FINAL REPORT

Co-Managing Risk or 'Parallel Play'? Examining Connectivity Across Wildfire Risk Mitigation and Fire Response in the Intermountain West

JFSP PROJECT ID: # 17-1-06-6

DECEMBER 2021

Emily Jane Davis
Oregon State University

Heidi Huber-Stearns
University of Oregon

Antony S. Cheng
Colorado State University

Darren McAvoy
Utah State University

Table of Contents

List of Tables

List of Figures

Keywords

Wildfire risk reduction, boundary spanning, collective action, firesheds

Acknowledgements

We thank the Joint Fire Science Program for their support of this project. We also wish to acknowledge the valuable contributions of key personnel Michael Caggiano, student partners Meredith Jacobson and Alison Deak, and design consultants Casey Davis and The Fire Writers.

Abstract

This research was designed to address the need for a more cohesive approach to managing wildfire risk in the western United States. This involves multiple entities with diverse, often competing policies, incentives, and practices who are not well-incentivized to work together or take collective accountability for wildfire risk, despite the growing collective impact of wildfires. Two major disconnects in particular are that while federal land management agencies increasingly recognize the need for wildfire's ecological role, most state and local entities are mandated to pursue full suppression strategies; and second, that even as entities managing wildfire risk seek to better coordinate their respective actions, they face administrative and policy limitations to sharing resources and responsibilities. As a result of these disconnects, there is a lack of strategies that can bridge mitigation treatments and suppression activities, and unify multiple agencies and organizations in implementing interconnected risk reduction at scale, which we characterize as a state of "parallel play."

Our central research question was: What factors can overcome organizational disconnects to foster co-management of firesheds in the U.S. West? Study objectives were to:

1. Characterize wildfire risk management at the fireshed scale.
2. Develop new knowledge of relationships between organizational structures/processes and values at risk.
3. Identify boundary spanning organizational attributes and causal factors
4. Inform more effective co-management with validated theories and actionable recommendations

We addressed these objectives through a primarily case study based approach of five purposively selected large landscapes (firesheds) in the U.S. West, which allowed for contextualized insights in specific settings as well as larger-scale theoretical generalizations about boundary spanning in wildfire risk reduction across forest and rangeland landscapes. A total of 93 interviews with 102 interviewees were conducted, and additional data for triangulation were gathered from documents, literature synthesis, and followup interviews.

We found that collective action to reduce wildfire risk is challenged by multiple types of boundaries, as well as a fluidity of framings of wildfire risk across social domains and boundary objects, creating some disconnection between how risks are defined and their potential solutions. Multiple forms of boundary spanning actors, functions, and features are needed to overcome these boundaries and disconnects. Community-based and collaborative coalitions are key boundary spanning organizations that can unite actors across organizational boundaries. The practices of prescribed fire and managing wildfire for natural resource objectives help span the boundaries between the functional realms of mitigation and fire response. Our research suggests the need for further investment in boundary spanning actors and functions at local scales, coordinated with efforts to align risk paradigms in broader-level venues; and future applied social science that can continue to identify strategic boundary spanning approaches in varying contexts.

Objectives

Our central research question was: What factors can overcome organizational disconnects to foster co-management of firesheds in the U.S. West? Hypotheses that formed the basis of this question were that: 1) well-recognized interactional factors (i.e., trust or learning) alone are insufficient, 2) various boundary spanning attributes are needed to bridge different risk paradigms (defined as the organizational structures and processes that shape risk management), and 3) firesheds with histories of large, cross-boundary wildfires and organizational partnerships will demonstrate more boundary spanning features and evidence of co-management. Our original study objectives were:

1. *Characterize wildfire risk management at the fireshed scale.* Result: Pre-field profiles and standards for comparative analysis.
2. *Develop new knowledge of relationships between organizational structures/processes and values at risk.* Result: Understanding of risk paradigm variation across scales, organizations, and firesheds.
3. *Identify boundary spanning organizational attributes and causal factors.* Result: New theories about boundary spanning in wildfire risk co-management.
4. *Inform more effective co-management with validated theories and actionable recommendations.* Result: Practical recommendations for managers and other stakeholders co-managing risk.

These objectives were developed in response to Research Needs 1, 2, and 4 in Task Statement 6 (No. FA-FON0017-001, which was due September 15th, 2016). We focused on understanding socio-organizational factors that affect successful co-management of wildfire risk across scalar and organizational boundaries, and variation by socio-ecological context. We sought to complement existing research by examining the organizational structures that underpin risk paradigms, using organizational theories and analysis to examine how collective action mechanisms can be applied and institutionalized. Objective 1 was a foundational objective that allowed us to characterize our case studies and pursue the other objectives. All objectives were met, although the planned procedures and scope for meeting Objective #2 were redesigned somewhat in light of staffing and capacity changes since the original proposal. Please see the Materials and Methods section for more detail.

Background

This research was designed to address the need for a more cohesive approach to managing wildfire risk in the western United States. Numerous researchers and managers have identified that the governance structure of wildfire risk is complex because it consists of multiple entities with diverse, often competing policies, incentives, and practices (Calkin et al. 2011), who are not well-incentivized to work together or take collective accountability for wildfire risk, despite the growing collective impact of wildfires. Two major disconnects in particular are, first, that while federal land management agencies increasingly recognize the need for wildfire's ecological role, most state and local entities are mandated to pursue full suppression strategies (Fleming et al. 2015); and second, that even as entities managing wildfire risk seek to better coordinate their respective actions, they face administrative and policy limitations to sharing resources and responsibilities (Cyphers and Schultz 2019, Kelly et al. 2019). As a result of these disconnects, there is a lack of strategies that can bridge mitigation treatments and suppression activities, and unify multiple agencies and organizations in implementing interconnected risk reduction at scale. We characterize this as a state of "parallel play", which stands in contrast to the ideals of "co-management" expressed by the Joint Fire Science Program's prior task statements and others.

To help address these challenges, the National Cohesive Wildland Fire Management Strategy (2014) has sought to clarify a common vision and three central goals, and then encourage the wildland fire community to "work

collaboratively among all stakeholders and across all landscapes." At the finer scale of firesheds, or landscapes that face similar fire risks (Kline et al. 2015), the implementation of such cohesive efforts to reduce wildfire risk has been inconsistent and variable around the West. National programs such as the Collaborative Forest Landscape Restoration Program and Joint Chiefs' Landscape Restoration Partnership have provided competitive funding that requires robust science-based collaborative processes and cross-boundary management (Cyphers and Schultz 2019, Schultz et al. 2012), as have state-level programs (e.g., Oregon Watershed Enhancement Board Focused Investment Partnerships, New Mexico Collaborative Forest Restoration Program grants). The implications for management are that networks of managers, practitioners, and other actors in some firesheds have been more successful than others in organizing to achieve funding and designations under these programs. However, even those that have can still face difficulty in actually accomplishing coordinated, strategic mitigation treatments that meaningfully reduce wildfire risk across boundaries (Kelly et al. 2019).

The state of parallel play that we described in our proposal is not well theorized in a cohesive way, but has been addressed in various studies over the last two decades from different social science fields such as forestry, public administration, and environmental management. These studies have sought to examine what drives successful coordination and collaboration across land ownership boundaries in both place-based planning and larger networks. Earlier research often focused on community or locally based efforts or regional networks, and delved into how social-interactional factors such as of trust, community capacity, leadership, and learning affected processes and outcomes (e.g., Lachapelle and McCool 2012, Butler and Goldstein 2010, Cheng and Sturtevant 2012). Further scholarship used social network analysis to depict the networks of organizations in and across different problem domains in wildfire such as mitigation and response (e.g., Fischer et al. 2016, Nowell and Steelman 2015). One line of work has attempted to characterize forms of "all lands management" or risk reduction activities across ownership boundaries (Charnley et al. 2020), and identify what enables and constrains it (Kelly et al. 2019); other interdisciplinary studies have pursued evidence of cross boundary risk transmission (e.g., Ager et al. 2019). Questions of what drives more cohesive strategies have also been examined in the arena of wildfire response, including a focus on interagency coordination (e.g., Steelman and Nowell 2019) and the involvement of non-agency, community actors in response (e.g., Davis et al. 2020); but most of the research has remained focused on mitigation.

Our project's design centered on the need to name and delve more deeply into the problem of parallel play from a pragmatic lens that could meaningfully engage managers and stakeholders with firsthand knowledge. From a conceptual standpoint, we sought to move beyond well-established themes in collaboration, such as process, networks, and trust, because these lines of inquiry have not completely addressed or been well applied to the challenge of collective action around wildfire risk at larger scales beyond communities or individual coalitions. For a methodological approach, we found it necessary to focus on in-depth, semi-structured interviews with key informants that included fire management and operations, and to triangulate with other data sources to situate finer-grained insights from practice within larger trajectories of organizational development in case study areas.

Materials and Methods

Our approach to this research centered on qualitative, comparative case studies that allowed for contextualized insights in specific settings as well as larger-scale theoretical generalizations about boundary spanning in wildfire risk reduction across forest and rangeland landscapes (Yin 2003). Case study research is well suited to complex social-organizational phenomena that are not well documented in secondary data; and qualitative methods can illuminate the multi-dimensionality of underlying motivations, issues, and opportunities. We chose our number and variation of cases for comparative rigor and applicability while also maintaining the capacity to explore key themes in sufficient depth (Stake 2013). Through the course of the project, we also adjusted our approach to gather more data as changes in policy and management direction occurred, and in the face of the COVID-19

pandemic. Research protocols were approved by Oregon State University's Institutional Review Board for compliance with human subjects research requirements (protocol #8821) and the other investigators' institutions deferred oversight to OSU.

Case study selection logic and context

We developed our case study focus and selection criteria during the proposal with insights from previous experience with wildfire risk management and targeted consultation with several fire response experts (USDA Forest Service fire operations, interagency coordination, and incident management) to determine research questions, themes to explore, and most suitable case study locations. After starting the project, we ultimately chose five case studies based on several selection criteria (Table 1, Figure 1).

