FINAL REPORT

Title: Policy Barriers to Prescribed Fire: Identifying Opportunities and Mechanisms for Change

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LIST OF ABBREVIATIONS AND ACRONYMS

BLM: Bureau of Land Management
CSU: Colorado State University
DEQ: Department of Environmental Quality
EPA: Environmental Protection Agency
EWP: Ecosystem Workforce Program
NAAQS: National Ambient Air Quality Standard
NEPA: National Environmental Policy Act
NFMA: National Forest Management Act
NGO: Nongovernmental Organization
PM10: Inhalable particles, with diameters that are generally 10 micrometers and smaller
USDA: United States Department of Agriculture
USDOI: United States Department of Interior
USFS or Forest Service: USDA Forest Service

KEYWORDS

Air quality; policy barriers; prescribed fire, agency capacity, leadership, training

ACKNOWLEDGEMENTS

ABSTRACT

Prescribed fire is an essential management tool for restoring and maintaining the resilience of fire-dependent ecosystems. Past studies indicated that the current policy environment significantly constrained decision-making around prescribed fire (USDA & USDOI 2014). This study utilized a mixed methods approach involving spatial analysis, legal analysis, and case studies to identify which policies present the greatest opportunities for change and what the mechanisms are for realizing those opportunities. Our objectives were to: 1) understand the origins of key policy barriers to increasing prescribed burning in the western United States, 2) identify opportunities and mechanisms for change, and 3) disseminate results to policy makers and the fire management community to accelerate learning and change. Key findings can be organized into three sections: spatial, legal, and case studies analyses.

Spatial analyses showed that existing air quality regulations do not appear to have constrained prescribed burning. Air quality measurements on both burn and non-burn days were, for the most part, below EPA thresholds for permitting prescribed burns. There were some notable significant differences in air quality between burn and non-burn days, and in air quality measurements across both state and regional levels, most notably with ozone, PM2.5, PM10, CO_2 and NO_2.

Legal analysis and qualitative interviews showed that air quality laws and regulations were not significant barriers to prescribed burning in most states. Notable exceptions included Oregon and Washington, where state standards for regulating air quality are relatively stricter. Every state was unique in its regulatory structure and interagency partnerships for overseeing air quality impacts from prescribed burning. Case study analysis further indicated that regulations and permitting were not the primary factors limiting the application of prescribed fire in most western states. Rather, key barriers that we identified included: lack of funding and workforce capacity (both field and administrative staff), difficulty sharing resources across and within agencies, administrative barriers and lack of capacity, perceived riskiness and liability for escaped burns, lack of prioritization of prescribed burning compared to wildfire suppression, communication and outreach challenges, and some place-specific challenges. USFS and BLM units were overcoming these challenges through strong leadership, collaborative partnerships and resource-sharing arrangements, building relationships with air quality regulators, seeking additional smoke monitoring, and using more efficient and flexible approaches to planning for opportunities to burn.

Our goal was to identify policy solutions to facilitate more prescribed burning across the West. Notably, we did not find consistent calls for federal policy change. Rather, we found that a multiplicity of strategies that can be tailored to different places will be necessary to increase prescribed burning. We identified four interrelated recommendations for the Forest Service, BLM, and their partners: (1) Prioritize and support prescribed fire with more staff capacity, especially during fire season; (2) Incentivize leaders and staff to build and sustain successful prescribed fire programs; (3) Increase funding and efficiencies for resource sharing, air quality monitoring, and planning; and (4) Ensure regular and consistent air quality-land manager communication through state-level collaborative forums and smoke management liaisons.

OBJECTIVES

This study used a multi-method research approach to: 1) understand the origins of key policy barriers to increasing prescribed burning in the western United States, 2) identify opportunities and mechanisms for change, and 3) disseminate results to policy makers and the fire management community to accelerate learning and change. We met all project objectives, which are listed below as they were stated in our project proposal.

Objective 1— Identify where current perceived policy barriers to implementing prescribed fire originate, intersect, and afford room for discretionary interpretation. We characterized the policy factors that affect prescribed fire application by the Forest Service and Bureau of Land Management (BLM) across the West using both spatial and legal analysis. We conducted a spatial analysis of the extent to which air quality conditions vary spatially and also characterized the legal-administrative structure that governs prescribed fire application, focusing on air quality regulation.

Research Questions:
1. How does prescribed fire vary spatially and by agency across the American West and to what extent does air quality condition explain the spatial variability in prescribed fire?
2. What is the legal-administrative structure surrounding prescribed fire, which policy barriers are fixed in law and regulation, which are a result of federal versus state policy, and where is there room to interpret existing laws and regulations in new ways?

Hypothesis 1.1. Variability in air quality is a significant, primary determinant of prescribed fire application.
Hypothesis 1.2. Current air quality regulations and other environmental laws and policies provide for more agency discretion than is currently perceived, and, therefore, there are opportunities to re-interpret air quality regulations at the state level and to modify current federal applications of other environmental regulations to increase prescribed fire use without legislative change.

Objective 2— Characterize actionable opportunities and available mechanisms for overcoming policy barriers.
We identified the primary barriers and actionable opportunities for overcoming barriers at multiple scales, from national policy revisions to changes in agency and individual practice in the field. We conducted interviews to characterize barriers across the West and then utilized case studies to examine how these barriers play out at the field level and how field units are working to overcome long-standing barriers to increase prescribed fire accomplishments.

Research Questions:
1. What are the actionable opportunities for overcoming policy and non-policy barriers in national- and state-level policy interpretation and what are the mechanisms for accomplishing change?

2. Where increases in prescribed fire application have occurred, how have field-level managers overcome perceived barriers and what factors have supported them?

<u>Hypothesis 2.1.</u> Policy makers and agency personnel can identify a subset of policy barriers that are interpreted with flexibility and where existing, perceived barriers can be addressed by changing regulations, agency guidance, and/or organizational practice.
<u>Hypothesis 2.3.</u> Units that have increased prescribed fire accomplishments will have found success at the local level by utilizing novel planning approaches and collaborating with regulators and stakeholders.

Objective 3— Disseminate key findings and lessons to policy makers, managers with land management and regulatory agencies, and other stakeholders and scholars invested in increasing in prescribed fire to meet land management objectives. We identified opportunities and mechanisms for overcoming existing barriers to prescribed fire implementation. We shared findings through direct visits with policy makers, presentations to the fire management community, and passive delivery through publications, working papers, and news articles (see Table 2, Appendix B for a full list of outreach accomplishments).

BACKGROUND

As stated in our project proposal (Schultz et al. 2015), prescribed fire is an essential management tool for restoring and maintaining the resilience of fire-dependent ecosystems; however, land managers have been unable to apply prescribed fire at the necessary levels to achieve land management objectives (Ryan et al. 2013). Past survey research identified a suite of barriers, many of which reside in law and policy, that fire management officers and other on-the-ground staff believed have restricted their ability to implement prescribed fire (Cleaves et al. 2000, Quinn-Davidson & Varner 2012). Fire managers indicated that air quality regulations were the most significant barriers to undertaking prescribed fire (Cleaves et al. 2000; USDA & USDOI 2014). Other policy barriers included restrictions under the Endangered Species Act (ESA) and requirements for protecting other sensitive species and their habitats (Cleaves 2000, Quinn-Davidson & Varner 2012). Environmental planning laws, such as the National Environmental Policy Act (NEPA) and National Forest Management Act (NFMA) were also identified as barriers (Cleaves et al. 2000). These studies indicated that the current policy environment, which resides in multiple regulatory and land management laws and policies, significantly constrained decision-making around prescribed fire (USDA & USDOI 2014).

Figure 1. The influence of law and policy on prescribed fire decision-making. From Schultz et al. 2015.
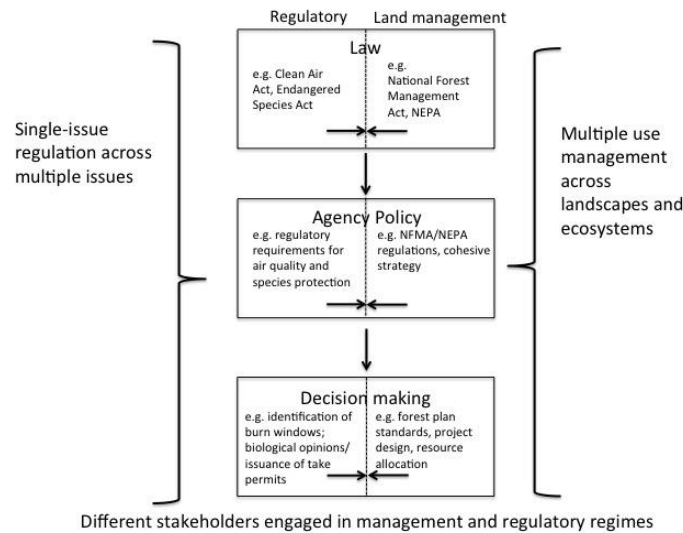
The purpose of this project was to increase understanding of which policies present the greatest opportunities for change and mechanisms for realizing those opportunities. In particular, we sought to identify if and how laws or federal policies have acted as a barrier to prescribed burning, or if barriers were a result of habit, culture, individual discretion, state-level policy interpretations, or lack of political will that was attributed to federal policy. To identify key leverage points, we distinguished between policy barriers that are fixed in congressional laws; those that are a result of state or federal agency policy (e.g., regulations and agency guidance); those that are a result of agency culture or habit; and barriers that are a result of individual decision-making at the field level, where decisions may be influenced by factors such as the social environment in which decision-makers act and their individual degree of risk-aversion (Figure 1; Moseley and Charnley 2014). Each policy barrier presents different opportunities and mechanisms for change. Regulations require executive action, while substantial changes to agency and individual behavior require improved communication, leadership, and changes in incentive structures (Fernandez & Rainey 2006).

MATERIALS AND METHODS

This study utilized a mixed methods approach involving spatial analysis, legal analysis, key informant interviews, and case studies. Below we have detailed our materials and methods by project phase and task number.

