

Integrating Ecological Impacts: Perspectives on Drought in the Upper Missouri Headwaters, Montana, United States[✉]

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ABSTRACT: Drought is a complex challenge experienced in specific locations through diverse impacts, including ecological impacts. Different professionals involved in drought preparedness and response approach the problem from different points of view, which means they may or may not recognize ecological impacts. This study examines the extent to which interviewees perceive ecological drought in the Upper Missouri Headwaters basin in southwestern Montana. Through semistructured interviews, this research investigates individuals' perceptions of drought by analyzing how they define drought, how they describe their roles related to drought, and the extent to which they emphasize ecological impacts of drought. Results suggest that while most interviewees have an integrated understanding of drought, they tend to emphasize either ecological or nonecological impacts of drought. This focus was termed their drought orientation. Next, the analysis considers how participants understand exposure to drought. Results indicate that participants view drought as a complex problem driven by both human and natural factors. Last, the paper explores understandings of the available solution space by examining interviewees' views on adaptive capacity, particularly factors that facilitate or hinder the ability of the Upper Missouri Headwaters region to cope with drought. Participants emphasized that adaptive capacity is both helped and hindered by institutional, cultural, and economic factors, as well as by available information and past resource management practices. Understanding how interviewees perceive the challenges of drought can shape drought preparedness and response, allowing those designing programs to better align their efforts to the perceptions of their target audience.

KEYWORDS: Social Science; North America; Drought; Ecosystem effects

1. Introduction

Drought is a complex phenomenon that is difficult to define (Kallis 2008; Wilhite and Vanyarkho 2000) but can be described by its impacts or drivers (Redmond 2002). While technical descriptions of drought often focus on the meteorological conditions that drive it, there is a wide range of possible indicators that can be used to measure these conditions (e.g., precipitation, temperature, snowpack, and so on; Heim 2002). Furthermore, many watersheds and river-scapes have a long history of human modification, making meteorological, hydrological, environmental, and social drivers and outcomes of drought difficult to tease apart (Van Loon et al. 2016; Dunham et al. 2018). How a drought is perceived or experienced can vary from person to person, even in the same location (Kohl and Knox 2016). Adding to this complexity, drought crosses sectors, regions, and even national boundaries, often causing impacts far afield (Wilhite and Vanyarkho 2000).

While many scholars of drought recognize this complexity, drought is frequently framed as a problem affecting agriculture and municipal water supplies. As Kallis (2008) notes in his review of drought literature, “all droughts that we humans care about are socioeconomic” (Kallis 2008, p. 87). For instance, damages from drought are often reported in terms of agricultural losses (Smith and Katz 2013). As such, one aspect of drought that has traditionally received less attention is its ecological impacts. Perhaps this is because ecological impacts are harder to measure and monitor (McEvoy et al. 2018; Cravens 2018) or because it is more difficult to assign a monetary value for damages to ecosystems (van Dijk et al. 2013). Despite the challenge of doing so, as droughts become more frequent and severe in many locations in the face of climate change, federal land management agencies have begun giving drought greater attention (e.g., Vose et al. 2016).

Responding to the comparative lack of focus on ecological impacts, Crausbay et al. (2017) highlight *ecological drought* as a distinct category of drought impacts. They define ecological drought as “an episodic deficit in water availability that drives ecosystems beyond thresholds of vulnerability, impacts ecosystem services, and triggers feedbacks in natural and/or human systems” (Crausbay et al. 2017, p. 2544). The authors delineate four distinct types of ecological drought: Type I (impacts and feedbacks to the natural system), Type II

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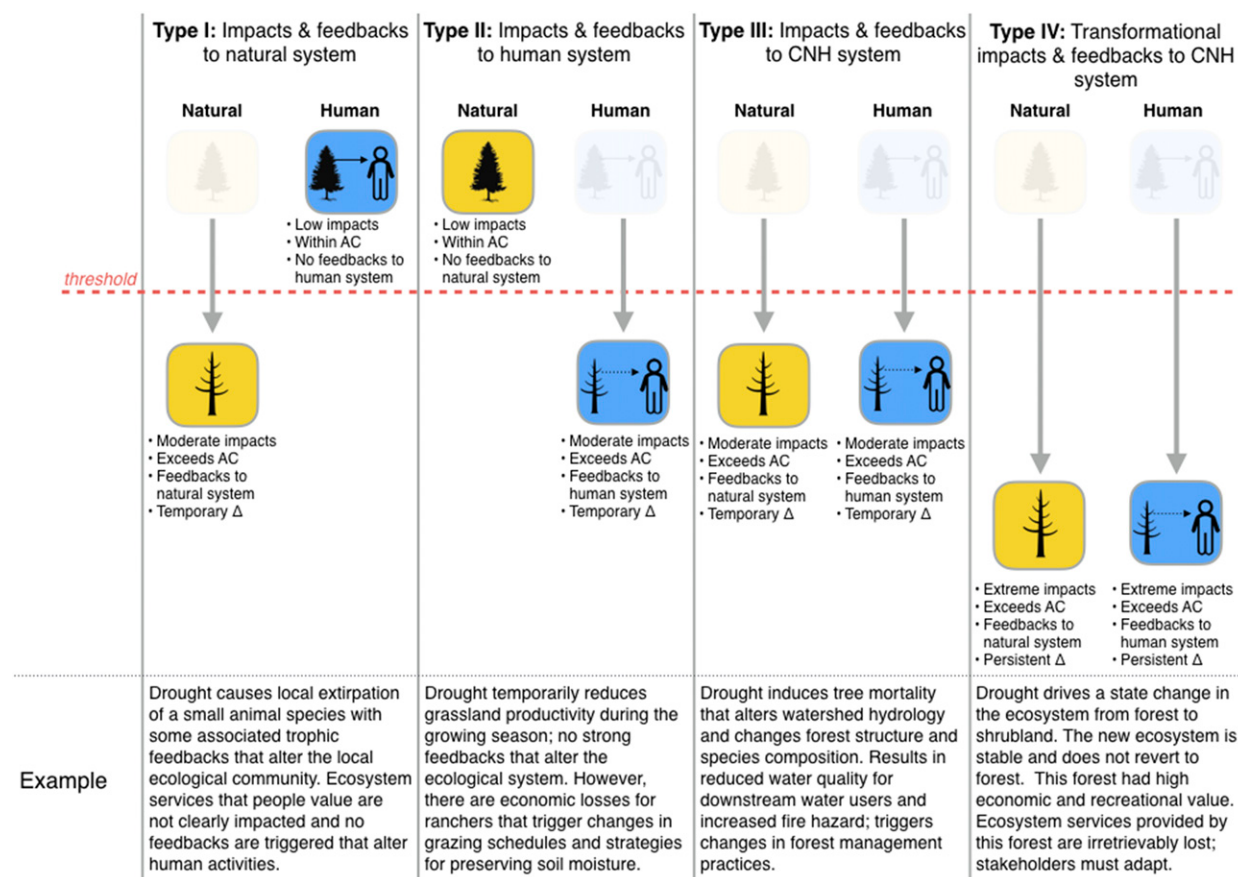


FIG. 1. Types of ecological drought are differentiated by which side of the coupled natural–human system crosses a threshold and experiences the strongest impacts. Ecological impacts (yellow) feed back to the natural system and ecosystem service losses (blue) feed back to the human system; AC = adaptive capacity, and CNH = coupled natural–human. [The figure and caption are reprinted from Crausbay et al. (2017); used with permission.]