Selection criteria category	Criteria
Practicality Feasibility of successfully completing interviews with relevant stakeholders	● Willingness and interest of potential interviewees to participate; not already experiencing fatigue from other research engagements ● Accessible location for researcher visits ● Current active programs, networks, organizations, or other efforts toward collective action in wildfire management
Comparative potential Potential to compare cases with similar attributes	● Contain a preponderance of federally managed (BLM and/or USFS) lands, and other landownership boundaries ● Representation of both forest and range land ● Multiple values at risk from cross-boundary fire events ● Areas with population centers, participating communities at risk/includes wildland urban interface
Relevance Work across landownership and organizational boundaries to collectively manage wildfire risks	● Appearance of innovative strategies for collectively addressing wildfire challenges ● Diverse jurisdictional, organizational, and functional boundaries (e.g., actors working across different landownerships, different public and private entities involved in wildfire management)

Table 1 Case study selection criteria

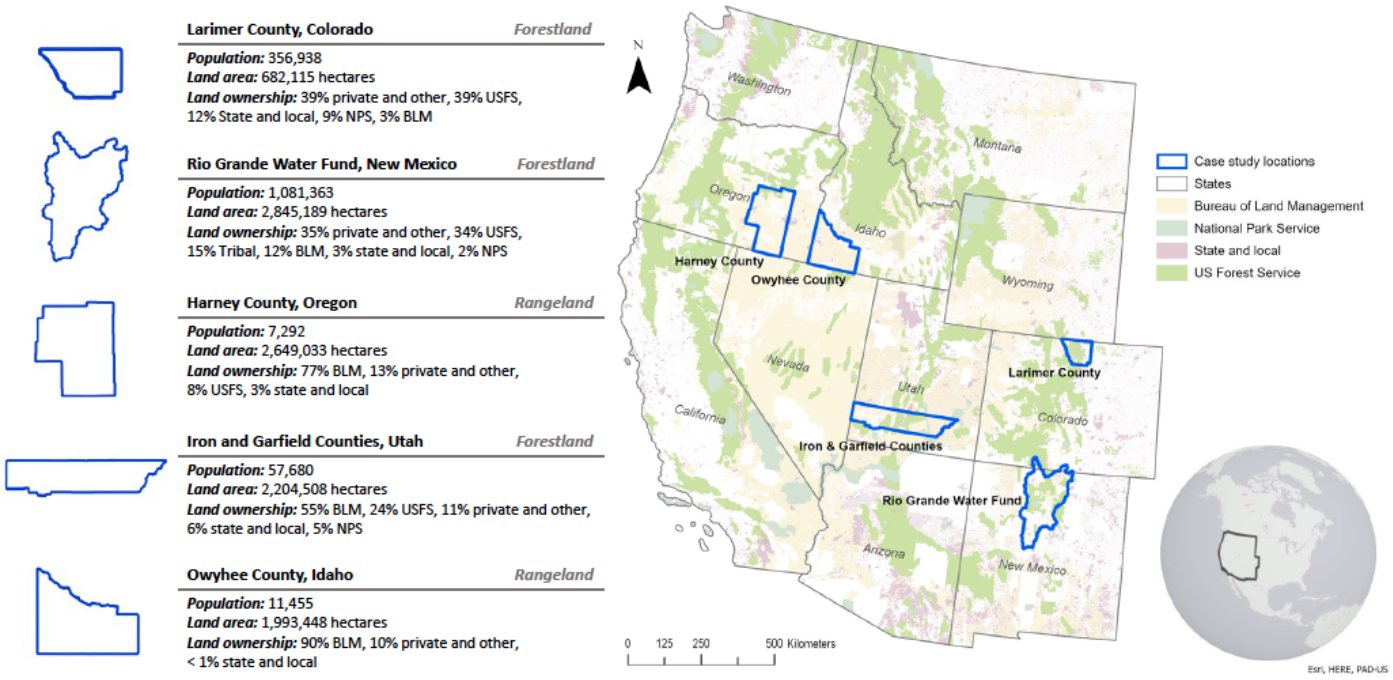

Figure 1. Case studies and key characteristics

Data collection and analysis methods

Multiple data collection and analysis approaches were employed:

1. Boundary spanning literature review: Because existing research on boundary spanning is scattered across multiple disciplines and domains of literature, we had to conduct a robust search to aggregate and synthesize this material to inform our central theoretical framework. This involved purposeful selection of foundational articles that established key boundary spanning terminology, and highly cited review pieces summarizing key theoretical contributions and citation searches stemming from these articles; then further keyword searches using Web of Science and Google Scholar. We included all literature that addressed boundary spanning in the context of a natural resources, wildfire, or adaptive governance-related topic published in the English language. Our search resulted in a database of 56 articles, which we used to develop a new boundary spanning features framework of the most common forms and concepts described in this literature (Davis et al. 2021) and to guide coding of our case study data and cross case findings (Huber-Stearns et al. in review).

2. Case study data research: In each case study area, we gathered data from multiple sources to triangulate insights. First, we obtained publicly available documents related to wildfire mitigation and suppression from 2006-2018, including National Environmental Policy Act documents, community wildfire protection plans, and collaborative group and partnership materials; as well as secondary data and shapefiles related to landownership, population, and burned area boundaries. We used these data to create pre-field profiles and timelines that summarized the trajectory of wildfire events, policy changes, and local partnerships and collaborations to address wildfire risk in each area. Second, we conducted key informant interviews by purposively sampling individuals from the initial document data collection and our knowledge, as well as snowball sampling of additional individuals. Key informants represented government and nongovernmental organizations that worked to address wildfire risk across boundaries in each study area. A total of 93 interviews with 102 interviewees were conducted between October 2018—June 2019, with

20 to 22 individuals per case. We recorded and transcribed all interviews, developed a coding framework of boundary spanning features and emergent codes using established social science thematic coding procedures (Saldaña 2014), and coded interview data with NVivo qualitative analysis software using pilot coding and inter-author checking procedures to ensure consistency. Coding proceeded from a first inductive stage to identify actors, boundary spanning features, and activities; and then we used a closed coding scheme to further organize these codes through the boundary spanning framework established in Davis et al. 2021. Third, we re-developed and refined our study timelines with interview data and member checking. Fourth, we returned (virtually) to three selected case studies (NM, UT, and CO) in 2021 to gather additional longitudinal data about changes in our key research questions since the onset of the COVID-19 pandemic and changes in state and federal wildfire policy in these locations, interviewing 12 key informants most familiar with policy and pandemic impacts in each case study.

3. Further purposive thematic data collection: Based on initial coding results and the interests of stakeholders as expressed through our ongoing science engagement processes, we identified several key themes for additional examination and chose to delve deeper on those themes in selected case studies for which there was suitable evidence and sufficient additional data sources.

a. Evaluating risk paradigms: In addition to the document data collection for our case studies, we investigated the availability of popular media coverage of wildfire risk and events from 2006-2018 in each study area. Among our cases, the northern Colorado case study had sufficient breadth and depth of media articles as well as other document types for us to undertake a discourse analysis exploring risk definition, cause, and solution framings (Creswell 2012, daSilva et al. 2019). A database of all materials was assembled and coded with NVivo qualitative analysis software using a framework of elements previously used in wildfire-related discourse analysis, a constant comparison approach (Boeije 2002), and intercoder reliability (O'Connor and Joffe 2020). Results of this analysis are shared in Jacobson et al. 2021.

b. *Examining the use of managed wildfire*: Through our initial case study data collection, we found that managing wildfire for natural resource objectives was more commonly discussed and used in northern New Mexico and southwestern Utah. We developed a coding guide of factors in incident decision making relevant to managed wildfire to further identify findings related to managed wildfire use in these cases. We then returned to conduct longitudnal data collection through interviews in these cases as described in #2, and sought additional data about managed wildfire in each case by collecting Incident Status Summary reports (ICS-209s) from the FAMWeb Data Warehouse for any managed wildfires discussed in interviews and all available reports for incidents on national forests in case study areas in 2020; and coding for text fields indicating incident objectives, strategy, values at risk, and planned activities. Results of this analysis are shared in Davis et al. in review.

Results and Discussion

Multiple types of boundaries challenge collective action in wildfire risk reduction; and multiple forms of boundary spanning actors, functions, and features are needed to overcome them.

We drew on a literature review of social science concerning collective action in wildfire risk management in order to characterize four major types of boundaries at hand: landownership, organizational, functional, and conceptual (Davis et al. 2021, Table 2). Most of the existing literature and management direction focuses on the need for cross-boundary treatments and coordination across landownerships (i.e., "all lands", "shared stewardship"), but does not articulate these other types of boundaries, how they manifest in accomplishing work across landownerships, or their respective roles in driving parallel play. Describing a broader range of boundary types helps inform more effective co-management (Objective 4) because it provides a framing and naming of issues that

managers have otherwise experienced as an undifferentiated set of challenges to working with others; and it is a first step in then developing potential ways to span those boundaries.

Boundary type	Boundaries exist between
Landownership	● Parcels of land ● Policies, laws, regulations, and liabilities governing different ownerships
Functional	● Wildfire risk management functions of prevention, mitigation and suppression
Organizational	● The missions, incentives, accountabilities, cultures, and scales of different organizations involved in managing wildfire risk; and their ability to share resources and work jointly on tasks
Conceptual	● Different individuals' and organizations' conceptions of and knowledge about wildfire risk

Table 2. Summary of major types of boundaries in wildfire risk management

We then conducted a novel synthesis of the disparate literature on boundary spanning in natural resources to create a conceptual framework of key "boundary spanning features" and explain how they operated (Table 3). This was a foundational step in identifying causal theories about boundary spanning in wildfire risk co-management (Objective 3) because the literature ranged across fields and in its depth of focus on some boundary spanning features, and required synthesis to then be applied to the wildfire risk management context. For example, there has been extensive emphasis on boundary spanning and intermediary organizations, particularly at science-policy or science-management boundaries; while less is known about the roles of other features such as boundary concepts, or the ways in which multiple boundary spanning features interact over time in a contextual setting like a fireshed.

