Drought Preparedness in Large Landscape Management: Using Adaptation Pathways and Decision-Support Tools to Increase Resilience

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Lily Fanok

Major Professor: Chloe Wardropper, Ph. D
Committee Members: Morey Burnham, Ph.D.; Teresa Cohn, Ph.D.
Department Administrator: Alistair Smith, Ph. D

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Authorization to Submit Thesis

This thesis of Lily Fanok, submitted for the degree of Master of Science with a Major in Natural Resources and titled "Drought Preparedness in Large Landscape Management; Using Adaptation Pathways and Decision-Support Tools to Increase Resilience," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor: _____ Date: _____
Chloe Wardropper, Ph.D.

Committee Members: _____ Date: _____
Morey Burnham, Ph.D.

_____ Date: _____
Teresa Cohn, Ph.D.

Department Administrator: _____ Date: _____
Alistair Smith, Ph. D

Abstract

Climate projections suggest the United States (US) Northern Rockies region of Idaho and Montana may experience future drought severity and frequency trends, with implications for the sustainable management of rangeland systems. Efforts to increase drought resilience across this large landscape must include multiple stakeholder groups because of the region's diverse mosaic of land ownership and priorities for land management, including sustaining ranching livelihoods and protecting wildlife connectivity. In partnership with a regional landscape collaborative, we conducted research in the High Divide region of the Northern Rockies of Idaho and Montana, a semi-arid sagebrush steppe rangeland system with similar ecological functions and socioeconomic context as many other US rangelands. This research looks to further understand drought preparedness and resilience in the High Divide region. Our study objectives were first to conduct focus groups to 1) *understand past experiences of drought across diverse stakeholder groups*, 2) *determine characteristics of drought resilient landscape management*, and 3) *conceptualize adaptation pathways for increased resilience*. Adaptation pathways are realistic trajectories created to inform potential futures of a system. Our findings suggest that shared conceptions of how to manage a resilient landscape, such as an emphasis on building social capital, while also acknowledging vulnerabilities, offer opportunity for collaboration towards drought adaptation. Secondly, we conducted interviews with landscape management organization employees in the High Divide region in order to, 1) *identify which drought decision-support tools are being used*, 2) *describe tool-supported management actions across different types of organizations*, and 3) *understand barriers to decision-support tool adoption*. Findings suggest a wide variety of tools are being used in this region by landscape management organizations to meet management objectives. However, use of decision-support tools for drought planning is limited and several barriers currently exist to increased adoption and use of tools, including lack of capacity and lack of management direction. This combined research informs future drought resilience collaborative action and specifically aims to inform regional tool development and decrease research – knowledge gaps.

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Dedication

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Statement of Contribution

Lily Fanok (L.F), Dr. Chloe Wardropper (C.B.), Dr. Morey Burnham (M.B.) and Bray Beltran (B.B.) conceived and designed the analysis. L.F. collected the data. L.F. performed the analysis, with analysis tools provided by C.B., M.B., and B.B. L.F. wrote the paper, with editing and corrections made by C.B., M.B., B.B., and Dr. Teresa Cohn (T.C.).

Chapter 1: Introduction

Drought is a reoccurring component of climate regimes worldwide, yet drought preparedness is often lacking in social systems (Wilhite, 2000). Drought impacts fish and wildlife biodiversity, species abundance and movement, the extent and nature of human wildlife interactions, and community well-being (Thomas, Wilhelmi, Finnessey, & Deheza, 2013). Drought is also considered one of the costliest natural hazards, due to its far-reaching impacts on social-ecological systems (Svoboda, Fuchs, Poulsen, & Nothwehr, 2015). Still, drought receives less attention than other natural hazards as it is typically a slow-onset phenomenon with a range of complex and interrelated impacts, making it difficult to quantify and define (Svoboda et al., 2015; Vicente-Serrano et al., 2012; Wilhite, Svoboda, & Hayes, 2007).

In the United States (US) West, drought trends are largely uncertain, but may suggest increasing frequency and severity of drought (Vose, Clark, Luce, & Patel-Weynand, 2016). A large proportion of the US West is rangeland – "biologically diverse working landscapes that include complex social-ecological systems ranging from arid deserts and shrublands to mesic grasslands and woodlands" (Roche et al., 2015, p. 1). Droughts in rangelands are particularly devastating, and have tremendous impacts on rangeland dependent social-ecological systems (Núñez, Rivera, Oyarzún, & Arumí, 2014; Vetter, 2009). Scholars call for a "major research thrust" (Vetter, 2009, p. 1) to find ways to decrease the impacts of drought in these systems (Brown, Kluck, McNutt, & Hayes, 2016; Núñez et al., 2014).

Increasing drought frequency and severity in rangelands (Brown et al., 2016) inevitably directs attention to natural resource-dependent livelihoods, such as ranching, which are at higher immediate risk to the impacts of changing environmental conditions (Fischer, 2018). Therefore, ranching has been thoroughly studied within the context of drought resilience (Coles & Scott, 2009; Coppock, 2011; Fuhlendorf, Engle, Elmore, Limb, & Bidwell, 2012a; Wilmer et al., 2018; Wilmer & Fernández-Giménez, 2015). Still, rangelands support a wide variety of stakeholder groups beyond ranchers, including recreationists, land managers, and tribal entities, all of which are impacted by drought but have received less attention in the context of drought resilience and impacts (Thomas et al., 2013; Vose et al., 2016; Wilhite et al., 2007). To consider multiple stakeholder groups, as well as drought related social, economic, and ecological "large-scale changes" (Vose et al., 2016, p. 156), a landscape-scale approach, which transcends ownership boundaries and includes a wide variety of stakeholders, is important for drought resilience management and achieving sustainable outcomes.

Effective large scale drought management is crucial to social-ecological system drought resilience and mitigating drought impacts (Brown et al., 2016; Vetter, 2009). Drought management and preparedness, which consist of "monitoring and early warning systems, risk assessment, and mitigation and response" (Wilhite, 2000, p. 81), can be improved with the use of decision-support tools (Nam, Choi, Yoo, & Jang, 2012). Decision-support tools can be defined broadly as ranging from processes (Schwartz et al., 2018) and simple spreadsheets to sophisticated software packages (Bagstad, Semmens, Waage, & Winthrop, 2013; Rose et al., 2016) that aid in fulfilling conservation initiatives. Use of decision-support tools is not exclusive to drought management and has been studied in many contexts from farmer decision-making (Nam et al., 2012; Prokopy, Mase, Perry-Hill, & Lemos, 2013; Rose et al., 2016) to ecosystem service (ES) valuation (Bagstad et al., 2013). Despite the usefulness of decision-support tools in management (Nam et al., 2012; Núñez et al., 2014; Rose et al., 2016; Schwartz et al., 2018), uptake rates are relatively low and limited in breadth (Rose et al., 2016; Schwartz et al., 2018). In drought decision-support literatures, scholars identify a range of challenges, such as issues of suitability and tool accuracy, which may contribute to lack of or issues with tool adoption (Redmond, 2002), offering a possible explanation to the lack of drought planning improvement in many parts of the world (Wilhite, 2000).

Drought management should consider social and ecological factors (Crausbay et al., 2017a; Slette et al., 2019). Decision-support tools can aid in climate change decision-making; however factors such as "social and political conditions...and the complex dynamics of social and ecological processes"(Wise et al., 2014, p. 327), are important in drought decision-making and the formation of sustained and desired drought management trajectories. As such, new decision-making approaches are needed that consider these dynamic factors within the context of climate change and "deep uncertainty" (Fazey et al., 2016; Haasnoot, Middelkoop, Offermans, van Beek, & van Deursen, 2012, p. 796). The notion of adaptation pathways is one such approach and can be described as "alternative possible trajectories which prioritize different goals, values and functions" (Leach, Scoones, & Stirling, 2010b). Within the context of drought resilience, "exploring adaptation pathways into an uncertain future can support decision-making in achieving sustainable water management in changing environmental conditions" (Haasnoot et al., 2012, p. 1).

This thesis explores drought resilience in the High Divide region, located in the Northern Rockies of Idaho and Montana. The first chapter uses a landscape scale, social-ecological systems-based approach to derive drought adaptation pathways amongst a diverse group of stakeholders with varying interests. These stakeholders included ranchers, non-governmental organizations, and federal and state agencies. We used an adaptation pathways approach as a guide in approaching the problem

of developing sustainable trajectories under uncertain future water availability in rural, natural resource dependent communities. We found that agricultural livelihoods, functioning ecosystems, and social capital were foundational to a drought resilient landscape and important considerations in path development. The second chapter of this thesis explores the use of drought decision-support tools and the barriers to usage in landscape management organizations within the High Divide region. We conducted individual interviews with non-governmental organizations and federal and state agencies to determine which tools were being used and how and what barriers existed to tool adoption. We found organizations to be using what we defined as processes, data, models, and geospatial/web-based tool types as decision-support, but that drought management was not a prominent tool supported management objective. We found that barriers such as lack of capacity and difficult interpretation exist to furthering drought decision-support tool use. This thesis research looks to reach academics and managers/decision-makers in related fields and aims to inform social-ecological system drought adaptation pathways, encourage increased awareness between researchers and managers about barriers to decision-support tool adoption, and inform future drought decision-support tool development in the High Divide region.

Chapter 2: Adaptation Pathways for Large Landscape Drought Resilience

Abstract

In the United States (US) Northern Rockies of Idaho and Montana, drought projections are largely uncertain. Still, trends suggest potential increased severity and duration of droughts, with implications for the sustainable management of rangeland systems. Efforts to increase drought resilience across this large landscape must include multiple stakeholder groups because of the region's diverse mosaic of land ownership and priorities for land management, including sustaining ranching livelihoods and protecting wildlife connectivity. We conducted research in the High Divide region of the Northern Rockies of Idaho and Montana, a semi-arid sagebrush steppe rangeland system with similar ecological functions and socioeconomic context as many other US rangelands. Our study objectives were to 1) *understand past experiences of drought across diverse stakeholder groups*, 2) *determine characteristics of drought resilient landscape management*, and 3) c*o-develop adaptation pathways, or possible future trajectories, for increased drought resilience* in the High Divide region. In coordination with a regional landscape collaborative, we convened focus groups that included representatives of multiple land management sectors: ranching and public land management agencies, land trusts, and other regional organizations. We found lack of foundational social capital between social groups was exacerbated by drought. Still, shared conceptions of the components of a drought resilient landscape, including sustainable agricultural livelihoods, functioning ecosystems, and established social capital, suggests drought management and planning may present new opportunities for awareness and increased dialogue between stakeholders. We present these findings as management implications and as informative for future collaborative drought resilience action in the High Divide region.

1. Introduction

Drought projections for the United States (US) vary from region to region and are largely uncertain (Vose et al., 2016). Drought affects fish and wildlife species abundance and movement, forest and rangeland productivity, agricultural production and livelihoods, and community well-being (Thomas et al., 2013; Wilhite et al., 2007). In the US Northern Rockies of Idaho and Montana, rangelands – "biologically diverse working landscapes that include complex ecosystems ranging from arid deserts and shrublands to mesic grasslands and woodlands" (Roche et al., 2015, p. 1) – make up a large proportion of the region, providing fish and wildlife habitat and a range of ES for people (Havstad et al., 2015). Drought in these systems is a natural component of climate (Brown et al., 2016; Havstad et al., 2015; Whitlock, Cross, Maxwell, Silverman, & Wade, 2017). Still, projections

indicate decreased precipitation in certain times of the year (Ficklin, Maxwell, Letsinger, & Gholizadeh, 2015; Whitlock et al., 2017), decreased snowpack resulting from long-term warming trends (Abatzoglou, McEvoy, & Redmond, 2017), increasing surface temperatures, changes in runoff timing, and loss of soil moisture holding capacity due to historic unsustainable use of rangelands (Thurow & Taylor, 2007), all of which will exacerbate drought "when and where it occurs" (Whitlock et al., 2017, p. XXXII) raising concern for social-ecological systems in large landscapes (Vose et al., 2016).

Rangeland-dependent communities are especially vulnerable to increasing drought events (Fischer, 2018; D. R. Nelson, Adger, & Brown, 2007). A number of studies have explored drought impacts on ranchers and grazing productivity in the US West (Coles & Scott, 2009; Coppock, 2011; Fuhlendorf, Engle, Elmore, Limb, & Bidwell, 2012b; Wilmer et al., 2018; Wilmer & Fernández-Giménez, 2015). However, rangeland ecosystems support a broad range of stakeholder groups beyond ranchers, ranging from recreationists to conservation organizations, and few studies have reported comprehensively on drought impacts across social groups (Thomas et al., 2013; Wilhite et al., 2007). Furthermore, drought impacts research on integrated social-ecological systems including impacts on ES is lacking (Crausbay et al., 2017b).

This research examines drought experiences and perceptions of drought resilience across multiple stakeholder groups in the High Divide region of Idaho and Montana, situated within the larger Northern Rockies landscape. Although projections are uncertain, rising surface temperatures, declining summer precipitation, decreased snowpack accumulation, and earlier spring snowmelt and runoff (Abatzoglou, Rupp, & Mote, 2014; Vose et al., 2016; Whitlock et al., 2017) in this region could suggest increases in drought severity and duration. The possibility of increasing droughts (Vose et al., 2016) is concerning for social-ecological systems that rely heavily on water in this already arid and drought prone region, motivating efforts to increase drought resilience. We draw on two primary bodies of literature, large landscape management and adaptation pathways. First, we take a large landscape approach to conceptualizing drought resilience.

Across the US West, conservation planners and policy-makers have increasingly advocated for landscape-scale management goals that transcend ownership boundaries to achieve desired regional outcomes (Folke, 2006; Schultz, Folke, Österblom, & Olsson, 2015; Travis Belote et al., 2016). Inherent in the push for landscape-scale management has been the recognition of large-scale climate change impacts, such as the cascading repercussions of drought and the management actions that follow (Vose et al., 2016). For example, loss of forage value due to drought (Vose et al., 2016) can trigger decisions to reduce access to public rangelands for grazing, leading to (a) intensifying ranch

operations on private lands adjacent to public land, or (b) abandonment of ranching operations and conversion of private rangelands to exurban development (Knapp, Stuart Chapin, & Cochran, 2015; Lewin, Wulfhorst, Rimbey, & Jensen, 2019; Roche et al., 2015; Rowe, Bartlett, & Swanson, 2001; Talbert, Knight, & Mitchell, 2007). Large landscape management approaches have been implemented in the US West, such as the Yellowstone to Yukon Initiative (Chester, 2015), and are increasingly called upon to manage complex issues such as water management that require attention at multiple scales (Scarlett & McKinney, 2016). In the Northern Rockies of Idaho and Montana, a landscape scale management approach is essential to maintain and improve connectivity for species under climate change (M. McClure, Beltran, & Hostetler, 2017) and for managing drought impacts on invasive plants and fire regimes (Graves, Williamson, Belote, & Brandt, 2019; Vose et al., 2016). To consider drought related "large-scale changes that warrant substantial management responses" (Vose et al., 2016), we apply a landscape approach to our understanding of social-ecological system drought resilience in the High Divide region.