(impacts and feedbacks to the human system through ecosystem services), Type III (impacts and feedbacks to both the natural and human system), and Type IV (transformational impacts and feedbacks that drive a persistent change) (Crausbay et al. 2017; Fig. 1). In the authors' formulation, these types of drought are used to classify the actual impacts of drought on the landscape and to distinguish which part of the coupled human–natural system is primarily affected. In this paper, we argue that these same categories may also describe how an individual perceives the impacts of drought.

Previous studies have shown how various individuals, communities, and economic sectors in a particular location experience and perceive the impacts of drought differently (Kohl and Knox 2016; Goldman et al. 2016; Woudenberg et al. 2008; Taylor et al. 1988). Past work has also examined the related questions of how individuals' perceptions of climate are constituted (e.g., Clifford and Travis 2018) and how understandings of drought influence management actions (e.g., Kohl and Knox 2016; McNeeley 2014). However, little attention has been given to whether—or how—individuals perceive and manage for the ecological impacts of drought.

To address this gap, we extend Crausbay et al.'s (2017) classifications of drought Types I, II, III, and IV (Fig. 1) to argue that these same categories may also describe how an individual perceives the impacts of drought based on their view of what is, or is not, encompassed in the problem of drought. In other words, a given drought event might have impacts on both the natural and human system when viewed at a watershed or landscape-wide scale by an omniscient observer (Type III). The same drought might be perceived by an individual as a Type-I or Type-II drought, based on the way that individual defines drought (Fig. 2). In contrast, another individual might view the drought in a more integrated fashion and recognize both types of impacts (Type III). Similar to Keenan and Krannich's (1997) assessment of the relationship between an individual's occupation and level of drought concern, this study explores how study participants understand, perceive, and manage for the ecological impacts of drought, based on their self-described professional role in drought preparedness and response.

In this paper, we examine how the challenges of drought are understood by participants in our case study of the Upper Missouri Headwaters (UMH) basin in southwestern Montana. We first examine participants' perceptions of drought by

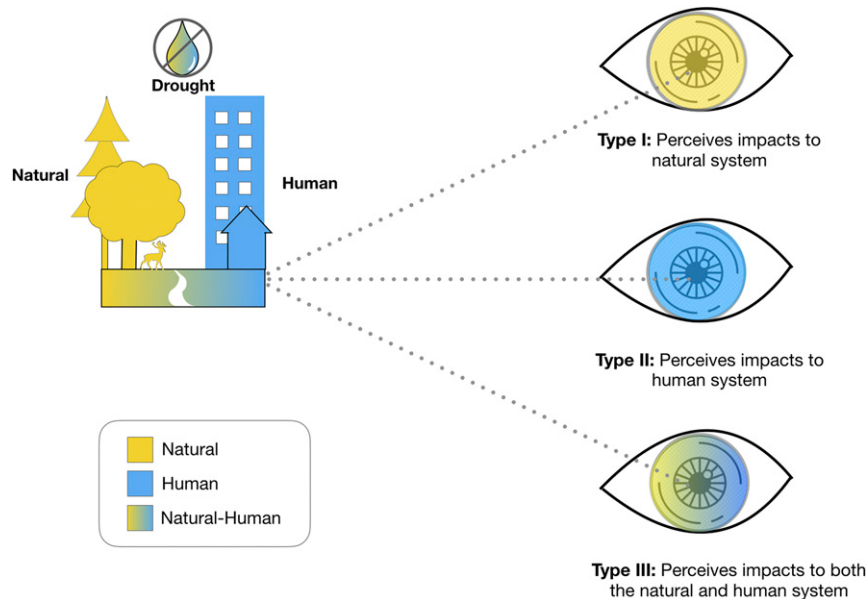


FIG. 2. Multiple ways of perceiving the same drought event yield multiple drought orientations. A drought event might have impacts to both the natural and human systems. Depending on the way an individual views that drought event, however, they might perceive the impacts to be primarily ecological (Type-I drought orientation) or primarily human (Type II). Another individual might view the same drought event in an integrated way and recognize both types of impacts (Type-III orientation).

analyzing how they define drought, how they describe their respective professional roles related to drought, and the extent to which they do, or do not, emphasize ecological impacts when asked to discuss specific drought impacts they manage or about which they are concerned. We then explore how study participants understand the causes of drought by analyzing how they describe the drivers of drought exposure. Finally, we explore how they understand the solution space available for addressing the challenges of drought in this landscape by examining participants' views on adaptive capacity, particularly factors that facilitate or hinder the ability of the UMH region to cope with drought. Our research builds on previous research of drought perceptions to provide new insights into the understudied area of the ecological impacts of drought. We discuss how these findings can inform drought preparedness and response in other watersheds and highlight the importance of identifying the ways in which various managers and other stakeholders understand drought.

2. Methods

a. Case-study description

The UMH basin (Fig. 3) is an 8.6 million acre (1 acre = 0.4 ha) expanse that encompasses the Missouri River's three forks—the Jefferson, Madison, and Gallatin Rivers—in addition to their tributaries—the Red Rock, Beaverhead, Big Hole, Ruby, and Boulder Rivers. Situated next to Yellowstone National Park, the elevation of this region varies from valleys as low as 4500 ft to mountains as high as 11 000 ft (1 ft = 0.3 m).

The average annual precipitation is 19 in. (1 in. = 2.54 cm), although this value ranges from 10 in. in the drier valleys and plains to 80 in. or higher in the mountains. Streams in the UMH are mainly snowmelt fed, and streamflow tends to peak between late May and mid-June. The basin comprises private land (~3.5 million acres) as well as state and federal land (~4.9 million acres). Most communities within the UMH basin are rural and agricultural communities. Across Montana, nearly 98% of surface water is diverted to irrigation; the UMH has some 474 000 acres of cropland (Raheem et al. 2019). The basin experiences frequent drought, which is compounded by the Gallatin Valley's rapidly growing population (which has doubled since 1990) and the region's shifting demographics and land use as the economy diversifies beyond its traditional base of agriculture and tourism (Rasker 2018). The basin is recognized for its outdoor recreation, which includes recreational fishing, skiing, hiking, and wildlife viewing (Montana Department of Natural Resources and Conservation 2014).