Boundary spanning feature (BSF)	Characteristics	Studied examples in literature
Boundary people/organizations	● Engage actors on both sides of a boundary ● Create and use other boundary spanning features (e.g., objects) in doing boundary work ● Create interactive settings, identify common interests	● Cooperative Extension ● Collaborative groups or organizations ● Multi-party land trusts ● Research and development organizations ● Science exchanges or networks
Boundary objects	● Joint reference points (e.g., classifications, standards) for communication and sharing across boundaries ● Broad enough to allow shared meaning and flexible interpretation among actors from both sides of a boundary ● May be broad, ill-defined, and open; or more specifically defined ● May be used similarly to "boundary concept"	● Concrete objects such as maps, models, or datasets ● Instruments such as agreements, MOUs, or organizational charters ● Concepts such as multi-use forestry
Boundary concepts	● Concepts that allow communications across a boundary by creating common vocabulary ● Broad enough to allow shared meaning ● Often used similarly to "boundary object"	● Ecosystem services ● Notion of resilience
Boundary settings	● Conducive settings for boundary work to occur ● May be internal to an organization (e.g., its structure or culture), or external (e.g., policy)	● Broader institutions, governance arrangements, funding sources, and policies ● Physical, localized sites of convening (e.g., meeting venues, committees, working tables, and joint projects)

Table 3 Framework of boundary spanning features

Following the establishment of understanding of boundary types and boundary spanning features, we examined prominent examples of these features in wildfire risk management. We specifically sought to characterize what types of boundaries these examples were emphasizing or attempting to overcome (Table 4). It appears that many of the existing examples of boundary spanning features seek to address organizational boundaries, but in different ways ranging from actual convening of diverse actors in collaboratives, coalitions, or networks; to specific exercises and outputs intended to codify shared meaning and goals. As a result of this analysis, we produced several hypotheses:

- Wildfire risk policy, management, and practice have generated several prominent features that vary in the types of boundaries that they seek to span. Further research could classify these features by their type, involved actors, funding sources, decision-making scales (i.e., national, regional, state,
- administrative unit, project), and developmental phases (i.e., formulation, planning, analysis, implementation, monitoring and evaluation).
- Existing boundary spanning features in wildfire risk management vary in the types of boundaries they attempt to span and their approaches for doing so. Future research could further ask if organizational boundaries are indeed a major factor that drives parallel play, and if spanning that boundary type is the key to encouraging more collective action.
- Arrangements of boundary spanning features will emerge, exist, and evolve in different settings given the variability in their local settings and in how boundaries in wildfire risk management manifest. Large wildfires serve as focusing events that trigger and shape trajectories of boundary spanning work to follow.

Boundary spanning feature (BSF)	**Prominent example of BSF in wildfire risk management**	**Wildfire risk boundary types emphasized**			
		Organizational	*Landownership*	*Conceptual*	*Functional*
Boundary organization	Fire science exchange networks			■	
	Fire Learning Network	■		■	
	Fireshed or wildfire collaboratives	■	■	■	■
Boundary object	Potential Operational Delineations (PODs)	■	■		■
	Risk model outputs and maps	■			
	Collaborative charters	■			
Boundary concepts	Fire-adapted communities	■			
	Risk transmission	■	■		
	Landscape scale	■	■		
Boundary settings	Joint Chiefs' Landscape Restoration Partnership	■	■		
	Cohesive Strategy	■	■		■
	Spaces wherein collaboratives convene	■			

Table 4 Boundary spanning features in wildfire risk management

We then further expanded our framework and hypotheses of boundary spanning features through a cross-case

analysis that sought generalizations about actors present and functions performed to span boundaries regardless of case context (Huber-Stearns et al. in review, Figure 2). This analysis focused on collective action to address wildfire risk through mitigation for and prevention of wildfire and applied our empirical data in response to Objective 3. Across our cases, interviews revealed that a diversity of types and scales of actors are involved in this work; a total of 137 different people and organizations (ranging from 27 to 45 actors per case, with some showing more organizational density and complexity than others). Most often, this involved functions that prior research has typically associated with boundary organizations, including engaging actors on both sides of a boundary, creating and using boundary spanning features, fostering interactive settings, and identifying common interests; however, different actors varied in how many and what type of boundary spanning they performed. Some actors, such as some of the coalitions, water and fire shed groups and related collaboratives, university programs, and individuals in liaison roles fit that traditional definition of boundary organizations and people operating across the landscape; but all identified actors functioned in some way to support cross boundary work. Our research therefore suggests the utility of a broader conception of what it means to be a boundary organization and what functions that role entails in practice.

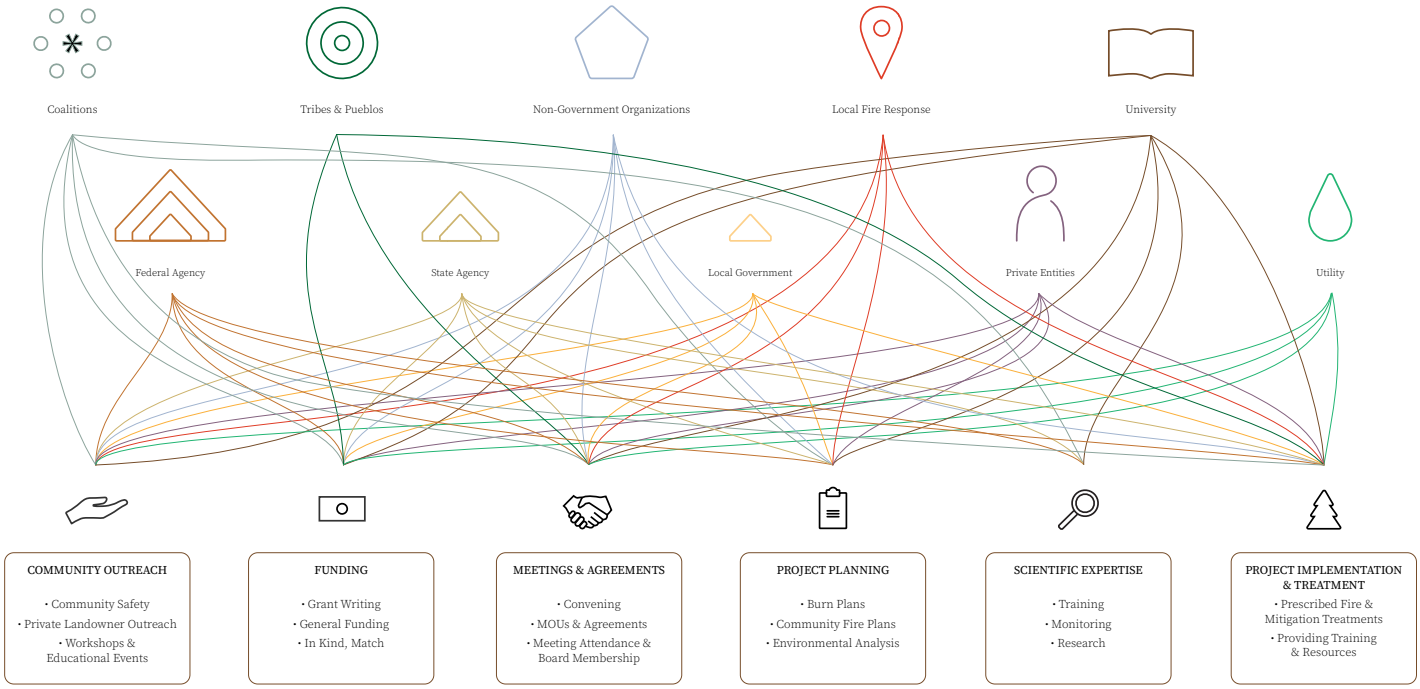

Figure 2. Actors and functions in wildfire risk management

Further, our case study data resulted in refined explanation of how different boundary spanning features operated in practice. We found that actors engaged to 1) create conductive *settings* for boundary work to occur, such as procuring funding or changing policy conditions; 2) discuss and develop *concepts* that created common vocabulary and shared meaning to connect across differences; and 3) develop concrete *objects* as joint reference points to codify, sustain, or advance common visions across multiple values, such as maps, documents, and partnership agreements or other instruments. Specific activities such as implementing prescribed fire particularly spanned boundaries as they required numerous novel forms of cooperation and investment.

We also found multiple pragmatic challenges to spanning boundaries that were difficult to overcome even when boundary spanning features were in use. These included an extensive focus on collective action in planning with

less attention to accomplishing implementation on the ground. For example, boundary spanning objects such as risk assessments can unite actors across diverse values in a planning process, but can also take extensive time and not end up being directly used. Interviewees also described inability to move from planning to action due to quantity or flexibility of staff, personnel, or funding capacities, particularly in job codes or authorities to use resources across boundaries and on other landownerships/jurisdictions than their own. These pragmatic barriers to collective action are recognized by others (e.g., Kelly et al. 2019, Cyphers and Schultz 2019), and will continue to warrant scrutiny as investment in wildfire risk reduction and policy makers' expectations of outcomes increase.

Framings of wildfire risk are fluid across social domains and boundary objects, creating some alignment and some disconnection between how risks are defined and their potential solutions.
We used a case study of the Northern Colorado Front Range to analyze social constructions of wildfire risk across four predominant domains of social discourse: mainstream media coverage, governmental planning documents, a fireshed collaborative group's documents, and Community Wildfire Protection Plans (Jacobson et al. 2021). This case study offered sufficient breadth and depth of documentation across these four domains for comparative analysis of risk paradigms (Objective 2). Multiple rounds of qualitative coding were employed to systematically determine 1) how values at risk, causes of risk, and solutions to mitigate risk were framed in each domain; and 2) which agencies, organizations, or other actors' voices were most prominent within each. We found that risk framings varied by domain (Table 5). Some emphasized risk definitions, causes, and solutions that were entirely absent in others. For example, while media sources focused on ignition and site specific conditions, NEPA and collaborative documents did not address these causes. This is likely due to the traditional purpose and focus of materials in each of these domains. Even when there was commonality across domains, such as the shared focus on safety and property values found in both the media and CWPP documents, the spatial and temporal scales of that focus varied.

	Media	**NEPA**	**Collaborative**	**CWPP**
Risk definition				
Human life and safety	Emphasized	Present	Present	Emphasized
Property	Emphasized	Present	Present	Emphasized
Social	Present	Present	Emphasized	Emphasized
Economic	Present	Present	Present	Present
Ecological	Present	Emphasized	Emphasized	Present
Risk cause				
Ignition	Emphasized	Absent	Absent	Present
Site specific conditions	Emphasized	Present	Present	Emphasized
Broad environmental factors	Present	Emphasized	Emphasized	Present
WUI characteristics	Present	Present	Present	Emphasized
Prevention logistics	Present	Absent	Emphasized	Present
Suppression logistics	Present	Absent	Present	Emphasized
Risk solution				
Suppression	Emphasized	Absent	Present	Emphasized
Post-fire recovery	Present	Present	Absent	Present
Community hazard mitigation	Emphasized	Absent	Present	Emphasized
Wildfire mitigation and prevention	Present	Emphasized	Emphasized	Emphasized

Table 5. Risk framing: Summary of presence/absence and emphasis across document types

These findings about the inconsistent framing of wildfire risk definition align with prior literature that recognizes functional boundaries between fire suppression and mitigation arenas, as well as disconnects between media representations of wildfire and the perspectives of resource managers and scientists (e.g., Crow et al. 2017). However, we also found that collaboratively planned mitigation projects involving coalitions of diverse actors and boundary spanning activities such as prescribed fire offered examples of potentially more integrative discourse. One such instance was the Magic Feather project planned by the Northern Colorado Fireshed Collaborative, which involved more diverse voices than the other domains and emphasized cross-cutting themes of wildfire impacts on human values (smoke and drinking water). This suggests that such collaborative efforts may help bridge otherwise disconnected risk paradigms.