Second, we use an adaptation pathways approach to guide our methodology. Adaptation pathways are "approaches for planning" (Fazey et al., 2016, p. 4) described as "alternative possible trajectories for knowledge, intervention, and change which prioritize different goals, values, and functions" (Leach, Scoones, & Stirling, 2010a, p. 5). In the High Divide region, there have been several top-down efforts to increase resilience, including foundation and federal funding. However, the adaptation pathways approach suggests that any external assistance must consider the local context of resources and vulnerabilities in order to enact sustainable and acceptable future change for communities. We use the adaptation pathways approach as a guide for our multi-stakeholder participatory study aimed at the development of practical visions and sustainable trajectories for natural-resource dependent communities in the High Divide region. The adaptation pathways approach is especially useful in navigating the inherit complexity of water management in natural resource dependent communities and as it considers changing environmental conditions (to which these communities are particularly vulnerable) in the development of sustainable trajectories (Haasnoot et al., 2012)

In coordination with a regional landscape collaborative, we convened focus groups that included representatives of multiple land management sectors: ranching and public land management agencies, land trusts, and other environmental non-governmental organizations. The objectives of this study include: 1) *understand past experiences of drought across diverse stakeholder groups*, 2) *determine the characteristics of drought resilient landscape management*, and 3) *co-develop adaptation pathways for increased drought resilience* in the High Divide of Idaho and Montana. We used an

adaptation pathways approach to guide our methodology and the development of practical visions and sustainable trajectories for drought resilience. Findings suggest that agricultural livelihoods, ES, and social capital are critical for drought resilient landscape management, and we argue for the consideration of these components in planning and management action.

2. Methods and Materials

2.1 Study Area

The High Divide region of Idaho and Montana covers 25-million acres from the Greater Yellowstone Ecosystem (GYE), Central Idaho Wilderness, and the Crown of the Continent Ecosystem (COC) (Figure 2-1). The region supports diverse vegetation communities, including sagebrush steppe, forest, and rangeland systems due to its steep topographic gradients, and contains the headwaters for the Missouri and Columbia watersheds. These headwaters are critical to providing spawning habitat for anadromous fish from the Pacific Ocean (M. M. McClure et al., 2008) and are important for social-ecological usages and benefits derived from these larger rivers. The High Divide region is crucial to maintaining connectivity in the Northern Rocky Mountains, particularly for key wildlife species such as grizzly bear and wolves (Carroll, Mcrae, & Brookes, 2012; Shafer, 2015). Privately owned lands, many of which are large scale ranchlands, take up approximately 40% of the total land area in the region and are vital to wildlife connectivity between public lands and protected areas (M. McClure et al., 2017). In addition to its importance to wildlife connectivity, historic family ranching is considered an uniquely American “cultural heritage” and as such, a “cultural resource” (Kirner, 2015, p. 85).

Because of the region’s significance to wildlife connectivity and ranching livelihoods, the High Divide region provides a unique opportunity to integrate a social-ecological large landscape approach to drought resilience. We partnered with the High Divide Collaborative (HDC), a group that brings together stakeholders from across the region to discuss and enact large landscape conservation goals, to understand drought experiences and perspectives across multiple stakeholder groups (High Divide Collaborative, n.d.). The HDC focuses on conservation and restoration of private and public lands within the High Divide region and includes public land managers, state wildlife agencies, landowners, local community leaders, scientists, and conservation non-governmental organizations (NGOs) that primarily included land trusts. Working with their partners, the HDC works specifically to restore lands of importance for local communities and protect ecological connectivity at the landscape scale. The group co-developed eight priority themes in 2014, one of which is drought resilience.

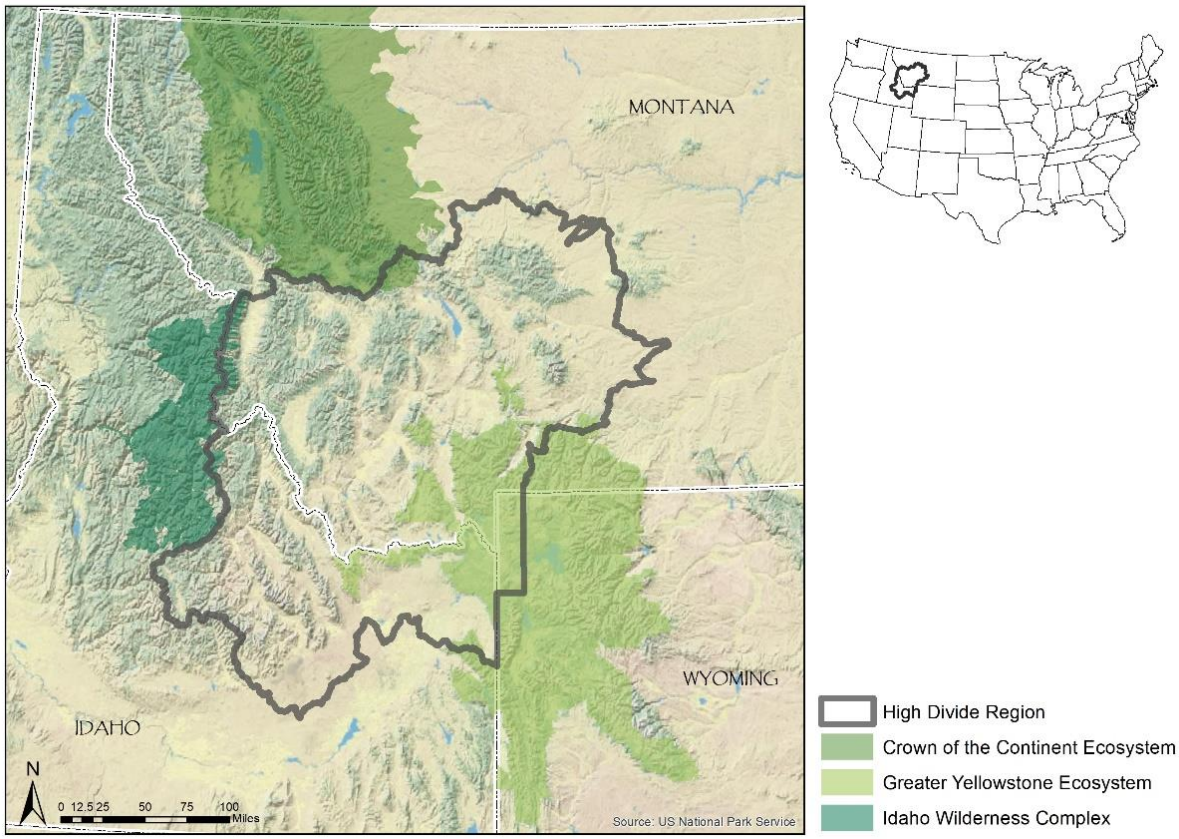

Figure 2-1. Location of the High Divide region in the United States and other protected areas. High Divide layer from Heart of the Rockies Initiative. Crown of the Continent Ecosystem layer from Crown Managers Partnership. Greater Yellowstone Ecosystem layer from USGS The National Map, National Boundaries Dataset. Idaho Wilderness Complex layer from USGS The National Map, National Boundaries Dataset.

2.2 Data Collection

We held focus groups during HDC's 2018 annual stakeholder meeting in Dillon, Montana. The meeting was attended by government agency officials, NGO representatives, ranchers, and University researchers. We separated 32 participants into five groups based on HUC 8 watershed sub-basins in which they lived and/or worked. We further combined adjacent sub-basins, Big Hole and Beaverhead, Salmon and Lemhi, Gallatin and Madison, and Upper and Lower Henrys Fork and Teton to maintain even numbers of participants across focus groups. Final focus groups included the Big Hole/Beaverhead, Salmon/Lemhi, Ruby, Henrys Fork/Teton, and Gallatin/Madison (Figure 2-2). See Table 2-1 for participant representation across focus groups.

Figure 2-2. Sub-basins in the High Divide region. Basins represented in focus group discussions are labeled and emphasized.

We asked the participants the following questions: (1) *How have you experienced drought in the past?* (2) *What are the defining characteristics of a drought resilient landscape?* (3) *What needs to change in order to achieve a more drought resilient landscape for wildlife connectivity, water availability, and ranch livelihoods?* Stakeholders participated in a group sharing of ideas relating to each question, which was captured through facilitator notetaking. Each group had at least one facilitator who guided discussion and a notetaker who took notes on large post it notes to capture the ideas presented. Notes were available to stakeholders throughout the session and were beneficial in the prioritization process and for minimizing repetitive ideas. Additionally, each participant was given a notecard to capture any ideas that were not openly talked about. At the end of the session we conducted a prioritization process of proposed drought resilience pathways. All focus groups were recorded with permission from the participants. The focus groups took place in separate rooms close to the meeting venue and took approximately 1.5 hours to complete. A full group session was initiated after the focus groups for a final share out of the most important ideas discussed in each sub-

basin. Objectives of this full group session were to (1) *discuss landscape priorities regarding drought* and (2) *how to effectively start implementing proposed pathways over the next year*.

Rangeland Management Sector:	Description:	Participants (#)
Ranchers	Landowners, land managers, grazing permittee holders	4
NGO Representatives	Land Trusts, Conservancies, Watershed Groups	21
Government Agency Officials	State and Federal agencies	7

Table 2-1. Number of participants by social group.

2.3 Data Analysis

The research analysis followed a qualitative analysis framework that involved coding of transcripts, combining codes into broader themes, and displaying and making comparisons between themes (Creswell 2013). Transcripts, facilitator notes, and participant notecards were analyzed with the assistance of a NVivo software program. Each participant was assigned an individual case, a sub basin specific case, and a case classification to reflect their professional affiliation (rancher, government agency, NGO). Transcripts were structurally coded by research question and participant name and participants were assigned an anonymous code to ensure privacy.

Transcripts were coded first for emergent themes, which were then compared to themes prevalent in the literature and adjusted accordingly. Overarching concepts were derived from the transcripts and notes to describe 1) *characteristics of a drought resilient landscape* and 2) *pathways for increased drought resilience* in the High Divide. We ran a series of coding matrix queries to characterize sectoral support for each pathway which is described in the following sections. Derived pathways were reported back to many of the study participants and others at the HDC annual meeting the following year (2019), with feedback, comments, and questions encouraged.

3. Results

3.1 Past experience with drought

We first inquired of the study participants, "*How has drought affected you or the region where you work in the past?*" to better understand the historical social dynamics of drought in the High Divide region. Although this was not our primary use of the pathways approach, a pathways approach suggests understanding historical conditions pathways as helpful in informing future trajectories. As such, we wanted to understand social group dynamics, relationships between stakeholders, and how

drought has influenced these components in the past, which we considered as contextual information in support of pathways.

3.1.1 Threats to ranching livelihoods

Lack of rancher resilience during drought was observed across all types of workshop participants. Ranchers spoke from personal experience about their inability to sustain their cattle herds during droughts, resulting in financial losses that could be difficult to recover from over multiple years.

> *Drought really affected me personally as far as I ended up selling 2/3rds of my cows that I thought I would be able to find a pasture for, but the competition for pasture, you couldn't even find it, much less…I was bidding double what the animal unit cost was normally. I couldn't, I still couldn't get pasture for them. So, I ended up having to sell down. [Rancher 1]*

"Selling down" means reducing the herd size. As rancher profitability decreases, selling the ranch altogether and the land being subdivided has become more of a reality for many ranchers throughout the US West.

Having less personal experience with drought, government agency officials observed the impacts of drought and the accompanying threats to ranching livelihoods through their work with ranchers, such as through grazing permit allotments or monitoring projects. One government agency official spoke of producers' struggles observed while conducting stream monitoring on private ranch lands. Ranching operations use water in various ways, including water for stock to drink, water for hay production, and water for forage. In a drought, lack of water leads to decreased available forage but also decreased availability of water for irrigated hay production. Hay production is a strategy for ranch operation resilience during drought years as it can be utilized for supplemental forage for cattle. This government agency official noted that the stream was "essentially completely dry" and that they and the others in their group could "see how they [ranchers] were struggling." [Government Agency Official 1]

NGO staff discussed concern about decreased profitability of ranching operations and threat of subdivision as a result of ranching operation vulnerability and lack of resilience to drought. The following quote illustrates thoughts on the possible consequences of drought conditions on producers from a large landscape conservation perspective.

> *…Some drought conditions have impacted the viability, profitability of farm and ranch operations in areas in which I work, which may have, and I don't know this, hastened a subdivision of those lands. Which then would impact visual pleasure in visiting those [lands]*

> *and to the extent that they have happened in the Gallatin Valley, where I live, more rural subdivisions mean higher taxes, they mean degraded water quality and loss of open space. [NGO Representative 15]*

This NGO representative alludes to the 'subdivision of lands' as less visually pleasing than ranchlands. "Visual pleasure" [NGO Representative 15] is a major driver in the recreational economy and is defined here by the participant as the natural beauty of the region, preserved by large scale ranches that protect against fragmentation and subdivision.

3.1.2 Threats to functioning ecosystems

In addition to threats to viable ranching operations, participants also talked about regional concerns related to the effect of drought on functioning ecosystems. Ranchers highlighted the need for functioning ecosystems that provide forage availability for cattle, especially during droughts. Functioning ecosystems are more resilient to stressors such as drought and can therefore withstand dry periods, while still supplying adequate forage availability. Additionally, ranchers expressed concern for riparian health during droughts due to heightened presence and intensity of cattle grazing in these areas. Ranchers spoke about "impact[ing] that ground so much", meaning degrading riparian areas from overgrazing, resulting in "swampy bogs" [Rancher 1].

Government agency officials also expressed concern for riparian ecosystem health and the impacts of drought on individual species such as cottonwood trees and ladies' tresses orchids:

> *For example, ladies' tresses is an orchid that has a very specific parameter for where it lives in the hydrograph. Now we have modified the hydrographs to such an extent that they are not being eradicated by it, but they are being impacted. [Government Agency Official 6]*

This government agency official went on to explain how certain species, such as cottonwoods, require a specific flooding regime, without which they cannot regenerate. Climate and infrastructure (dams, stream bank alterations, and levees) induce alterations in water level and flow, which profoundly impact many species and can create conflict between what people see as a desirable ecosystem state and what species need to survive.

NGO representatives expressed rancher's concern for adequate forage availability during droughts but focused more wildlife accessibility to forage as opposed to cattle:

> *And it is not just about the cattle too, it is about all wildlife losing their forage spaces. For the elk, which then decreases the amount of hunting passes that they give out, so then you are*

> *not getting that revenue of okay I can only sell 50 versus 100 hunting passes this year. [NGO Representative 1]*

This NGO representative connects the importance of functioning ecosystems for recreation and sustenance to the local economy of the region.

3.1.3 Threats to social capital

Drought was the impetus for conflict between social groups, illuminating a lack of foundational social capital. Ranchers described their conflict with other social groups over water, referencing the differences in morals, priorities, and levels of dependence across stakeholder groups concerning water supply:

> *The one thing that I thought of goes back to our sprinkler system, because the city of Victor and some of the new subdivisions come off the sprinkler system. So sometimes it is hard to convince people that my crop is more important than their lawn, because everybody wants a green lawn, whether it is a drought year or not. They want a green lawn. So sometimes they are not willing to go, "Oh gosh, we can't water that everyday anymore." So just the problems that you have dealing with individual people and how they interpret water usage in a drought year is very difficult. [Rancher 4]*.