Phase 1 Materials and Methods

Task 1. Develop regression and geographically weighted regression models to understand the degree to which variability in localized air quality and weather explain the variability in prescribed fire across land management units (Obj. 1).

We performed an extensive statistical analysis that examined the relationship between the location of prescribed fire accomplished by field unit (national forest and BLM field office) and estimated local air quality measurements on the day that prescribed fire was accomplished. The analysis aimed to address three main queries that fall under RQ1: (i) to what degree have prescribed burns in the Western U.S. been constrained by federal air quality regulations?; (ii) were air quality measurements significantly different on days when prescribed fire was implemented versus days that were absent of prescribed fires?; and (iii) are some states more constrained from specific air quality regulations than others? We partitioned prescribed fires into those administered by the USFS and BLM. Data on prescribed fire were accessed from the U.S. National Fire Plan Operations and Reporting System (NFPORS), an inter-agency reporting system that is maintained through a collaboration between the USDOI and the U.S. Department of Agriculture (USDA). We chose the NFPORS dataset for this study because it provided abundant point location data for historical prescribed burns that were administered by both the USDOI and USFS regardless of fire size. It also classified points based on the type of prescribed burn enacted: broadcast burn, jackpot burn, hand pile burn, and machine pile, of which only the first two are of interest to this study as they pertain to fuel treatment (while the latter two focus on the burning of vegetation piles resulting from management activities).

We analyzed data from 2007 to 2014 because we were able to obtain consistent prescribed fire and air quality data for this period. We assigned each prescribed fire location with air quality measurements from the closest air quality monitoring station on the day of the prescribed burn. To address the first two queries, we performed a Kruskal-Wallis one-way analysis of variance test to determine if air quality measurements differed significantly between days when prescribed fires took place (burn days) versus those days when prescribed fires were absent (non-burn days). In addition, we examined frequency plots comparing relative frequency of air quality measurements between burn and non-burn days to determine if observable patterns in air quality conditions for prescribed burning could be detected, specifically relative to the threshold set by the EPA for each measurement. To address the third query, we compared air quality measurements across states on burn days to determine if prescribed burning took place in significantly different air quality conditions. We performed a separate Kruskal-Wallis test for each air quality measurement using the values on burn days for each state as individual samples. Next, we performed a post-hoc Dunn's test to determine which states differ from one another. The Dunn test provided a test statistic and a p-value stating the level of significance in determining independence between samples so that we could draw conclusions about whether or not states burn under different air quality conditions.

Task 2. Perform a legal analysis to identify which barriers are fixed in law and high-level policy and which are subject to discretionary interpretation (Obj. 1).

We built a legal framework and appendix to characterize the land management and regulatory laws and administrative policies at the federal level and state level (for air quality regulations) that governed the use of prescribed fire (Schultz et al. 2018, Quirke 2018). We used standard legal research methods (Algero et al. 2012) to build a description of the relevant statutory, regulatory, and policy landscape for evaluating policy barriers to the use of prescribed fire. These

methods included: evaluation of the statutory language and its legislative history for each statute; examination of implementing regulations that the responsible agencies have promulgated to carry out the statutory mandate; analysis of any agency guidance or policy documents that are applicable to the agencies' decision-making process; and review of any judicial decisions that have interpreted the statutory, regulatory, or guidance language. We began with an analysis of the major policies that constrained prescribed fire, including a detailed investigation of state-level air quality regulation under the federal Clean Air Act. For the state-level investigation, we initially identified references to prescribed fire, smoke management, and visibility or regional haze in state implementation plans (SIPs), which are required by the Clean Air Act. We reviewed state laws pertaining to prescribed fire and additional state laws, policies, or plans relevant for prescribed fire on federal lands.

Subsequent interviews with practitioners (Task 3) generally revealed more specific details regarding the implementation of laws and policies on the ground and brought to light additional laws and policies having an effect on implementation of prescribed fire. We reviewed these as necessary to complete our legal analysis.

Task 3. Conduct key informant interviews to identify the range of interpretation of policy barriers across agencies and regions and identify actionable opportunities and mechanisms for change (Obj. 1&2).

We conducted key informant interviews to build upon our legal analysis and gain a more comprehensive understanding of the degree of interpretation among policy barriers and opportunities for policy change. We interviewed high-level policy makers, personnel in the regulatory and land management agencies, and key stakeholders acting at regional and national levels. A better understanding of the degree of policy interpretation helped us to understand how perceptions about policy barriers varied by region and agency. Additionally, we investigated opportunities and avenues for change, which included amending the content and interpretation of federal and state-level regulations and expanding flexibility, either through regulatory or organizational change. Interviews allowed us to identify the opportunities for actionable policy change, as opposed to those that are unlikely to be successful, due to lack of either feasibility or political support.

We identified interviewees using purposive sampling (i.e., based on individuals' positions and areas of expertise) and snowball sampling (i.e., based on recommendations from other interviewees or contacts) (Singleton & Straights 2005). Our approach included interviewing a fuels program manager and smoke management liaison (where these existed) for the BLM and Forest Service in each state. We also reached out to state forestry agencies to identify a contact for each state, and to state departments of environmental quality to include perspectives from air quality regulators. In the states where they existed, we also spoke to chairs of prescribed fire councils. We targeted at a minimum one Forest Service, one BLM, one state forestry, one air quality regulatory, and one prescribed fire council individual for all 11 states. Our total number of interviews was 56, with some state-to-state variation. We interviewed until we approached information saturation of information regarding our research questions (Schultz et al. 2018). Our semi-structured interviews (Charmaz 1991) focused on: 1) goal-setting processes and progress

towards goals for the land management agencies; 2) regulatory processes for regulatory agencies; 3) barriers to increasing accomplishments; 4) strategies/suggestions for increasing prescribed fire, and 5) the role of partners and communication in supporting the use of prescribed fire.

We analyzed interviews by recording, transcribing, and coding for themes according to standard qualitative data analysis techniques (Singleton & Straights 2005). We utilized a modified grounded theory approach (Strauss & Corbin 1990). This process involved identifying themes and developing codes to label recurrent themes within transcriptions. We identified the most relevant barriers and differences in policy interpretation between regions, agencies, and personnel within agencies; this helped us to understand where opportunities exist to promote or limit policy interpretation, as well as the most promising avenues for overcoming barriers. We coded for key opportunities for overcoming policy barriers, priorities, and the specific pathways for accomplishing change.

Phase 2 Materials and Methods

Task. 4. Conduct case studies where units have increased their prescribed fire accomplishments to understand opportunities and mechanisms for overcoming policy barriers (Obj. 2).

We planned to use our weather and air quality model to randomly sample five units that have increased their application of prescribed fire but changed our approach to a purposeful case study selection based on findings from Phase One. We selected case studies for Phase Two based on geographic representation and diverse land management contexts, and prioritized places that were increasing the amount of prescribed burning or were employing innovative strategies to accomplish their burn programs. We identified potential case studies by asking all interviewees during Phase One for recommendations of units across the West that might serve as exemplars for other units.

In Phase One we discovered the importance of cross-jurisdictional partnership for increasing prescribed burning, so we also decided to select four case studies, two of which were joint BLM-Forest Service case studies, rather than five single-jurisdiction case studies as originally proposed. To allow for cross-regional analysis, each case came from a different Forest Service region/BLM state. Case studies included document review (e.g., land management plans, internal policy guidance, and NEPA documents) and semi-structured interviews. We identified interviewees and conducted interviews with the same methodology utilized in Task 3: utilizing purposive and snowball sampling to identify interviewees and interviewing until we approached information saturation. We interviewed line officers, fire management officers, interdisciplinary team leaders, local regulators, and key stakeholders (e.g., members of local prescribed fire councils, fire program managers with organizations such as The Nature Conservancy and Forest Stewards Guild that partner closely with land management agencies). In total we heard from 62 interviewees across 53 interviews (between 11 to 22 interviewees per case study).

Interview questions focused on three themes:

- Barriers and facilitators to prescribed burning: Which policies and other factors have historically acted as barriers to increasing the use of prescribed fire? How have interviewees found ways to overcome barriers? What barriers have not been overcome and why?
- Context: Which factors are most relevant for determining the nature of the prescribed fire program on the unit? For example, how do non-policy factors, such as leadership, collaboration with partners, or strategic agency investments, interact with policies to affect the prescribed fire program? How have accomplishments changed over time and what has been the unit's history with prescribed burning?
- Recommendations: How could the gains made in this case be replicated elsewhere or at larger scales?

We analyzed interviews according to methods outlined under Task 3. Our analysis then involved identifying themes to understand the confluence of factors that explain outcomes for the case. Our analysis also considered how cases compared to each other and the identification of variables that either consistently encouraged successful outcomes across cases or that were specific to local contexts. We identified themes within and across case studies to highlight how stakeholders overcame policy barriers, how local conditions were relevant, how strategies were tailored to local contexts, and factors that consistently contributed to success (Schultz et al. 2020a, Schultz et al. 2020b). Partnerships emerged as an important theme so we further examined the diversity of partners and the roles they played with respect to accelerating prescribed fire (Huber-Stearns et al. in review).

Task 5. Integrative analysis.

Our study concluded with integrative analysis of findings across tasks, building upon our mixed methodology for investigation, to characterize the relative influence of policy barriers, their origins and interpretation, and the key opportunities and mechanisms for change. We synthesized findings to clarify the specific role of law and policy in constraining prescribed fire, the relative influence and degree of interpretation among policy barriers, and how these vary between the agencies and across the West. We also synthesized findings to highlight the importance of capacity to accomplish prescribed fire, much of which is accomplished through governance and organizational change at multiple scales. These synthesized findings from across our research provided high-level policy perspectives on transforming fire management (Schultz and Moseley, 2019), and more detailed information on specific partner capacities (Schultz et al. 2020 and Huber-Stearns et al. in review). Our conclusions address how different actors can capitalize on opportunities to overcome barriers through mechanisms at multiple levels of government.

