of different ways of knowing. Although it may not be possible or productive to try to convince others of a particular epistemological approach to evaluating conservation projects or environmental governance decisions, we argue that recognizing how different communities evaluate evidence can lead to a better understanding of environmental conflicts. Such recognition may in turn feed into social learning and dialogue that leads to new and different approaches to addressing conflicts (Muro and Jeffrey 2008).

On the one hand, our findings suggest a cautionary tale for implementing conservation projects without sufficient scientific data. Painting beaver mimicry as a panacea that promises a wide range of benefits, including hydrological benefits, e.g., water storage and increased late-season streamflows, may run the risk of losing stakeholders' trust if these outcomes are not achieved (Stern and Baird 2015). Having a more realistic understanding of what benefits these projects can deliver would help avoid potential negative impacts and likely increase trust in the long-term (see also Nash et al. 2021).

On the other hand, in many areas of environmental governance, it is necessary to make decisions in the face of uncertainty and unsettled science (Milly et al. 2008), especially as the results of peer-reviewed studies can take significant time to become publicly available. As such, the production of science is not always able to keep pace with "wicked" problems (Rittel and Webber 1973) or emerging questions, and managers and decision makers must take action based on the information that they have available and that they perceive as salient, credible, and legitimate. There have been increasing calls for useful and usable science (e.g., National Research Council 2009, Lemos et al. 2012, Beier et al. 2017) but scientists may need to consider broadening the community's technocratic perceptions of salience, credibility, and legitimacy to meet this goal. In the case of beaver mimicry, enthusiasm for the practice has outpaced the production of peer-reviewed science, as demonstrated by those Goldfarb (2018a) terms "beaver believers."

Our study suggests that evaluating an environmental management practice like beaver mimicry requires the integration of scientific and practice-based knowledge. To increase the actionability of their research, scientists could consider the production of interim scientific products that can meet the needs of practitioners, managers, and decision makers on rapid time scales. An analogous rapid response by the scientific community in the face of an urgent challenge is highlighted by the early release of scientific information and data in support of the COVID-19 pandemic via preprint servers and community databases. Project proponents could recognize that scientists' skepticism arises not just from a desire for scientific proof, but also from concerns about betraying the trust of those who expect particular outcomes from projects. Funding agencies could consider investing in not just implementation or pilot projects, but also in long-term monitoring. With greater understanding of how different groups assess evidence and evaluate beaver mimicry, it is more likely that the resulting projects will fulfill the promise that is claimed for them.

Responses to this article can be read online at:
https://www.ecologyandsociety.org/issues/responses.php/13006

Author Contributions:

AEC conceptualized and designed the project. MAM collected and analyzed the landowner data under JM's supervision. TP analyzed the scientist and practitioner data and conducted the comparative reanalysis of both datasets under AEC's supervision. TP and MAM drafted the results. ABD and JM conducted the literature review. All authors jointly wrote the final paper.

Acknowledgments:

We thank the interviewees for both projects for their time and insights. The scientist and practitioner interviews were funded by the U.S. Geological Survey National and North Central Climate Adaptation Science Centers; thank you to Adam Wilke for assistance with study design and data collection. The landowner interviews were funded by Montana State University and The Nature Conservancy. Nicola Ulibarri, Rebecca Nelson, Anne Siders, Julia Goolsby, Emily Brooks, and three anonymous reviewers provided helpful comments on earlier versions of this manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Data Availability:

The data that support the findings of this study are not are publicly available because they contain information that could compromise the privacy of research participants. Because of the sensitive nature of the information, USGS data cannot be publicly released. For more information, please contact Amanda Cravens, U.S. Geological Survey, Fort Collins Science Center. Montana State University data may be available upon request from Megan A. Moore. Ethical approval for this research study was granted by the Montana State University Institutional Review Board and conducted under the U. S. Geological Survey's Fundamental Science Practices.

LITERATURE CITED

Alexander, S. M., K. Jones, N. J. Bennett, A. Budden, M. Cox, M. Crosas, E. T. Game, J. Geary, R. D. Hardy, J. T. Johnson, S. Karcher, N. Motzer, J. Pittman, H. Randell, J. A. Silva, P. P. da Silva, C. Strasser, C. Strawhacker, A. Stuhl, and N. Weber. 2020. Qualitative data sharing and synthesis for sustainability science. Nature Sustainability 3:81-88. https://doi.org/10.1038/s41893-019-0434-8

Baker, S. R., N. Bloom, and S. J. Davis. 2016. Measuring economic policy uncertainty. Quarterly Journal of Economics 131:1593-1636. https://doi.org/10.1093/qje/qjw024