Government agency officials echoed ranchers in that they shared a level of frustration directed at other social groups concerning water usage and mindset. The following quote illustrates one government agency official's frustration with recreationist/tourism communities:

> *…West Yellowstone is also having issues, because their water right is a spring fed water right and two years ago it has been reducing its production capacity. Two years ago, like on June 15th, their demands were at exactly what their capacity was on that day. If you think about the economy of West Yellowstone and all the hotels and everybody with vacation brain using the water and they only have the one system. We keep reaching out to them saying, "Do you want some help planning?" And they don't call back. Okay, well they must have it figured. But they put a moratorium on building particularly any new hotels. [Government Agency Official 2]*

This quote from a government agency official and the previous quote by a rancher suggest different perspectives on the importance of water and the threat of drought across social groups in the region. These differences have resulted largely in conflict, an *us versus them* mentality, and further

degradation of social capital. Still, the government agency official in the second quote acknowledged that the moratorium on building was a positive step.

NGO representatives added to this discussion of conflict by describing "infighting" in communities as a result of water scarcity. "Infighting" [NGO Representative 18] was described as pertaining to small, economically connected communities and was not described as a problem in larger, economically diverse urban centers. NGO representatives attributed this contrast to a lack of connection between social groups and between social groups and producer economies in large urban areas, compared with intimately connected social groups in small rural communities. This perspective contrasts with rancher depictions of conflict between themselves and homeowners in small communities such as Victor, ID (as described in a previous quote), further emphasizing different perspectives across groups. Still, this NGO representative concludes by conveying drought and associated conflict as an opportunity for increased dialogue and new awareness between social groups.

3.2 Characteristics of drought resilient landscape management

Second, we asked participants; "*What are the ideal characteristics of a drought resilient landscape?"* to generate practical visions of a drought resilient landscape and to begin the process of pathway development. We then asked; *"What needs to change to achieve a drought resilient landscape for wildlife connectivity, water availability, and ranching livelihoods"* which we interpreted as formulated pathways toward a more drought resilient future. We synthesized responses from both questions in our interpretation of participant development of adaptation pathways for increased drought resilience in the High Divide region. In the following sections we present three overarching focus areas or pathways which include *sustaining agricultural livelihoods, supporting functioning ecosystems,* and *building social capital,* which we frame as informative for landscape scale drought management.

3.2.1 Sustaining Agricultural livelihoods

Agricultural livelihoods were an important focus area for drought resilience management in the High Divide region for all social sectors. Proximity to producer economies influenced sectoral concerns and perspectives. Discussions illuminated heightened rancher vulnerability to drought when compared with other social groups. The following quote illustrates ranchers' perceptions of being especially vulnerable to drought when compared to other stakeholder groups:

> *I am trying to come at it from an overall view, but when it comes down to it, I am a rancher. I raise animals. And I can survive a year. I can buy hay for a year. But eventually, depending*

> *on the length of that drought and the impacts on the landscape, I am going to have to sell my animals. It is going to impact me more so than it might somebody that is in the tourism business…So the ranchers, the people out on the landscape are more directly impacted in the Madison Valley than somebody that is fishing on the river…A drought could far more impact those people who are trying to make a living on the land than it would a lot of the businesses or lifestyles. [Rancher 1]*

This rancher exemplifies the hardships of making a living off the land and gives insight into the struggles that characterize resource-dependent livelihoods.

Government agency officials also acknowledged rancher drought vulnerability while emphasizing the importance of ranching livelihoods to the larger community, suggesting agricultural livelihoods as equal to municipalities in rights to water storage. Traditionally in dammed communities, most of the reservoir water is reserved for municipal uses. Suggesting agricultural livelihoods as equal to municipalities in rights to water storage suggests participants perceive ranchers as important to the larger community. NGO representatives also recognized rancher drought vulnerability by describing how ranchers need the additional financial capacity to carry "surpluses" in terms of feed for cattle during drought years without going into dept and being "really handicapped" [NGO Representative 2]. NGO representatives also emphasized the importance of agricultural livelihoods to a "working landscape" [NGO Representative 2] and to the "local community" [NGO Representative 19] and to drought resilience decision-making processes.

In the context of rancher vulnerability, participants suggested enabling rancher participation in collaborative decision-making and diversification of ranching livelihoods as pathways for achieving sustainable ranching livelihoods. The ranching livelihood requires ranchers to be physically present, especially during calving seasons and other transitionary periods, making it difficult for ranchers to attend meetings which often require travel and multi-day commitments. Lack of trust between social groups further discouraged ranchers from committing time and money to attend such meetings. Participant described solutions to these issues included disseminating group discussions and information to ranchers at local "hubs" [NGO Representative 19], which would require minimal travel for ranchers while providing opportunity for rancher input to be voiced and considered. Additionally, making sure ranchers can see their "values in the outcomes" [NGO Representative 7] of decision-making processes and being considerate of rancher calving seasons when scheduling collaborative events were described as helpful in building trust between social groups. Lastly, diversification of rancher income, especially in years of drought when producers are often

forced to sell down their cattle herds, and diversifying ranchers' access to water resources were described as additional pathways for achieving sustainable agricultural livelihoods.

3.2.2 Supporting Functioning Ecosystems

In describing a drought resilient landscape, all sectors relayed the importance of having and maintaining long-term functioning ecosystems. Ranchers were particularly concerned about functioning ecosystems within the context of grazing availability for cattle, which is crucial to ranching livelihoods. Droughts in rangelands significantly decrease the land area available for grazing while also reducing water available for livestock, which often results in over-grazed riparian areas. Lack of forage availability due to drought often forces ranchers to sell down or reduce their herds, purchase additional grazing permits, or buy supplemental feed.

Government agency officials also talked about the importance of functioning ecosystems in a drought resilient landscape, emphasizing the need for "consistent sufficient flows" [Government Agency Official 2] and "dispersed water on the landscape" [NGO Representative 17] for human and wildlife uses. Government agency officials also spoke about functioning fire regimes, which have been suppressed in the West to a large extent, as crucial for the survival of many species. Naturally occurring fire regimes improve resilience in forest systems in that they enable natural growth cycles, promote regeneration of species, and maintain diversity.

Similar to government agency officials, NGO representatives focused on the importance of ecological processes in a drought resilient landscape, adding to the discussion the importance of flooding regimes and ground water recharge:

> *…I guess it mostly connects with water availability. It's just basically as close as you can get to ecologically intact systems and properly functioning systems. If you have a stream that has access to its flood plains, then that whole area is probably more wet to start out with. You have a lot more groundwater to start out with, and then you can probably weather a year or two of drought without seeing too much trouble because there is so much moisture stored on the land. If it is incised, it all just flows out. [NGO Representative 4]*

Flooding regimes, like fire regimes, often prove hazardous to human safety and therefore are suppressed in various ways. However, flooding replenishes the aquifer as described by NGO Representative 4, which is important for irrigation, and it improve ecosystem drought resilience.

When prompted to describe necessary changes needed to achieve a more drought resilient landscape, participants reiterated the importance of functioning ecosystems by suggesting payments, incentives, and compensations for ES use. For instance, participants encouraged "bigger penalties for draining wetlands or bigger incentives to not drain wetlands" [NGO Representative 1]. Participants also encouraged "compensate[ing] natural resource managers upstream for managing for all of us [community members] downstream" [NGO Representative 5]. Lastly, participants described rewarding sustainable use of ES, with the idea of making it "cool to conserve" [Rancher 1].

3.2.3 Social Capital

Social capital as a drought resilience management focus was the most prevalent and evenly represented management focus across all stakeholder groups. Ranchers talked extensively about the need for social capital as it pertains to community connectedness, mutual respect, cooperation, and communication. In the following quote, a rancher describes the importance of community:

> *Community is really important to me, so my family has a place to stay. If we don't have the local schools, what is the incentive? We will have to move away, either send your family away to go to school or move away with them. So, it is hard to keep families together and make them want to stay on the land. Also, when you work 12- and 14-hour days and then have your families split up too… [Rancher2]*

This rancher describes how social capital is important to the sustainability of ranching livelihoods. High social capital creates communities with opportunities, such as availability of "local schools" [Rancher 2], which encourages local growth. In recent decades, transition from what is referred to as the "Old West", supported by resource extraction, to the "New West", supported largely by service economies and outdoor enthusiasts, has resulting in many ranchers selling and sub-dividing their land, decreasing ranching presence on the landscape. As such, creating stable communities that encourage growth and will support generations of families is important for sustaining agricultural livelihoods.

Government agency representatives also talked extensively about social capital as it pertains to collaborative drought resilience planning and management. Specifically, government agency representatives elaborated on "building the trust" [Government Agency Official 2] between social sectors, as previously discussed in the agricultural livelihoods section, where historic tensions exist. Lack of trust, particularly between ranching communities and government agencies, has been a point of bitter contention, particularly around wildlife protections and regulations. As collaborative management is starting to gain footing as a strategy for resilience to climate change, building trust

between social sectors is an important first step to "get[ting] everyone there" and doing "good planning" [Government Agency Official 2].

NGO representatives added to the social capital discussion by talking further about collaboration, including the need for "willing legislatures" [NGO Representative 1] and flexibility in decision-making:

> *I think that you need a combination of collaborative efforts. It shouldn't be just one or two groups working on this. You need the backing of the ranchers and the farmers and the recreationists, but you also need your local community to come out, your federal community, your state community. You need everybody really willing to work together. That also requires flexibility. You need to be able to say this isn't working for us anymore in our community, so we are going to change our strategy. [NGO Representative 1]*

This NGO representative describes social capital as the "willingness" of all stakeholder groups to work together in decision-making processes for effective drought resilience management at the landscape scale. The importance of attitudes is implied within the context of flexibility and willingness.

All stakeholder groups acknowledged social capital as an avenue for increasing landscape wide drought resilience and described strategies to build social capital that would encourage sustainable water use and improve drought management outcomes. For instance, participants encouraged environmental drought education and awareness and marketing strategies to foster human connection to the landscape and instill environmental consciousness, encouraging deliberate water consumption and decreasing conflict between stakeholders. Establishing drought concern and awareness across stakeholder groups was described by participants as "buy in" [Rancher 3], a necessary precursor for the "social and monetary investment" [Rancher 3] needed to implement drought resilience pathways for sustaining agricultural livelihoods and supporting functioning ecosystems. We understand participants depiction of social capital as a necessary first step to implementing and attaining larger drought management goals.

4. Discussion

In the US Northern Rockies of Idaho and Montana, drought projections are largely uncertain (Vose et al., 2016) but may suggest exacerbated periods of dryness due to warming temperatures, decreases in precipitation during the summer months, decreasing snowpack accumulation, and earlier spring snowmelt (Whitlock et al., 2017). Under this uncertainty, new approaches are needed to support decision-making (Fazey et al., 2016; Haasnoot et al., 2012). The adaptation pathways

approach, which considers social-ecological systems and the possibility of transformational change, is one way to adjust decision-making under climate change to encourage sustainable outcomes (Fazey et al., 2016; Smith, Horrocks, Harvey, & Hamilton, 2011; Wise et al., 2014). In the High Divide region of Idaho and Montana there have been top-down efforts to increase resilience including federal and foundation funding. However, an adaptation pathways approach suggest that any external assistance must consider the local context of resources and vulnerabilities in order to enact sustainable and acceptable future change for communities. To the best of our knowledge such an approach has yet to be taken in this region with the goal of increasing drought resilience in the communities therein. We used the adaptation pathways approach to guide our participatory method, which included engagement of stakeholder groups at multiple levels of management with diverse values and perceptions. We also used the pathways approach in an applied manner in the co-development of drought resilience pathways for a sustainable future landscape. Using the pathways approach in this way allowed us to engage diverse viewpoints, consider social-ecological and large landscape drought perspectives, and incorporate climate variability in our development of pathways.

It is important to note however, that our use of the adaptation pathways approach is just one among many other conceptions and frameworks associated with adaptation pathways. For instance, used as an analytical tool, the pathways approach can provide valuable insights into "past conditions that have shaped vulnerability" (Fischer, 2018, p. 237) and the "challenges of dealing with the complex dynamics of social and ecological processes" over time (Wise et al., 2014, p. 327), to inform future pathways (Fazey et al., 2016). Back-casting, a method with which actors envision an ideal future state and then work backwards to the present, linking future and current states through pathways, is another application of the adaptation pathways approach. Using these other pathways frameworks could have led to differently framed conclusions and may have provided additional insight into historical contexts in the region that influence the development of pathways. Still, we choose to use pathways as an applied methodology as we saw it to be the most applicable and appropriate given our study context and the nature of our data collection.

We asked participants about their experiences with drought, perceptions of ideal drought resilient landscape characteristics, and changes necessary to achieve a more drought resilient landscape for wildlife connectivity, water availability, and ranch livelihoods. In response, participants identified *sustaining ranching livelihoods*, *supporting functioning ecosystems,* and *building social capital* as main areas of concern.

Sustaining ranching livelihoods was a focal point in drought resilience discussions. In line with what many other scholars have reported (Coppock, 2011; Roche et al., 2015; Wilmer et al.,

2018; Wilmer & Fernández-Giménez, 2015), the ranchers in our focus groups described themselves (and were perceived by others) as the most vulnerable social group to drought on the landscape due to their high level of dependence on natural resources. Our participants' perspectives on rancher vulnerability in this context corresponds with larger literatures which suggest that the degree of social group dependence on natural resources is deterministic of resilience and ability to absorb stressors (Adger, 2000). Further, environmental variability, such as drought can increase risk associated with natural resource dependence (Adger, 2000), which was conveyed by ranchers in their retellings of drought experiences. Still, we found the focus on sustaining ranching livelihoods as primarily driven (although all stakeholders agreed) by ranchers themselves. It was clear that ranchers were given ample opportunity to speak during the focus groups and were seen perhaps as commanding forces in discussion. As such, ranchers had a way of guiding conversation despite being the least represented focus group with only four individuals. The perception of ranching as a uniquely American "cultural heritage" (Kirner, 2015, p. 85) that has been challenged by recent "rural restructuring" (P. B. Nelson, 2001, p. 1) and transitions across the US West, may have contributed to other stakeholder groups allowing increased, and perhaps disproportional, influence of ranchers in focus groups. Additionally, historic tension between ranchers and federal agencies and established perceptions of historical rancher suppression by federal agencies through enforcement of environmental laws and policy (Krannich & Smith, 1998) could have contributed to other stakeholders feeling pressured to overemphasize the needs of ranchers in certain circumstances. Still, the importance of ranching livelihoods was significant to all social groups and described as a core management focus for increasing drought resilience in the High Divide region.

To achieve sustainable ranching livelihoods, our participants encouraged increased access to capitals. The importance of capital access (such as natural, social, human, etc.) for rural livelihood sustainability is well supported (Bebbington, 1999; Coppock, 2011; Scoones, 1998). Participants particularly focused on improving access to social capital by suggesting ways to increase rancher participation in collaborative processes, such as building trust between stakeholder groups and alleviating livelihood related factors that prohibit participation. Social capital is important within the sustainable agricultural livelihoods literature as it allows access to other capitals and resources (Bebbington, 1999; Scoones, 1998). Our participants also described improving access to natural capital (water) during droughts through increased and diversified water storage in an effort to ensure "natural resource base stability" (Scoones, 1998, p. 6), which is a necessary component of sustainable livelihoods and is challenged by environmental variability or drought. Lastly, participants encouraged a diversified income for ranchers as a strategy for resilience, particularly during drought years. Others report on the usefulness of diversification (also referred to as intensification) for

achieving sustainable livelihoods in rural contexts (Bebbington, 1999; Coppock, 2011; Scoones, 1998).