The National Drought Resilience Partnership (NDRP) was initiated in 2013 as part of President Obama's Climate Action Plan. This interagency partnership, "leverages technical and financial federal resources, strengthens communication, and fosters collaboration among its members to productively support state, tribal, and local efforts to build, protect, and sustain drought resilience capacity at regional and basin scales" (USDA 2019, p. 1). It is a collaborative effort that involves "federal and state agencies, non-governmental organizations (NGOs) and watershed stakeholders" (Montana Drought Demonstration Partners 2015, p. 2). The NDRP selected the UMH as one of two national demonstration projects to build

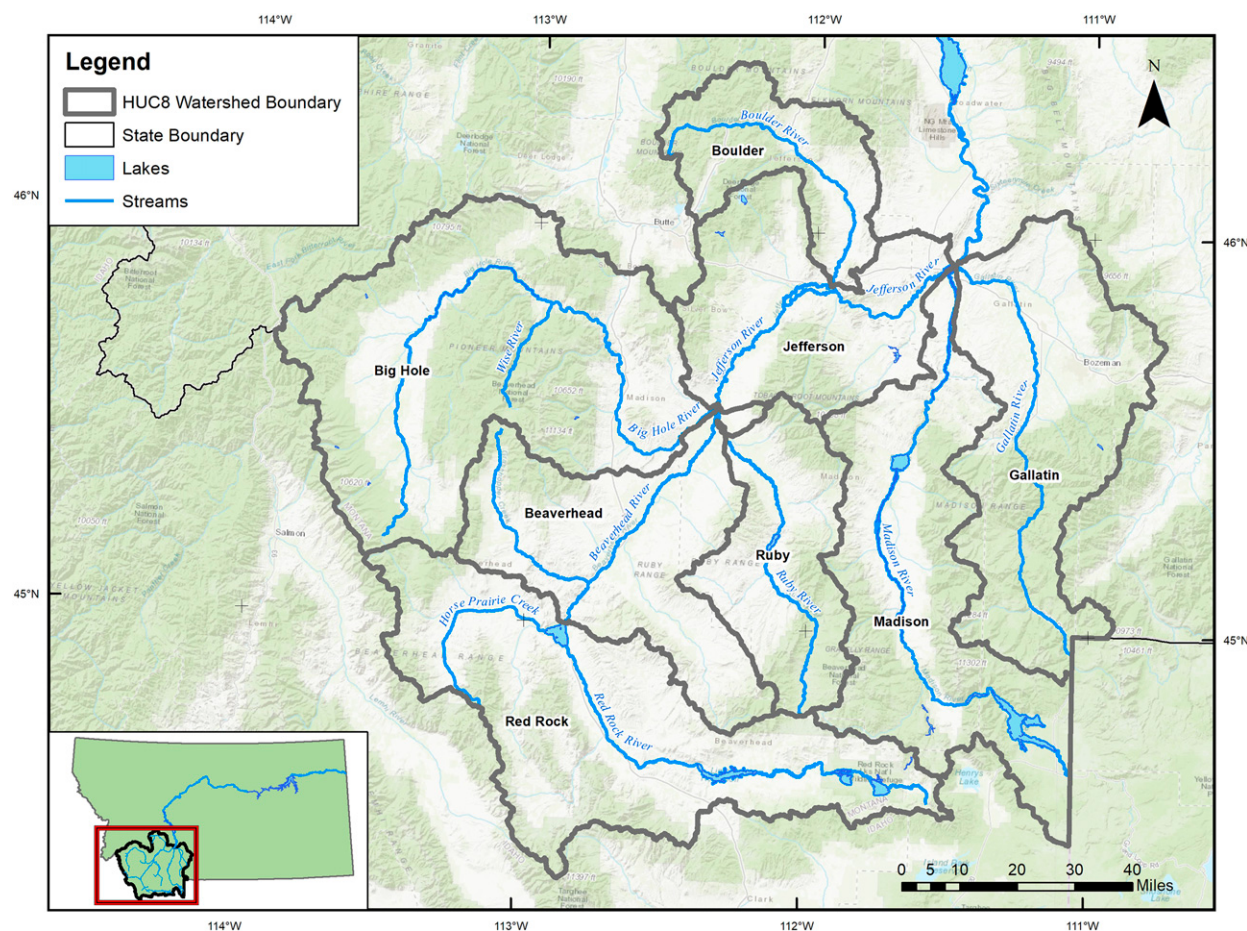


FIG. 3. The Upper Missouri Headwaters basin. The UMH is a hydrologic unit code 8 (HUC8) subbasin, which is a hydrologic unit equivalent to a medium-size river basin.

drought resiliency. Since 2014, the NDRP has been working alongside the State of Montana to address drought in the UMH. The Montana demonstration project of the National Drought Resilience Partnership (MT NDRP) offers state and federal resources to help local communities “prepare for and mitigate the impacts of drought on livelihoods and the economy” (Montana Drought Demonstration Partners 2015, p. 2). Various community-based conservation organizations work across the UMH’s eight watersheds. Although these groups have somewhat different missions, they all collaborate closely with local communities to manage natural resource issues. Since collaboration and community engagement are central tenets of the NDRP approach, many local organizations were selected to contribute to the MT NDRP planning process and help draft local drought management plans (Montana Drought Demonstration Partners 2015). The MT NDRP’s long-term goal is to foster lasting drought resilience and provide the scientific resources necessary to guide local drought planning efforts. By engaging local leaders, communities are able to identify and prioritize issues that have the greatest impact in their watershed. The MT NDRP framework aids partners to work together to address drought resilience across the basin.

Staff of NOAA’s National Integrated Drought Information System (NIDIS) described southwest Montana to the author team as a place where ecological drought impacts receive greater attention than elsewhere in the western United States. Both the State of Montana (Montana Department of Natural Resources and Conservation 2015) and the MT NDRP leadership (Montana Drought Demonstration Partners 2015) have recognized certain ecological impacts of drought—especially impacts on fisheries—as priorities. Thus, examining how drought is understood in the UMH provided an opportunity to assess the extent to which different types of professionals involved in drought preparedness and response share the state and project leaders’ integrated framing of drought.

b. Data collection and analysis

The MT NDRP demonstration project workplan identifies 49 partner organizations (Montana Drought Demonstration Partners 2015). In consultation with MT NDRP leadership, we adjusted this list to obtain a list of 41 selected organizations, as described in the footnotes to Table S1 in the online supplemental material. Our sampling strategy was then to interview

as many representatives from the selected MT NDRP partner organizations as possible. Overall, the team interviewed individuals from 30 of the 41 selected organizations. The partners were grouped into categories, and we ensured that interviewees were included from each category (see Table S1). In some cases, we interviewed multiple individuals from the same organization with different job titles or who work in different units. Most interviews consisted of a single interviewee, but three individuals requested that additional staff from their organization be present.¹ For simplicity throughout the results, we report counts as number of interviews rather than number of individuals. In total, we conducted 44 semistructured interviews with 48 individuals from 30 different organizations associated with the MT NDRP demonstration project.

Interviewees included resource managers with direct responsibility for drought management, preparedness and/or response decisions [e.g., Bureau of Land Management (BLM) hydrologist or local conservation district administrator], as well as employees of other MT NDRP partner organizations who play a role in supporting drought preparedness or response but do not refer to themselves as “managers” (e.g., U.S. Geological Survey scientist or Montana Climate Office staff). For clarity and consistency, we use the terms “interviewee(s)” or “participant(s)” to collectively refer to the managers and other stakeholders we interviewed. In 31 of the interviews, participants described drought management, preparedness, and/or response as central to their job responsibilities, in nine they described playing a more peripheral role, and in five cases it was not possible to determine the extent of their job responsibilities related to drought from the interviewees’ description.

Given the interdisciplinary nature of our research questions, we felt it was important to have ecologists as well as social scientists involved in the interview process. Two ecologists and two social scientists jointly developed the interview protocol. Each of the 44 semistructured interviews were conducted by one social scientist and one ecologist. Interviews lasted an average of 53 min; total interview time was 39 h 12 min.

The interview protocol consisted of 14 open-ended questions (see Table S2 in the online supplemental material for a copy of the interview protocol). The study protocol and procedures were approved by the Montana State University Institutional Review Board. The interviews examined how participants conceptualize drought and approach drought preparedness and response. Questions assessed how interviewees define drought, which impacts they manage or deem particularly pressing, how drought science and monitoring data are used and what gaps exist, how they prepare for and respond to drought, and what innovative drought management solutions they have encountered and/or implemented. Individual

consent to participate and record the interviews was obtained. All interviews were recorded and transcribed.