Managing wildfire for natural resource objectives is an opportunity that galvanizes diverse actors, but is limited by terminology, risk perception, and ownership boundaries.

Managing wildfire for natural resource objectives is a key boundary spanning activity that can bridge the functional boundaries of mitigation and suppression; for example, by allowing the use of control lines and treatments created before a fire to aid in incident response (Thompson 2014). We asked questions about "managed wildfire" in all five case studies and then as described in the Materials and Methods section, we conducted further longitudinal and purposive data collection in the two case studies with the most evidence of use of this strategy (northern New Mexico and Southwestern Utah). We brought together interview data about opportunities and challenges for managed wildfire over time from before and during the pandemic with additional evidence from incident reports in each case study, and compared for common themes across cases. To guide analysis, we synthesized the limited social science literature on factors in the use of managed wildfire as a response strategy to create a cohesive framework (Table 6).

Theme	**Code name**	**Examples**
Factors shaping response strategies	External influences	● Perceptions of support or lack of for managed wildfire from public or other non-agency entities ● Importance of research in justifying need for managed wildfire ● External partner engagement in pre-planning or risk analysis
	Institutional influences	● Leadership support ● Performance measures and targets ● Agency culture, beliefs, norms ● Plans and processes that allow managed wildfire use ● Internal enablers and barriers of managed wildfire use
	Individual risk	● Individual decision biases ● Individual concerns for risk to oneself ● Individual liability
	Decision support tools/ risk analytics	● References to support tools or analytics used in pre-planning, during incidents, or post-incident evaluation
Examples of using managed wildfire	Stories	● Specific incidents on which managed wildfire was used; descriptions of how, why, and outcomes in context

Pandemic impact	Pandemic impact	• Direction to not use managed wildfire during pandemic and for full suppression • Risks considered during pandemic
Emergent codes	Managed wildfire as hidden	• Examples of fires being managed for natural resource objectives, but the term not being used • Examples of blurred lines between different response strategies, and similarity of tactics
	Interagency	• Differences in agency missions and responsibilities • Restrictions and inhibitions to use of managed wildfire related to these differences • Organizational liability • Examples of interagency involvement and cooperation.

Table 6. Interview coding framework and relevant literature on managed wildfire

We found differences in how use of managed wildfire was fostered in each case's unique context (Davis et al. in review). In the New Mexico case, there was an active and long-term network of civil society partnerships among non-agency stakeholders and agencies that deliberately sought increased use of prescribed and managed fire through approaches that included explicitly advancing the scientific need for the strategy, increasing public awareness, and working together to foster enabling state policy conditions. In the Utah case, strong interagency cooperation and existing policies and plans rather than civil society actors were pivotal. In both cases, we found that the use of managed wildfire was difficult to identify due to ambiguous terminology, or at times obscured by limited open discussion. The COVID-19 pandemic, drought, and agency direction in 2020-2021 also curtailed its use, suggesting how local context shapes wildfire response strategies, yet centralized decision making and policy can also enable or constrain them.

Our findings support previous research that has already identified the influence of multiple factors in fire manager decision making, such as external public and internal agency pressures (e.g., Williamson 2007; Thompson 2014). However, case studies of managed wildfire outside of agency after action reviews have been rare, so our project offered more detail about how these factors came into play in decision making and is methodologically unique for the topic. This aspect of our research also contributed to multiple project objectives because it suggested ways in which different agencies and stakeholders can advance managed wildfire across multiple boundaries (Objective 3), characterized wildfire risk management in different case settings (Objective 1), and resulted in several implications for management (Objective 4). Primarily, these implications were that understanding of enabling social and internal institutional conditions is necessary to facilitate more opportunity for use of managed wildfire, not just improved risk analytics and decision support tools; and that this may be achieved through increased use of social science to provide evidence, structure, and frameworks for managing wildfire risk, specifically in formats such as lessons learned, expanded use of after action reviews, process monitoring, briefings with leadership, and science application through boundary-spanning organizations such as fire science consortia.

Science Delivery Activities

Science delivery was an integral component of this project throughout its life. From developing the proposal to conducting the research and creating outputs, we continuously engaged with stakeholders and partners at multiple scales and in multiple venues. Given our positions as Cooperative Extension faculty (Davis, Cheng, McAvoy) and applied researchers and technical assistance providers (Huber-Stearns and Caggiano), we were able to draw on existing relationships and experience with multi-way listening and learning to identify needs and provide delivery outputs that met them. Specific venues where these multi-way exchanges occurred included the Rural Voices for Conservation Coalition, several fire science exchange networks, our forestry and natural resources Extension

programs at our home institutions, and community-based partnerships and collaboratives in several of our case study areas. This allowed us to track and adapt to changes in wildfire risk reduction policies and direction over the course of the project, and to adjust in response to the questions and needs that our partners raised. Given the broad framing of our project, the relevance of the problem of parallel play and the need for many forms of boundary spanning, we had extensive interest from stakeholders across the West as well as within specific local settings.

To further describe this multi-way form of engagement, we offer some description of how we interacted with entities at different scales, and the contexts in which our past and future planned work is embedded:

1. *Local:* Prior to this project, we each had prior experience and relationships working in these case study firesheds with community-based collaboratives and coalitions in particular. This helped inform study design and offered opportunities for interaction and other related projects. For example, Davis had led prior research on rangeland fire protection associations and other questions of collective action in a rangeland fire setting in southeastern Oregon and southwestern Idaho. In conducting data collection for this project, she worked closely with the Harney County Wildfire Collaborative and High Desert Partnership, shared a briefing and fact sheet draft back for member checking that helped cohere and put framing to their work, and evolved several of the themes that arose in the Harney case into a related project about how to utilize social science in collaborative processes to foster stronger connections between those efforts and community wellbeing outcomes (this spinoff project resulted in several educational presentations, a report, and two briefing papers). She also helped recruit new local leadership dedicated to boundary spanning wildfire risk reduction efforts in the form of a regional rangeland wildfire Extension specialist based in Harney County. This JFSP project as well as other efforts are part of Davis's larger professional commitment to understanding and fostering fire-adapted communities and collective action around wildfire risk in a rangeland context. In 2022, she will use data from the Harney and Owyhee cases to produce an additional manuscript on this topic. In a similar vein, this project has informed Caggiano and Cheng's ongoing embedded roles in the northern Colorado fireshed, as we provided a briefing on initial project findings and opportunities to leadership of the Arapaho-Roosevelt National Forest, and these were applied as lessons learned as the fireshed collaborative continued to develop its focus and identity.

2. *State*: During this JFSP project period, extreme wildfire seasons and impacts spurred increased state level policymaking and other forms of action around wildfire risk reduction across the U.S. West. These policies have varied by state but generally increase investment in mitigation and suppression capacity, and encourage greater coordination across agencies and stakeholders to achieve outcomes at larger scales. For example, in Oregon, a new Extension Fire Program was founded at Oregon State University in 2019, and an omnibus fire bill (Senate Bill 762) passed in 2021 is directed unprecedented funding and mandates at 11 state agencies for the 2021-2023 biennium and requiring the development of a 20-year state level strategic plan. Davis's work on boundary spanning through this JFSP project allowed her to contribute to the development of the Extension Fire Program at the request of her institutional colleagues, who engaged her to develop detailed social-organizational profiles of actors, partnerships, and strategies in sub-regions around the state as well as a report on the governance of wildfire. In 2021, Davis was asked to join the program as Interim Director to support its Extension personnel around the state in serving as boundary spanners to reduce wildfire risk at more meaningful scales and applying her expertise from this JFSP project. Through this new position, she is also contributing to the implementation of SB762 through several workgroups and processes, which have already offered the opportunity to share and act on concepts about boundary spanning from this JFSP project directly with decision makers and stakeholders.
In addition, Co-PI Huber-Stearns' work on this project and the recently completed policy barriers to prescribed fire (JFSP 16-1-02-8) have generated opportunities to leverage lessons learned. For example, Huber-Stearns is currently engaged with state and regional level partners such as RVCC and the Watershed Research and Training Center, to develop applied research and related work to help identify opportunities for recruiting, training, and retaining prescribed fire (and other labor-intensive restoration) trained workforces to conduct wildfire risk

reduction work in Northern California, as well as other parts of the west. For Co-PI Cheng, the Colorado Forest Restoration Institute has been explicitly using the term "boundary spanning" and using BSFs to informing their work. They have found, similar to results noted here, that providing researchers and practitioners with different ways of organizing how they think about and communicate what they do through a framework of BSFs can help systematize work planning and resource investment in work streams in more coherent ways. The Colorado Forest Restoration Institute has been investing more in people and products to span conceptual boundaries, resulting in new podcasts, story maps, short videos, and other engagement targeted to general audiences, not just their core audience.

3. *Regional*: We have had multiple opportunities to inform design and share our project in regional venues:

- Huber-Stearns and Cheng are part of the management team and institutional PIs for the Northwest Fire Science Consortium and Northern Rockies Fire Science Exchange Network, respectively, and Cheng and McAvoy also work closely with the Southern Rockies exchange. We shared our project findings through webinars and a Northwest Fire Science Consortium-based website at various points throughout the grant period to obtain feedback from these communities and reach their broad audiences; and further elevated the reach of our work through a story map created with The Fire Writers.
- We engaged with other regional and national networks:
    - Davis, Cheng, and McAvoy briefed the Western Coordinating Committee of Extension Foresters to share the project concept and receive input about how to engage with Extension in project implementation (2017).
    - The Senior Advisor to the Under Secretary for Natural Resources and Environment requested a briefing with us to discuss our project's boundary spanning propositions and application to current management issues in the national forest system (2017).
    - The Fire-Adapted Communities Network requested that we produce blog posts and a webinar, which allowed us to share some targeted findings on managed wildfire and fire-adapted rangeland communities, as well as more broad knowledge resulting from this JFSP project (2018, 2019, 2020).
    - The Southern Rockies TREX requested that Davis deliver a presentation on rangeland fire protection and boundary spanning to their participants (2018).
    - Findings and themes from this project also informed Davis and Huber-Stearns's work with the Rural Voices for Conservation Coalition on major strategies for cross-boundary wildfire risk reduction. Both PIs collaborated with RVCC staff and stakeholders on applied research and new materials about how to accomplish all-lands restoration projects, and on performances measures for shared stewardship (throughout project).
    - Huber-Stearns and Davis served as organizers of a national Conservation Conversations webinar series that convened academic and manager thought leaders around the country on articulating top conservation priorities; this included one webinar with Cheng and colleagues about the need for more boundary spanning to reduce wildfire risk in the West (2020).
    - We briefed the leadership of the Western Regional Strategy Committee on application of our findings to the ongoing implementation of the Cohesive Strategy in the West and develop ideas for future products and briefings targeted at the issues that will be the most pressing for the 2022 fire season and beyond (2021).
    - Huber-Stearns was selected as a Visiting Associate Professor of Practice, with the Theodore Roosevelt Visiting Professorship in Ecosystem Management for 2022-2023 with the new Western Forests and Fire Initiative at the University of Michigan's School for Environment and Sustainability, where she will continue to apply boundary spanning concepts to the creation of a new co-produced western US wildfire research agenda with multiple scientists and practitioners (2021).