The dependence of the ranching community on functioning ecosystems or natural capital was apparent in our focus groups and supported by wider literature. However, participants also described the importance of functioning ecosystems at a much broader, social-ecological system scale, focusing specifically on the services that functioning ecosystems provide. We found that ES described in our focus groups reflected services reported on in other studies (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005b; Ouyang et al., 2015; Wardropper et al., 2020) and focused on the following ES: fresh water supply provisioned by aquifers, rivers, and reservoirs; hunting and fishing opportunities supported by healthy species populations; recreational opportunities supplied by scenic landscapes, river flows, and snowpack; agricultural products derived from forage and pasture availability; and water purification from wetlands and riparian areas. We found participant discussions of ES as closely tied to their role in sustaining local agriculture and recreational economies. As reported by many others (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005b; Ouyang et al., 2015; Wardropper et al., 2020) ES have high monetary value, are crucial to sustainable social and economic development (Costanza et al., 1997; Ouyang et al., 2015) and are often difficult to replace (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005b). We found participants perceive the general irreplaceability of certain ES as they encouraged larger fines for ecosystem service degradation and larger incentives for sustainable ES use. In concordance with resilience and ES literature (Folke et al., 2010; Levin & Lubchenco, 2008), we find focus on sustaining functioning ecosystems in the described contexts as indicative of participants' belief that maintaining the "natural resource base" (Scoones, 1998, p. 5) increases the potential for sustainable future trajectories in social-ecological systems.

To successfully implement pathways for increased drought resilience in the High Divide region, such as sustaining agricultural livelihoods and supporting functioning ecosystems, participants described the necessity of social capital. As previously discussed, social capital is crucial to sustainable agricultural livelihoods as an asset that allows producers to access other necessary capitals (Bebbington, 1999; Scoones, 1998). In the context of sustainable use of ecosystem services, social capital decreases the likelihood of individual's "engaging in unfettered actions which result in resource degradation" (Pretty & Ward, 2001, p. 211). In recent decades, many collaborative resource management programs which focus on building social capital across social groups have been largely effective in agriculture, fisheries, and wildlife management sectors (Pretty, 2008). Despite participant perceived and widely supported benefits of social capital, individuals expressed a lack of foundational

social capital between social groups in the High Divide region, highlighted and exacerbated by drought events. Still, Ooi et al (2015) described conflict as a force that can "instigate social capital development", a viewpoint that was reflected in participant discussions.

We found the motivation behind each of the participant developed pathways was to maintain a sense of regional identity in the face of drought stress. In the High Divide region, communities are largely supported by recreation-based economies. This is due largely to transitions in the wider western landscape in recent decades, constituting a shift to a "New West" driven primarily by service based economies (Ooi et al., 2015) and characterized by "amenity migrants [seeking] actual or perceived higher environmental quality and/or cultural differentiation from the destination" (Glorioso & Moss, 2007, p. 138). Still, much of the recreation-based economy is driven by outdoor enthusiast's desire to experience "unspoiled" (Glorioso & Moss, 2007, p. 138) and pristine environments. In this sense, the identity of the High Divide region, which our participants described as the presence of open ranchlands, scenic landscapes, and abundant fish and wildlife species that contribute to visual pleasure and recreational opportunity, constitutes the foundation of the recreational economy which supports communities. As stated by a participant in the words of Aldo Leopold, we have to "save all the parts" [NGO Representative 2] of the landscape, including agricultural livelihoods and ecosystems, not only in the sense of a land ethic, but also in the sense of surviving in a rapidly changing landscape. As such, a large landscape approach was necessary in the development of adaptation pathways in this region. Other large landscape scale management approaches have been adopted in the US West such as the Yellowstone to Yukon Initiative (Chester, 2015) and have been increasingly called upon to deal with complex problems, such as climate change adaptation and water management, which require attention at multiple scales (Scarlett & McKinney, 2016). Large landscape approaches describe networks and multi-stakeholder group engagement as necessary for achieving landscape wide initiatives (Bixler et al., 2016; Scarlett & McKinney, 2016). Thus, we use a landscape approach as necessary and complimentary to our understanding and conception of adaptation pathways for increased drought resilience in this region.

This research utilizes an adaptation pathways approach, rooted in local conditions yet landscape wide in vision, to co-develop adaptation pathways for increased drought resilience in the natural-resource dependent communities in the High Divide region of Idaho and Montana. Based on our conclusions, we suggest building social capital in the ways described as a first step to fulfilling larger drought resilience initiatives in order to minimize conflict and encourage investment in drought resilience pathways for successful implementation. We also encourage continued collaborative, participatory action in the region, such as the events hosted by the High Divide Collaborative, as

similar efforts have increased social capital in other rural, natural resource management contexts (Wagner & Fernandez-Gimenez, 2008). The pathways we present are largely region specific due to the unique landscape and social structure of the High Divide region. However, we encourage the potential for cautious application and tailoring of these findings to other resource-dependent rangeland systems with similar social structures and geographies. Largely, we understand this research as informative for stakeholders in the High Divide region of Idaho and Montana and for informing collaborative drought resilience management of large landscapes in increasingly uncertain times.

Chapter 3: Use of Drought Decision-Support Tools by Large Landscape Management Organizations

Abstract

Although largely uncertain, climate projections suggest trends toward increased frequency and severity of droughts in the Northern Rockies of Idaho and Montana. Droughts in arid or semi-arid regions, which make up much of the Northern Rockies in Idaho and Montana, have significant social, ecological, and economic impacts. Thus, improved drought decision-making and planning is necessary within the context of uncertain future drought conditions and impacts. Governmental and NGOs managing large landscapes across the region have access to a variety of drought decision-support tools, such as temperature and precipitation indices. Yet little is known about decision-support tool usage in this region. We conducted interviews with representatives of federal and state agencies and NGOs in order to, 1) *identify which drought decision-support tools are being used*, 2) *describe tool-supported management actions across different types of organizations*, and 3) *understand barriers to decision-support tool adoption and use*. Findings suggest a wide variety of tools are being used in this region by landscape management organizations to meet management objectives. However, use of drought decision-support tools for drought planning is limited. Several barriers currently exist to increased adoption and use of tools, including lack of capacity and lack of management direction. Understanding current tool use and barriers to implementation could aid in addressing research-knowledge gaps and informing future tool development.

1. Introduction

Climate change is increasing drought frequency and severity in many parts of the world (Adger, Huq, Brown, Declan, & Mike, 2003; Ficklin et al., 2015) and drought preparedness and resilience, particularly at smaller spatial scales, is of urgent necessity for the persistence of social-ecological systems (Redmond, 2002). Drought affects fish and wildlife species abundance and movement, forest and rangeland productivity, agricultural production and livelihoods, and community well-being (Thomas et al., 2013; Wilhite et al., 2007). Drought projections for the United States (US) vary from region to region and are largely uncertain (Vose et al., 2016). In the US Northern Rockies of Idaho and Montana, drought is a natural part of climate, particularly in rangeland dominated ecosystems (Brown et al., 2016; Whitlock et al., 2017). Still, projections indicate decreased precipitation in certain times of the year (Ficklin et al., 2015; Whitlock et al., 2017), decreased snowpack resulting from long-term warming trends (Abatzoglou et al., 2017), increasing surface temperatures, changes in runoff timing, and loss of soil moisture holding capacity due to historic unsustainable use of

rangelands (Thurow & Taylor, 2007), all of which will exacerbate drought "when and where it occurs" (Whitlock et al., 2017, p. XXXII) raising concern for social-ecological systems in large landscapes (Vose et al., 2016). In rangeland systems – "biologically diverse working landscapes that include complex ecosystems ranging from arid deserts and shrublands to mesic grasslands and woodlands" (Roche et al., 2015, p. 1) – drought has tremendous impacts on range and wildland dependent social-ecological systems.

Increasing drought resilience – defined as the "ability to recover from water shortages" (Scanlon, Reedy, Faunt, Pool, & Uhlman, 2016, p. 2) through short-term coping strategies and long-term adaptive capacity – is imperative in this context. Use of decision-support tools in decision making and planning processes can aid in achieving landscape management and conservation goals (J. A. Keyantash & Dracup, 2004; Schwartz et al., 2018; Vicente-Serrano, Beguería, & López-Moreno, 2009). We draw on relevant literatures (Bagstad et al., 2013; Schwartz et al., 2018; Vose et al., 2016) to define drought decision-support tools as any process, data, index, model, geospatial application, or web-based tool that includes climate or drought information or is used to support drought management within a larger framework. Scholars have reported on the usefulness of decision-support tools for drought, such as early warning systems and other indicators, in different management settings (Hannaford, Collins, Haines, & Barker, 2019b; J. Keyantash, 2002). Yet there are multiple challenges to using drought decision-support tools, including lack of published tool information to inform tool use and application (Redmond, 2002; Schwartz et al., 2018).

This research explores the use of drought decision-support tools for large landscape management by organizations working in the High Divide region of Idaho and Montana, situated within the larger Northern Rockies landscape (Figure 2-1). Federal and state government agencies and non-governmental organizations (NGOs) are positioned to increase social-ecological resilience to drought across large landscapes. Efforts to increase resilience in the High Divide region requires collaborative action due to the large degree of spatial overlap between management organizations (Bergmann & Bliss, 2004). We conducted semi-structured interviews with staff of NGOs and state and federal agencies to 1) *determine which decision-support tools are used*, 2) *describe tool supported management actions across organization types*, and 3) *describe barriers to tool adoption and usage*. We present a usage table of decision-support tools, which focuses on variations in organization types and associated management actions. We argue that this organization will help inform drought tool development, increase coordination and collaboration across organizations, and aid in addressing information-use gaps. In the following sections we review relevant decision-support tool literatures

with implications for drought management, the findings of our study, and a discussion of wider implications for drought management.

2. Methods and Materials

2.1 Study Area

The High Divide region provides a unique opportunity to study drought management through a social-ecological systems lens. The High Divide region of the Northern Rockies of Idaho and Montana covers 25-million acres from the Greater Yellowstone Ecosystem (GYE), Central Idaho Wilderness (CIW), and the Crown of the Continent Ecosystem (COC) (Figure 2-1). The region supports diverse vegetation communities including sagebrush steppe, forest, and rangeland systems, while also containing the headwaters for the Missouri and Columbia watersheds. These headwaters are particularly critical as they provide spawning habitat for anadromous fish from the Pacific Ocean (McClure et al. 2008). Additionally, the region provides connectivity between protected areas such as the GYE, CIW, and COC for key fish and wildlife species such as grizzly bear and wolves (Carroll et al., 2012; Shafer, 2015). Private ranchlands are vital to connectivity between public lands and become increasingly important within the context of increasing climatic and anthropogenic pressures on ecological systems (Graves et al., 2019; M. McClure et al., 2017; Travis Belote et al., 2016).

The High Divide region is equally important to communities and livelihoods as it is to wildlife. While public lands in this region make up approximately 60% of the total land area, there is a higher proportion of privately-owned lands than in neighboring regions (Graves et al., 2019). Most of the private land in this region is sparsely populated and used to support large ranching operations (Graves et al., 2019). As ranching livelihoods are often generational in nature, ranching on rangelands remains part of western rural communities' cultural identities and is considered a "cultural resource" unique to the US West (Kirner, 2015). Ranching as a cultural resource has gained concern as western landscapes "experience large-scale [social and economic] transitions" (Ooi et al., 2015, p. 59).

For this research, we partnered with the High Divide Collaborative (HDC), "an effective partnership of public land managers, state wildlife agencies, landowners, local community leaders, scientists, and conservation groups working together to conserve and restore lands of importance for local communities and to protect ecological integrity at the landscape scale" (High Divide Collaborative, n.d.). Drought resilience, or "clean and abundant water for headwaters fisheries, wildlife, healthy riparian communities, and human uses" is one of eight priority themes that direct the work of HDC (High Divide Collaborative, n.d.).

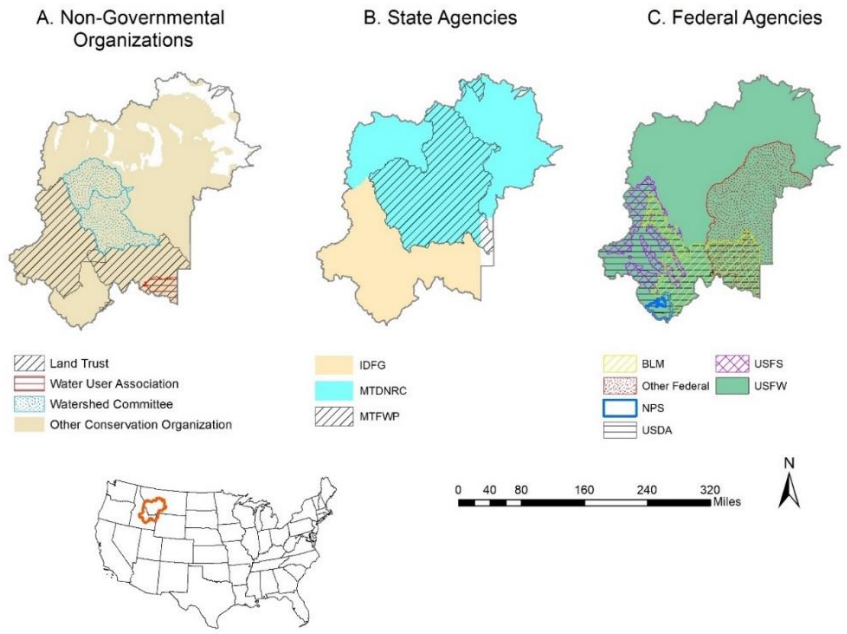

Figure 3-1. Location of the High Divide region spanning Idaho and Montana in the United States. Location and land ownership of (A) NGOs, (B) State Agencies, and (C) Federal Agencies.

2.2 Data Collection

Data collection consisted of 31 interviews with federal, state, and non-governmental organization employees working in the High Divide region. Interviewees were selected based on their attendance at one or both High Divide Collaborative annual stakeholder meetings, held in Dillon, MT in 2018 and in Idaho Falls, ID in 2019. Requests for interviews were sent to meeting attendees via email, with one additional email sent 1 to 2 weeks after initial contact if no response was received. Additional interviews were added via snowball sampling. We prioritized employees with decision-making roles and water or drought management responsibilities. Interviewees belonged to a range of federal, state, and NGOs including land trusts, watershed committees, and water user associations (Table_Apx 4-5).

Organization Type	Organization Subtype	Interviewees (#)
NGOs	Land Trust	4
	Watershed Committee	4
	Water User Association	1
	Other Conservation Organization (Center for Large Landscape Conservation, Greater Yellowstone Coalition)	8
State Agencies	Idaho Fish and Game	4
	Montana Fish Wildlife and Parks	1
	Montana Department of Natural Resources Conservation	2
Federal Agencies	US Forest Service	2
	National Park Service	1
	US Fish and Wildlife Service	3
	Bureau of Land Management	2
	United States Department of Agriculture	1
	Other Federal	1

Table 3-1. Summary of interviewees and organization types.