After transcription, three researchers open coded four interviews each to isolate emergent themes (Corbin and Strauss 2008). The team extensively discussed identified themes to establish consensus and develop a reliable qualitative coding scheme. One researcher coded the remaining interviews into themes in the NVIVO 11 software package using the agreed-upon scheme. Later, more complex or larger themes (e.g., definitions of drought, ecological drought impacts) were broken down into smaller subthemes and recoded. The details of the axial coding methods used are described in the relevant results sections.

3. Results

a. *How do study participants in the UMH understand the challenges of drought?*

In comparison with other natural disasters such as a hurricane, drought generally has a slower onset, lasts longer, and it is more difficult to clearly delineate starting and ending points (Wilhite 2000). When contrasted with climate change, on the other hand, drought appears as a recurring short-term hazard. However, the increasing chance of multidecadal or “megadroughts” (Cook et al. 2010; Cook et al. 2015; Ault et al. 2016) and increasing water scarcity (Gosling and Arnell 2016) challenge this definition, leading to discussions about how to distinguish drought from aridity (Colorado River Research Group 2018; Udall and Overpeck 2017; Pereira et al. 2002). These diverse definitions of drought emphasize 1) that drought is inherently an interdisciplinary challenge and may be approached from multiple points of view and 2) that how drought is framed influences one’s understanding of the problem’s causes, salient characteristics, and potential solution space.

Scholars of problem framing emphasize that the process of understanding an issue is a situated one; in other words, a person’s understanding is intimately related to their individual perspectives and past experiences (Schön and Rein 1994; Elliott 2003). How an individual frames a challenge shapes their definition of the main problem to be solved, and subsequently influences the ways in which it can be solved (i.e., the solution space). Schön and Rein (1994, p. 29) observe, “[actors’] problem formulations and preferred solutions are grounded in different problem-setting stories rooted in different frames.” Similarly, Dery (1984) highlights that how someone defines a problem influences how they ultimately solve it. Moreover, different characterizations of an issue at the framing stage can lead to addressing what certain stakeholders view as the “wrong” problem—or can result in increased or even intractable conflict over solutions (Satterfield 2002). With regard to drought, Kohl and Knox (2016) observe how the political ecology of scale (e.g., power interrelations, institutional framings, scale of water governance), personal experience, and societal context interact to shape how stakeholders understand the challenges. Developing a comprehensive understanding of how the problem of drought is constituted—how various individuals

¹ The total numbers of interviews in each category as reported in the results and the number of individuals in Table S1 of the online supplemental material do not add up as expected because of multiperson interviews and an individual whose work crossed categories.

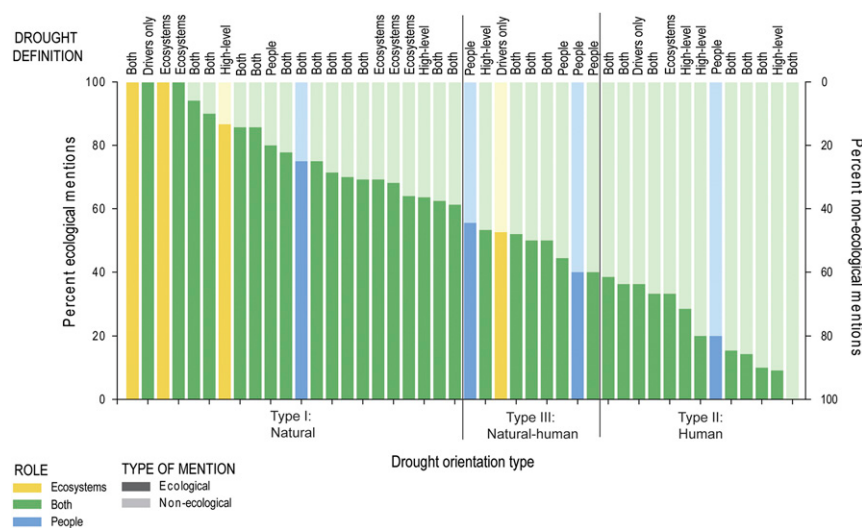


FIG. 4. Roles, definitions, and drought orientations by interview. Each bar represents an individual interview. The color of the bar denotes how the interviewee’s (or group’s, in the case of the three multiperson interviews) description of their role was coded. The text at the top of the bar shows how they defined drought when asked. The bar itself depicts drought orientation; the proportion of the bar that is shaded vs unshaded shows the percentage of ecological to nonecological impacts mentioned over the course of the entire interview conversation. We defined the threshold between drought orientations as Type I = >60% ecological mentions, Type II = <40% ecological mentions, and Type III is $\geq 40\%$ and $\leq 60\%$ ecological mentions. For instance, the bar on the far left represents a participant whose role description was coded as ecosystem focused, who defined drought by referencing impacts to both the human and natural systems, and who mentioned only ecological impacts during the rest of the interview.

perceive a challenge and how certain viewpoints might emphasize different aspects of the problem(s) and possible solution space(s)—is therefore vital to creating and implementing effective management solutions (Elliott 2003; Hisschemöller and Hoppe 1995).

To examine how interviewees understand the challenges of drought in the UMH, we characterized a person’s understanding of drought as reflected in an interviewee’s professional role related to drought preparedness and/or response, in their definition of drought, and in the drought impacts they manage for and/or about which they are particularly concerned (Fig. 4; Table S3 in the online supplemental material).

First, to characterize professional roles, participants’ descriptions of their roles were coded (i) if their role focused on drought preparedness and response as it related to natural systems, human systems, or elements of both (Table S3, column 3); and (ii) whether the participant mentioned climate change or managing for future droughts as part of their role (Table S3, column 9). Despite job titles that might suggest the opposite, our analysis showed that when interviewees were asked to describe their own role in drought preparedness and response, in the majority of interviews (36) they did so in a way that referenced, to at least some degree, drought preparedness and response related to water for people (e.g., agriculture, water supply) and water for ecosystems (e.g., fisheries, habitat, other species). For example, a federal hydrologist described the interaction of grazing and ecosystem health:

In my role . . . we’re most interested in sustaining the yields of the lands that we’re managing. That means that during drought periods, they’re being grazed appropriately . . . We get these concentration zones of grazing that really are problematic. When you have these short periods of rainfall that come in and people see the grass growing up, but it hasn’t replenished the hydrological reservoirs yet, there’s conflicting views within the public and within the resource agencies on how to manage that. Because the distribution of water’s still not good, but they may be getting some upland vegetation regeneration. It’s this balance between managing those two droughts as well as just building natural ecosystem resiliency . . . [one of our interests right now is finding ways to] help keep the water on the landscape longer and provide resources for all of the uses that are out there from wildlife to livestock to everything else (UMH2).

In only 8 of the 44 interviews did participants describe their role as focused on drought preparedness and response related solely to water for people (four interviews) or solely for ecosystems (four interviews). In other words, most participants described their roles in drought preparedness and response in an integrated way that considered water for both people and ecosystems.