Project products, which were developed from our research and through the influence of these diverse audiences, are listed in Appendix B but summarized here for additional reference (Table 7). We expanded the number of most deliverables in response to interest and needs that our audiences articulated.

Product type	Committed in proposal	Accomplished	Description
Scientific manuscripts	4	4	Two published, two submitted and in review as of October 2021
Story maps	2	2	One focused on boundary spanning features and one focused on prescribed fire use in northern Colorado
Briefing papers	2	6	Four fact sheets were developed to highlight key management implications in case study areas; one case study was developed through CFRI; and material about rangeland fire protection was contributed to one Extension case study
Video hot spot	1	1 (podcast)	Filming a video became infeasible during the pandemic and work and travel restrictions for ourselves and partners. We adapted by developing a podcast for the UO Fire Story podcast series focused on rangeland fire and the Harney County wildfire collaborative.
Blog posts	2	3	Fire Adapted Communities Network (2) and Agriculture Climate Network (1)
Conference presentations	3	9	Association for Fire Ecology (3), Fire Continuum conference (1), SESNYC Boundary Spanning: Advances in Socio-Environmental Systems Research (1), Restoring the West (1), Society for Range Management (1), Osher Lifelong Learning Institute at University of Oregon (1), International Association for Society and Natural Resources (1)
Webinars	4	5	Fire Adapted Communities Network (2), Northern and Southern Rockies Fire Science Exchange Networks and Utah State University Learn at Lunch (1), Northwest Fire Science Exchange Network (2)
Targeted briefings	2	9	Senior Advisor to the Undersecretary for Natural Resources and the Environment (1); Western Coordinating Committee of Extension Foresters (1); Annual University of Idaho/Washington State University Family Foresters Workshop (1); Southern Rockies TREX (1); leadership of the Arapaho-Roosevelt National Forest (1); Harney County Wildfire Collaborative (1); Washington State House Rural Development, Agriculture & Natural Resources Committee (1); Conservation Conversations series (1); Western Regional Coordinating Committee (1)

Table 7. Summary of science delivery outputs and venues

Conclusions and Implications for Management/Policy and Future Research

The focus and research questions of this project were developed with practitioner and manager input to target pressing issues that they faced in successfully scaling up wildfire risk reduction across boundaries and through collective action. Over the course of the project, our questions about how to overcome parallel play became even more timely as the West endured several challenging wildfire seasons, and there were a number of developments in state policies and federal land manager direction that further encouraged cohesive strategies. Succinctly put, our project's primary contributions were to characterize and name the problem of parallel play, including a refined understanding of the multiple types of boundaries that inhibit collective action. We also identified a framework of boundary spanning features that can help overcome parallel play, empirical evidence of how they function through the activities of diverse actors and coalitions, and hypotheses for future research. We delved further into specific dimensions of risk paradigm communication across stakeholder domains and managing wildfire for natural resource objectives—two major arenas that have potential to unlock further scaling up of wildfire risk reduction outcomes.

Our research has numerous policy and management implications as well as questions for future research,

particularly applied research that is conducted in close alignment with stakeholder communities. Our case studies suggest that different landscapes will have different levels of investment, and types and sequencing of boundary spanning features over time. What works well and is useful in one place at one time may not readily transfer to another. However, the following considerations would be applicable to managers and practitioners in any fireshed.

First, the presence and integration of community-connected groups (i.e., forest collaboratives, watershed coalitions, community wildfire councils) are often essential for creating the settings from which boundary spanning features can emerge and be used; it is important for firesheds to engage these key actors, not just professional wildland fire people and organizations. Collaborative venues and coalitions are also necessary to help establish more clear and consistent communication of fire risk concepts and elements across domains and particularly to then bring those consistent concepts into media coverage. This is important because disconnected risk paradigms across these domains fundamentally affect the framing of who is responsible, and what should be done to solve the problem (which contributes to inhibition of collective action). These findings align with established research about the importance of boundary spanning organizations, but add detail to how these operate beyond just science-policy boundaries. Future funding for these types of collaborative venues should incentivize and support activities beyond consensus building and planning and be designed to help stakeholders overcome multiple types of boundaries. This would include the development of boundary spanning features that can lead to future outcomes. For example, potential operational delineations processes carried out in the northern Colorado case study resulted in the ability to locate Joint Chiefs' Landscape Restoration Program projects that, when combined with completed mechanical and prescribed fire treatments, altered the progression of the Cameron Peak Fire. We also need further research that can explore how specific boundary spanning features are involved in the trajectory of collective action in firesheds over time, and what contributes to some landscapes being able to successfully achieve this action and investment.

Second, collective action must be fostered at multiple scales. Larger scale venues like those created by Cohesive Strategy leadership also have a role to play in maintaining common boundary concepts and connecting the growing community that uses them; as well as in naming the realities of "hard boundaries" such as liability and decision making responsibility. This will become ever more crucial as the amount of money and actors and initiatives in wildfire continues to grow, which increases the likelihood of parallel play, redundancy, and competition. In addition, although policies increasingly demand evidence of use of boundary spanning features and a record of outcomes, the reality is that not every fireshed will have the capacity to develop a full suite of these features. The future research described above as well as high quality peer lessons learned processes will be needed to help identify conditions under which certain boundary spanning features are key in order to make more targeted and strategic investments. This knowledge will be crucial in places like Oregon, where a 20 year strategic plan for wildfire risk reduction is to be developed by June 2023; and other states such as Washington where strategic plans are underway.

Finally, certain wildland fire activities—prescribed fire and managed wildfire—are pivotal arenas for boundary spanning between the functional realms of mitigation and suppression, and are a primary means to accomplish risk reduction at meaningful scales. Our research and that of others has demonstrated how prescribed fire serves as a gateway and pilot space for diverse actors to figure out how to work together across their organizational boundaries by sharing human and other resources to plan and implement burns. The fire science community resoundingly recognizes the need for more prescribed fire at scale, and in parallel, social science research like ours further emphasizes the need to also scale up the social systems of cooperation and boundary spanning inherent in prescribed fire. Prescribed fire is also a gateway to increased use of managed wildfire. Managed fire is a "dark boundary concept" that unites actors who want to return fire to the landscape, but cannot typically communicate this when there are expectations for full suppression from elected officials, the public, or other stakeholders—or changes in policy direction as during the pandemic and record fire seasons. Prior research recognizes the various

constraints on managed wildfire but solutions are elusive. Going forward, more support systems for more open discussion of managed fire and lessons learned are needed, particularly in settings that bring together agency personnel and non-agency stakeholders for collective dialogue and normalization of the strategy. This dialogue, should help expand common understanding of enabling social and internal institutional conditions for use of managed wildfire, which are crucial in addition to improved risk analytics and decision support tools.

Literature Cited

Ager AA, Palaiologou P, Evers CR, Day MA, Ringo C, Short K. Wildfire Exposure to the Wildland Urban Interface in the Western US. Applied Geography. 2019 Oct 1;111:102059.

Boeije, H. A Purposeful Approach to the Constant Comparative Method in the Analysis of Qualitative Interviews. Quality and Quantity 2002, 36 (4): 391–409.

Calkin, D.C.; Finney, M.A.; Ager, A.A.; Thompson, M.P.; Gebert, K.M. Progress towards and Barriers to Implementation of a Risk Framework for US Federal Wildland Fire Policy and Decision Making. For. Policy Econ. 2011, 13, 378–389.

Charnley, S.; Kelly, E.C.; Fischer, A.P. Fostering Collective Action to Reduce Wildfire Risk across Property Boundaries in the American West. Environ. Res. Lett. 2020, 15, 025007.

Cheng A.S. & Sturtevant, V.E. A Framework for Assessing Collaborative Capacity in Community-Based Public Forest Management. Environmental Management 2012 Mar 1;49(3):675-89.

Creswell, John W. 2012. Qualitative Inquiry and Research Design: Choosing among Five Approaches. Thousand Oaks: Sage Publications.

Crow, D.A., Berggren, J.,. Lawhon, LA.,. Koebele, E.A., Kroepsch, A., and Huda, J. Local Media Coverage of Wildfire Disasters: An Analysis of Problems and Solutions in Policy Narratives. Environment and Planning C: Politics and Space 2017, 35 (5): 849–871.

Cyphers, L.A.; Schultz, C.A. Policy Design to Support Cross-Boundary Land Management: The Example of the Joint Chiefs Landscape Restoration Partnership. Land Use Policy 2019, 80, 362–369.

da Silva, N.T.C., Fra.Paleo, U., and Ambrósio Ferreira Neto, J. Conflicting Discourses on Wildfire Risk and the Role of Local Media in the Amazonian and Temperate Forests. International Journal of Disaster Risk Science 2019, 10 (4): 529–543.

Davis EJ, Abrams J, Wollstein K. Rangeland Fire Protection Associations as Disaster Response Organisations. Disasters. 2020 Jul;44(3):435-54.

Davis EJ, Huber-Stearns H, Cheng AS, Jacobson M. Transcending Parallel Play: Boundary Spanning for Collective Action in Wildfire Management. Fire. 2021 Sep;4(3):41.

Fischer AP, Vance-Borland K, Jasny L, Grimm KE, Charnley S. A Network Approach to Assessing Social Capacity for Landscape Planning: The Case of Fire-Prone Forests in Oregon, USA. Landscape and Urban

Planning, 2016 Mar 1;147:18-27.

Fleming, C.J.; McCartha, E.B.; Steelman, T.A. Conflict and Collaboration in Wildfire Management: The Role of Mission Alignment. Public Adm. Rev. 2015, 75, 445–454.

Goldstein, B.E.; Butler, W.H. The U.S. Fire Learning Network: Providing a Narrative Framework for Restoring Ecosystems, Professions, and Institutions. Soc. Nat. Resour. 2010, 23, 935–951.