Interview questions were designed based on our research objectives and a preliminary literature review of decision-support tools for drought management. Each interview lasted approximately one hour and was recorded with the participants' permission, in accordance with a protocol approved by the University of Idaho Institutional Review Board. Most interviews were held in person at the interviewees' place of work, with a smaller portion conducted via video conference. Interview questions were divided into the following areas of focus: 1) *what were the interviewees' or organizations' management priorities*, 2) *which decision-support tools were used and how did they support management actions*, 3) *what characteristics are important in current or desired tools*, and 4) *what are the barriers to decision-support tool use*. Some interviewees supplied supplementary documents during interviews, such as copies of management plans, which were used as complimentary and contextual information during analysis.

2.3 Data Analysis

Interview transcripts were analyzed with an NVivo software program using an iterative deductive coding approach to understand drought decision-support tool usage and the barriers to tool adoption in the High Divide region (Jennings, 2012). Qualitative deduction focused on understanding interviewee responses within the context of our research objectives. To do this, we conducted an initial organization process of the interview guide, assigning each interview question to the objective it was most likely to inform (Table 3-2). We then identified and assigned all decision-support tools as

individual first-level codes to satisfy Objective 1 (Jennings, 2012). To determine how decision-support tools are applied in management settings (Objective 2), we created a typology of tool usage across different organization types and associated management actions (Table 3-3). This process involved secondary-cycle coding of first-level tool identification codes, which we categorized into different tool types based on interviewee supplied information about the tool, additional tool research, and interviewee follow-ups. During this process we identified related management actions. Finally, we coded the transcripts for perceived barriers to decision-support tool use (Objective 3) using a similar approach to the coding process for Objective 1.

Research Objective	**Associated Interview Questions**
Determine which decision-support tools have been used in NGOs and state and federal agencies.	- What types of information does your organization use to make decisions about or plan for environmental changes? - Has your organization used drought indices in the past or currently for drought mitigation planning? - Has your organization used drought indices to predict or monitor any drought impacts? - What resources has your organization used for drought mitigation planning in the past? How and when were they used?
Describe tool supported management actions across organization types.	- What are the primary management priorities in your organization?
Determine barriers to using drought decision-support tools in landscape management organizations.	- What are the barriers, or potential barriers to using drought indices in your organization?

Table 3-2. Research objectives and informative interview questions.

3. Results

3.1 Use of decision-support tools in management organizations

We identified approximately 100 decision-support tools used by landscape management organizations in the High Divide region. These tools fell into four broad categories including process-based (Appendix A), data (Appendix B), models (Appendix C) and geospatial/web-based tools (Appendix D). The most common decision-support tools used are summarized in Table 3-3. Overall, the most frequently used tools across all three organization types fell into the data category, consisting of tools such as snowpack data such as Snow Telemetry (SNOTEL), or automated data collection from high mountain watersheds used to monitor snowpack and other climate conditions, streamflow data, and climate publications (Table 3-3;Table_Apx 4-2).

Tool Type	Tool	Tool Source	Organization Subtype	Organization Type	Tool Supported Management
Process	Vegetation monitoring*	Henry's Fork Foundation	OTC	NGO	Conservation effectiveness monitoring for reducing irrigation demand
		Center for Large Landscape Conservation	OTC	NGO	Conserve habitat, climate change adaptation management
		USFS	USFS	Federal	Drought planning
	Water monitoring*	Henry's Fork Foundation	OTC	NGO	Water quality monitoring; inform fishery conservation
		Henry's Fork Foundation	OTC	NGO	Flow measurements; inform fishery conservation
		MTFWP	MTFWP	State	Flow measurements; implement water management directives for species protection; inform watershed committee decision-making
	GPS recording*	Not stated	OTC	NGO	Conservation effectiveness monitoring for reducing irrigation demand
		Not stated	BLM	Federal	Fuels monitoring
Data	Climate Science Publications	Not stated	LT	NGO	Informs management on acquired easements with respect to resilient lands
		Not stated	WUA	NGO	Supports landscape familiarity; guides conservation projects; used in grant writing
		Holden et al., 2015	IDFG	State	Applied to species and habitat modeling to inform number of management objectives and refine field surveys
		Parks et al., 2017	USFS	Federal	Identify current and predicted vegetation for fire planning
		Not stated	OTC	NGO	Helps address climate change impacts in current water or wildlife related projects
	Streamflow	BOR	IDFG	State	Guides natural resource management; species management
		USGS	MTFWP	State	Informs drought management conservation directives; inform watershed groups
		USGS River Conditions Webpage	WG	NGO	Informs conservation effectiveness. Determine when to enact drought plan steps.
		USGS	OTC	NGO	Informs seasonal water prediction models to protect fishery
		USGS	USFWS	Federal	Guides water release to support bird habitat
		USGS	WG	NGO	Informs projects; slowing down flows, keeping water on the landscape longer
		Not stated	USFWS	Federal	Informs habitat rehabilitation
		Not stated	USFWS	Federal	Informs habitat rehabilitation

		Not stated	LT	NGO	Inform restoration projects for salmon
	Snowpack	NRCS	MTFWP	State	Informs streamflow report, conservation directives, watershed groups
		NRCS	OTC	NGO	Informs predictive modeling to protect fishery
		MTFWP	WG	NGO	Informs drought plan
		NRCS	USFWS	Federal	Guides water release to support bird habitat
		NRCS	IDFG	State	Informs deer and fish management
Models	Climate Forecasts	ClimateWNA – University of Alberta IPCC	IDFG	State	ClimateWNA – used to raise awareness, inform monitoring, direct action. IPCC – Generate range of potential impacts on areas or species.
		USDA	OTC	NGO	Informs biodiversity preservation actions; used to minimize habitat loss; informs climate change adaptation
		Climate Prediction Center National Weather Service Northwest River Forecast Center	OTC	NGO	Used to direct management to maintain rivers and streams for fish
		IPCC	OTC	NGO	Informs potential short-term and long-term impacts in project areas; inform conservation action
		MTFWP	WG	NGO	Inform drought plan and when to enact drought plan steps
		Climate Prediction Center	MTFWP	State	ENSO diagnostics; inform streamflow report, conservation directives, watershed group decision-making
		Fire Weather	USFS	Federal	Informs fire planning and fire resource allocation
		NITUS National Weather Service USDA	USFWS	Federal	Used to predict drought to inform native plant management
Geospatial/Web-Based	Climate Resilient Lands Layer	TNC	LT	NGO	Informs where to focus land acquisitions and projects
		TNC	WUA	NGO	Informs prioritization of projects; highlights areas of drought concern
		TNC	LT	NGO	Guides where to do conservation work; shows priority areas

Table 3-3. Summarized drought decision-support tool use in organizations.

Table Notes: OTC (Other Conservation Organization); USFS (United States Forest Service); USFWS (United States Fish and Wildlife Service); LT (Land Trust); WUA (Water Users Association); WG (Watershed Group); IDFG (Idaho Department of Fish and Game); MTFWP (Montana Fish Wildlife and Parks); BLM (Bureau of Land Management)

3.1.1 NGOs

NGOs relied the most heavily on data decision-support tools for management and planning. The most commonly used data tools included stream flow data, climate science publications, precipitation data, and water supply outlooks. After data, NGOs most commonly relied on geospatial or web-based decision-support tools, with a commonly used tool being the Nature Conservancy's Climate Resilient Lands layer in a Geographic Information System. Slightly fewer respondents reported using process-based tools, with models being the least commonly used across tool types in NGOs.

3.1.2 State Agencies

As with NGOs, state agencies relied most heavily on data-based tools to support their management actions and decision-making, with snowpack and streamflow data being the most commonly used. Slightly fewer respondents reported using models as decision-support tools such as climate forecasting models. Processes and geospatial or web-based tools were used the least in state agencies.

3.1.3 Federal Agencies

Like NGOs and state agencies, federal agencies reported using data related decision-support tools, such as such as streamflow and drought indices. After data, federal agency employees reported use of models, such as climate forecasting models, and processes such as in-house monitoring. Geospatial and web-based tools were used the least within federal agencies in our sample.

3.2 Tool supported management actions

Tool supported management was specific to organizations and their respective management priorities (Table 3-3; Table_Apx 4-2; Table_Apx 4-3; Table_Apx 4-4). Tool supported management ranged from aiding in understanding of conservation action effectiveness to determining individual species management (Table 3-3; Table_Apx 4-2; Table_Apx 4-3; Table_Apx 4-4). Although we distinguish these decision-support tools as drought or climate related, tools were rarely used exclusively to aid in drought decision-making or planning. Still, drought preparedness was recognized as important in most organizations and was included at least indirectly in planning processes, within the scope of more immediate priorities. In this way, drought decision-support tools were often leveraged within organizations to fulfill primary management objectives, most of which consisted of seasonal or shorter-term management plans. For example, tools were used to inform fisheries management, aid in species and habitat modeling, and inform conservation easement acquisitions and projects (Table 3-3).

3.3 Barriers to using decision-support tools

We asked participants what barriers exist to adoption and implementation of various drought decision-support tools in management settings. We report on five significant barriers described by our interviewees; *individual preferences; lack of capacity; difficult interpretation; lack of management direction; and low suitability.* These barriers were evident within NGO's and state and federal agencies and were quantitatively reported on based on the number of people who spoke about respective barriers in each organization type.

3.3.1 Individual preference

Interviewees described two themes related to mental barriers and biases, including being overwhelmed by an overabundance of tools and a bias towards older more traditional methods for management. This theme was described predominantly in NGOs but was also mentioned within state and federal agencies as a barrier to tool adoption at the manager level. The idea of bias against more cutting-edge decision-support tools and a preference for more "tried and true" methods is described in the following quote:

> *One of [a landowner's] requirements is to use soil moisture sensors for management purposes. And so, we paid $3,600 last year subscription fee. The provider came out and installed the sensors and supplied us with the data. And neither the farmer nor I could make heads or tails of the data. They were just absolutely worthless. Anyway, my personal bias is to keep using the shovel. [NGO 1]*

This NGO employee works routinely on projects with landowners (who in this case is contracted through an easement with the Nature Conservancy), specifically soil health related projects. NGO 1 describes this work with landowners as being much easier without the use of advanced decision-support tools such as soil moisture sensors, advocating to "keep using the shovel" or to continue using simple, less expensive, and more traditional methods.

Many NGO employees described being overwhelmed by the number of tools available. This was particularly apparent with interviewees who worked in smaller organizations such as watershed committees. The following quote describes the overabundance of tools in some instances, leading to general dismissal of tool usage:

> *I don't know if this is the same everywhere, but I mean, we have more models thrown at us. I mean, I've had so many thrown at me that I just stopped even paying attention there. [Watershed Committee 1]*

This watershed committee employee describes an overwhelming number of tools available to the point that it inhibited the employee's motivation to implement or adopt tools. In this case, the overabundance of tools and lack of capacity to evaluate all of them for the best fit spurred immediate dismissal of any and all tools and was a barrier to adoption.

3.3.2 Lack of capacity

Capacity was the largest barrier to tool use in NGOs but was significant across all types of organizations and was talked about within the context of expertise, funding, and time. These three components were described as the foundation of capacity. In the following quote an NGO employee describes the intersection between time, expertise, and financial capability when considering a new conservation planning process:

> *We're well aware that there's tools out there and that we can use [them]. But to devote a staff member to potentially putting a year's salary into a conservation plan, it's just it's cost prohibitive. [Land Trust 1]*

This land trust employee describes the time and funding it will take to implement decision-support tools as a barrier to implementation.

NGO employees also described lack of expertise on staff, and the inability to allocate time for employee training on tool usage and adoption. State agency staff reiterated NGO employees, describing agency biologists and managers as "swamped with what comes in on a day to day basis" [State Agency 1], referencing the time component of capacity as lacking. Federal agency employees added to this idea of lack of time when they described their currently heavy workload which they described as "many other projects that we are responsible to provide input on" [Federal Agency 3] that come before long term drought management. Each of the three organization types described lack of time, funding, and expertise as the crux of a general lack of capacity to implement decision-support tools for drought management purposes.

3.3.3 Difficult interpretation

Interviewees talked about ease of interpretation as a barrier to implementing drought decision-support tools. More specifically, interviewees talked about steep learning curves associated with decision-support tools and the lack of understanding or ability to apply tools to their management practices. One land trust employee describes this challenge in the following quote:

> *I think really understanding the indices and how to use them would be a barrier because again, that's not how we right now are going about planning. I think the learning curve*

> *would be the big one. It's just like understanding how to interpret it and use that tool. [Land Trust 2]*

This land trust employee describes both fundamental issues: 1) steep learning curves associated with tools and 2) lack of tool understanding and therefore inability to apply tools in specific contexts.

Some of the interviewees described the need for additional staff or someone outside the organization to explain tools to managers and decision-makers as a potential solution to the interpretation barrier. The following quote by a land trust employee summarizes this idea:

> *I think having access to experts in the field, that could essentially kind of walk us through what we need to consider, what models, or what information would be most appropriate for us to incorporate into our planning - just because we don't have that expertise on staff and we don't really have the time for folks to become experts and dig through all the literature out there. [Land Trust 3]*

State agency employees had an interesting perspective on the need for "experts in the field" in that some of our interviewees were experts themselves. The following quote from a state agency official describes the *general lack* and the *increasing need* for tool synthesizers within agencies and organizations:

> *I responded [to the call for more information on climate impacts on wolverine] and said, "Yes, I can." And I wrote a very lengthy response very well supported from scientific literature both on the climate side and the species side of things. And that really cemented my place in the agency as the climate-change person. Suddenly we realized that [State Agency] had somebody that could fill that [climate] knowledge gap, that could translate between all the mumbo jumbo acronyms in the climate world and translate what that really meant from a wildlife standpoint. There are other people now, in some of the surrounding states, that have kind of filled those same roles for other state agencies. I'm not sure it's to the same degree that I do it. [State Agency 1]*

Within the context of the interview, the state agency staff member described in more detail the events that led up to becoming the "climate change person" and describes her current role as such in the organization. This state agency representative describes the value of having a "climate change person" in an organization but also conveys its rarity. Federal agency staff supported the need for personnel to stand in informative roles within the context of decision-support tool implementation by describing tools as "tak[ing] a while to learn to use" as the "biggest barrier" [Federal Agency 1].

Each of the three organization types described difficult interpretation as a barrier to decision-support tool implementation. Part of this barrier was described as a lack of experts who are willing and able to supply information about tools to decision-makers.

3.3.4 Lack of management direction

Lack of management direction was the largest barrier to tool adoption in state and federal agencies, but it was also significant in NGOs. This barrier encompassed themes related to challenges of adopting tools within a management hierarchy and lack of drought decision-support tool interest due to authoritative direction. NGO employee talked about how "it helps if your board makes it [drought management] a priority" [Land Trust 3] for drought decision-support tools to be adopted at a land manager level. One NGO employee described a new organization wide climate resiliency plan as failing to come to fruition until the board declared "this is the priority" and gave permission to "set everything else aside" [Land Trust 3]. State agencies describe a similar dynamic:

> *As an agency, we're more driven by short term goals. A lot of resources, or department resources, are focused on creating those short-term opportunities in the next few years. What are the opportunities that we're going to have available for our paying customers? [State Agency 2]*

This state agency employee described how upper level management determines agency objectives and therefore greatly determine priorities at lower levels of management. "Short-term goals" [State Agency 2] are a priority in this case, making drought decision-support tools less likely to be implemented unless they can be used to meet immediate priorities.