Second, we coded responses to the first question asked in each interview—“What is your definition of drought, especially in the Montana context?”—in the following way: (i) whether the interviewee(s) defined drought by reference to drivers, impacts, or both [Table S3, column 4] and (ii)

whether any impacts referenced in their definition pertained to human uses of water, ecosystem uses of water, both, or whether the impacts were described in such general terms that we could not determine which uses the interviewee meant [Table S3, column 5]. We found that in 30 interviews, drought was defined by referencing both drivers and impacts; 3 interviews only described drivers; and 11 interviews only referenced impacts.² We then coded the 41 definitions that mentioned impacts by type of impact. We found that as a whole, interviewees defined drought in an integrated fashion, mentioning impacts related to both people and ecosystems. Six interviews' definitions described impacts related to water for people, six described impacts related to ecosystems or water for species, six described high-level impacts that could not be classified into either of the two preceding categories, and 23 described impacts that fit into both categories. For instance, "[drought] is low water availability for use by either the landscape as the system, a vegetative system or wildlife, as well as human use, societal use" (UMH3). Thus, more than half of the interviews defined drought in an integrated fashion, mentioning impacts to human communities as well as ecosystems. Only 12 interviews described impacts exclusive to either people or ecosystems.

Last, we analyzed the drought impacts mentioned throughout each interview conversation. Over 100 distinct impacts of drought were identified across the 44 interviews, as our team reported in detail in a previous article (Raheem et al. 2019). We classified each impact as ecological or not. We then summed the total number of impacts mentioned in each interview (Table S3, columns 6 and 7) and calculated the percent of ecological impacts mentioned. We used the percentage of mentions of ecological impacts to assign each interview a drought orientation of Type I (more ecological impacts), Type II (more human impacts), or Type III (a relatively equal number of ecological and human impacts discussed) (Fig. 4; also see Table S3, column 8). Precisely, we defined the threshold between these classifications as Type I = >60% ecological mentions, Type II = <40% ecological mentions, and Type III as ≥40% and ≤60% ecological mentions.

When we considered how drought was discussed throughout the interviews, we found that in contrast to the results of the roles and definitions analysis, the majority of interviews placed greater emphasis on the impact of drought on either ecosystems or human communities. Less than one quarter—nine interviews—named relatively equal numbers of ecological and other impacts and were assigned an integrated, Type-III drought orientation. Half (22) were classified with an ecological, Type-I orientation. The remaining 13 were assigned a

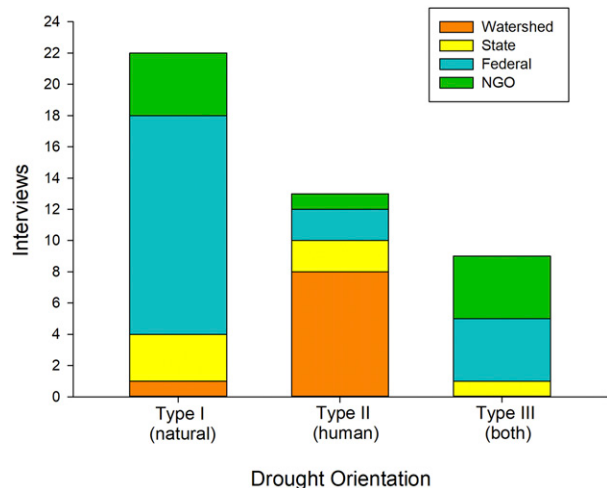


FIG. 5. Drought orientations by participant type.

human Type-II orientation. Despite interviewees' integrated descriptions of their roles and relatively integrated definitions of drought, their descriptions of drought impacts generally focused on either natural or human aspects of the system, and most interviews named twice as many impacts of one type as the other. In southwestern Montana, it appears drought professionals are generally aware of various aspects of the drought problem and cognizant of how their roles influence both human communities and ecosystem health. Simultaneously, however, their conversations focused more on either the natural or human system. While the frequency with which someone discusses something in an interview is perhaps an imperfect proxy for their day-to-day concern, we interpret the split between how participants described their roles and defined drought and how they described their impacts of concern to indicate the need for most interviewees to focus more intently on one aspect of the problem most of the time.

When we compared assigned drought orientation with participant type (Fig. 5), we found that interviewees who work at the watershed/local level were predominantly (eight out of nine) assigned a human-focused Type-II drought orientation. Interestingly, the one watershed/local interviewee who had an ecologically focused Type-I drought orientation had been one of the six interviewees to define drought by exclusive reference to its impacts on people. This focus on drought's impacts on people may suggest the need to pay greater attention to specific community and economic needs for water by those in watershed council, conservation district, or local government roles. Interviews with participants who work at the state level were assigned mixed drought orientations: three as Type I, two as Type II, and one as Type III. The majority of interviews with participants who work at the federal level (14 of 20) had an ecological Type-I orientation. Four were assigned an integrated Type-III orientation and only two had a human-focused Type-II orientation. The NGO participants also had more ecologically focused (Type I) orientations (four) and integrated Type-III orientations (four), with only one NGO participant being assigned a human-focused Type-II orientation.

² We note, however, that a number of interviewees mentioned that giving a definition of drought is a challenging task and were essentially thinking out loud during the interview. Thus, it is possible that some participants who did not mention either impacts or drivers would indeed include the other component they did not mention as part of a definition of drought if given more time to prepare.

These trends suggest that individuals who work at the local level and manage for drought locally are particularly concerned about water for people and individual community needs. Concern about specific ecological impacts may be more common among those working at state and federal levels and/or on public lands, especially those managed by federal agencies whose mandate includes consideration of ecosystem impacts.

Last, we coded which participants included climate change as part of their job description and which mentioned climate change and/or other types of ecological transformation as part of their definition of drought [i.e., which interviews mentioned Crausbay et al. (2017)'s Type-IV drought] (Table S3, columns 9 and 10; also see Fig. 1). In about one-quarter of the interviews (13), participants described their role in relation to drought as including climate change. In even fewer interviews (9), participants mentioned transformation when defining drought. Interestingly, these were not always the same people. For some interviewees, it seems, climate change and drought are part of the same problem space, but for many they are not.

b. How do study participants in the UMH understand drought vulnerability?

The second aim of this research was to investigate how participants understand drought vulnerability in the UMH, including how they assess the region's overall drought risk and how they understand the region's exposure to drought. The Intergovernmental Panel on Climate Change (IPCC 2007), along with many scholars and practitioners, defines vulnerability as a function of exposure and adaptive capacity (and sensitivity, which our study did not address). Adger (2006) defines exposure as "the nature and degree to which a system experiences environmental or socio-political stress" and adaptive capacity (addressed in section 3c) as "the ability of a system to evolve in order to accommodate environmental hazards or policy change and to expand the range of variability with which it can cope" (Adger 2006, p. 270).

1) UNIVERSAL AGREEMENT ON DROUGHT AS A SERIOUS RISK IN THE UMH

To assess interviewees' overall perception of drought vulnerability in southwestern Montana, we asked a broad, open-ended question about drought risk: *To what extent do you view drought as a risk in this region?*

Interviewees unanimously agreed that drought is a significant risk in the study region.³ A sampling of typical responses to this question illustrates this consensus: a "huge risk" (UMH15), "really significant" (UMH32), "number one threat" [along with wildfire risk from drought conditions] (UMH4), and "dramatically impactful in every way" (UMH28). As one interviewee noted, "all our livelihoods, whether it be recreation, or agriculture, or forestry are completely dependent on having enough water" (UMH31). In six interviews, people qualified their answers or put

drought risk in comparative perspective. For instance, one interviewee pointed out that drought might be more of a risk to the recreational sector than to agriculture. Another interviewee noted there are other longer-term risks like acid mine drainage facing the region. Someone else observed that while southwestern Montana faces drought risk it is actually comparatively more "water rich" (UMH34) than other parts of the western United States such as Arizona. But even with these caveats, participants fundamentally agreed that drought represents a significant challenge for the region.