Task 6. Write up results and conduct presentations and briefings for diverse audiences.
and Task 7. Conduct science delivery in collaboration with fire consortia and prescribed fire councils.

We met or exceeded all proposed deliverables for this project (Table 1; Appendix B) with the exception of briefing paper, as we were not able to do in-person briefings, and an in-person workshop that was cancelled due to COVID-19. Our manuscripts differed somewhat in content

from our proposal, as we adapted our deliverables to the identified needs, findings, and policy implications of our research. Our deliverables are further detailed in the results section.

Table 1. Description of planned and actual deliverables. See Appendix B for complete list.

Deliverable	Planned	Actual
Refereed publications	Four peer-reviewed publications	**We developed four peer review manuscripts:** 1. Schultz, C.A., McCaffrey, S., Huber-Stearns, H. 2019. Policy barriers and opportunities for prescribed fire application in the Western United States. *International Journal of Wildland Fire* 28, 874-884 2. Schultz, C.A., Moseley, C. 2019. Collaborations and capacities to transform US fire management. *Science* 366(6461), 38-40 3. Bone, C. et al. In review. Evaluating air quality conditions during prescribed fire events across the Western U.S. *Applied Geography*. 4. Huber Stearns, H., et al. In review. Network governance in the use of prescribed fire: What roles for bridging organizations and other actors in the western United States? *Regional Environmental Change.*
Conferences	Two applied research conference presentations (e.g., ISSRM; Human Dimensions of Wildfire) and one at the Colorado Wildland Fire Conference	**We presented results at six research conferences:** 1. Southwest Ecological Restoration Institutes Cross-Boundary Landscape Restoration Conference (March 2020, Albuquerque) 2. 8th International Fire Ecology and Management Congress (Nov. 2019, Tucson) 3. 7th International Fire Ecology and Management Congress (Nov. 2018, Orlando) 4. High Altitude Revegetation – Society for Ecological Restoration-Rocky Mountains Conference (May 2018, Fort Collins) 5. Fire Continuum Conference (May 2018, Missoula) 6. Society of American Foresters National Convention (2018)
Non-refereed publications	Two Ecosystem Workforce Program working papers and associated briefing papers	**We developed eight non-refereed publications:** 1. Schultz, C., H. Huber-Stearns, S. McCaffrey, D. Quirke, & G. Ricco. 2017. Policy Barriers to Prescribed Fire. Colorado State University Public Lands Policy Group Briefing paper #1. 2. Schultz, C., H. Huber-Stearns, S. McCaffrey, D. Quirke, G. Ricco, and C. Moseley. 2018. Prescribed Fire Policy Barriers and Opportunities: A Diversity of Challenges and Strategies Across the West. 3. Quirke, D. 2018. Legal appendix: An overview of the Clean Air Act and state-level air quality regulation. 4. Schultz, C.A., C. Moseley. 2018. "Better forest management won't end wildfires, but it can reduce the risks – here's how." The Conversation, November 20, 2018 5. Schultz, C.A., C. Moseley, H. Huber-Stearns. 2019. "Planned burns can reduce wildfire risks, but expanding use of 'good fire' isn't easy." The Conversation, April 25, 2019. 6. Northwest Fire Science Consortium. 2020. "Policy Barriers & Opportunities for Prescribed Fire Application in the Western US." Research Brief #22. 7. Schultz, C., A. Santo, H. Huber-Stearns, and S. McCaffrey. 2020a. Strategies for Increasing Prescribed Fire Application on Federal Lands: Lessons from Case Studies in the U.S. West. 8. Schultz, C., A. Santo, H. Huber-Stearns, S. McCaffrey. 2020b. Appendices: Case Study Details.
Presentations	8-10 policy briefings in Washington, D.C. with policy makers who could use our information to further policy change. We also will coordinate presentations with our local prescribed fire councils.	We briefed ~20 policy makers in Washington, D.C. We presented to five local councils, collaboratives, or practitioners (e.g. Rural Voices for Conservation Coalition, California Fire MOU Partnership, North America Forests Workshop; see Appendix B for a complete list).
Webinars	Two webinars on our findings (with the fire science consortia)	We conducted two webinars with the Southwest and Northwest Fire Science Consortia in November 2018 and January 2020 with hundreds of attendees.
Workshop	Hold workshop in OR or WA with NWFSC to disseminate results to fire managers and air quality regulators.	Due to the COVID-19 pandemic, we did not hold an in-person workshop.

Study Sites

Our study focused on National Forest System and BLM lands in the 11 western states. The Forest Service and BLM manage more land and conduct more prescribed fire across these states than any other land management agency (NIFC 2015). We focused on the West because of the prevalence of public land in these states, the existence of extensive fire-dependent ecosystems, and the relative paucity of research in this area compared to other regions, such as the Southeast (e.g., Kobziar et al. 2015). The legal analysis included land management policies and regulatory policies across this geography relevant to managing public lands but controlled by multiple agencies. The case studies involved specific national forests and BLM districts located within the 11 western states, including: the Tres Rios Field Office of the BLM's Southwest District and the San Juan National Forest in Colorado, the Socorro Field Office of the BLM's Albuquerque District and the Cibola National Forest in New Mexico, the Sierra National Forest in California, and the Rogue River-Siskiyou National Forest in Oregon (see Figure 2).

Figure 2: Map of case study areas

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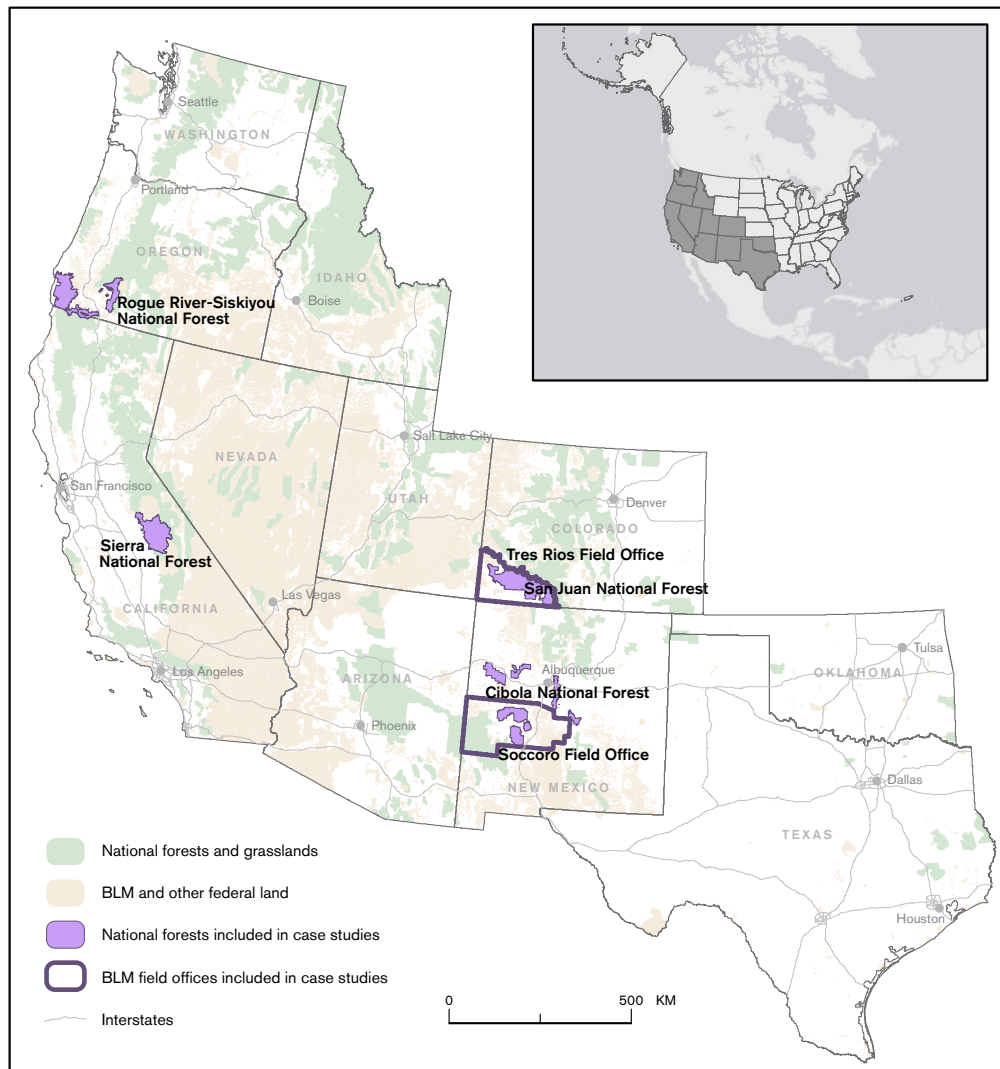
RESULTS AND DISCUSSION

Phase 1 Results and discussion

Task 1. Develop regression and geographically weighted regression models to understand the degree to which variability in localized air quality and weather explain the variability in prescribed fire across land management units (Obj. 1).

Our findings present an initial broad-scale look into how air quality regulations affect prescribed burning across the Western U.S. Existing air quality regulations do not appear to have constrained prescribed burning. Frequency distributions show that air quality measurements on both burn and non-burn days were, for the most part, below EPA thresholds for permitting prescribed burns. In fact, most days during the burning window exhibited very low air quality pollutant observation values relative to the respective thresholds. Prescribed burns did take place on some days when the threshold was surpassed, but the infrequent nature of these occurrences suggested that these were anomalous and a result of other events affecting air quality. These results lead us to reject Hypothesis 1.1.

Results also suggest that there were significant differences in air quality between burn and non-burn days for all states, although results vary by air quality measure. However, the frequency plots for each measure demonstrated that differences did not appear to be related to air quality permitting thresholds. One notable exception was ozone. Unlike all other measurements, ozone exhibited relatively normal distributions of observations for both burn and non-burn days, and observations were closer to the threshold than for other measurements. In Arizona and California ozone levels were notably higher on a number of burn days compared to non-burn days (i.e. the burn day frequency plot was slightly to the right of non-burn days), which could imply that these states had prescribed burn windows that were subjected to higher ozone levels (but still, for the most part, below allowable levels), while other states were administering prescribed burns during times when ozone levels were notably lower. Further analysis of the relationship between ozone and prescribed burns could assist in future planning, especially given projections of ozone level increases under future climate change scenarios.