Jacobson M, Smith H, Huber-Stearns HR, Davis EJ, Cheng AS, Deak A. Comparing Social Constructions of Wildfire Risk Across Media, Government, and Participatory Discourse in a Colorado Fireshed. Journal of Risk Research. 2021 Jul 30:1-8.

Kelly, E.C., Charnley, S., & Pixley, J.T. Polycentric Systems for Wildfire Governance in the Western United States. Land Use Policy 2019, 89: 104214.

Kline, J.; Ager, A.A.; Fischer, P. A Conceptual Framework for Coupling the Biophysical and Social Dimensions of Wildfire to Improve Fireshed Planning and Risk Mitigation. In Proceedings of the 13th International Wildland Fire Safety Summit & 4th Human Dimensions of Wildland Fire Conference, Boise, ID, USA, 20–24 April 2015; International Association of Wildland Fire: Missoula, MT, USA, 2015; pp. 215–223.

Lachapelle P.R., McCool SF. The Role of Trust in Community Wildland Fire Protection Planning. Society & Natural Resources. 2012 Apr 1;25(4):321-35.

Nowell B, Steelman T. Communication under Fire: The Role of Embeddedness in the Emergence and Efficacy of Disaster Response Communication Networks. Journal of Public Administration Research and Theory. 2015 Jul 1;25(3):929-52

O'Connor, C., and Joffe, H. Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines. International Journal of Qualitative Methods 2020, 19: 160940691989922.

Saldaña J. Coding and Analysis Strategies. In The Oxford handbook of qualitative research 2014.

Schultz, C.A.; Jedd, T.; Beam, R.D. The Collaborative Forest Landscape Restoration Program: A History and Overview of the First Projects. J. For. 2012, 110, 381–391.

Stake RE. Multiple Case Study Analysis. Guilford press; 2013 Apr 29.

Steelman, T.; Nowell, B. Evidence of Effectiveness in the Cohesive Strategy: Measuring and Improving Wildfire Response. Int. J. Wildland Fire 2019, 28, 267–274.

Thompson MP. Social, Institutional, and Psychological Factors Affecting Wildfire Incident Decision Making. Society & Natural Resources. 2014 Jun 1;27(6):636-44.

Williamson MA. Factors in United States Forest Service District Rangers' Decision to Manage a Fire for Resource Benefit. International Journal of Wildland Fire. 2007 Dec 17;16(6):755-62.

Yin RK. Design and Methods. Case Study Research. 2003;3(9.2).

Appendix A
Contact Information for Key Study Personnel

Emily Jane Davis
Associate Professor, Department of Forest Ecosystems and Society
Interim Director, Extension Fire Program
Oregon State University
EmilyJane.Davis@Oregonstate.edu
541-520-2688

Heidi Huber-Stearns
Associate Professor
Director, Institute for a Sustainable Environment and Ecosystem Workforce Program
University of Oregon
hhuber@uoregon.edu
541-346-4545

Antony Cheng
Professor, Department of Forest and Rangeland Stewardship
Director, Colorado Forest Restoration Institute
Colorado State University
Tony.cheng@colostate.edu
970-491-1900

Darren McAvoy
Extension Assistant Professor, Wildland Resources
Utah State University
Darren.mcavoy@usu.edu
435-797-0560

Michael Caggiano
Research Associate, Colorado Forest Restoration Institute
Colorado State University
Michael.Caggiano@colostate.edu
970-491-3134

Appendix B
List of Completed/Planned Scientific/Technical Publications/Science Delivery Products

Articles in peer-reviewed journals

Davis, E.J., Huber-Stearns, H., Cheng, A.S., & Jacobson, M. 2021. Transcending Parallel Play: Boundary Spanning for Collective Action in Wildfire Management. *Fire* (4)3: 41.

Jacobson, M., Smith, H., Huber-Stearns, H., Davis, E.J., Cheng, A.S., & Deak, A. 2021. Comparing Social Constructions of Wildfire Risk Across Media, Government, and Participatory Discourse in a Colorado Fireshed. *Journal of Risk Reduction:* 1-18.

Davis, E.J., Huber-Stearns, H., Caggiano, M., McAvoy, D., Cheng, A.S., Deak, A., & Evans, A. Managed Wildfire: A Strategy Limited by Terminology, Risk Perception, and Ownership Boundaries. In review, *Society and Natural Resources* (submitted October 2021).

Huber-Stearns, H., Davis, E.J., Deak, A., & Cheng, A.S. Spanning Boundaries for Managing Wildfire Risk in Forest and Range Landscapes: Lessons From Case Studies in the Western United States. In review, *International Journal of Wildland Fire* (submitted October 2021).

Davis, E.J., Wollstein, K., Huber-Stearns, H., Deak, A., & Cheng, A.S. Collective Action for Overcoming Parallel Play in Rangeland Wildfire. Planned manuscript for future submission to the *Journal of Environmental Management.*

Technical reports
NA

Text books or book chapters
NA

Graduate thesis (masters or doctoral)
NA; however, we engaged two students as research assistants who contributed significantly to the project and served as coauthors (Meredith Jacobson and Alison Deak).

Conference or symposium proceedings scientifically recognized and referenced (other than abstracts)
NA

Conference or symposium abstracts
Davis, E.J., Huber-Stearns, H., & A.S. Cheng. 2021. The Institutional Work of Managing Wildfire for Natural Resource Objectives. Presented at the annual meeting of the International Association for Society and Natural Resources. 21 June 2021. Online.
In the western United States, there is growing urgency around mitigating wildfire's impacts on human communities, managing vegetation to reduce risks of uncharacteristic events, and restoring fire's historic and cultural roles in many social-ecological systems. There is also a mounting recognition that the scale of these activities to date has been insufficient to address these challenges. Although full suppression of fire events remains most common, under some circumstances, fire managers have used other strategies such as "managing "natural ignitions for natural resource objectives", allowing fires that begin naturally to act as a tool to reduce fuel

levels and restore ecological conditions at larger scales while also potentially reducing suppression costs. Federal policy guidance released in 2009 explicitly permits federal fire managers to manage events for multiple objectives, including such natural resource objectives. Managers must assess and act in the face of multiple risks, uncertainties, and tradeoffs when choosing management objectives and strategies. This research examines managers' decision-making when managing fire for natural resource objectives in three case studies in Colorado, Utah, and New Mexico in the Intermountain US West, where we conducted semi-structured interviews with a total of 60 key informants (20 per case). We used qualitative inductive analysis informed by a practice perspective on institutional work to identify findings about how managers worked within and maintained the institution of wildfire suppression while simultaneously exploring and applying practices that disrupted it as they operated in the emergent setting of fire events. We found that managers created and utilized a scaffolding of institutionalized processes and plans to mitigate risks, but that external actors such as collaborative partners were also important in fostering a social environment that legitimized opportunities to manage for natural resource objectives.

Davis, E.J. 2020. Fire on the Range: "Co-Managing" Risk Among Agencies and Landowners in the Great Basin. Presented at the annual meeting of the Society for Range Management in Stakeholder Engagement to Improve Federal Rangeland Wildfire Mitigation and Response symposium. 18 February 2020. Denver, CO.
Rangeland wildfires have grown in size, frequency, and length of season due to factors that include increasing human use of rangelands, vegetation state change (e.g., cheatgrass invasion), drought, and climate change. For example, the largest wildfires ever recorded in all four Great Basin states have been rangeland fires that have occurred in 2007 or later. In response, land managers and researchers have proposed solutions such as novel grazing systems, pre-emptive restoration, fuel break provision, and more. Because western U.S. rangelands are largely managed by the federal government for multiple uses, and because wildfires frequently cross jurisdictional boundaries, implementing successful strategies to reduce wildfire risk and impact or to improve post-wildfire recovery is likely to require involvement by multiple actors beyond the federal rangeland management agencies. This symposium presents results of new research exploring options for engagement between land management agencies and multiple stakeholders to improve federal wildfire mitigation and response. Emily Jane Davis will describe her findings in studies of evolving partnerships for rangeland wildfire mitigation and suppression in Oregon and Idaho.

Davis, E.J., Huber-Stearns, H., Cheng, T., McAvoy, D., & Caggiano, M. Prescribed Fire: How Does it Span Boundaries for More Effective Co-Management of Wildfire Risk? Presented at the 8th International Fire Ecology and Management Congress, Association for Fire Ecology. 21 November 2019. Tucson, Arizona.
There is increased recognition of the importance of prescribed fire treatments for managing wildfire risk in the US West. Implementing prescribed fire can be challenging due to factors such as manager capacity, resources, and air quality effects near large communities. Disconnects and differences in risk tolerance among organizations and landowners ('risk paradigms") in the same geographic area can also pose limitations. Understanding divergent risk paradigms and how they can be bridged is central to improved co-management. Through three case studies of predominately federal land in the Intermountain West, we examined prescribed fire use as a form of "boundary work" that fosters this bridging. We found that the planning and implementation of prescribed fire involved several types of boundary work. It created common concepts and language, engaged actors in shared activities, and necessitated boundary objects that codified understandings or organized action across gaps. We share these findings to illuminate how boundary work can generate and legitimate new shared risk paradigms, and the need to institutionalize those to induce durable changes in systems for collectively managing wildfire risk.

Davis, E.J., Huber-Stearns, H., Cheng, T., McAvoy, D., & Caggiano, M. Boundary-Spanning for Collective Action: Managing Wildfire Risk in the West. Presented at the 8th International Fire Ecology and Management Congress, Association for Fire Ecology. 20 November 2019. Tucson, Arizona.
The governance of wildfire risk management in the United States is organizationally complex. Landscapes with

similar wildfire threats contain multiple entities undertaking a variety of pre-wildfire mitigation and fire response actions across scales from neighborhoods to watersheds. Despite laws, policies, and agreements calling for cohesive strategies, these entities differ in their organizational structures, processes, and tolerances for risk, which can inhibit collective accountability and action in managing wildfire risk. Through two case studies in Colorado and New Mexico, we examined how the issue of wildfire impacts on forested municipal watersheds has acted as a boundary-spanning force that reoriented involved actors toward more collective action across organizations and ownerships; as well as the complex meanings and limitations of sharing risk that were revealed in these efforts.

Huber-Stearns, H., Davis, E.J., Cheng, A.S., McAvoy, D., & Caggiano, M. 2019. Boundary-Spanning to Collectively Manage Wildfire Risk in the West. Invited presentation at the 2019 Restoring the West conference. 8 October 2019. Logan, Utah.