Federal agency employees brought to the discussion the idea of challenges related to adopting new policy in government systems:

> *I would say [the biggest barrier] would be vetting it through our national team. We have national discipline specialists who oversees evaluating tools to address resource concerns. So, you would need to have some sort of linkage to a resource concern and approval from whoever that discipline lead was to adopt that tool. And then there would be the other requirements for the way that the information is displayed to the public. It's got to have equal opportunity, all that kind of stuff. [Federal Agency 2]*

In this quote, the federal agency employee describes the lengthy process involved in adopting new drought decision-support tools as a barrier to use.

3.3.5 Low suitability

The idea that tools need to be suited to the needs of the user was described by all three organization types. NGO employees described the challenges associated with trying to use tools that were not really suited for their specific management needs, with reference to the importance of scale. A few of the NGO interviewees provided interesting insights into tool suitability from the standpoint of tool creators or synthesizers. One such employee gives insight into the importance of tool suitability for "end user's" [NGO 2] or managers:

> *I guess the onus is on us as folks who deliver these kinds of tools to really make it well-suited toward that end user's goal. What is that end user trying to do day-to-day, and how do you help them get there? [NGO 2]*

This NGO employee was involved in the creation of an ecological web-based tool that could be used in management scenarios to evaluate drought impacts on ecological function across large landscapes. In the above quote, the NGO employee describes the importance of fine-tuning tools to be specific to organization's needs.

State agency employees shared a similar perspective to NGO employees described the following quote:

> *You talk to the manager about what their question is. You go back, you look at the science, you evaluate the science with the manager in the room saying, "Okay. So, here's all the different climate tools we have." You know? "What's your real question? How can we address--" And it might be that none of these tools, none of your drought tools really give the answer to the question that they have. But we might be able to tweak them so that we can get to that question. [State Agency 1]*

The preceding quote describes the perspective of a state agency employee whose role involves management and decision-making and tool synthesis for others in the organization.

Suitability was briefly mentioned as a barrier in federal agencies by a federal agency employee we categorized as a tool synthesizer. This federal agency representative reiterated the importance and challenge of providing tools to managers who can utilize them for their needs.

4. Discussion

As improvements in drought management have stagnated over recent decades (Wilhite, 2000) and climate change continues to threaten social-ecological systems worldwide (Millennium Ecosystem Assessment, 2005a; Wise et al., 2014), managers are forced to make decisions in increasingly

complex and uncertain contexts (Schwartz et al., 2018; Wise et al., 2014). In the High Divide region of the Northern Rockies of Idaho and Montana, drought projections are largely uncertain but may suggest increases in severity and frequency of droughts (Abatzoglou et al., 2017; Ficklin et al., 2015; Vose et al., 2016; Whitlock et al., 2017). Droughts in arid or semiarid regions are particularly devastating (Núñez et al., 2014), which make up much of the Northern Rockies landscape (Havstad et al., 2015). Thus, scholars call for increased drought resilience in rangeland systems (Vetter, 2009) and for improved drought decision-support tools to address increasing climate variability (Nam et al., 2012; Svoboda et al., 2015). In the High Divide region, stakeholders representative of different stakeholder groups, echo the call for improved information to aid in "high stake (such as drought declaration) decisions" (Abatzoglou et al., 2017). There is a need for increased synergy between researchers and managers to better inform tool development and usage and to encourage willingness to adopt tools for improved management outcomes (Prokopy et al., 2013; Schwartz et al., 2018; Sunderland, Sunderland-Groves, Shanley, & Campbell, 2009). Within the context of drought management and preparation, we analyze currently adopted drought decision-support tools to further understand drought management in the region and inform future tool development. Through interviews and qualitative analysis, we identified a wide variety of decision-support tools currently used in management contexts within the rangeland dominated High Divide region in the Northern Rockies of Idaho and Montana. We also identify the barriers to tool usage in this region.

Use of decision-support tools can aid in landscape level planning and fulfilling conservation initiatives in many contexts (Bagstad et al., 2013; J. A. Keyantash & Dracup, 2004; Prokopy et al., 2013; Rose et al., 2016; Schwartz et al., 2018; Vicente-Serrano et al., 2009). Within the framing of drought management, our results show that there are drought decision-support tools being used in the High Divide region, despite the challenges to adoption that scholars and our interviewees suggest (Brown et al., 2016; Núñez et al., 2014; Redmond, 2002). However, we found that these tools were not always used for drought decision-making or planning purposes. Instead, we understood organizations' use of drought decision-support tools as firstly supporting organizational objectives or goals, which were often short-term or reactive in nature. Drought planning or climate resilience was rarely mentioned as an organizational priority (although there were a few exceptions to this) but was often an underlying consideration in more specific management actions.

The barriers that interviewees described to tool usage, including *individual preferences against tools, lack of capacity, difficult interpretation, lack of management direction,* and *low suitability* may lend an explanation to lack of drought management tool applications. We understand 1) *lack of fundamental capacity for long-term proactive management* and 2) *lack of drought*

resilience management direction as the two main causal barriers to drought management tool applications. We understand other barriers, such as *difficult interpretation* and *low suitability* as relating back to *lack of capacity*, as ability to invest staff time and money into tool adoption helps to ensure successful tool usage. Similarly, interviewee *individual preferences* could be derived or adopted from higher management directives. However, additional in-depth qualitative analysis which focuses on social factors and interviewee attributes that influence perceptions of barriers is necessary to inform this claim.

We found barriers reported by our interviewees supported many of the same barriers reported on by other scholars in the decision-support tool literatures (Brown et al., 2016; Redmond, 2002; Schwartz et al., 2018; Sunderland et al., 2009). For example, within discussions of *difficult tool interpretation*, interviewees voiced the need for someone to stand in an explanatory or expert role to help inform the use and application of tools, bridging the "gap" between researchers and managers as discussed in Sunderland et al., (2009). In *individual preference* discussions, interviewees described the overwhelming abundance of tools as hindering tool implementation which is commonly reported due the complexities of drought and its various definitions (Hannaford, Collins, Haines, & Barker, 2019a; Schwartz et al., 2018; Vicente-Serrano et al., 2012; Wilhite et al., 2007). Further study of *individual preferences* and biases that inhibit adoption of tools is a promising line of future research. Focusing on the relevance and presence of social stigmas associated with tool adoption could inform further understanding of tool use in management organizations.

Our results, presented in an organization of tool use across organization types, provide organization specific insight into which decision-support tools are used and how, within landscape management organizations in the High Divide region. The barriers reported offer potential avenues for researcher-manager collaborative action to encourage increased use of drought decision-support tools for drought management across the region. This research could support multiple lines of future research including assessing issues of fit between drought decision-support tools and management contexts (Brown et al., 2016; Redmond, 2002; Schwartz et al., 2018), and more qualitative analysis of barriers. We acknowledge the unequal organization type representation among our pool of interviewees; ensuring equal representation from each organization could improve results and allow for quantitatively supportive information. Still, our report on the current dynamic of tool usage in this region and the barriers associated we see as informative for future tool development in the High Divide region, and for addressing the research-knowledge gap that exists between managers and researchers in natural science fields (Sunderland et al., 2009).

Literature Cited

Abatzoglou, J. T., McEvoy, D. J., & Redmond, K. T. (2017). The West Wide Drought Tracker: Drought Monitoring at Fine Spatial Scales. *Bulletin of the American Meteorological Society*, (September), BAMS-D-16-0193.1. https://doi.org/10.1175/BAMS-D-16-0193.1

Abatzoglou, J. T., Rupp, D. E., & Mote, P. W. (2014). Seasonal Climate Variability and Change in the Pacific Northwest of the United States. *Journal of Climate*, *27*(5), 2125–2142. https://doi.org/10.1175/JCLI-D-13-00218.1

Adger, W. N. (2000). Social and ecological resilience: Are they related? *Progress in Human Geography*, *24*(3), 347–364. https://doi.org/10.1191/030913200701540465

Adger, W. N., Huq, S., Brown, K., Declan, C., & Mike, H. (2003). Adaptation to climate change in the developing world. *Progress in Development Studies*, *3*(3), 179–195. https://doi.org/10.1191/1464993403ps060oa

Bagstad, K. J., Semmens, D. J., Waage, S., & Winthrop, R. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, *5*, 27–39. https://doi.org/10.1016/j.ecoser.2013.07.004

Bebbington, A. (1999). Capitals and Capabilities : A Framework for Analyzing Peasant Viability , Rural Livelihoods and Poverty. *World Development*, *27*(12).

Bergmann, S. A., & Bliss, J. C. (2004). Foundations of cross-boundary cooperation: Resource management at the public-private interface. *Society and Natural Resources*, *17*(5), 377–393. https://doi.org/10.1080/08941920490430142

Bixler, R. P., Johnson, S., Emerson, K., Nabatchi, T., Reuling, M., Curtin, C., … Grove, J. M. (2016). Networks and landscapes: A framework for setting goals and evaluating performance at the large landscape scale. *Frontiers in Ecology and the Environment*, *14*(3), 145–153. https://doi.org/10.1002/fee.1250

Brown, J. R., Kluck, D., McNutt, C., & Hayes, M. (2016). Assessing Drought Vulnerability Using a Socioecological Framework. *Rangelands*. https://doi.org/10.1016/j.rala.2016.06.007

Carroll, C., Mcrae, B. H., & Brookes, A. (2012). Use of Linkage Mapping and Centrality Analysis Across Habitat Gradients to Conserve Connectivity of Gray Wolf Populations in Western North America. *Conservation Biology*, *26*(1), 78–87. https://doi.org/10.1111/j.1523-1739.2011.01753.x

Chester, C. (2015). Yellowstone to Yukon: Transborder conservation across a vast international landscape. *Environmental Science and Policy*.

Coles, A. R., & Scott, C. A. (2009). Vulnerability and adaptation to climate change and variability in semi-arid rural southeastern Arizona, USA. *Natural Resources Forum*.

Coppock, D. L. (2011). Society for Range Management Ranching and Multiyear Droughts in Utah: Production Impacts, Risk Perceptions, and Changes in Preparedness. *Rangeland Ecology & Management*, *64*(6), 607–618.

Costanza, R., Arge, R., DeGroot, R., Farberk, S., Grasso, M., Hannon, B., … Sutton, P. (1997). Costanza et al. - 1997 - The value of the world ' s ecosystem services and natural capital. *Nature*, *387*(May), 253–260. https://doi.org/10.1038/387253a0

Crausbay, S. D., Ramirez, A. R., Carter, S. L., Cross, M. S., Hall, K. R., Bathke, D. J., … Sanford, T. (2017a). Defining ecological drought for the twenty-first century. *Bulletin of the American Meteorological Society*, *98*(12), 2543–2550. https://doi.org/10.1175/BAMS-D-16-0292.1

Crausbay, S. D., Ramirez, A. R., Carter, S. L., Cross, M. S., Hall, K. R., Bathke, D. J., … Sanford, T. (2017b). Defining Ecological Drought for the Twenty-First Century. *Bulletin of the American Meteorological Society*, *98*(12), 2543–2550. https://doi.org/10.1175/BAMS-D-16-0292.1

Fazey, I., Wise, R. M., Lyon, C., Câmpeanu, C., Moug, P., & Davies, T. E. (2016). Past and future adaptation pathways. *Climate and Development*, *8*(1), 26–44. https://doi.org/10.1080/17565529.2014.989192

Ficklin, D. L., Maxwell, J. T., Letsinger, S. L., & Gholizadeh, H. (2015). A climatic deconstruction of recent drought trends in the United States. *Environmental Research Letters*, *10*(4). https://doi.org/10.1088/1748-9326/10/4/044009

Fischer, A. P. (2018). Pathways of adaptation to external stressors in coastal natural-resource-dependent communities: Implications for climate change. *World Development*, *108*, 235–248. https://doi.org/10.1016/j.worlddev.2017.12.007

Folke, C. (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*, *16*(3), 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, *15*(4). https://doi.org/10.5751/ES-03610-150420

Fuhlendorf, S. D., Engle, D. M., Elmore, R. D., Limb, R. F., & Bidwell, T. G. (2012a). Conservation of Pattern and Process: Developing an Alternative Paradigm of Rangeland Management. *Rangeland Ecology and Management*, *65*(6), 579–589. https://doi.org/10.2111/REM-D-11-00109.1

Fuhlendorf, S. D., Engle, D. M., Elmore, R. D., Limb, R. F., & Bidwell, T. G. (2012b). Conservation of Pattern and Process: Developing an Alternative Paradigm of Rangeland Management. *Rangeland Ecology and Management*, *65*(6), 579–589. https://doi.org/10.2111/REM-D-11-00109.1

Glorioso, R. S., & Moss, L. A. G. (2007). Amenity migration to mountain regions: Current knowledge and a strategic construct for sustainable management. *Social Change*, *37*(1), 137–161. https://doi.org/10.1177/004908570703700108

Graves, R. A., Williamson, M. A., Belote, R. T., & Brandt, J. S. (2019). Quantifying the contribution of conservation easements to large-landscape conservation. *Biological Conservation*, *232*(August 2018), 83–96. https://doi.org/10.1016/j.biocon.2019.01.024

Haasnoot, M., Middelkoop, H., Offermans, A., van Beek, E., & van Deursen, W. P. A. (2012). Exploring pathways for sustainable water management in river deltas in a changing environment. *Climatic Change*, *115*(3–4), 795–819. https://doi.org/10.1007/s10584-012-0444-2

Hannaford, J., Collins, K., Haines, S., & Barker, L. J. (2019a). Enhancing drought monitoring and early warning for the United Kingdom through stakeholder coinquiries. *Weather, Climate, and Society*, *11*(1), 49–63. https://doi.org/10.1175/WCAS-D-18-0042.1

Hannaford, J., Collins, K., Haines, S., & Barker, L. J. (2019b). Enhancing Drought Monitoring and Early Warning for the United Kingdom through Stakeholder Coinquiries, 49–63. https://doi.org/10.1175/WCAS-D-18-0042.1

Havstad, K., Peters, D., Allen-Diaz, B., Bartolome, J., Bestelmeyer, B., Briske, D., … Yao, J. (2015). The Western United States Rangelands: A Major Resource. *Grassland Quietness and Strength for a New American Agriculture*, 75–93. https://doi.org/10.2134/2009.grassland.c5

High Divide Collaborative. (n.d.). High Divide Collaborative: About. Retrieved from https://highdivide.org/about/

Jennings, G. R. (2012). *Qualitative research methods*. *Handbook of Research Methods in Tourism: Quantitative and Qualitative Approaches*. https://doi.org/10.4337/9781781001295

Keyantash, J. (2002). An Evaluation of a Drought. *American Meteorological Society*, (August), 1167–1180.