Our results further indicated significant differences between states' air quality measurements on burn days, but these differences were measurement specific. The most notable discrepancy was in PM2.5 measurements, as California (for USDOI-administered burns) and Idaho (for USFS-administered burns) were significantly higher in PM2.5 than most other states. The remaining states were similar to one another. Other measurements, such as CO_2 and NO_2, were significantly different between states, suggesting that states administered prescribed burns under a wide range of air quality conditions.

Beyond these general observations, we found regional differences in some air quality measurements. CO_2, for example, was highest in the northernmost states (ID, MT, and WA). Similarly, Colorado, New Mexico, and Utah had significantly higher concentrations of PM10 during burn days than other states. While it is difficult to fully unpack these results, the findings

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indicate a need to consider regional air quality permitting, especially given that policy impacting air quality in one state is very likely to impact the ability of a neighboring state to administer prescribed burning.

Finally, results showed that small differences in air quality observations between prescribed fires administered by the USDOI versus the USFS were negligible when considering the differences between burn and non-burn days. Therefore, we conclude that although the USDOI and USFS administer prescribed burns under somewhat different conditions, these differences are not significant as neither agency appears to be constrained by air quality regulations.

Task 2. Perform a legal analysis to identify which barriers are fixed in law and high-level policy and which are subject to discretionary interpretation (Obj. 1).

Our detailed analysis of laws that affect the use of prescribed fire is available in a technical appendix (Quirke 2018; see Table 1) and we present key findings here. Policy in this area is complex, and a concise explanation of how regulation works under the Clean Air Act may be necessary in order to interpret our findings (see Schultz et al. 2018, p. 7).

Our legal analysis showed that every state was unique in its regulatory structure and interagency partnerships for overseeing air quality impacts from prescribed burning (Table 1). Most states had a Department of Environmental Quality (DEQ) or equivalent office that handled air quality permitting for prescribed burning. Exceptions included, among others, California, where the California Air Resources Board oversaw 30+ air pollution districts or control boards that handle permitting for specific areas.

All states had unique permitting processes that depended on their smoke management plans, regulatory structure, and local considerations (see Table 2 for state-by-state overview). Some states, like New Mexico and Wyoming, had a permit-by-rule system, whereby burners were required to register burns and notify DEQs about burning activities, but did not receive a permit. In Colorado and Washington, air quality agencies wrote permits for each burn plan, usually with daily acreage limits that varied depending on ventilation conditions. In other states, such as Montana and Idaho, the DEQ wrote a single permit for the entire year for each "major burner," a category that included each land management agency. During much of the burn season, daily coordination calls were held between DEQ and with major burners to minimize conflicts and potential smoke impacts. In Arizona, burners registered their burns and smoke management prescriptions with the DEQ annually and then sought a daily permit, based on daily conditions and considerations. Permitting in California proceeded similarly, with annual registration of planned burns in the Prescribed Fire Information Reporting System and then a daily coordination call to communicate whether burning was allowable on a particular day and for coordinating and approving planned burns within 24 hours of ignition. States generally required 24-hour-prior notification of plans to burn and postburn reporting

Oregon and Washington had relatively stricter state standards for regulating air quality. Both states limited smoke intrusions into communities, even in cases where intrusions would not have caused an exceedance of a National Ambient Air Quality Standard (NAAQS). For example, a

prescribed fire might have resulted in a temporarily unhealthy level of smoke that the state regulator deemed intolerable, even when it might not have triggered an exceedance if the NAAQS is based on a 24-hour standard. Both Oregon and Washington were revising their smoke management plans, which required demonstration to EPA that changes to regulation would not lead to a greater chance of an exceedance of a NAAQS.

Table 2. State-by state overview of air quality regulatory process and interagency relationships to support burning.

	Regulatory overview: Responsible agencies and applicable law	Prescribed fire planning and approval[11]
Arizona	Arizona Department of Environmental Quality (ADEQ)	Land managers must make best efforts to register all planned burn projects before December 31 each year, but no later than January 31
	Arizona Administrative Code	ADEQ required to hold meeting after January 31 and before April 1 between ADEQ and land managers to evaluate program and cooperatively establish "annual emission goal" ("planned quantifiable value of emissions reduction from prescribed fires and fuels management activities")
		Land managers must submit burn plans to ADEQ at least 14 days before burn date
		Daily burn request must be submitted to ADEQ by 2 P.M. on business day preceding burn
		ADEQ approval of request required before ignition, with constructive approval where explicit approval is not received from ADEQ by 10 P.M. on the day request was submitted (burner must make effort to confirm that request was received by ADEQ)
California	California Air Resources Board and California's 35 air districts	Smoke management programs for air districts with "prescribed burning in wildlands or urban interfaces" must include annual or seasonal registration of all planned burn projects; burns are registered online in Prescribed Fire Information Reporting System (PIFRS)
	Smoke Management Guidelines for Agricultural and Prescribed Burning (codified in California Code of Regulations)	Each of California's 35 air districts must have a smoke management program that includes a daily burn authorization system
		Air districts' burn authorization systems issue "48-hour forecasts, 72-hour outlooks, and 96-hour trends" for burns
		Air district burn authorization systems must include procedures "for authorizing . . . prescribed burns 24 hours prior to ignition"
		By 3 PM each day, California Air Resources Board must normally announce whether following day is a "permissive burn day" or a "no-burn day" for each of California's 15 air basins
Colorado	Colorado Air Quality Control Commission	Significant users of prescribed fire must submit planning documents to Colorado Air Quality Control Commission for each area in which the user intends to use prescribed fire addressing the use and role of prescribed fire and resulting air quality impacts
	Colorado Department of Public Health and Environment or an authorized local agency	Air Pollution Control Division of Colorado's Department of Public Health and Environment must review planning documents and present comments and recommendations to the Commission
	Colorado Code of Regulations	Commission must hold a public hearing and complete review within 45 calendar days of receipt unless significant user of prescribed fire agrees to longer review period
	Colorado Smoke Management Program Manual	APCD may take up to 30 days to review permit application
		"Notification of Ignition" must be submitted 2 to 48 hours before ignition
		"Daily Actual Fire Activity" report due by 10:00 AM on business day following each proposed ignition day

Regulatory overview: Responsible agencies and applicable law	Prescribed fire planning and approval[11]
Idaho/Montana Montana/Idaho Airshed Group with Missoula-based "Smoke Management Unit" that coordinates/administers Idaho and Montana DEQs and local regulatory authorities also have roles Montana/Idaho Airshed Group MOU committing to agreed-upon smoke management program and operating guide Idaho and Montana DEQ regulations	Preseason burn lists entered into Airshed Management System between Dec 1 and Feb 28 for Spring Season burns (March 1 to May 31) and between June 1 and Aug 31 for Fall Season burns (Sep 1 to Nov 30) "Burns that will require more than one consecutive day of ignition to complete require additional coordination" "Special notification and direct approval from both DEQs" required for "Extended-duration Landscape-scale Prescribed Burns" ("ignited and managed over weeks of time to mimic the natural progression of fire on the landscape within parameters identified in the burn plan" and "monitored, additionally ignited, or partially extinguished until season-ending precipitation puts them out completely") Smoke dispersion forecasts posted to Airshed Group web page by approximately 10:00 am Mon through Fri Burns proposed via Airshed Management System by noon day before proposed burn (noon Fri for Sat/Sun/Mon burns) after reviewing dispersion forecast Idaho and Montana DEQs and local air agencies "may review the forecast and burn proposals by 2:30 pm . . . and relay any issues or concerns" Restrictions/burn recommendation posted by 4 pm "Local regulatory authorities . . . may impose additional burn restrictions after the . . . burn recommendations have been posted"
Nevada Nevada Division of Environmental Protection (NDEP) for all of state except Clark County and Washoe County, which administer program in their jurisdictions Nevada Revised Statutes Nevada Smoke Management Program	Permit application must be submitted at least 30 days prior to planned ignition date for fires emitting more than 10 tons of PM10 Permit application must be submitted at least two weeks prior to planned ignition date for projects emitting between 1.0 and 10 tons of PM10 Land managers must notify the Division as soon as practicable, but no later than 2 pm of the business day preceding the burn Division must issue final decision on the burn (approval, approval with conditions, or disapproval) by 5 pm on the business day prior to ignition or burn is deemed approved Notification to relevant regulatory authorities is required prior to ignition for projects that emit more than 10 tons of PM10 and are within 15 miles of the state border, BIA trust lands managed under the jurisdiction of a tribal air quality agency, or the borders of Washoe or Clark counties
New Mexico New Mexico Environment Department New Mexico Administrative Code	Different requirements for burn projects with < 1 ton PM-10 emissions per day (SMP-I) and burn projects with one or more ton PM-10 emissions per day (SMP-II) SMP-I: ▪ Notification of populations w/i one mile between 2 and 30 days prior to ignition ▪ Registration by 10 am one business day prior to planned ignition SMP-II: ▪ Registration by two weeks prior to planned ignition ▪ Public notification between 2 and 30 days prior to ignition for burns within 15 miles of a population or w/ wind blowing toward a population ▪ Notification to Dept. between 7 days prior to ignition and 10 am one business day prior to planned ignition Notification of local fire authority prior to ignition required for both