The governance of wildfire risk management in the United States is organizationally complex. Landscapes with similar wildfire threats contain multiple entities undertaking a variety of pre-wildfire mitigation and fire response actions across scales from neighborhoods to watersheds. Despite laws, policies, and agreements calling for cohesive strategies, these entities differ in their organizational structures, processes, and tolerances for risk, which can inhibit collective accountability and action in managing wildfire risk. Through two case studies in Colorado and New Mexico, we examined how the issue of wildfire impacts on forested municipal watersheds has acted as a boundary-spanning force that reoriented involved actors toward more collective action across organizations and ownerships; as well as the complex meanings and limitations of sharing risk that were revealed in these efforts.

Huber-Stearns, H., Davis, E.J., & Cheng, A.S. 2018. SESYNC Boundary Spanning: Advances in Socio-Environmental Research: Boundary work and natural resource management in the western US. 25 June 2018. Annapolis, Maryland.

Persistent change in socio-environmental systems directly impacts lands and people in the western United States. At the same time, natural resource governance in the region is multifaceted, with a mismatch between administrative boundaries and the social and ecological complexities on the landscape. Challenges such as inconsistent policies and budgets, organizational structures and processes, and jurisdictional boundaries can discourage joint accountability and action, leading to fragmented understanding of the implications of system changes.

Boundary work, specifically activities, concepts, organizations, and objects, can build both understanding and collective action across boundaries between science and decisionmaking, or policy and practice. This presentation synthesizes lessons learned from boundary work in natural resource management in the region, focusing on communicating implications and generating actionable responses. We provide examples from research on:
1) Helping land managers both understand and communicate impacts of forest management and policies in the Pacific Northwest, and connections between management decisions and communities.
2) Identifying risk paradigms at different spatial scales of wildfire risk management, and in different organizational arrangements of pre-fire mitigation and fire response to improve co-management of wildfire risk.
Our lessons learned highlight boundary work around science communication, action-oriented research and collaboration for understanding implications of social and environmental transitions. We discuss linking between organizations and across scales and jurisdictions, with more effective and targeted communication processes, facilitating information flows for decision-making, and creating mechanisms for joint accountability and action. All of this is critical to informed and efficient decisionmaking that bridges boundaries to sustain systems in transition.

Davis, E.J., Huber-Stearns, H., Cheng, A.S, McAvoy, D., & Caggiano, M. 2018. Co-Managing Risk or Parallel Play? Examining Connectivity across Wildfire Risk Mitigation and Fire Response in the Intermountain West. Presented at the Fire Continuum Conference: Preparing for the Future of Wildland Fire. 23 May 2018. Missoula,

Montana. (Part of a special session convened by Davis)
Landscapes with similar wildfire threats ("firesheds") contain multiple entities undertaking a variety of pre-wildfire mitigation and fire response actions across scales from neighborhoods to watersheds. Despite laws, policies, and agreements calling for cohesive strategies, these entities often do not work closely for efficient and effective risk management. They face inconsistent policies and budgets, organizational structures and processes, and conceptions of values at risk. Collectively, these challenges discourage joint accountability and action, and contribute to rising fire suppression costs. Our research question is: What factors can overcome organizational disconnects to foster co- management of firesheds? We will use comparative case studies of six firesheds in varied socio- ecological settings to analyze how boundary-spanning attributes enable co-management across spatial scales and between mitigation and fire response. We present initial results from case study development, preliminary spatial analysis, and literature synthesis.

Davis, E.J., Huber-Stearns, H., Cheng, A., McAvoy, D., & Caggiano, 2017. M. Co-Managing Risk or Parallel Play? Examining Connectivity across Wildfire Risk Mitigation and Fire Response in the Intermountain West. Presented at the 7th International Fire Ecology and Management Congress, Association for Fire Ecology. 29 November 2017. Orlando, Florida.
The governance of wildfire risk management in the United States is organizationally complex. Landscapes with similar wildfire threats ("firesheds") contain multiple entities undertaking pre-wildfire mitigation and fire response actions across scales from neighborhoods to watersheds. Despite laws, policies, and agreements calling for cohesive strategies, these entities often do not work closely for efficient and effective risk management. They face inconsistent policies and budgets, organizational structures and processes, and conceptions of values at risk. Collectively, these challenges discourage joint accountability and action, and contribute to rising fire suppression costs. We provide an overview of a new research project starting in late 2017 that will examine factors that may overcome organizational disconnects to foster co-management of firesheds. We hypothesize that well-recognized interactional factors (i.e. trust or learning) alone are insufficient. Research on inter-organizational collaboration indicates that boundary spanning work is also needed to bridge different risk paradigms, defined as the organizational structures and processes that shape risk management. We will use comparative case studies of six firesheds in varied socio-ecological settings across the US West to analyze how boundary-spanning attributes may enable co-management between spatial scales and between mitigation and fire response.

Posters
NA

Workshop materials and outcome reports
NA

Field demonstration/tour summaries
NA

Website development
Project site: https://www.nwfirescience.org/CoManagingRisk

Boundary spanning features story map: https://storymaps.arcgis.com/stories/2a58e04588e643238dffa24cab21778a

Northern Colorado prescribed fire story map:
https://storymaps.arcgis.com/stories/1d03a9c78dfe4f6681ab4eef4240356d

Presentations/webinars/other outreach/science delivery materials

Caggiano, M.D., Beeton, T.A., Gannon, B.M., & White, J. 2021. The Cameron Peak Fire: Use of Potential Operational Delineations and Risk Management Assistance Products. CFRI-2106.

Davis, E.J., Sharp, T., & Wollstein, K. 2021. Episode 5: Rangeland Fires. Podcast and accompanying resource guide produced through the The Fire Story podcast series, facilitated by Smith, H., & Blaine, M. University of Oregon. Aired 16 April 2021.

Cheng, T., Davis, E.J., & Bertone-Riggs, T. 2020. From Parallel Play to Co-Management: Conserving Landscapes at Risk of Wildfire in the American West. Invited webinar and discussion within Conservation Conversations series. 9 September 2020. Online.

Davis, E.J., & Hall, S.A. 2020. Rangeland Fire Protection Associations – An Important Tool, Now and in the Future. Blog post for the Agriculture Climate Network. 31 August 2020.

Davis, E.J., & Cheng, A.S. Boundary-Spanning for Collective Action: Managing Wildfire Risk in The West. Invited webinar with the Fire-Adapted Communities Network. 19 August 2020. Online.

Huber-Stearns, H., & *Davis, E.J. 2020. Managing Fire for Water: Lessons Learned from Watershed Protection Partnerships for Wildfire Risk Reduction. Invited webinar delivered through the Northwest Fire Science Consortium. 27 May 2020. Online.

Davis, E.J. Co-Managing Wildfire Risk in Rangelands: Lessons Learned and Implications for Fire-Adapted Communities. Would have been presented at the Central Oregon Fire Science Symposium, 19 March 2020. Bend, Oregon. [*canceled due to covid-19 and not rescheduled*]

Davis, E.J., Cheng, A.S, & McAvoy, D. 2020. Boundary-Spanning for Collective Action: Managing Wildfire Risk in the West. Invited webinar delivered through Utah State University "Learn at Lunch" series and the Northern and Southern Rockies Fire Science Network. 25 February 2020. Online.

Hall, S.A., Hudson, T.D., Jensen, K.S., Neibergs, J.S., Reeves, M.C., Yorgey, G.G., & Davis, E.J. 2020. Building Resilience Through Engagement - Brenda and Tony Richards. Rancher-to-Rancher Case Study series: Increasing resilience among ranchers in the Pacific Northwest. Pacific Northwest Extension Publications.

Cheng, A.S., & Caggiano, M. 2020. Burning Across Boundaries: Cooperatively Managing Wildfire Risk in Northern Colorado. Co-Managing Wildfire Risk Fact Sheet Series, Project Fact Sheet #4.

Davis, E.J., & McAvoy, D. 2020. Co-Managing Wildfire Suppression in Southwestern Utah. Co-Managing Wildfire Risk Fact Sheet Series, Project Fact Sheet #3.

Huber-Stearns, H., Davis, E.J., Evans, Z., & Caggiano, M. 2019. Letting Nature Do the Work: Managing Wildfires for Resource Objectives in New Mexico. Co-Managing Wildfire Risk Fact Sheet Series, Project Fact Sheet #2.

Davis, E.J. 2019. Boots on the Ground, Boots Around the Table: Managing Rangeland Wildfire Risk in Oregon and Idaho. Co-Managing Wildfire Risk Fact Sheet Series, Project Fact Sheet #1.

Davis, E.J., Evans, Z., Caggiano, M., & Huber-Stearns, S. 2019. Risks and Rewards: Managing Wildfire for

Resource Objectives in Northern New Mexico. Blog post for the Fire-Adapted Communities Learning Network. 19 September 2019.

Davis, E.J., Huber-Stearns, H., Cheng, T., McAvoy, D., & Caggiano, M. 2019. Co-Managing Wildfire Risk in Rangelands. Invited presentation to the Harney County Wildfire Collaborative. 18 July 2019. Burns, Oregon.

Davis, E.J. Rangeland Fire Protection: Lessons Learned from Research in Oregon and Idaho. Presentation at information session for WA HB 1188, House Rural Development, Agriculture, and Natural Resources Committee. 18 January 2019. Olympia, Washington.

Davis, E.J. Rangeland Fire Protection: Partnerships for Mitigation and Suppression. Invited webinar with the Fire-Adapted Communities Network. 13 November 2018. Online.

Davis, E.J. Rangeland Fire Protection. Invited presentation at the Southern Rockies Prescribed Fire Training Exchange (TREX). 24 October 2018. Vermejo Park, New Mexico.

Davis, E.J. Reducing Fire Risk Across Mixed Ownerships. Invited presentation to the Annual University of Idaho/Washington State University Family Foresters Workshop. Coeur d'Alene, Idaho, 19 January 2018.

Davis, E.J., Huber-Stearns, H., Cheng, A., McAvoy, D., & Caggiano, M. Co-Managing Risk or Parallel Play? Examining Connectivity across Wildfire Risk Mitigation and Fire Response in the Intermountain West. Presentation to the Western Coordinating Committee of Extension Foresters, annual meeting, Fort Collins, Colorado. 8 August 2017.

Appendix C
Metadata

Content of Metadata[1]

Storage of metadata and access to data

After reviewing the Forest Service Research and Development Data Archive guidance, we determined that the qualitative data coding structures we were storing were most appropriate to be stored at the University of Oregon's Scholars' Bank, particularly since it is not comprehensive metadata for the dataset but rather the qualitative analysis codes and constructs. The Scholars' Bank is an open access repository for the intellectual work of individuals at the University of Oregon and partner institutions. We worked with the archivist at Scholars' Bank to store our final analysis codes and constructs according to their formats and standards. This included providing information on the purpose and history of the data, data collection methods, sources, scale, and temporal coverage, all of which linked to the documents in which we reported the findings from the analyses.