2) COMPONENTS OF DROUGHT EXPOSURE IN THE UMH

To more deeply examine how interviewees understand factors influencing drought vulnerability, we coded for drivers of drought exposure mentioned by participants. Following the framework developed by Crausbay et al. (2017), we categorized these drivers into four components of drought exposure: meteorological drought (meteorological conditions during a dry period), landscape characteristics (natural features like topography and soils), human land and water use (human modifications of hydrological processes such as reservoirs and irrigation), and (anthropogenic) climate change.

Participants described drought exposure related to each of these components (Table 1; also see Table S3, column 11). Most interviewees discussed multiple components of exposure. In 19 of the 44 interviews, interviewees mentioned two categories, in 18 they mentioned three categories, and in one they discussed all four. Only six interviews mentioned just one category; no interviews mentioned landscape characteristics alone. Figure 6 depicts the number of interviews assigned each drought orientation who mentioned each component.

Besides describing drivers that could be categorized into one of these categories, participants also described how these components interacted, resulting in increased drought exposure. For instance, landscape characteristics can exacerbate the impacts of human land and water use. By concentrating where grazing happens, for example, topographical features (i.e., shape of the land surface) can increase grazing stress in particular areas, especially riparian corridors. In an inverse example, return flows from irrigation may provide a buffer to drought in lower-elevation areas that is not available when water is diverted from headwaters tributaries. Climate change was also described as exacerbating existing drought risk in the region and interacting with existing patterns of water use. For instance, in the Gallatin Valley, reduced snowpack from climate change is projected to increase drought risk in areas already experiencing water stress from rapid urban development.

Regardless of their drought orientations, most participants appear to be aware of multiple components of drought exposure. This indicates that interviewees in the UMH view drought as a complex problem with multiple causes driven by both human and natural factors.

c. How do study participants in the UMH assess the region's ability to cope with drought?

Adaptive capacity refers to "the ability of a system to evolve in order to accommodate environmental hazards or policy

³ In two interviews, this question was not asked because of time constraints.

TABLE 1. Examples of exposure by component.

Component of exposure [adapted from Crausbay et al. (2017)]	Specific examples from interviews
Meteorological drought	• Concern about intensity and duration of dry periods • Concern about soil moisture being too low for too long • Concern about periods of abnormally low precipitation
Landscape characteristics	• Wind leads to high evapotranspiration rates during dry periods • Arid climate: annual precipitation is low • High desert climate; drought is normal and cyclical • Snowpack-driven system • Spatial heterogeneity of risk: differences by elevation, slope, and aspect • Importance of microclimates • Contribute to variations in snowpack depth and runoff timing
Human land and water use	• Increasing demand and new kinds of (urban) demand with amenity migration into area • Lack of flexibility in system because of need to continue irrigating crops once they have been planted • Uncertainty caused by lack of measuring at many diversion points • Fully allocated water rights leave little for fish or ecosystem in some parts of basin • Water diversions increase stream temperatures, especially in late summer
Climate change	• Risk of more frequent or severe droughts • Form and timing of future precipitation are uncertain • Shifts to earlier snowmelt and peak flows increase the risk of late-summer shortages • May amplify impacts seen with current droughts and/or cause new impacts, e.g., increases in invasive species, increased wildfire risk, and conflicts over water • Likely will not be uniform across the landscape

change and to expand the range of variability with which it can cope” (Adger 2006, p. 270). In this study, responses to questions about adaptive capacity provided insight into how managers view the solution space for mitigating and responding to drought. This aligns with Klein and Smith’s (2003) conceptualization of adaptive capacity as “enabling environments” that allow communities to plan for and deal with the impacts of climate change, including drought. While some literature focuses on the adaptive capacity of ecosystems (e.g., Beever et al. 2016), or attempts to integrate social and ecological adaptive capacity (e.g., Petersen et al. 2018), our analysis found that responses coded as “adaptive capacity” primarily referred to characteristics of the social system. However, interviewees did mention how past resource management practices have influenced the adaptive capacity of today’s landscape. We identified and coded five main characteristics that interviewees saw as helping or hindering adaptive capacity: institutions, culture, knowledge, economics, and past resource management practices. We analyzed how often each drought orientation mentioned these characteristics; there did not seem to be meaningful differences between Type-I, Type-II, and Type-III individuals (Figs. 7 and 8; also see Table S3, columns 12 and 13).

1) INSTITUTIONS

Our institutions category included comments related to formal organizations, laws, and policies. Local community organizations (especially local watershed groups) and legal frameworks (such as instream flows) that allow water rights to serve ecological purposes were mentioned as institutions that help build adaptive capacity. Flexibility was mentioned as a key element of adaptive capacity, such as the need to increase

flexibility in the operations and timing of reservoir water releases. As one interviewee noted, “with water rights and water law and water policy, oftentimes, a lot of reservoir managers and water managers are trapped—they have to make certain deliveries, whether the water is there or not” (UMH18). Similarly, the rigidity of the prior appropriations framework (Fanning et al. 2017) for water rights was commonly mentioned as a hindrance to adaptive capacity. As one interviewee noted, “we have huge opportunities in Montana to adjust our water management to drought [but] we’ve structured our water allocation system such that it is all built on grabbing as much as you can and defending it against everybody else. It’s built around conflict” (UMH25). The complexity of water law and how that interacts with natural resource management was also seen as an institutional hindrance. For example, an interviewee described how water conserved from tree thinning could end up going to a junior irrigator rather than to instream flows because of the water rights system. Another commonly mentioned hindrance was the challenge of maintaining the long-term capacity of local community organizations. As one interviewee noted, many watershed groups are “raring to go [but] they need people and they need money” (UMH8). Other institutional hindrances mentioned by interviewees include the siloing of issues (e.g., agricultural and ecological management), the lack of integration among planning processes (e.g., drought planning and watershed restoration planning), and the focus on species-specific fisheries management (rather than building broad drought resiliency).