Beier, P., L. Hansen, L. Helbrecht, and D. Behar. 2017. A how-to guide for coproduction of actionable science. Conservation Letters 10:288-296. https://doi.org/10.1111/conl.12300

Biggs, D., N. Abel, A. T. Knight, A. Leitch, A. Langston, and N. C. Ban. 2011. The implementation crisis in conservation planning: could "mental models" help? Conservation Letters 4:169-183. https://doi.org/10.1111/j.1755-263X.2011.00170.x

Bouwes, N., N. Weber, C. E. Jordan, W. C. Saunders, I. A. Tattam, C. Volk, J. M. Wheaton, and M. M. Pollock. 2016. Ecosystem experiment reveals benefits of natural and simulated beaver dams to a threatened population of steelhead (*Oncorhynchus mykiss*). Scientific Reports 6:28581. https://doi.org/10.1038/srep28581

Brick, P., and K. Woodruff. 2019. The Methow Beaver Project: the challenges of an ecosystem services experiment. Case Studies in the Environment 3:1-14. https://doi.org/10.1525/cse.2017.001057

Cash, D., W. C. Clark, F. Alcock, N. M. Dickson, N. Eckley, and J. Jäger. 2002. Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making. KSG Working Papers Series RWP02-046. John F. Kennedy School of Government, Harvard University, Cambridge, Massachusetts, USA. https://doi.org/10.2139/ssrn.372280

Cash, D. W., and P. G. Belloy. 2020. Salience, credibility and legitimacy in a rapidly shifting world of knowledge and action. Sustainability 12(18):7376. https://doi.org/10.3390/su12187376

Charnley, S., H. Gosnell, R. Davee, and J. Abrams. 2020. Ranchers and beavers: understanding the human dimensions of beaver-related stream restoration on western rangelands. Rangeland Ecology & Management 73:712-723. https://doi.org/10.1016/j.rama.2020.04.008

Clifford, K. R., L. Yung, W. R. Travis, R. Rondeau, B. Neely, I. Rangwala, N. Burkardt, and C. Wyborn. 2020. Navigating climate adaptation on public lands: how views on ecosystem change and scale interact with management approaches. Environmental Management 66:614–628. https://doi.org/10.1007/s00267-020-01336-y

Cook, C. N., M. B. Mascia, M. W. Schwartz, H. P. Possingham, and R. A. Fuller. 2013. Achieving conservation science that bridges the knowledge-action boundary. Conservation Biology 27:669-678. https://doi.org/10.1111/cobi.12050

Corbin, J., and A. Strauss. 2008. Basics of qualitative research: techniques and procedures for developing grounded theory. Third edition. SAGE, Thousand Oaks, California, USA. https://doi.org/10.4135/9781452230153

Crausbay, S. D., A. R. Ramirez, S. L. Carter, M. S. Cross, K. R. Hall, D. J. Bathke, J. L. Betancourt, S. Colt, A. E. Cravens, M. S. Dalton, J. B. Dunham, L. E. Hay, M. J. Hayes, J. McEvoy, C. A. McNutt, M. A. Moritz, K. H. Nislow, N. Raheem, and T. Sanford.

2017. Defining ecological drought for the twenty-first century. Bulletin of the American Meteorological Society 98:2543-2550. https://doi.org/10.1175/BAMS-D-16-0292.1

Cravens, A. E., and N. M. Ardoin. 2016. Negotiating credibility and legitimacy in the shadow of an authoritative data source. Ecology and Society 21(4):30. https://doi.org/10.5751/ES-08849-210430

Davidson, E., R. Edwards, L. Jamieson, and S. Weller. 2019. Big data, qualitative style: a breadth-and-depth method for working with large amounts of secondary qualitative data. Quality & Quantity 53:363-376. https://doi.org/10.1007/s11135-018-0757-y

Epstein, K., J. H. Haggerty, and H. Gosnell. 2021. With, not for, money: ranch management trajectories of the super-rich in Greater Yellowstone. Annals of the American Association of Geographers. https://doi.org/10.1080/24694452.2021.1930512

Forrest, N., Z. Stein, and A. Wiek. 2020. Transferability and scalability of sustainable urban water solutions: a case study from the Colorado River Basin. Resources, Conservation and Recycling 157:104790. https://doi.org/10.1016/j.resconrec.2020.104790

Goldfarb, B. 2018a. Eager: the surprising, secret life of beavers and why they matter. First edition. Chelsea Green, White River Junction, Vermont, USA.