	Regulatory overview: Responsible agencies and applicable law	Prescribed fire planning and approval[11]
Oregon	Oregon Department of Forestry Oregon Department of Environmental Quality Oregon Administrative Rules Operational Guidance for the Oregon Smoke Management Program	Land managers must register burns with the State Forester at least seven days before the first day of ignition (requirement may be waived if federal policies met) Land managers may request special forecast and instructions at least two days in advance for multi-day burns and burns with > 2,000 tons of fuel loading Smoke Management Forecast Unit issues daily forecasts and instructions no later than 3:15 p.m. during periods of substantial prescribed burning (forecasts and instructions are for the day following issuance) Land managers must provide location, method of burning, and fuel loading tonnages to Smoke Management forecast unit by the day of the burn Land managers must obtain current smoke management forecast and instructions prior to ignition and must conduct burn in compliance with instructions Land managers must follow land management agency policies that provide for affirmative "go-no go decision" before ignition as documented and approved by line officer
Utah	Utah Department of Environmental Quality Division of Air Quality Utah Administrative Code	Director of Utah Department of Environmental Quality's Division of Air Quality must provide opportunity for an annual meeting with land managers to evaluate and adopt annual emission goal, which must be developed in cooperation with states, federal land management agencies and private entities to control prescribed fire emissions increases to the maximum feasible extent; goal is established prior to the beginning of fire season, either at the beginning of the calendar year or before the year begins Land managers must provide director with "long-term projections of future prescribed fire activity" and "list of areas treated using non-burning alternatives to fire during the previous calendar year" by March 15; land managers planning prescribed fire that will burn more than 50 acres annually must also submit a "burn schedule" at this time Land managers must submit pre-burn information to director for approval at least 2 weeks before beginning of the "burn window" Land managers must submit burn requests for large prescribed fires to the director by 10 AM at least two business days before planned ignition time
Washington	Washington Department of Natural Resources Washington Department of Ecology Smoke Management Plan codified in Washington Administrative Code	Multiple day burns require landowner to give burn plan information to DNR for review three months before the burn, with DNR notification of any additional requirements two months before the burn If DNR determines that the burn has potential to affect communities, landowner must notify public of the burn at least one week before they plan to burn Approval process for "large prescribed fires" (those with potential to create significant smoke impacts beyond the immediate fire area) Land managers responsible for gathering and entering pre-burn site data into smoke management reporting system Land managers screen, pre-authorize/pre-approve and prioritize burns daily, and submit prioritized pre-approvals to Smoke Management Section via Forest Service/DNR data exchange process Smoke Management Section approves or disapproves each burn Land managers give final approval to burns (taking into consideration a list of factors)
Wyoming	Wyoming Department of Environmental Quality's Air Quality Division Wyoming Smoke Management Standards and Regulations (codified as Chapter 10 of Wyoming Administrative Rules)	Burners/land managers "whose total planned burn projects in a year are projected to generate greater than 100 tons of PM10 emissions" must submit written reports to Administrator of Wyoming Department of Environmental Quality's Air Quality Division "by January 31 every third year"; reports must "include documentation of . . . long-term burn estimates for the next three years, including the location, burn area or pile volume, vegetation type, and type of burn for each planned burn project Burns projected to generate ≥ 2 tons/PM10 per day (classified as "SMP-II") must be registered with Air Quality Division at least 2 weeks prior to ignition Public notification required at least 2 days prior to ignition notification to Air Quality Division 1 hour prior to ignition for SMP-I burns and by 10 A.M. on business day prior to ignition for SMP-II burns Notification to relevant "jurisdictional fire authorities" prior to ignition

Task 3. Conduct key informant interviews to identify the range of interpretation of policy barriers across agencies and regions and identify actionable opportunities and mechanisms for change (Obj. 1& 2), and Task. 4 Conduct case studies where units have increased their prescribed fire accomplishments to understand what were the opportunities and mechanisms for overcoming policy barriers (Obj. 2)

Below we present select results that support overall conclusions derived during this project regarding perceived policy barriers and actionable opportunities for overcoming policy and non-policy barriers to prescribed burning (see Schultz et al. 2018, Schultz et al. 2020a, Schultz et al. 2020b for additional detail). We addressed this question in Phase 1-Task 3 and Phase 2-Task 4 of this project. **Findings from Phase 2 interviews were largely consistent with findings from Phase One** (Schultz et al. 2020a, Schultz et al. 2020b).

Barriers to burning

Air quality regulations and permitting were not the primary variables limiting the application of prescribed fire in most western states. The exceptions were in Oregon and Washington, where interviewees said that state-level smoke management programs restricted their ability to burn. Interviewees in the Intermountain West told us that, while air quality was a consideration and potential constraint, other factors were more limiting.

Funding and workforce

The most common challenge identified was lack of funding and workforce capacity. People said lack of funding, limited firefighter workforce capacity, and other staffing gaps made it difficult to plan for and conduct prescribed burning, especially when fire-qualified personnel were on standby, in training, or involved in wildland fire efforts. People said their units were often understaffed during the shoulder seasons due to the loss of seasonal workforces and the exhaustion of full-time staff members after fire season. Interviewees said they needed to seek outside grant funds and use contractors and partners to accomplish burning, and that a lack of resources had sometimes caused their units to decrease the size and scope of their projects, leave projects in incomplete states, or drop potentially important restoration efforts. Even when contractors were available to help burn, federal agencies sometimes did not have the funding or administrative capacity to hire them.

Specific staffing gaps created administrative bottlenecks on units. Staffing limitations identified in all cases included personnel for planning, conducting required environmental clearances for wildlife and archaeological resources, working on grants and agreements that could leverage outside resources, and hiring. We heard that federal agency employees were overworked and that forests were often understaffed and faced high levels of turnover and vacancies, all of which compromised their ability to successfully implement a fuels program.

Interviewees across cases also discussed the need for more formalized resource-sharing agreements with partners, especially with other Department of Interior agencies. Across

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cases, interviewees described "handshake" agreements that made "everyone a little uncomfortable" in which local leaders of neighboring national forests or BLM units agreed to share staff members and equipment across boundaries to support each other. They explained that they made these informal agreements in lieu of formalized resource-sharing agreements because they did not have the administrative capability or authority to share resources among units.

Administrative challenges made hiring, resource sharing, and retaining agency workforce more difficult. Federal agencies' intensive and sometimes time-restricted hiring processes created challenges for hiring sufficient staff. Other administrative barriers mentioned included: high liability insurance requirements that limited contractor interest and receiving money too late in the fiscal year to be able to hire.

Leadership

Prescribed fire accomplishments were difficult to achieve when line officers or individual fuels program leaders were more risk-averse or less committed to burning. Across cases, interviewees expressed that agency priorities seemed to be strongly focused on wildfire suppression and timber targets at the expense of prescribed fire. Furthermore, interviewees said that leadership tended to prioritize the limited fuels treatment dollars for new projects over needed maintenance work.

Interviewees noted that for prescribed fire accomplishments to steadily increase, agency leadership would need to more consistently prioritize funding and workforce development for prescribed fire. Key aspects of prioritization described by interviewees included making sure staff members were available to conduct prescribed fire, even during wildland fire season, offering leadership direction and support, and providing clear incentives for line officers and staff members to burn, such as offering equal pay for prescribed burning and wildfire suppression, or including prescribed fire accomplishments in performance reviews.

Outreach and public opinion

Inadequate communication between the Forest Service or BLM and the general public limited success in some places. Across cases, interviewees explained that it was important to be proactive in providing accurate information to the public to both combat misinformation as well as build basic awareness of the personal and collective benefits of prescribed burning. The agencies' NGO partners, according to interviewees, often have more capacity to manage outreach and may be able to reach more diverse audiences.

Place-specific challenges

Place-specific challenges, such as state-level smoke regulations, species protection, or public tolerance of smoke impacts, also factored into the success of programs. Place-specific challenges included factors such as state-level smoke regulations, species protection requirements, or limited public tolerance of smoke impacts.

Facilitative strategies to increase burning

Leadership

Interviewees told us that forest- and district-level leadership (i.e., line officers and others in fuels program leadership positions) played a critical role in supporting an active prescribed fire program by: providing general support for staff activities; seeking out partnership opportunities; dedicating time to working on agreements, planning, and clearances; and supporting creative staffing and planning approaches.

Interviewees said supportive leadership was a central factor for expanding prescribed fire in light of professional disincentives and competing priorities. Individual fuels program staff members, planners, and Fire Management Officers played critical roles in spearheading establishment of successful burning programs and working to overcome the many challenges associated with conducting prescribed fire. Some success hinged on the personal investments and efforts of specific individuals, often fire management officers or fuels program leaders, to reach out directly to members of the public, air quality regulators, other units who could offer capacity, or potential local partners. Some motivated individuals spent time applying for grants or turned down opportunities to work on wildland fire events, despite the financial benefits, to implement burns on their units.

Interviewees also said the support of leadership from the Washington and Regional Offices of the Forest Service and BLM, state partners, and NGO collaborators were critical factors for success. In particular these leaders were able to increase financial support and workforce capacity for prescribed burning, identify creative strategies for adding capacity, build agreement among stakeholders around the importance of prescribed fire, and sometimes lobbying for legislative changes that would support prescribed fire implementation.

Partnerships

In light of limited capacity, people said that partnerships and resource sharing were essential to staffing burn teams and facilitating prescribed fire programs in other ways. State-, federal-, and NGO partners shared staff, equipment, and funding for conducting burns. Across cases, interviewees explained that non-federal workforce crews could be more flexible, available, and reliable than federal staff members during fire season. Non-federal crews also provided a venue through which federal agencies could engage burners with different levels of availability and experience. Partners also participated in collaborative problem-solving or assisted with communication with the general public about the importance of prescribed fire. Interviewees also said that different partners had positive rapport with different sectors of the public, and that having multiple messengers in their outreach had helped them effectively engage different audiences. Partners came from a variety of sectors and played diverse roles, ranging from providing on-the-ground workforce help, equipment, funding and fundraising, communication and outreach support, advocacy work, expertise and specialized training in prescribed burning, project coordination support, survey and planning work, science support, and more (Huber Stearns et al. in review). Notably, some types of partners tended to play particular

supporting roles across case studies. For instance, Fire Protection Districts and private contractors tended to provide prescribed burning labor when surge capacity was needed, state agencies and NGOs often provided funding/fundraising as well as communication and outreach support. Some organizations (e.g., state agencies, NGOs, coalitions) tended to play a broad range of diverse roles, whereas other partners (e.g., private landowners, fire protection districts, federal agencies), tended to play a more narrow range of roles.