2) CULTURE

Our category for culture included comments related to community norms, traditions, and shared values. Several interviewees

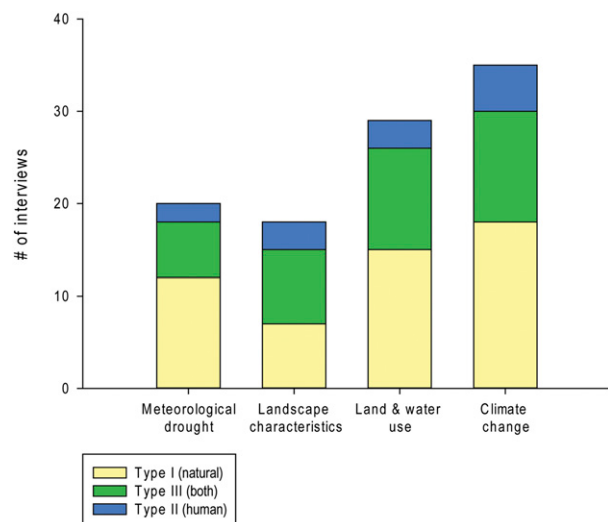


FIG. 6. Mentions of exposure categories by participant drought orientation.

mentioned a culture of collaboration, especially through local watershed groups that can serve as a venue for sharing information, working together, and taking on new challenges. However, some noted that the “will” to work together was “uneven” across watersheds or that it would “take time to bring all partners to the table.” The importance of trust was also mentioned. As one interviewee noted, rural towns “rely heavily on federal partners for capacity . . . [but] they need to build trust in the community. They need to have people in the community that aren’t just feds with different mandates and missions” (UMH11). Interviewees noted that the people they work with care about Montanan landscapes and have a desire to balance the needs of agriculture and resource-based tourism. Some saw these shared values as a basis for building adaptive capacity. However, others noted that value differences among different stakeholders can make collaboration difficult. Other cultural aspects that were mentioned as hindering adaptive capacity include the fact that “our memories are often short [after disasters]” (UMH31) and growing numbers of secondary homeowners who are not as invested in the community. Perhaps more fundamental to achieving adaptive capacity, as one interviewee observed, a “change in cultural mindset” (UMH2) is required, while another emphasized the need to move from a “crisis drought response program” to a “drought resiliency planning program” (UMH8).

3) KNOWLEDGE

Comments in the knowledge category related to how interviewees and the people they work with learn and use information. Local knowledge, previous experience in dealing with drought, and learning through conflict resolution were seen as factors that increase adaptive capacity. Some interviewees felt that rural communities know more about drought because they experience the impacts more directly than urban communities. The information provided in formal climate assessments was also identified as helping to build adaptive capacity. A lack of

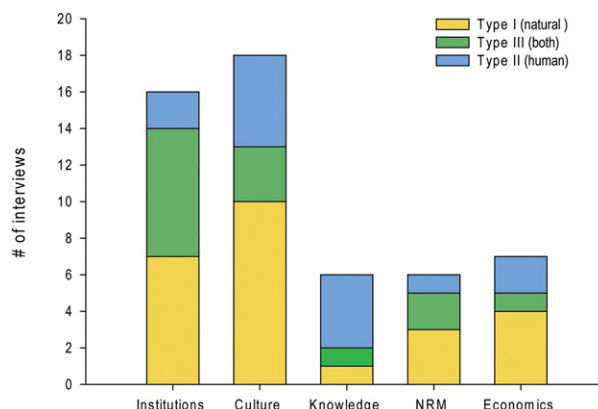


FIG. 7. Mentions of adaptive capacity facilitators by participant drought orientation; NRM = past natural resource management.

coordinated information at the basin scale and a lack of understanding of complex forest and water interactions were seen as hindering factors by some interviewees.

4) ECONOMICS

We coded comments related to people’s occupations and the region’s economic systems as “economics.” The close connection between how people make a living and natural resource management (e.g., agriculture or fisheries-based tourism) was seen as a factor that promotes adaptive capacity in the region, with interviewees noting cultural dimensions of livelihoods as well as economic. As one interviewee explained, “The irrigators are trying to find that balance between making a livelihood and supporting the ecological infrastructure in Montana that also supports their community, which they fully realize” (UMH33). Some interviewees felt that given the relatively low human population and lack of urban development, there were still opportunities to shape the region’s economic development pathway toward resiliency before a tipping point is reached. However, there were many more comments that highlighted the ways in which economic factors hinder adaptive capacity. Interviewees noted that most livelihoods are dependent on water, which is a finite resource, and are sensitive to drought, although others pointed out that people in Montana have long experience making a living with little water. As one interviewee explained, this aridity makes the land “fragile,” which results in marginal agriculture. They went on to describe how this can have “a huge impact [on] ranchland turnover” with “all the ensuing impacts of different kinds of land use development” (UMH24). Another interviewee explained that the marginal nature of agriculture can be exacerbated by outside economic forces, such as market volatility and farm subsidies. Interestingly, a conservationist at an NGO explained that drought makes agricultural easements less desirable.

5) PAST NATURAL RESOURCE MANAGEMENT

Descriptions of past management actions on public and private lands were coded into this category. Interviewees noted that past resource management influenced the adaptive

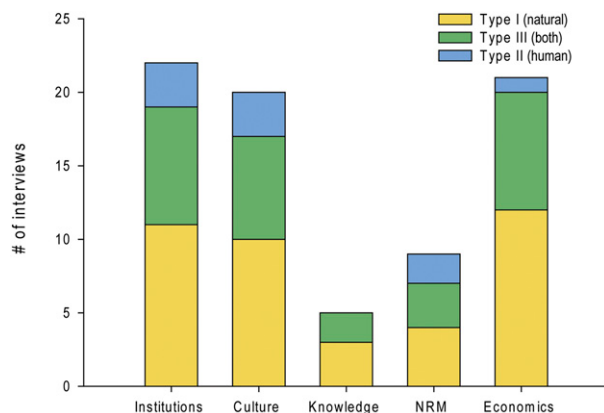


FIG. 8. Mentions of adaptive capacity barriers by participant drought orientation.

capacity of today's landscape and shaped future management options, echoing what other adaptation scholars have noted about how current adaptation choices are constrained by historical choices (i.e., path dependence) (e.g., Barnett et al. 2015). Some practices, such as forest thinning, proper range-land management, and ecological restoration were noted as actions that could be taken that make the landscape more resilient to drought. For example, one interviewee described the benefits of restoration, stating, "all the restoration work that [NGOs] have done has helped us prepare and get a lot of tributaries in shape. It's helping protect the [fisheries and] in a lot of ways probably easing what could be worse on the main stem of the [river] in a drought year" (UMH42). Managing existing and restored fish habitat as refugia was also mentioned as a practice that increases the adaptive capacity of the landscape. Several interviewees viewed historic flood irrigation as a practice that contributed to groundwater recharge. One interviewee noted that urban landscaping uses a lot of water but saw that as an opportunity for water conservation. Past resource management strategies were also seen as a hindrance to adaptive capacity. Historic fire suppression was commonly mentioned as having negative legacy effects, including increased forest fire risk and conifer encroachment. As one interviewee described, "We have just rampant conifer encroachment in some areas and that's affecting infiltration of water into the soil. We walk through miles and miles of riparian areas that are now conifer that have dead willow and aspen skeletons under them. There's just a lot of vegetative changes that subtly change, so people might not notice it. It really affects wildlife habitat and the economy over the long-term." (UMH39). Overgrazing, especially in riparian areas, was mentioned as a practice that leads to a loss of woody stabilizing species, increases sensitivity to drought and reduces the capacity of the soil to hold water.

4. Discussion and conclusions

This research highlights how understanding drought—and in particular ecological drought—requires understanding the perceptions and problem definitions of those preparing for

and responding to the challenge. We examined how interviewees associated with the MT NDRP demonstration project in southwestern Montana define drought and its impacts, how they understand the causes of the problem, and how they assess the region's ability to cope in the face of drought conditions.