Goldfarb, B. 2018b. Beaver dams without beavers? Artificial logjams are a popular but controversial restoration tool. Science News, 7 June. [online] URL: https://www.sciencemag.org/news/2018/06/beaver-dams-without-beavers-artificial-logjams-are-popular-controversial-restoration

Hacking, I. 1999. The social construction of what? Harvard University Press, Cambridge, Massachusetts, USA.

Hatanaka, M. 2020. Technocratic and deliberative governance for sustainability: rethinking the roles of experts, consumers, and producers. Agriculture and Human Values 37:793-804. https://doi.org/10.1007/s10460-019-10012-9

Hegger, D., M. Lamers, A. V. Zeijl-Rozema, and C. Dieperink. 2012. Conceptualising joint knowledge production in regional climate change adaptation projects: success conditions and levers for action. Environmental Science & Policy 18:52-65. https://doi.org/10.1016/j.envsci.2012.01.002

Holmes, D., J. McEvoy, J. L. Dixon, and S. Payne. 2017. A geospatial approach for identifying and exploring potential natural water storage sites. Water 9(8):585. https://doi.org/10.3390/w9080585

Interaction Design Foundation (IDF). 2020. Key question in user experience design - usability vs desirability. The Interaction Design Foundation. [online] URL: https://www.interaction-design.org/literature/article/key-question-in-user-experience-design-usability-vs-desirability

Irwin, S., J. Bornat, and M. Winterton. 2012. Timescapes secondary analysis: comparison, context and working across data sets. Qualitative Research 12:66-80. https://doi.org/10.1177/1468794111426234

Jarvis, R. M., S. B. Borrelle, N. J. Forsdick, K.-V. Pérez-Hämmerle, N. S. Dubois, S. R. Griffin, A. Recalde-Salas, F. Buschke, D. C. Rose, C. L. Archibald, J. A. Gallo, L. Mair, A. N. Kadykalo, D. Shanahan, and B. K. Prohaska. 2020. Navigating spaces between conservation research and practice: Are we making progress? Ecological Solutions and Evidence 1:e12028. https://doi.org/10.1002/2688-8319.12028

Lave, R. 2012. Fields and streams: stream restoration, neoliberalism, and the future of environmental science. University of Georgia Press, Athens, Georgia, USA.

Lave, R. 2015. The future of environmental expertise. Annals of the Association of American Geographers 105:244-252. https://doi.org/10.1080/00045608.2014.988099

Lemos, M. C., C. J. Kirchhoff, and V. Ramprasad. 2012. Narrowing the climate information usability gap. Nature Climate Change 2:789-794. https://doi.org/10.1038/Nclimate1614

Majerova, M., B. T. Neilson, N. M. Schmadel, J. M. Wheaton, and C. J. Snow. 2015. Impacts of beaver dams on hydrologic and temperature regimes in a mountain stream. Hydrology and Earth System Sciences 19:3541-3556. https://doi.org/10.5194/hess-19-3541-2015

Milly, P. C. D., J. Betancourt, M. Falkenmark, R. M. Hirsch, Z. W. Kundzewicz, D. P. Lettenmaier, and R. J. Stouffer. 2008. Stationarity is dead: whither water management? Science 319:573-574. https://doi.org/10.1126/science.1151915

Montana Department of Natural Resources and Conservation (MT DNRC). 2015. Montana State Water Plan. MT DNRC, Helena, Montana, USA.

Moore, M. A. 2018. Understanding rancher's beliefs and behaviors regarding drought and natural water storage in southwest Montana. Thesis. College of Letters and Science, Montana State University, Bozeman, Montana, USA. [online] URL: https://scholarworks.montana.edu/xmlui/handle/1/15094

Munir, T. M., and C. J. Westbrook. 2021. Thermal characteristics of a beaver dam analogues equipped spring-fed creek in the Canadian Rockies. Water 13(7):990. https://doi.org/10.3390/w13070990

Muro, M., and P. Jeffrey. 2008. A critical review of the theory and application of social learning in participatory natural resource management processes. Journal of Environmental Planning and Management 51:325-344. https://doi.org/10.1080/09640560801977190

Nash, C. S., G. E. Grant, S. Charnley, J. B. Dunham, H. Gosnell, M. B. Hausner, D. S. Pilliod, and J. D. Taylor. 2021. Great expectations: deconstructing the process pathways underlying beaver-related restoration. BioScience 71:249-267. https://doi.org/10.1093/biosci/biaa165

National Research Council. 2009. Informing decisions in a changing climate (No. 978- 0-309-13737-9). National Academies Press, Washington, D.C., USA.