Active collaboration and coordination

A consistent theme in our case studies was that land managers and air quality regulators worked closely together to identify and take advantage of opportunities to burn. When air quality regulation was a constraint, successful units had strong, collaborative relationships with local regulators and participated in collaborative forums that brought air and land managers together. For example, some forests hosted state air quality agency staff members for field visits. They worked with regional smoke management liaisons to communicate their plans, identify opportunities to improve burn permit flexibility, and clarify where additional monitoring information would be helpful. Statewide collaborative forums had facilitated problem-solving around: better utilizing available burn days, building mutual understanding among air and land managers, working to improve public outreach and communication strategies, and investing in monitoring equipment to collect better data and identify more opportunities to permit burning.

Efficient and flexible planning approaches

Finally, the importance of effective planning documents was a consistent theme throughout interviews. People discussed the importance of forest plans, landscape- and project-level NEPA approaches, and flexible burn plans. Two forests were pursuing district- or forest-wide planning documents, which they believed would bring efficiencies for planning and clearance processes, allow them to conduct more burning without being constrained by project boundaries, and facilitate application of naturally ignited fire to meet resource objectives. At least two forests were pursuing programmatic agreements with their State Historic Preservation Offices to streamline needed archeological clearances. Some interviewees discussed particular strategies they were using in their plans to address constraints; approaches included burning outside of traditional fire seasons when there was more firefighter availability and less risk of fire escape, trying to integrate natural fire barriers, and building cross-boundary fire plans to reduce the amount of resources needed to hold a fire line.

Task 5. Integrative analysis.

Much of our integrative analysis is captured in our paper in *Science* where we discuss the importance of collaboration to share resources and work across boundaries (Schultz and Moseley 2019). For prescribed fire, this is especially important at the state level, given the role of state regulatory agencies and the capacity that resides in state forestry agencies. We write that despite policy approaches that have facilitated larger scale planning, *"It has been challenging to implement prescribed fire without addressing barriers elsewhere in the system. Prescribed fire requires planning and permitting, is logistically complicated to execute (requiring trained staff*

and equipment to be available during narrow burn windows), and can be controversial. To overcome these hurdles, federal and state land managers and air-quality regulators have emphasized that in addition to leveraging local capacity, state-level interagency collaboration, because of the role of state regulatory and land management agencies, is key for facilitating communication, resource sharing, and problem solving." In essence, we emphasize that to address capacity issues and facilitate collaboration and communication across state and federal agencies working in both land and air quality management, state-level collaboration is key for success. We offer several examples including: 1) the Montana-Idaho Airshed Group, which works to coordinate burners and employs a liaison to communicated with air quality agencies on behalf of burners, and 2) the California Fire MOU Partnership, which has helped connect land and air managers, improve communication with the public, and served as a venue for identifying barriers to burning and pathways for overcoming them.

We also note that, *"Improved resource-sharing tools and increased funding and human resource capacity, perhaps dedicated teams, also are needed, along with consistent direction, support, and incentives from Congress and agency leadership to indicate that prescribed fire is a priority, given that state and federal policies focus on an array of goals that may compete with increasing the presence of fire on the landscape."* As potential solutions, we point to dedicated funding streams for prescribed fire at the state and federal level, clearer incentives to do prescribed fire, dedicated human resources capacity, and leadership support.

We also recommend increased funding for air quality monitoring and people in positions that connect air and land managers. We acknowledge that there is a need simply for more funding and capacity to burn, at the same time, we recognize that significantly scaling up burning will raise new challenges and require ongoing assessment of barriers and opportunities in the policy and organizational environments. To that end, we also highlight the importance of funding for applied research under programs like the JFSP to advance understanding of important fire management issues.

In our publication in the *International Journal of Wildland Fire,* we also synthesize across multiple tasks to make recommendations. We suggest two state- or regional-level policy changes that we think could potentially facilitate the increased use of prescribed fire. They include: 1) smoke management programs in Oregon and Washington, where such revisions are underway, and 2) policies that could potentially facilitate easier approaches to interagency resource sharing.

In addition, we argue that changes to internal practices within the Forest Service may be warranted. These include: incentive structures within the Forest Service to pursue prescribed burning, and practices leading to current capacity limitations. Some suggestions drawn from our interviews include:

- **Ensuring air quality liaisons are in place** for all states and exploring whether additional state-level groups, modeled after practices in California and Montana/Idaho, are needed to coordinate among burners and with air quality regulators.

- **Improving internal incentives to burn** through redesign of some performance measures or the creation of special initiatives with funding for which units and collaborative partners could compete.
- **Identifying more efficient and effective avenues for resource sharing.** Suggestions include: centralizing contracts and agreements staff, or finding other ways to ensure they are knowledgeable about all options and give consistent advice; creating other agreement mechanisms that are less cumbersome than current options; and finding ways to charge more easily to single budget lines when using resources from multiple agencies.
- **Ensuring capacity is available** through improved strategic planning, use of dedicated prescribed fire crews, greater flexibility to use fire personnel across units, and more effective use of partner capacity.
- **Improving measurement of smoke generation and dispersion** in order to identify additional opportunities to burn and promote transparency in decision making. Investments could be directed to necessary equipment and meteorologist positions.

Task 6. Write up results and conduct presentations and briefings for diverse audiences. and Task 7. Conduct science delivery in collaboration with fire consortia and prescribed fire councils.

We met or exceeded all proposed science delivery objectives (Table 1; Appendix B), except for an in-person planned workshop which was cancelled due to COVID-19. Our manuscripts differed somewhat in content from our proposal. One targeted a natural resource management journal as planned, with an applied focus on the prescribed fire policy context and opportunities for change. Another detailed our spatial analysis as planned (Bone et al. in review). For a third article, we proposed producing a law review article that integrated findings from our legal analysis and interviews but instead produced a related article for *Science* that allowed us to share the results of our work more broadly. A fourth article was intended for a policy studies journal, with a focus on factors that influence policy ossification, policy interpretation, and organizational change. We instead produced an article that focused on key lessons learned from our case studies regarding successful partnership strategies being used to increase prescribed burning by particular federal units across the West.

We wrote two working papers and two briefing papers as planned, as well as a Research Brief for the NWFSC that distilled key findings for fire managers, policy makers, and other practitioners (http://www.nwfirescience.org/biblio/keyword/316). These publications focused on the current policy framework for prescribed burning and on findings from our case studies about opportunities for overcoming barriers at the field level. Briefing papers were shared during in-person briefings with managers, policy makers, and key stakeholders in Washington, D.C.

Finally, we wrote two articles for The Conversation and conducted one Colorado Public Radio interview that were not included in our proposal, but that we chose to do to further disseminate key findings from our research and contextualize them in light of current events, such as California's catastrophic fire season and new Smoke Management rules in the Pacific Northwest.

We disseminated our publications and presentations through our own channels as well as through the Northwest Fire Science Consortium (NWFSC) and Southern Rockies Fire Science Consortium (SRFSC). This included a project webpage we developed with all project deliverables (see http://ewp.uoregon.edu/RxFire_Policy).

In addition, we conducted two webinars in coordination with the consortia, and posted brief slide decks (i.e. "HotSpots") on the SRFSC's website. We planned to participate in the Colorado Wildland Fire Conference, and collaborate with the NWFSC to put on a workshop for fire managers and air quality regulators in the Northwest region, but both of these events were cancelled due to the COVID-19 pandemic. Instead we did other virtual outreach, such as linking our study results to an online discussion of how to overcome barriers to prescribed burning in Central Oregon. We targeted our outreach to our interviewees, including members of prescribed fire councils and other fire learning networks, as they are particularly focused on reducing barriers to prescribed fire, and were in support of this project.

CONCLUSIONS AND IMPLICATIONS FOR MANAGEMENT, POLICY, AND FUTURE RESEARCH

A primary goal of this work was to identify policy solutions to facilitate more prescribed burning across the U.S. West. Notably, we did not find consistent calls for federal policy change. This finding speaks to the difficulty of addressing the need to increase prescribed fire. There did not appear to be a simple policy solution that would allow units across the region to increase prescribed burning; rather, a multiplicity of strategies that can be scaled to different places were necessary to address the heterogeneous contexts in which units were trying to implement more prescribed burning.

Our findings shed light on the fact that many federal units across the American West are facing different sets of social, economic, and ecological factors that challenge their ability to conduct prescribed burns. While many challenges faced by units across contexts followed similar overarching themes, we saw evidence that challenges manifested themselves differently across different on-the-ground contexts, and that each unit we studied faced its own unique combination of primary and secondary barriers.

This work documented key strategies used by units that have the reputation of being leaders in prescribed burning across the West. We heard of a variety of useful strategies, from stronger communication with the public, working directly with regulators, leveraging partnerships partners, to developing more adaptive or strategic project planning approaches.

The findings from this research provide important insights about the opportunities that exist to support units across the West in increasing their prescribed fire accomplishments. Creative problem-solving at the local level appears core to success, which underscores the need for building a policy framework and culture in which creative problem solving is encouraged and units are supported with sufficient resources to implement solutions. Information about both

successful innovations and ineffective strategies should be shared broadly among units to support learning and creativity and find efficiencies. Finding ways for staff members and partners to come together and share their strategies in regional or statewide networks is essential for supporting creativity and fostering effective learning across federal land management units and with partners.

Recommendations

Overall, we identified four interrelated, overarching recommendations based on our findings that we make to the Forest Service, BLM, and their partners:
(1) Prescribed fire will need to be clearly prioritized and supported by federal agencies with more staff capacity in order to increase burning on federal lands in the West, especially during fire season.
(2) Individual fuels program staff members need clear support and incentives from leadership to build and sustain successful programs.
(3) Stronger emphasis on the importance of prescribed fire from line officers and agency leadership at all levels is needed.
(4) It will be important for agencies to find ways to remove obstacles and increase efficiencies for resource sharing because partners are critically important for adding needed capacity to address the scale of the need for prescribed burning.