Keyantash, J. A., & Dracup, J. A. (2004). An aggregate drought index: Assessing drought severity based on fluctuations in the hydrologic cycle and surface water storage. *Water Resources Research*, *40*(9), 1–14. https://doi.org/10.1029/2003WR002610

Kirner, K. D. (2015). The Cultural Heritage of Family Ranches. *Rangelands*, *37*(2), 85–89. https://doi.org/10.1016/j.rala.2015.01.007

Knapp, C. N., Stuart Chapin, F., & Cochran, J. O. (2015). Ranch Owner Perceptions and Planned Actions in Response to a Proposed Endangered Species Act Listing. *Rangeland Ecology and Management*, *68*(6), 453–460. https://doi.org/10.1016/j.rama.2015.08.003

Kohl, E., & Knox, J. A. (2016). My Drought is Different from Your Drought: A Case Study of the Policy Implications of Multiple Ways of Knowing Drought. *Weather, Climate, and Society*, *8*(4), 373–388. https://doi.org/10.1175/WCAS-D-15-0062.1

Krannich, R. S., & Smith, M. D. (1998). Local perceptions of public lands natural resource management in the rural west: Toward improved understanding of the "revolt in the west." *Society and Natural Resources*, *11*(7), 677–695. https://doi.org/10.1080/08941929809381111

Leach, M., Scoones, I., & Stirling, A. (2010a). *Dynamic Sustainabilities*.

Leach, M., Scoones, I., & Stirling, A. (2010b). Governing epidemics in an age of complexity: Narratives, politics and pathways to sustainability. *Global Environmental Change*. https://doi.org/10.1016/j.gloenvcha.2009.11.008

Levin, S. A., & Lubchenco, J. (2008). Resilience , Robustness , and Marine Ecosystem-based Management, *58*(1), 27–32.

Lewin, P. A., Wulfhorst, J. D., Rimbey, N. R., & Jensen, K. S. (2019). Implications of declining grazing permits on public land: An integrated social and economic impact analysis. *Western Economics Forum*, *17*(1), 86–97.

McClure, M., Beltran, B., & Hostetler, S. (2017). *Informing adaptation strategies for maintaining landscape connectivity for Northern Rockies wildlife in the face of climate change : challenges and limitations*. https://doi.org/10.5066/F7VM49FN.

McClure, M. M., Carlson, S. M., Beechie, T. J., Pess, G. R., Jorgensen, J. C., Sogard, S. M., … Carmichael, R. W. (2008). Evolutionary consequences of habitat loss for Pacific anadromous salmonids. *Evolutionary Applications*, *1*(2), 300–318. https://doi.org/10.1111/j.1752-4571.2008.00030.x

Millennium Ecosystem Assessment. (2005a). Ecosystems and Human Well-Being: Biodiversity Synthesis. *World Resources Institute*.

Millennium Ecosystem Assessment. (2005b). Ecosystems and Human Well-being: Synthesis. *World Resources Institute*.

Nam, W. H., Choi, J. Y., Yoo, S. H., & Jang, M. W. (2012). A decision support system for agricultural drought management using risk assessment. *Paddy and Water Environment*, *10*(3), 197–207. https://doi.org/10.1007/s10333-012-0329-z

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environment and Resources*. https://doi.org/10.1146/annurev.energy.32.051807.090348

Nelson, P. B. (2001). Rural restructuring in the American West: Land use, family and class discourses. *Journal of Rural Studies*, *17*(4), 395–407. https://doi.org/10.1016/S0743-0167(01)00002-X

Núñez, J., Rivera, D., Oyarzún, R., & Arumí, J. L. (2014). On the use of Standardized Drought Indices under decadal climate variability : Critical assessment and drought policy implications. *JOURNAL OF HYDROLOGY*, *517*, 458–470. https://doi.org/10.1016/j.jhydrol.2014.05.038

Ooi, N., Laing, J., & Mair, J. (2015). Sociocultural change facing ranchers in the Rocky Mountain West as a result of mountain resort tourism and amenity migration. *Journal of Rural Studies*, *41*, 59–71. https://doi.org/10.1016/j.jrurstud.2015.07.005

Ouyang, Z., Li, S., Keeler, B. L., Bateman, I. J., Duraiappah, A., Reyers, B., … Kareiva, P. M. (2015). Natural capital and ecosystem services informing decisions: From promise to practice. *Proceedings of the National Academy of Sciences*, *112*(24), 7348–7355. https://doi.org/10.1073/pnas.1503751112

Pretty, J. (2008). Social Capital and the Collective Management. *Science*, *1912*(2003), 10–13. https://doi.org/10.1126/science.1090847

Pretty, J., & Ward, H. (2001). Social capital and the environment. *World Development*. https://doi.org/10.1016/S0305-750X(00)00098-X

Prokopy, L. S., Mase, A. S., Perry-Hill, R., & Lemos, M. C. (2013). Assessing Vulnerabilities and Adaptation Approaches: Useful to Usable Tools. *Climate Vulnerability: Understanding and Addressing Threats to Essential Resources*, *2*, 129–137. https://doi.org/10.1016/B978-0-12-384703-4.00224-0

Redmond, K. T. (2002). The Depiction of Drought: A Commentary. *Bulletin of the American Meteorological Society*, 1143–1148. https://doi.org/10.1175/1520-0477(2002)083<1143:TDODAC>2.3.CO;2

Roche, L. M., Schohr, T. K., Derner, J. D., Lubell, M. N., Cutts, B. B., Kachergis, E., … Tate, K. W. (2015). Sustaining Working Rangelands: Insights from Rancher Decision Making. *Rangeland Ecology and Management*, *68*(5), 383–389. https://doi.org/10.1016/j.rama.2015.07.006

Rose, D. C., Sutherland, W. J., Parker, C., Lobley, M., Winter, M., Morris, C., … Dicks, L. V. (2016). Decision support tools for agriculture: Towards effective design and delivery. *Agricultural Systems*, *149*, 165–174. https://doi.org/10.1016/j.agsy.2016.09.009

Rowe, H. I., Bartlett, E. T., & Swanson, L. E. (2001). Ranching motivations in 2 Colorado Counties. *Journal of Range Management*, *45*(1), 57–62.

Scanlon, B. R., Reedy, R. C., Faunt, C. C., Pool, D., & Uhlman, K. (2016). Enhancing drought resilience with conjunctive use and managed aquifer recharge in California and Arizona. *Environmental Research Letters*, *11*(3). https://doi.org/10.1088/1748-9326/11/3/035013

Scarlett, L., & McKinney, M. (2016). Connecting people and places: The emerging role of network governance in large landscape conservation. *Frontiers in Ecology and the Environment*, *14*(3), 116–125. https://doi.org/10.1002/fee.1247

Schultz, L., Folke, C., Österblom, H., & Olsson, P. (2015). Adaptive governance, ecosystem management, and natural capital. *Proceedings of the National Academy of Sciences*, *112*(24), 7369–7374. https://doi.org/10.1073/pnas.1406493112

Schwartz, M. W., Cook, C. N., Pressey, R. L., Pullin, A. S., Runge, M. C., Salafsky, N., … Williamson, M. A. (2018). Decision Support Frameworks and Tools for Conservation.

Conservation Letters, *11*(2), 1–12. https://doi.org/10.1111/conl.12385

Scoones, I. (1998). Sustainable Rural Livelihoods : A Framework for Analysis. *IDS Working Paper 72*.

Shafer, C. L. (2015). Land use planning: A potential force for retaining habitat connectivity in the Greater Yellowstone Ecosystem and Beyond. *Global Ecology and Conservation*, *3*, 256–278. https://doi.org/10.1016/j.gecco.2014.12.003

Slette, I. J., Post, A. K., Awad, M., Even, T., Punzalan, A., Williams, S., … Knapp, A. K. (2019). How ecologists define drought, and why we should do better. *Global Change Biology*, gcb.14747. https://doi.org/10.1111/gcb.14747

Smith, M. S., Horrocks, L., Harvey, A., & Hamilton, C. (2011). Rethinking adaptation for a 4°C world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *369*(1934), 196–216. https://doi.org/10.1098/rsta.2010.0277

Sunderland, T., Sunderland-Groves, J., Shanley, P., & Campbell, B. (2009). Bridging the gap: How can information access and exchange between conservation biologists and field practitioners be improved for better conservation outcomes? *Biotropica*, *41*(5), 549–554. https://doi.org/10.1111/j.1744-7429.2009.00557.x

Svoboda, M. D., Fuchs, B. A., Poulsen, C. C., & Nothwehr, J. R. (2015). The drought risk atlas: Enhancing decision support for drought risk management in the United States. *Journal of Hydrology*, *526*, 274–286. https://doi.org/10.1016/j.jhydrol.2015.01.006

Talbert, C. B., Knight, R. L., & Mitchell, J. E. (2007). Private ranchlands and public land grazing in the southern Rocky Mountains. *Rangelands*, *29*(3), 5–8. https://doi.org/10.2111/1551-501X(2007)29[5:PRAPLG]2.0.CO;2

Thomas, D. S. K., Wilhelmi, O. V., Finnessey, T. N., & Deheza, V. (2013). A comprehensive framework for tourism and recreation drought vulnerability reduction. *Environmental Research Letters*, *8*(4). https://doi.org/10.1088/1748-9326/8/4/044004

Thurow, T. L., & Taylor, C. A. (2007). Viewpoint: The Role of Drought in Range Management. *Journal of Range Management*, *52*(5), 413. https://doi.org/10.2307/4003766

Travis Belote, R., Dietz, M. S., McRae, B. H., Theobald, D. M., McClure, M. L., Hugh Irwin, G., … Aplet, G. H. (2016). Identifying corridors among large protected areas in the United States. *PLoS ONE*, *11*(4), 1–17. https://doi.org/10.1371/journal.pone.0154223

Vetter, S. (2009). Drought, change and resilience in south africa's arid and semi-arid rangelands. *South African Journal of Science*, *105*(1–2), 29–33. https://doi.org/10.1590/S0038-23532009000100017

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2009). A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index. *Journal of Climate*, *23*(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Vicente-Serrano, S. M., Beguería, S., Lorenzo-Lacruz, J., Camarero, J. J., López-Moreno, J. I., Azorin-Molina, C., … Sanchez-Lorenzo, A. (2012). Performance of drought indices for ecological, agricultural, and hydrological applications. *Earth Interactions*, *16*(10). https://doi.org/10.1175/2012EI000434.1

Vose, J. M., Clark, J. S., Luce, C. H., & Patel-Weynand, T. (2016). *Effects of Drought on Forests and Rangelands in the United States: A Comprehensive Science Synthesis*. *Gen.Tech.Rep. WO-93b. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 289 p.*

Wagner, C. L., & Fernandez-Gimenez, M. E. (2008). Does community-based collaborative resource management increase social capital? *Society and Natural Resources*, *21*(4), 324–344. https://doi.org/10.1080/08941920701864344

Wardropper, C. B., Mase, A. S., Qiu, J., Kohl, P., Booth, E. G., & Rissman, A. R. (2020). Ecological worldview, agricultural or natural resource-based activities, and geography affect perceived importance of ecosystem services. *Landscape and Urban Planning*, *197*(April 2019), 103768. https://doi.org/10.1016/j.landurbplan.2020.103768

Whitlock, C., Cross, W., Maxwell, B., Silverman, N., & Wade, A. (2017). 2017 Montana Climate Assessment. *Montana Institute on Ecosystems*, 269. Retrieved from http://montanaclimate.org/chapter/title-page%0Ahttp://ieeexplore.ieee.org/document/6340318/

Wilhite, D. A. (2000). Drought preparedness and response in the context of Sub-Saharan Africa. *Journal of Contingencies and Crisis Management*, *8*(2), 81–92. https://doi.org/10.1111/1468-5973.00127

Wilhite, D. A., Svoboda, M. D., & Hayes, M. J. (2007). Understanding the complex impacts of drought: A key to enhancing drought mitigation and preparedness. *Water Resources Management*, *21*(5), 763–774. https://doi.org/10.1007/s11269-006-9076-5

Wilmer, H., Augustine, D. J., Derner, J. D., Fernández-Giménez, M. E., Briske, D. D., Roche, L. M., … Miller, K. E. (2018). Diverse Management Strategies Produce Similar Ecological Outcomes on Ranches in Western Great Plains: Social-Ecological Assessment. *Rangeland Ecology and Management, 71*(5), 626–636. https://doi.org/10.1016/j.rama.2017.08.001

Wilmer, H., & Fernández-Giménez, M. E. (2015). Rethinking rancher decision-making: A grounded theory of ranching approaches to drought and succession management. *The Rangeland Journal*. https://doi.org/10.1071/RJ15017

Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Archer, E. R. M., … Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*. https://doi.org/10.1016/j.gloenvcha.2013.12.002

Chapter 4: Conclusion

Drought is a complex and multifaced phenomena that impacts climate regimes worldwide, yet drought planning and preparation are lacking in many contexts (Kohl & Knox, 2016; Wilhite, 2000). Scholars call for improved drought responses in rangeland systems that include "policy, programs, and management" which consider diverse stakeholder groups and other social and ecological factors (Brown et al., 2016, p. 162). In response, this research engaged a wide variety of stakeholders in the High Divide Region of the Northern Rockies of Idaho and Montana to increase understanding of drought resilience and management as it applies to natural resource dependent rangeland systems.

Using an adaptation pathways approach as an analytical lens, we aimed to determine past experiences of drought across multiple stakeholder groups and how those experiences shaped and contextualized current drought resilience perceptions. We found that sustaining functioning ecosystems, supporting agricultural livelihoods, and fostering social capital or connectedness between social groups are the foundational aspects crucial to increasing landscape wide drought resilience across stakeholder groups in this region. Within these core areas of focus, our interviewees described a variety of pathways for increased drought resilience including diversifying agricultural livelihoods and adopting an ecosystem services approach to natural-resource consumption.

This research also aimed to understand the current use of and barriers to drought decision-support tool implementation in upper level management organizations in the High Divide Region. To do this, we created a typology of tool use and associated management actions across different organization types present in the region. Our results suggest that decision-support tools are being implemented to varying degrees in non-governmental organizations and federal and state agencies in this region. However, tools were rarely used specifically for drought mitigation or planning purposes, indicating that drought management falls below organizations' more immediate management goals. Our results also suggest a range of barriers to further implementation of drought decision-support tools including but not limited to a general lack of capacity, lack of management direction, and difficult interpretation.

This research aims to inform academic related fields and managers and decision-makers in the High Divide region. Based on our findings, we suggest a focus on building social capital between stakeholder groups as an initial step toward large landscape, social-ecological system-based drought resilience management for sustainable outcomes, focused on supporting ranching livelihoods and functioning ecosystems. Second, we suggest researchers and managers collaboratively address

currently existing barriers to decision-support tool usage, such as low suitability and difficult interpretation, before the development of additional regionally based decision-support tools. This research and associated recommendations are largely region specific, due to the unique social structure and geography of the High Divide region but could be cautiously tailored to similar natural resource dependent communities and contexts in the Western US. Broadly, the goals of this research are to inform current and future drought management and resilience strategies in the High Divide region and to encourage and improve researcher manager synergy.