Pilliod, D. S., A. T. Rohde, S. Charnley, R. R. Davee, J. B. Dunham, H. Gosnell, G. E. Grant, M. B. Hausner, J. L. Huntington, and C. Nash. 2018. Survey of beaver-related restoration practices in rangeland streams of the Western USA. Environmental Management 61:58-68. https://doi.org/10.1007/s00267-017-0957-6

Podolak, K., R. Kelsey, S. Harris, and N. Korb. 2016. Why The Nature Conservancy is restoring streams by acting like a beaver. Cool Green Science, 20 May. [online] URL: https://blog.nature.org/science/2016/05/20/beaver-dam-nature-conservancy-is-restoring-streams-water-freshwater/

Pollock, M., T. Beechie, J. M. Wheaton, C. E. Jordan, N. Bouwes, N. Weber, and C. Volk. 2014. Using beaver dams to restore incised stream ecosystems. BioScience 64:279-290. https://doi.org/10.1093/biosci/biu036

Rittel, H. W. J., and M. M. Webber. 1973. Dilemmas in a general theory of planning. Policy Sciences 4:155-169. https://doi.org/10.1007/BF01405730

Robbins, P. 2006. The politics of barstool biology: environmental knowledge and power in greater Northern Yellowstone. Geoforum 37:185-199. https://doi.org/10.1016/j.geoforum.2004.11.011

Saldaña, J. 2016. The coding manual for qualitative researchers. SAGE, Thousand Oaks, California, USA.

Sayre, N. F. 2017. The politics of scale: a history of rangeland science. University of Chicago Press, Chicago, Illinois, USA. https://doi.org/10.7208/chicago/9780226083391.001.0001

Silverman, N. L., B. W. Allred, J. P. Donnelly, T. B. Chapman, J. D. Maestas, J. M. Wheaton, J. White, and D. E. Naugle. 2019. Low-tech riparian and wet meadow restoration increases vegetation productivity and resilience across semiarid rangelands. Restoration Ecology 27:269-278. https://doi.org/10.1111/rec.12869

Stern, M. J., and T. Baird. 2015. Trust ecology and the resilience of natural resource management institutions. Ecology and Society 20(2):14. https://doi.org/10.5751/ES-07248-200214

Thompson Jr., B., J. Leshy, R. Abrams, and S. Zellmer. 2018. Legal control of water resources: cases and materials. Sixth Edition. American Casebook Series. West Academic Publishing, Saint Paul, Minnesota, USA.

Trout Unlimited Staff. 2020. Federal omnibus funding bill includes money for issues critical to TU in the West. Trout Unlimited, 22 December. [online] URL: https://www.tu.org/magazine/conservation/federal-omnibus-funding-bill-includes-money-for-issues-critical-to-tu-in-the-west/

Turner, K. M., J. Percival, D. Kessler, and J. L. Donovan. 2019. Synthesizing qualitative data sets to improve the design of trials and complex health interventions: a worked example. Qualitative Health Research 29:693-699. https://doi.org/10.1177/1049732318803894

Ulibarri, N., N. E. Garcia, R. L. Nelson, A. E. Cravens, and R. J. McCarty. 2021. Assessing the feasibility of managed aquifer recharge in California. Water Resources Research 57(3): e2020WR029292. https://doi.org/10.1029/2020WR029292

United States Congress. 1972. Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C.: Navigable Waters. U.S. Congress, Washington, D.C., USA.

United States Congress. 2021. Consolidated Appropriations Act, 2021. U.S. Congress, Washington, D.C., USA.

Vanderhoof, M. K., and C. Burt. 2018. Applying high-resolution imagery to evaluate restoration-induced changes in stream condition, Missouri River Headwaters Basin, Montana. Remote Sensing 10(6):913. https://doi.org/10.3390/rs10060913

Vogler, D., S. Macey, and A. Sigouin. 2017. Stakeholder analysis in environmental and conservation planning. Lessons in Conservation 7:5-16.

White, D. D., A. Wutich, K. L. Larson, P. Gober, T. Lant, and C. Senneville. 2010. Credibility, salience, and legitimacy of boundary objects: water managers' assessment of a simulation model in an immersive decision theater. Science and Public Policy 37:219-232. https://doi.org/10.3152/030234210X497726

Zhang, Y., and B. Wildemuth. 2016. Unstructured interviews. Pages 239-247 in B. A. Wildemuth, editor. Applications of social research methods to questions in information and library science. Second edition. ABC-CLIO, Santa Barbara, California, USA.