Additive value of this work

Previous dialogue around the need for prescribed fire has originated primarily from the biophysical sciences and has indicated that policy limitations (e.g., air quality permitting) are the primary barriers to increasing prescribed fire accomplishments. However, our results indicate that pursuing legislative change to air quality laws is not a clear need at this time, nor the primary pathway to increasing the pace and scale of prescribed burning in the U.S. West. Our conversations with people who plan and conduct prescribed burns revealed a complex suite of challenges that must be addressed using a diverse set of tools based on the particular limitations they face in localized contexts. We found that staff capacity, funding, clear incentives, and strong leadership all were more important factors that must be addressed to support increase burning.

The information generated in this project is already being put to use by managers and legislators. We have formally documented in peer-reviewed literature many issues that managers and prescribed fire practitioners experience on a daily basis but that may have been otherwise disregarded as simply anecdotal. Collecting this information in a systematic way and making it available in a peer-reviewed literature allows managers to share information about challenges and potential solutions with lawmakers and agency leadership in a new light. The results of this investment by the JFSP have already contributed to dialogue around draft legislation at the federal level and state-level collaborative efforts, both of which are now being advanced in more informed ways based on this research, according to our partner networks. This is critically important given the dearth of information about how to successfully achieve the greater levels of prescribed burning.

Our analyses demonstrate that federal air quality regulations are not overtly driving when and where prescribed fire takes place by both the BLM and USDOI, as prescribed fire has largely taken place well below EPA air quality limits. However, we note that subtle differences in air quality conditions during prescribed fire events may mean that jurisdictions could face challenges under current regulations as climate change worsens regional air quality in some parts of the western U.S. This will be a matter for more attention going forward, particularly as burn programs grow.

Future research

This project opened up several new lines of inquiry. First, our statistical analyses highlighted opportunities to assist policy makers and forest managers in identifying under-utilized opportunities for prescribed fires, and how air quality windows may vary based on location. Results revealed that air quality conditions have not been constraining the USDOI and USFS from implementing prescribed fire in the past, although climate change impacts on air quality could change that in the future, particularly concerning ozone levels. Of all the air quality measurements used to evaluate prescribed fire plans, ozone levels were closest to threshold levels, and previous work has shown how climate change will likely lead to long-term increases in ozone levels into the future.

Furthermore, future work could consider regional air quality zones in prescribed fire planning, as multiple air quality measurements demonstrated regional similarities. However, the success of future work in this area will depend on the quality of data that can be collected and utilized in various analyses. A challenge faced in this study was accessing consistent data for prescribed fire events, even though data were all provided through NFPORS. This data has been collected by third party partners, which has led to inconsistencies in reporting and missing data points. Moving forward, it is imperative that agencies such as the USFS and USDOI develop data standards for prescribed fire reporting, database development, and the creation of metadata to provide information about how and when various data points were created. Such frameworks will allow for more detailed analysis of the relationship between prescribed fire and air quality, and improve our understanding of the opportunities to apply fire as a management tool across the Western U.S.

Our legal and case study analyses revealed a detailed understanding of the challenges that Forest Service and BLM units face for increasing the use of prescribed fire and the opportunities to overcome those challenges. Our work was rooted in interviews across the West and just four case studies; future work could explore whether these same patterns hold true across a larger number of purposefully selected case studies or a larger survey of individuals or units that are representative of qualitatively different contexts. Such work could help uncover additional challenges and the strategies that units are employing to overcome them, as well as explore how strategies to overcome challenges are changing over time and space. Furthermore, many strategies we documented in this work have been employed relatively recently, and it is yet to be seen if they will be effective in terms of desired social and ecological outcomes. Further research

could help illuminate the efficacy of these strategies over time. Pilot experiments could be established to test the efficacy of these new strategies in different case study units. This information could be synthesized into an index of strategies to address particular challenges that could be widely used by units across the West to advance their prescribed burning programs.

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APPENDIX A. Contact information for key project personnel

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  Alyssa Bonini, J.D.
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  Jason Kelley, B.S.
  Daniel Lawler, J.D.
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  G. Ricco, M.S.
  Anna Santo, M.S.

Project layout and design
  Autumn Ellison, M.L.A.

APPENDIX B. Completed and planned deliverables

Peer-reviewed journal articles

Bone, C, C. Shultz, H. Huber-Stearns, J. Kelley, and E. Cunnin. *In review*. Evaluating air quality conditions during prescribed fire events across the western U.S. Target journal: *Applied Geography*.

Huber-Stearns, H., Santo, A., Schultz, C., and McCaffrey, S. *In review*. Network governance in the use of prescribed fire: What roles for bridging organizations and other actors in the western United States?. Target journal: *Regional Environmental Change*.

Schultz, C.A., McCaffrey, S., Huber-Stearns, H. 2019. Policy barriers and opportunities for prescribed fire application in the Western United States. *International Journal of Wildland Fire* 28, 874-884; doi: 10.1071/WF19040

Schultz, C.A., Moseley, C. 2019. Collaborations and capacities to transform US fire management. *Science* 366(6461) , 38-40; doi:10.1126/science.aay3727

Schultz, C.A., McCaffrey, S., Huber-Stearns, H. 2019. Policy barriers and opportunities for prescribed fire application in the Western United States. *International Journal of Wildland Fire* 28, 874-884; doi: 10.1071/WF19040

Media, other news

Schultz, C.A., Moseley, C., Huber-Stearns, H.R. 2019. "Planned burns can reduce wildfire risks, but expanding use of 'good fire' isn't easy." *The Conversation*, April 25, 2019.

Schultz, C.A., Moseley, C. 2018. "Better forest management won't end wildfires, but it can reduce the risks – here's how." *The Conversation*, November 20, 2018

2021. Schultz, C.A. Interview for "The United States of fire: How "good" fire may be able to help save forests across America from being devastated by "bad" fires. *American Forests* Winter/Spring 2021. Available at: https://www.americanforests.org/wp-content/uploads/2021/02/AF_Winter21_low-res.pdf

January 2021. Schultz, C.A. Provided background to reporter Michael Elizabeth Sakas for her story with Colorado Public Radio on prescribed fire in Colorado. https://www.cpr.org/2021/01/28/foresters-want-more-prescribed-burns-to-avoid-future-wildfire-disasters-in-colorado-but-the-state-forest-service-isnt-allowed-to-conduct-them/

March 12, 2020. Schultz, C.A. Interview for "Fighting fire with fire: The social barriers to controlled burns. *Medium, Anna von Pechmann*. Available at: https://medium.com/@avonpechmann

June 10, 2019. Huber-Stearns, H. Interview to inform article "Change To Oregon Smoke Rules Seeing Early Results For Prescribed Burns." *Oregon Public Broadcasting*. Available at: https://www.opb.org/news/article/oregon-smoke-rules-prescribed-fires-wildfire-air-quality/

December 20, 2018. Schultz, C.A. Interview for " Here's how California can use fire to solve its wildfire problem.". *Los Angeles Times. Available at: https://www.latimes.com/science/sciencenow/la-sci-sn-controlled-burns-forests-20181220-story.html*

Technical reports and briefings

Northwest Fire Science Consortium. 2020. Policy barriers and opportunities for prescribed fire application in the western US. Research Briefing #22. Available at: http://www.nwfirescience.org/sites/default/files/publications/NWFSC_RB22_RxFirePolicy%20%28002%29_0.pdf

Schultz, C., A. Santo, H. Huber-Stearns, and S. McCaffrey. 2020a. Strategies for Increasing Prescribed Fire Application on Federal Lands: Lessons from Case Studies in the U.S. West. CSU Public Lands Policy Group Practitioner Paper #6/Ecosystem Workforce Program Working Paper #99. Available at: https://ewp.uoregon.edu/sites/ewp.uoregon.edu/files/WP_99.pdf

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Schultz, C., H. Huber-Stearns, S. McCaffrey, D. Quirke, G. Ricco, and C. Moseley. 2018. Prescribed Fire Policy Barriers and Opportunities: A Diversity of Challenges and Strategies Across the West. CSU Public Lands Policy Group Practitioner Paper #2/Ecosystem Workforce Program Working Paper #86. Available at: https://ewp.uoregon.edu/sites/ewp.uoregon.edu/files/WP_86.pdf and codebook available at: https://scholarsbank.uoregon.edu/xmlui/handle/1794/23861

Quirke, D. 2018. Legal Appendix for Prescribed Fire Policy Barriers and Opportunities: A Diversity of Challenges and Strategies Across the West. CSU Public Lands Policy Group Practitioner Paper #2/Ecosystem Workforce Program Working Paper #86. Available at: https://ewp.uoregon.edu/sites/ewp.uoregon.edu/files/WP_86Appendix.pdf

Schultz, C., Huber-Stearns, H., McCaffrey, S., Quirke, D., Ricco, G. (2017). Policy Barriers to Implementing Prescribed Fire. CSU Public Lands Policy Group Briefing Paper 1, Fall 2017. Available at: https://sites.warnercnr.colostate.edu/courtneyschultz/wp-content/uploads/sites/23/2018/05/Policy-Barriers-to-Prescribed-Fire-BP-Updated.pdf

Websites

University of Oregon Ecosystem Workforce Program: http://ewp.uoregon.edu/RxFire_Policy

Colorado State University Public Lands Policy Group: https://sites.warnercnr.colostate.edu/courtneyschultz/prescribed-fire/

Presentations and webinars

July 09, 2020. Huber-Stearns, H., Santo, A. "Policy barriers and opportunities: strategies for increasing prescribed fire application on federal lands from case studies in the US West." Deschutes Collaborative Forest Project - Prescribed Fire Subcommittee. Zoom presentation and discussion. (~20 participants)

March 2, 2020. Schultz, C.A. "Research perspective on shared stewardship, cross-boundary restoration and collaborative partnerships." Southwest Ecological Restoration Institute Cross-Boundary Landscape Restoration Conference, Albuquerque, NM. Oral presentation.