Appendix A

Decision-Support Tool Type: Process				
Tool	**Tool Source**	**Organization Subtype**	**Organization Type**	**Tool Supported Management**
Soil monitoring*	Henry's Fork Foundation	OTC	NGO	Improve soil health to reduce irrigation requirement and diversion
State Water plan*	MTDNRC	MTDNRC	State	Guiding document for projects by sub-basin
Water monitoring*	Henry's Fork Foundation	OTC	NGO	Water quality monitoring; inform fishery conservation
	Henry's Fork Foundation	OTC	NGO	Flow measurements; inform fishery conservation
	MTFWP	MTFWP	State	Flow measurements; implement water management directives for species protection; inform watershed committee decision-making
Drought plan*	Big Hole Watershed Committee	Watershed Group	NGO	Help to inform drought plan and when to enact drought plan steps
Idaho Nutrient Transport Risk Assessment	University of Idaho, ARS	USDA	Federal	Determines if water quality concerns exist related to intended management practices; informs water quality protection and management
Temperature monitoring*	MTFWP	MTFWP	State	Implement water management directives for species protection; inform watershed committee decision-making
Stream Visual Assessment Protocol*	USDA	USDA	Federal	Determine severity of resource concern and determines projects
Vegetation monitoring*	Henry's Fork Foundation	OTC	NGO	Effectiveness evaluation of conservation actions to improve soil to reduce irrigation requirement
	Center for Large Landscape Conservation	OTC	NGO	Conserve habitat, climate change adaptation management
	USFS	USFS	Federal	Drought planning
Conservation Effect System Protocol	USDA	USDA	Federal	Watershed scale effects of conservation management
Rangeland Health Assessment*	USDA	USDA	Federal	Determine severity of resource concern and determines projects
National Forest System Land Management Planning Rule	USDA	USFS	Federal	Guides management for sustained "health, diversity, and productivity of national forests; outlines steps for climate change adaptation
GPS recording*	Henry's Fork Foundation	OTC	NGO	Aids in conservation effectiveness monitoring for reducing irrigation demand
	USFWS	USFWS	Federal	Fuels monitoring
Fuels monitoring*	USFS	USFS	Federal	Fuels status to inform fire planning and where to put fire protection resources

Table_Apx 4-1. Process decision-support tools used by organizations.

Appendix B

Decision-Support Tool Type: Data

Tool	Tool Source	Organization Subtype	Organization Type	Tool Supported Management
Crop production documentation	All Western Land Grant Universities	Other Conservation Organization	NGO	Determines where to do conservation actions; cover crop implementation
Precipitation	Not stated	Other Conservation Organization	NGO	Informs mine reclamation plan
	Not stated	Watershed Group	NGO	Determines when to enact drought plan steps
	Not stated	Other Conservation Organization	NGO	Informs river flow, need for water storage, and irrigation demand models used to protect fishery
	Not stated	USFWS	Federal	Inform habitat restoration, planting projects
Total Maximum Daily Load	DEQ	Watershed Group	NGO	Guides projects in the watershed based on stream status and use
Climate Science Publications	Not stated	Land Trust	NGO	Informs management on acquired easements with respect to resilient lands
	Not stated	Water User Association	NGO	Supports landscape familiarity; guides conservation projects; used in grant writing
	Holden et al., 2015	IDFG	State	Applied to species and habitat modeling to inform number of management objectives and refine field surveys
	Parks et al., 2017	USFS	Federal	Identify current and predicted vegetation for fire planning
	Not stated	Other Conservation Organization	NGO	Helps address climate change impacts in current water or wildlife related projects
Watershed data	Friends of the Teton River Henry's Fork Foundation Conservation District	Water User Association	NGO	Supports project planning
Water Supply Outlook	IDWR	IDFG	State	Species management
	Henry's Fork Foundation: Dr. Rob VanKirk	Water User Association	NGO	Inform drought resilience projects
	USDA	Watershed Group	NGO	Contributes to watershed restoration projects; sustain resources for agriculture and fishing
	USDA	Watershed Group	NGO	Helps to inform drought plan and when to enact drought plan steps
Temperature	Not stated	Other Conservation Organization	NGO	Informs river flow, need for storage, and irrigation demand models used to protect fishery
	Not stated	Other Conservation Organization	NGO	Informs mine reclamation plan
	MTFWP	Watershed Group	NGO	Helps to inform drought plan and when to enact drought plan steps

	Holden et al., 2015	State Agency	IDFG	Applied to species and habitat modeling to inform number of management objectives and refine field surveys
Weather Reports	Not stated	USFS	Federal	Informs fire planning and fire suppression
Long range data sets	Not stated	USFS	Federal	Guides natural resource management; species management
Streamflow	BOR	IDFG	State	Guides natural resource management; species management
	USGS	MTFWP	State	Inform drought management conservation directives; inform watershed groups
	USGS & River Conditions Webpage*	Watershed Group	NGO	Conservation effectiveness. Determine when to enact drought plan steps.
	USGS	Other Conservation Organization	NGO	Inform seasonal water prediction models to protect fishery
	USGS	USFWS	Federal	Guides water release through water control structures to support habitat for birds
	USGS	Watershed Group	NGO	Inform projects aimed at keeping water on the landscape longer, slowing down flows
	USGS	USFWS	Federal	Inform habitat restoration, planting projects
	USGS	Land Trust	NGO	Help inform restoration projects for salmon
Turbidity	IDEQ	IDFG	State	Species management
Stream Temperature	IDEQ	IDFG	State	Species management
Reservoir levels	Reservoir gauges in Henry's Fork watershed	Other Conservation Organization	NGO	Inform reservoir release model to protect fishery
Regional Climate Assessment Report	USDA	USFS	Federal	Climate adaptation planning
National Fuel Moisture Database	National Weather Service	USFS	Federal	Flammability measurement; fire planning, suppression, resource allocation
Composite Trend Data	Missoula Fire Sciences Lab	USFS	Federal	Inform fire planning and allocation of fire resources
Water Quality	IDEQ	USDA	Federal	Landscape scale monitoring
	Not stated	Other Conservation Organization	NGO	Inform mine reclamation plan
AgriMet	BOR and NRCS	Other Conservation Organization	NGO	Determine whether to irrigate a farm; reduce irrigation requirement to support fishery
	BOR and NRCS	Other Conservation Organization	NGO	Determine irrigation demand to maintain rivers and streams for fish
Moisture Availability	Multiple sources	Other Conservation Organization	NGO	Inform decision-making to protect fishery
BioClim Variables	CliMond Climate Data	IDFG	State	Species response to climate change, species conservation
US Drought Monitor	National Drought Mitigation Center	Other Conservation Organization	NGO	Understand drought trends across the West to provide context to local area conditions to inform management to protect fishery

	Not stated	MTFWP	State	Make broad generalizations about drought in the region to support streamflow reports and enact conservation directives to support fishery
Evapotranspiration Index Mapping	University of Idaho	Other Conservation Organization	NGO	Screening tool for candidate parcels for water user agreements; identified past irrigation pattern
Palmer Drought Severity Index	UCAR	Other Conservation Organization	NGO	Preserving biodiversity and minimizing habitat loss, climate change adaptation
Energy Release Component	National Fire Danger Rating System	USFS	Federal	Fire planning and suppression, where to allocate fire protective resources
NDVI	USGS	Other Conservation Organization	NGO	Creating more drought resilient landscapes
	PRISM data	State Agency	IDFG	Informs forage availability for species management
Drought Reports	BOR, Fisheries stream gauges, NOAA climate outlook, historical climate outlook	Watershed Group	NGO	Fulfilling public outreach objectives
Surface Water Supply Index	NRCS	Other Conservation Organization	NGO	Use statewide information as context and comparison to local conditions to inform management to protect fishery
Snowpack data	NRCS	MTFWP	State	Informs streamflow report; used to enact conservation directives for species protection; inform watershed group decision-making
	NRCS	Other Conservation Organization	NGO	Informs predictive modeling to protect the fishery
	MTFWP	Watershed Group	NGO	Help to inform drought plan and when to enact drought plan steps
	NRCS	USFWS	Federal	Guides water release through water control structures to support habitat for birds
	NRCS	IDFG	State	Deer and fish management

Table_Apx 4-2. Data decision-support tools used by organizations.

Appendix C

Drought Decision-Support Tool Type: Models

Tool	Tool Source	Organization Subtype	Organization Type	Tool Supported Management
Runoff and Peak Discharge	USDA - NRCS	USFWS	Federal	Guides water movement through water control structures to support habitat for birds
Soil Erosion Model: RUSLE2	USDA - ARS	NRCS	Federal	Determines resource concerns and project implementation
Overwinter deer survival	IDFG	IDFG	State	Species conservation action
Wind Erosion Prediction System	USDA - NRCS	USDA	Federal	Informs soil health conservation action priority
Wildlife Connectivity Model	Rocky Mountain Research - USFS	IDFG	State	Informs wolverine conservation management action
Rangeland Productivity Model	USDA	Other Conservation Organization	NGO	Preserving biodiversity and minimizing habitat loss, climate change adaptation
Climate Forecasts	Western North America IPCC	IDFG	State	Western North America: used in combination with other tools to raise awareness, inform monitoring, and direct action; IPCC used with other models to generate range of potential impacts on areas or species
	USDA	Other Conservation Organization	NGO	Preserving biodiversity and minimizing habitat loss, climate change adaptation
	Climate Prediction Center National Weather Service Northwest River Forecast Center	Other Conservation Organization	NGO	Seasonal in-house models and publicly available models used to maintain rivers and streams for fish
	IPCC	Other Conservation Organization	NGO	Informs potential short-term and long-term impacts in project areas; informs conservation action
	MTFWP	Watershed Group	NGO	Help to inform drought plan and when to enact drought plan steps
	Climate Prediction Center	MTFWP	State	ENSO diagnostics; informs streamflow report; used to enact conservation directives for species protection; inform watershed group decision-making
	NOAA	USFS	Federal	Fire planning and fire resource allocation
	NOAA National Weather Service USDA	USFWS	Federal	Drought prediction to inform native plant population management, when to do plantings and which species to plant

Table_Apx 4-3. Model decision-support tools used by organizations.

Appendix D

Drought Decision-Support Tool Type: Geospatial Applications and Web-based tools				
Tool	**Tool Source**	**Organization Subtype**	**Organization Type**	**Tool Supported Management**
Climate Mapper	Climate Toolbox	IDFG	State	Used in combination with other tools to raise awareness, inform monitoring, and direct action
Historical Tracker				
Historical Climate Scatter				
Future Box Plots				
Strategic Conservation Plan [Wetland Layer Vegetation cover layer Agricultural Lands layer Omni directional connectivity layer]	NRCS TNC IDFG	Land Trust	NGO	Guides where to do conservation work; shows areas of highest priority
Climate Resilient Lands Layer	TNC	Land Trust	NGO	Informs where to focus land acquisitions and projects
	TNC	Water User Association	NGO	Prioritize projects, highlights areas of drought concern
	TNC	Land Trust		Guides where to do conservation work; shows areas of highest priority (included in strategic conservation plan above)
River Conditions Webpage*	Henry's Fork Foundation	Other Conservation Organization	NGO	Protect the fishery by informing anglers when not to fish based on water temps and fish stress
	Big Hole Watershed Committee	Watershed Group	NGO	Guides when to enact drought plan steps
Next Generation Fire Severity Mapping	Fire Research and Management Exchange System: Parks et al.	USFS	Federal	Current and anticipated conditions for fire planning
Soil Maps	NRCS	Other Conservation Organization	NGO	Determine fit for improved irrigation method for reducing water use
AQUARIUS	DNRC	MTFWP	State	Build streamflow rating curves to better understand tributaries; inform watershed committees and enact conservation directives
Infrared Imagery from Satellite*	TNC	Other Conservation Organization	NGO	Creating more drought resilient landscapes

Table_Apx 4-4. Geospatial and Web-based decision-support tools used by organizations.

Appendix E

Organization Type	Organization Type	Description	URL
NGO	Henry's Fork Foundation	The only not-for-profit organization whose sole purpose is to conserve, protect, and restore the Henry's Fork watershed and its legendary wild trout.	https://henrysfork.org/
	Teton Water Users Association	A diverse group led by ag producers, conservation groups, municipal and county leaders, and experts in hydrology and economics of the rural west working together to develop a more stable water supply for all users in Teton Valley.	https://tetonwaterusersassociation.org/
	Rocky Mountain Elk Foundation		
	Yellowstone to Yukon Initiative	Strives to support people, all wildlife and natural systems in the region between the Greater Yellowstone Ecosystem and Canada's Yukon Territory.	https://y2y.net/about/
	Big Hole Watershed Committee	A consensus-based nonprofit organization dedicated to conservation of the Big Hole River and surrounding watershed.	https://bhwc.org/
	Beaverhead Watershed Committee	The function of the BWC is to coordinate a local, citizen-based approach to maintaining public awareness and continuous improvement of Beaverhead riparian health.	http://www.beaverheadwatershed.org/
	The Nature Conservancy	Conserving the lands and waters on which all life depends.	https://www.nature.org/en-us/
	Sagebrush Steppe Land Trust	Protect and enhance natural lands, wildlife habitat, and working farms and ranches in Southeast Idaho, now and for future generations.	https://sagebrushlandtrust.org/
	Center for Large Landscape Conservation	We develop science, craft policy, and support planning for use by more than 2,000 community-based conservation efforts. Together with our partners, we form a world-wide network of conservation professionals, scientists, and decision makers.	https://largelandscapes.org/
	Conservation Science Partners	To apply human ingenuity to the preservation of species, populations, and ecosystems using scientific principles, innovative approaches, and lasting partnerships with conservation practitioners.	https://www.csp-inc.org/
	Greater Yellowstone Coalition	Permanently protect vital public and private lands, secure crucial habitat for Yellowstone's iconic wildlife, safeguard wildlife migration routes from Yellowstone to the Northern Rockies.	http://greateryellowstone.org/
	Teton Regional Land Trust	Teton Regional Land Trust's mission is to conserve working farms and ranches, fish and wildlife habitat, and scenic open spaces in Eastern Idaho for this and future generations.	https://tetonlandtrust.org/
	Lemhi Regional Land Trust	A locally governed, founded and staffed non-profit organization dedicated to voluntary private lands conservation.	http://www.lemhilandtrust.org/
Government Agencies	US Fish and Wildlife	The only agency in the federal government whose primary responsibility is management of fish and wildlife for the American public.	https://www.fws.gov/help/about_us.html
	Montana Department of Natural Resources	To help ensure that Montana's land and water resources provide benefits for present and future generations.	http://dnrc.mt.gov/
	US Forest Service	To sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.	https://www.fs.usda.gov/
	Idaho Fish and Game	Protect, preserve, perpetuate and manage Idaho's wildlife resources.	https://idfg.idaho.gov/

	National Park Service	Preserve unimpaired the natural and cultural resources and values of the National Park System for the enjoyment, education, and inspiration of this and future generations.	https://www.nps.gov/index.htm
	Greater Yellowstone Coordinating Committee	Allow the federal land managers of the GYA to pursue opportunities for voluntary cooperation and coordination at the landscape scale	https://www.fedgycc.org/
	Bureau of Land Management	To sustain the health, diversity, and productivity of public lands for the use and enjoyment of present and future generations	https://www.blm.gov/
	Camas National Wildlife Refuge	Manage habitat to benefit nesting waterfowl, and to provide resting and feeding habitat for spring and fall migration pf ducks, geese, and other waterfowl.	https://www.fws.gov/refuge/camas/
	US Fish and Wildlife Service Partners for Fish and Wildlife	Provide technical and financial assistance to landowners interested in restoring and enhancing wildlife habitat on their land. Projects are custom designed to meet landowners' needs.	https://www.fws.gov/partners/
	USDA: Natural Resources Conservation Service	Deliver conservation solutions so agricultural producers can protect natural resources and feed a growing world.	https://www.usda.gov/
	Montana Fish Wildlife and Parks	Provide for the stewardship of the fish, wildlife, parks, and recreational resources of Montana, while contributing to the quality of life for present and future generations.	http://fwp.mt.gov/

Table_Apx 4-5. Descriptions of organizations represented in focus groups.