We archived all shared data in commonly available, non-proprietary formats, and included citations and links to the data in final publications (as well as links in manuscripts currently under review). In the event of unanticipated errors in data after publication, we will notify the archive and/or provide UO Scholars' Bank with an updated dataset so that it can update the data and metadata.

Below is a list of our original final data storage plans for externally-accessible data and deliverables, updated with the current status of each data type. Human subjects data (e.g., transcripts, audio files) have all been stored per the original data management plan (not released as they cannot be de-identified).

Data type	Data repository	Current status
Organizational charts	Per original DMP, individual or organization-specific charts were not released-cannot be de-identified, but timelines for each case study landscape are publicly shared, as well as aggregated data about the organizational landscape across the five case studies.	Timelines for each case study and key events, and organizational landscape and roles are located at: fire-boundary-spanning.org
Spatial data	Datasets were not archived as no new variables or datasets were created in this analysis.	See Section #3 below for details about sources used.
Risk paradigm content database	UO Scholars Bank	Data storage and metadata complete, see Section #s 1a and 2 below (Comparing social constructions of wildfire risk across media, government, and participatory discourse in a Colorado fireshed**")**
Delphi survey results	This analysis was not conducted, but followup interviews to three of the five cases were used instead, informing two manuscripts.	See 1b and 1c below for final metadata storage and details. Manuscripts currently in review
Final analysis codes	UO Scholars' Bank	See 1a, 1b and 1c below for final metadata storage and details
Briefing papers	UO Scholars' Bank; co-PI websites; Fire Science Exchanges	Complete
Peer reviewed journal articles	Print and electronic journals	Data and metadata sorge complete for all

[1] Hyperlinks to data sources provided as blue, underlined text throughout document

1. **Interview data**

   Interview data will exist in our NVivo database because, as stated in our data management plan, interview audio files, transcripts, and coding databases cannot be de-identified. As part of our publicly released data, we have included our final analysis codes and constructs, which can be accessed at Scholars' Bank:

   a. Code Descriptions and data for "Comparing social constructions of wildfire risk across media, government, and participatory discourse in a Colorado fireshed"

      Authors: Jacobson, Meredith; Smith, Hollie; Huber-Stearns, Heidi R.; Davis, Emily Jane; Cheng, Antony S.; Deak, Alison

      URI: https://doi.org/10.1080/13669877.2021.1962954

      Abstract: This study examined how wildfire risk is framed by different entities and actors within a common region, during and after experiencing several large wildfire events. Using a social constructionist lens, we viewed wildfire risk as a fluid and variable concept that is socially constructed and framed through public discourse. Inconsistent social constructions of wildfire risk may pose challenges for effective wildfire risk governance and management, which requires the coordination of diverse entities including government, land managers, homeowners, and community groups. We sought to understand differing social constructions of wildfire risk within one region, the Northern Colorado Front Range, across four domains of social discourse: mainstream media coverage, governmental planning documents, a community collaborative group's meeting notes, and Community Wildfire Protection Plans. Through multiple rounds of qualitative coding, we compared how values at risk, causes of risk, and solutions to mitigate risk are framed across discourse domains. We also identified which agencies, organizations, or other actors' voices were most prominent within each domain. Our results show inconsistent framings of wildfire risk definition across the data, building upon past literature that has identified divides between fire suppression and mitigation work, as well as disconnects between media representations of fire and perspectives of resource managers and scientists. Lastly, we highlight two examples of cross-cutting discourses - public drinking water and smoke – as concepts that span boundaries and may have the power to generate broader coordination and support for wildfire policy solutions and action.

   b. **Code Descriptions for "Managed wildfire: A strategy limited by terminology, risk perception, and ownership boundaries."**

      URI: https://scholarsbank.uoregon.edu/xmlui/handle/1794/26917

      Authors: Davis, Emily Jane; Huber-Stearns, Heidi R.; Cheng, Antony S.; Deak, Alison; Evans, Alexander; Caggiano, Michael; McAvoy, Darren J.

      Abstract: Federal land managers in the United States are permitted to manage wildfires with strategies other than full suppression under appropriate conditions to achieve natural resource objectives. However, policy and scientific support for "managed wildfire" appear insufficient to support its broad use. We conducted case studies in northern New Mexico and southwestern Utah to examine how managers and stakeholders navigated shifting barriers and opportunities to use managed wildfire from 2018-2021. Use of managed wildfire was fostered through an active network of civil society partnerships in one case, and strong interagency cooperation and existing policies and plans in the other. In both, the COVID-19 pandemic, drought, and agency direction curtailed recent use. Local context shapes wildfire response strategies, yet centralized decision making and policy also can enable or constrain them. Future research could refine understanding of social factors in incident decision making, and evaluation of risks and tradeoffs in wildfire response.

c. **Code Descriptions for "Spanning boundaries for managing wildfire risk in forest and range landscapes: Lessons from case studies in the western United States."**
URI: https://scholarsbank.uoregon.edu/xmlui/handle/1794/26916
Authors: Huber-Stearns, Heidi R.; Davis, Emily Jane; Cheng, Antony S.; Deak, Alison.
Abstract: Managing wildfire risk across boundaries and scales is critical in fire-prone landscapes around the world, as a variety of actors undertake mitigation and response activities according to jurisdictional and administrative boundaries; and available human, organizational, technical, and financial resources. There is a need to catalyze their coordination more effectively to collectively manage wildfire risk. We interviewed 102 people across five large landscape case studies in the western US to categorize how boundary spanning people, organizations, settings, concepts, and objects were deployed in range and forestlands to collectively address wildfire risk. Across all cases, actors spanned jurisdictional, conceptual, and administrative boundaries to create: 1) conductive settings for boundary work to occur; 2) concepts to communicate across boundaries; and 3) concrete objects as joint reference points, and to navigate challenges to implementing work on the ground. This work highlights context-specific ways to advance cross-boundary wildfire risk reduction efforts, and uses a boundary spanning lens to provide insight into how collective action in wildfire management evolves in different settings. This research also shows prescribed fire as a gateway for future collective action in wildfire risk, including managing naturally ignited wildfires for resource benefits or improved coordination and communication during wildfire suppression efforts.

2. **National Environmental Policy Act documents, community wildfire protection plans, media coverage, and collaborative group organizational documents**
We did not archive the following secondary data as they were all publicly accessible or privately obtained from sources involved in collaborative efforts. However, the coded components of these data sources used in this content analysis, along with the corresponding analysis codes and constructs have been stored at this Scholars' Bank link. The following secondary data sources were each used in content analysis, as further detailed in the JRR_readme.txt document archived at the above link.
   i. ***Arapaho-Roosevelt National Forest National Environmental Policy Act (NEPA) project documents.*** This publicly available database provides NEPA documents for all proposed actions on the Arapaho-Roosevelt National Forest Canyon Lakes Ranger District. Published NEPA documents (i.e., records of decision, decision memos, categorical exclusions, and decision notices) obtained from the official US Forest Service site that were relevant to forested watershed wildfire risk reduction in the categories of fuels management, grazing management, and forest products were analyzed. Fourteen total NEPA documents from our study period (2008-2018) that met our criteria were examined in the content analysis.
   ii. **Larimer County Community Wildfire Protection Plans (CWPPs).** CWPPs are local wildfire protection plans developed by communities for local wildfire response, hazard mitigation, structure protection or preparedness of the community for preventing and responding to catastrophic wildfire. CWPPs vary in geographic scope, and for this study all 26 CWPPs available for the study area were analyzed (including one at the Larimer County scale).
   iii. ***Media coverage from the Denver Post news archive.*** The Denver Post is Colorado's largest circulation paper. We identified fourteen total fire names through a query search of historical fire data from Geomac.gov (geospatial fire data clearinghouse) for Larimer County between 2008 and 2018. We searched the names of all identified fires within *The Denver Post* news archive on Newsbank.com to find articles mentioning the respective fire names and downloaded the resulting news articles. Of the 164 news articles found in *The Denver Post,* 89 were kept for analysis. Articles were discarded if the

fire was not the primary focus of the article, if the article was less than two sentences in length, or if it was a duplicate.

iv. ***Northern Colorado Fireshed Collaborative (NCFC) organizational documents.*** NCFC organizational documents, including structure and agreement documents and meeting notes from collaborative group meetings between 2008 and 2018, were obtained from NCFC leaders and members and verified by a key informant.

3. Land ownership, fire, and population data

We did not archive the following secondary data that was used solely for geospatial analysis. These data were all publicly accessible and we did not create new variables, analyses, metadata or other data which would be appropriate for archiving. Below we list the sources and types of secondary data used for these analyses.

i. ***Population data and county shapefiles from the United States Census Bureau.*** 2018 US Census data were used to estimate the population of the Idaho, Oregon, and Utah case studies as this was the most recent estimate available for Census Defined Places (CDPs) within the case study boundaries. 2010 US Census data were used to estimate the population of the New Mexico case study as this was the most recent available population estimate available for CDPs within the case study boundaries. County shapefiles for the Idaho, Oregon, Utah, and Colorado Shapefiles were also used from the Census for data visualization

ii. ***Population data from Colorado State Demography office.*** The Colorado State Demography Office provides population estimates for each county in Colorado based on US Census data. 2010 population data from this data set was used to estimate population within the Colorado case study.

iii. ***Rio Grande Water Fund Boundary shapefile.*** This shapefile was used to visualize the New Mexico case study area.

iv. ***Land ownership data from the US Geological Survey Protected Areas Database of the U.S. (PAD-US).*** This database provides a regularly revised inventory of land ownership data in the United States. We downloaded data from this source in 2020 to quantify and visualize land ownership within and between case studies using the following PAD-US land ownership classifications: (1) Bureau of Land Management; (2) Forest Service; (3) National Park Service; (4) American Indian Areas; (5) state and local, consisting of state trust land, state fish and wildlife, state park and recreation, other state (NHP, DOT, HS, etc.), county/regional agency land, and city land; and (5) other, consisting of all other PAD-US identified land ownership categories not classified above

v. ***US Forest Service Monitoring Trends in Burn Severity National Burned Area Boundaries Dataset.*** This dataset provides boundaries of all burned areas greater than 1,000 acres in the western United States beginning in 1984. We used these data to quantify and visualize burned areas between 1984 and 2015 within each of our case studies.