February 06, 2020. Huber-Stearns, H. "Forest and wildfire policy." University of Oregon - Intro to Public Policy. Eugene, OR. Guest lecture and discussion. (~150 participants)

January 27, 2020. Schultz, C.A., Huber-Stearns, H., Santo, A. "Strategies for increasing prescribed fire application on federal lands from case studies in the US West." Webinar for Northwest Fire Science Consortium. Webinar, discussion, and Q&A follow up responses. Available at: https://www.youtube.com/watch?v=vzoEHTnnmHgwith (229 attended, 414 registered, 298 views as of Jan 2021)

November 21, 2019. Schultz, C.A., Hoffman, C., Hiers, K. "The unique considerations of prescribed fire research and application." Organized symposium - sequential 2-hour sessions on social and biophysical science. 8th International Fire Ecology and Management Congress. Tucson, AZ. Oral presentation.

November 21, 2019. Schultz, C.A., Huber-Stearns, H., Santo, A., McCaffrey, S. "Policy approaches for increasing application of prescribed fire on federal   lands." 8th International Fire Ecology and Management Congress. Tucson, AZ. Oral presentation.

November 20, 2019. Schultz, C.A., Moseley, C. "Policy design to support collaboration and capacity-building for improving federal fire management." 8th International Fire Ecology and Management Congress. Presentation. Tucson, AZ. Oral presentation.

October 22, 2019. Schultz, C.A. "New directions and challenges for collaborative forest management." The Nature Conservancy's Annual North America Forests Workshop, Estes Park, CO. Oral presentation.

October 11, 2019. Huber-Stearns, H. "Communication and wildfire in the West." University of Oregon Honors College course. Eugene, OR. Guest lecture. (16 students)

September 4, 2019. Huber-Stearns, H. "Wildfires and forest management." University of Oregon Museum of Natural and Cultural History - Ideas on Tap public "pub talk" series. Eugene, OR. Oral presentation, Q&A, discussion. (~70 participants).

April 5, 2019. Schultz, C.A., Huber-Stearns, H., McCaffrey, S., Quirke, D., Ricco, G., Moseley, C. "Policy barriers to increasing prescribed fire accomplishments on federal lands: A diversity of challenges and approaches across the West." California Fire MOU Partnership Meeting, Sacramento, CA. Oral presentation.

March 14, 2019. Schultz, C.A. "Policies to support forest and fire restoration efforts." High Altitude Restoration—Society for Ecology Restoration Rocky Mountain Chapter Meeting, Fort Collins, CO. Oral presentation.

March 14, 2019. Schultz, C.A. "Policies to support forest and fire restoration efforts." High Altitude Restoration—Society for Ecology Restoration Rocky Mountain Chapter Meeting, Fort Collins, CO. Oral Presentation.

March 12, 2019. Schultz, C.A. "Achieving forest restoration through increased prescribed fire application." High Altitude Restoration—Society for Ecology Restoration Rocky Mountain Chapter Meeting, Fort Collin, CO. Oral Presentation.

January 29, 2019. Schultz, C.A. "Prescribed fire policy barriers and opportunities." Rural Voices for Conservation Coalition Annual Meeting. Santa Fe, NM. Oral Presentation and facilitated discussion/problem-solving.

November 27, 2018. Schultz, C.A., Huber-Stearns H. "Policy barriers to prescribed fire: Challenges and opportunities across the West." Southwest and Northwest Fire Science Consortia. Webinar. Available at: https://www.youtube.com/watch?v=_2tjDndbZpQ&feature=youtu.be (~250 registered, 257 views)

October, 2018. Schultz, C.A. " Policy barriers and opportunities for prescribed fire on federal lands across the western US." Colorado State University Fire Lab. Ft. Collins, CO. Oral presentation.

October 12, 2018. Schultz, C.A. "Scale, science, and stakeholders: The changing landscape of US forest policy and governance." CU-Denver Integrative Biology Seminar Series, Denver, CO. Oral presentation.

March 21, 2018. Schultz, C.A. "Policy changes to support integrated and collaborative forest restoration." Montana-Idaho Regional Forest Collaboratives Meeting, Coeur d'Alene, ID. Oral presentation.

May 23, 2018. Schultz, C.A., Huber-Stearns, H., McCaffrey, S., Quirke, D., Ricco, G., Moseley, C. "Policy barriers to increasing prescribed fire accomplishments on federal lands: A diversity of challenges and approaches across the West." Fire Continuum Conference, Missoula, MT. Oral Presentation in Organized Session.

November 28, 2017. Schultz, C.A., Huber-Stearns, H., McCaffrey, S., Quirke, D., Ricco, G., Moseley, C. "Policy barriers to prescribed fire: A diversity of approaches across the West." International Fire Ecology and Management Congress, Orlando, FL. Oral presentation.

November 17, 2017. Schultz, C.A. "A preliminary analysis of laws and policies governing prescribed fire." Society of American Foresters National Convention, Albuquerque, NM. Oral presentation.

In-person briefings with policy makers

August 16-19, 2019. Schultz, C.A., Moseley, C., Huber-Stearns, H. Meetings on Capitol Hill, Washington, D.C. with House and Senate staff to discuss ongoing legislation development and share our research insights.

September 09, 2018. Schultz, C.A., Moseley, C. Visits with Brandon Bragato (House Natural Resources committee staff), Bryan Petit (Senate Energy and Natural Resources committee staff), and Clint Cross (USFS) to discuss our research and inform policy development.

July 10, 2018. Schultz, C.A., Moseley, C. Senior Fire Leadership Meeting. Invited in-person presentation and facilitated discussion (2 hours). Presented project findings to Senior Fire Leaders in the US Forest Service and shared our PLPG Practitioner Paper #2/EWP Working Paper #86.

June 26, 2018. Huber-Stearns, H. FFWG members, including Oregon DEQ, ODF and USFS. Shared key aspects of RxFire project, then shared EWP Working Paper #86 when it was complete.

May 1, 2018. Schultz, C.A., Moseley, C. Shared findings with multiple congressional offices, USFS agency leadership, Undersecretary, BLM Office of Wildland Fire.

November 13-17, 2017. Schultz, C.A., Moseley, C. Shared findings with Senate Energy and Natural Resources committee staff and Forest Service leadership including the Chief, head of Legislative Affairs, and the Undersecretary of Agriculture.

Other outreach

2020 (approximately 10 hours). Schultz, C.A. Advised the Hewlett Foundation on building their giving program for fire, with a focus on prescribed fire as one of four priorities.

2020. Huber-Stearns, H. Provided monthly updates to and discussion with Northwest Fire Science Consortium about project updates, findings and potential application(s) in Consortium outreach and communication.

June 01, 2020. Huber-Stearns, H., Santo, A., Schultz, C.A. Emailed research products to all project interviewees and other key stakeholders. Posted research products in the news section on EWP and PLPG websites, and in EWP organizational newsletter.

September 05, 2019. Huber-Stearns, H. Interviewed by a University of Oregon Master's in Journalism student about prescribed fire for their class paper.

April 01, 2019. Schultz, C.A. Handed out research products at Coexist with Wildfire Conference.

July 11, 2018. Schultz, C.A. Distributed research produced via Rural Voices for Conservation Coalition email listserv, personal and organizational Twitter accounts, newsletters.

APPENDIX C. Metadata

1. Interview data.

Data for the interviews will exist in our NVivo database; however, the data therein cannot be reasonably de-identified. As stated in our data management plan, interview audio files, transcripts, and coding databases will not be released because they 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:

· Schultz et al. 2020: https://scholarsbank.uoregon.edu/xmlui/handle/1794/25859
· Schultz et al. 2018: https://scholarsbank.uoregon.edu/xmlui/handle/1794/23861

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 for storing at the University of Oregon Scholars' Bank, particularly since it is not comprehensive metadata for the dataset (since the data are not publicly stored), but rather, are just the 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 (see Schultz et al. 2020 a and b and Schultz et al. 2018-all of which are also archived with the Scholars' Bank).

2. Air quality modeling data

As noted in our data management plan, we did not archive secondary data that is publicly available elsewhere. For our air quality measurement analysis we originally anticipated creating new spatial datasets that we would then archive, with corresponding metadata (as described in our DMP). However, we ultimately did not generate any new data or manipulations of secondary data that would warrant archiving or the creation of metadata. To achieve this part of our research objectives on air quality and prescribed fire, we obtained publicly accessible data, on air quality measurements and prescribed fire application. The analyses we performed using these two datasets did not generate new variables, spatial layers or other new forms of data that would be appropriate to archive. We describe here the two sets of publicly available data that we used, and our related methods. Additional information about the methodology and analyses conducted in under this research objective can be found in the Bone et al. manuscript, created as a project deliverable.

1. **Air quality measurement data from the United States and Environmental Protection Agency (EPA), publicly available at: https://www.epa.gov/outdoor-air-quality-data.** The EPA tracks this air quality data at outdoor monitors across the United States, and stores it in this outdoor air quality data repository. We downloaded data from this source in order to obtain outdoor air quality data collected from state, local and tribal monitoring agencies across the United States. We then selected data for the 11 contiguous western states in the United States, which was the focus and scope of our analysis. We selected an 8-year period of time from the data, from 2007 to 2014, which is a recent

timeframe for which reasonably complete data were available. This was also a time period for which consistent prescribed fire and air quality data could both be obtained.

2. **Prescribed fire data from the National Fire Plan Operations and Reporting System (NFPORS) database, publicly available at: https://www.nfpors.gov.** This is an interagency reporting system maintained by the Department of Interior and the US Department of Agriculture. This data set was selected for the study because it provides point location data for prescribed burns, administered by DOI and USFS, regardless of fire size and it also classifies points based on the type of prescribed burn that was enacted. We selected from this data broadcast and jackpot burns for the purposes of our analysis.

These data were all publicly accessible and we did not create new metadata or other data which would be appropriate for archiving. Therefore we did not archive our data from this analysis.