Through 44 interviews with representatives from 30 different organizations associated with the MT NDRP demonstration project, we found that most participants defined drought in an integrated fashion that included natural and human components of the social–ecological system. The majority of interviewees also defined their professional role related to drought in an integrated way, referencing to some degree how drought preparedness and response efforts do (or should) relate to water for people *and* ecosystems. This may reflect the fact that all our study participants were NDRP partners. Recognizing the ecological values in the region for species conservation and tourism, the NDRP Montana demonstration project leadership has emphasized an integrated view of drought for the region and thus chose to invite participation from a wide variety of partners, including natural resource management agencies at various levels (Laidlaw and Schwend 2017). This model suggests that how project leaders frame a problem might influence how other partners understand the challenge. However, from our single study, it is difficult to determine how applicable this finding is to other watersheds, especially watersheds where recreational uses of water are less prominent.

Despite the integrated nature of most interviewees' definitions of drought and descriptions of their roles, when we analyzed the specific impacts each person discussed throughout each interview, the findings were more siloed, with most participants emphasizing more impacts in either the ecological or nonecological category. Extending Crausbay et al.'s (2017) formulation of drought types, we used the relative percentage of impacts each person discussed to assign them a drought orientation. Half of the interviews (22) reflect a Type I orientation with greater emphasis on ecosystem impacts. Thirteen interviews reflect a Type II orientation with greater emphasis on human impacts. Just 9 of the 44 interviews reflect a Type III orientation with a more integrated view of impacts. These results may reflect the institutional constraints of drought preparedness and response. While an individual might have a broad understanding of the drought problem, the number of impacts they focus on or manage for—as indicated by how many they discussed in detail in an interview—is generally much smaller, reflecting the narrower scope of many professional roles.

In particular, interviewees at the local/watershed level were (with one exception) more focused on nonecological impacts. This may reflect their roles working more closely with individual water users. Interviewees who work for federal agencies, on the other hand, focused more on ecological impacts, perhaps reflecting their agencies' mandates for the long-term health of public lands and resources. This suggests that inter-agency and interjurisdictional efforts like the NDRP are valuable for helping partners work across roles to accomplish goals that transcend any individual's focus or an agency's

mandate. Confirming what previous literature has described (e.g., [Kohl and Knox 2016](#)), these results also highlight the importance of understanding that different stakeholders are likely to have different priorities and concerns in terms of drought impacts. While the stated mission of the MT NDRP focused on leveraging state and federal resources in a particular location, our results suggest the social learning and knowledge-sharing functions of such a partnership might be equally significant ([Reed et al. 2010](#); [Wilder et al. 2010](#)).

We then explored interviewees' understanding of drought vulnerability in the UMH. There was unanimous agreement that drought is a serious risk in the region. Using the Ecological Drought Framework ([Crausbay et al. 2017](#)), we analyzed how interviewees conceptualized drought exposure. We found that regardless of drought orientation, interviewees displayed a nuanced understanding of a range of drought drivers, from meteorological fluctuations and landscape characteristics to human land and water use. They also pointed out how these drivers interact, particularly emphasizing how climate change exacerbates existing causes of drought. We interpret this to mean that interviewees in the UMH view drought as a complex problem driven by both human and natural factors. Acknowledgment of the role of human land and water use and anthropogenic climate change as drivers of water scarcity that should be considered part of drought is fairly new within the drought science community ([Van Loon et al. 2016](#)). Our results suggest that those working in drought management, preparedness and response may be well aware of this complexity, suggesting that future studies would be better served by viewing drought exposure as an outcome of both human and natural forces.

Last, we examined how participants assessed factors that can help or hinder the region's ability to cope with drought. This provided insight into how managers view the available solution space for mitigating and responding to drought. Interviewees reported five main characteristics that help or hinder adaptive capacity, including institutions, culture, knowledge, economics, and past resource management practices. A key institutional factor identified was the rigidity of the water rights system, which can make innovation difficult. The same finding has been noted elsewhere in the western United States ([Schilling 2018](#)). However, interviewees agreed that southwestern Montana's distinct "culture of collaboration," especially within local watershed groups, provides one means to overcome this barrier to adaptation. The close connection between regional livelihoods and resource management (including both agriculture and tourism) was described as a source of shared values and motivation. However, the comparative lack of economic diversity across the region might increase exposure since so many people depend on water. As one interviewee summarized, "all our livelihoods, whether it be recreation, or agriculture, or forestry are completely dependent on having enough water" (UMH31). Interviewees also described how the adaptive capacity of the landscape today is influenced by past resource management actions.

Ecological resources play an important role in the economy and culture of the study region (and indeed, throughout much of Montana). As a result, the area may be more vulnerable to

ecological drought and thus participants have a greater awareness of ecological drought impacts as compared to other regions. Recreational livelihoods, particularly the world-class fishing industry, directly rely on sufficient water, including during late summer when water is also needed for irrigation. Fishing outfitters have successfully negotiated "shared sacrifice" agreements with agricultural water users that require reductions in both agricultural and recreational water use when water is scarce ([McEvoy et al. 2018](#); [Anderson et al. 2016](#)). Such an agreement is, to our knowledge, very rare within the western United States. We speculate that these shared sacrifice agreements may reflect a more even balance of economic power between agriculture and tourism (particularly fishing) than is present in other locations. A similar balance in how water use for agriculture and recreation is viewed arises from interviewees' shared interest in conserving Montana landscapes. For example, interviewees emphasized that the impact of drought on ecosystems harms recreationalists as well as those whose occupations are dependent on water.

Despite the distinctiveness of Montana and the UMH basin, we believe these results hold insights that apply more broadly. First, how someone views the problem of drought is not necessarily determined by their job title or formal role, suggesting the importance of looking beyond formal role definitions to understand who makes decisions regarding drought management, preparedness, and response. We found that many participants defined their roles in an integrated way, even when their job title would suggest otherwise. We also found that how someone understood their role did not always translate into the specific set of impacts they told us they cared about. What seemed to matter more is what we termed an interviewee's drought orientation, or the specific set of drought impacts that someone is actively managing for and/or most concerned about. The majority of our interviewees defined their professional role related to drought in an integrated way, but then focused primarily on either human or ecosystem impacts. Understanding how various regional managers and other stakeholders perceive the challenges of drought and their respective roles can shape drought preparedness and response, allowing those designing programs to better align their efforts to the problem frames of their target audience and, like the MT NDRP, create partnerships to leverage resources without duplicating efforts.

The second insight that we highlight is an open question: how can integrated management of human and ecological impacts of drought best be achieved? Is the goal for most managers to do that integration in their individual roles, or, as with the MT NDRP project, is the goal to create processes that integrate across organizations and roles to incorporate various perspectives and constituents? Given agency mandates and the nature of day-to-day drought preparedness and response, which may require a narrower focus by any given individual, our results suggest that an interjurisdictional and interagency project, like the NDRP, may be more effective than trying to integrate across individuals' roles. In watersheds where resources like those associated with the NDRP are not available, any degree of interagency collaboration and shared learning could help expand the scope of drought management. Third,

we suspect that our interviewees' lack of mentions of transformational drought would be similar to those of people in many other locations, despite the attention being given to the topic in the scientific literature (e.g., Jacobsen and Pratt 2018). Last, we note that while recognizing the challenge of ecological drought is necessary, it is not sufficient. Addressing a drought problem, no matter how one defines it, requires detailed indicators and monitoring information (Wilhite 2014). As yet, indicators for ecological drought are more experimental than operational and monitoring is rare (McEvoy et al. 2018; Kovach et al. 2019), suggesting the need for researchers and agencies to focus on developing and implementing ecological drought indicators.

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