

Policy barriers and opportunities for prescribed fire application in the western United States

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Abstract. Prescribed fire is an important management tool on US federal lands that is not being applied at the necessary or desired levels. We investigated the role of policy barriers and opportunities for prescribed fire application on US Forest Service and Bureau of Land Management lands in the western United States. We conducted 54 semi-structured interviews with federal and state land managers and air quality regulators, and with several non-federal partners. We found that lack of adequate capacity and funding were the most commonly cited barriers to increasing application of prescribed fire. Interviewees also emphasised that owing to a lack of incentives and the prevalence of risk aversion at multiple agency levels, active prescribed fire programs depend on the leadership and commitment of individual decision-makers and fire managers. Successful approaches also rely on collaborative forums and positions that allow communication, problem-solving and resource sharing among federal and state partners, and that facilitate dialogue between air-quality and land managers. We did not find that air quality regulation was consistently cited as a major barrier, except in specific locations. Our findings highlight the importance of contextualised investigation into policy barriers and the role of collaborative and multilevel governance approaches for addressing complex land management challenges.

Additional keywords: collaborative governance, federal land management, fire management, forest policy, policy implementation.

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Introduction

Prescribed fire is an important tool for increasing the resilience of fire-dependent ecosystems, particularly in the face of climate change (North *et al.* 2012; North *et al.* 2015; Schoennagel *et al.* 2017). Researchers and fire management practitioners from fire-prone regions around the world emphasise the importance of prescribed fire, and many are working to maintain or increase its application (Burrows and McCaw 2013; Fernandes *et al.* 2013; Ryan *et al.* 2013; Moritz *et al.* 2014). In the United States, current national forest management focuses on improving the ecological integrity of forest ecosystems through the restoration of natural processes such as fire (US Forest Service (USFS) 2015; Wurtzebach and Schultz 2016). The National Cohesive Wildland Fire Management Strategy emphasises as one of its three objectives the importance of restoring and maintaining resilient landscapes through the use of both fire and mechanical treatments (WFEC 2014a). Prescribed fire is an important aspect of this strategy, often used to complete and maintain restoration activities or ‘treatments’ that begin with mechanical thinning. These treatments, particularly when followed by prescribed fire, can reduce the severity of wildland fires in many forest types (Kalies and Kent 2016).

Despite broad recognition of its value, managers are not applying prescribed fire at the necessary levels in the western US (Ryan *et al.* 2013; USDA and USDI 2014; Kolden 2019). While in some places vegetation management via forest thinning is occurring at an increased pace and scale, managers have struggled to increase the application of prescribed fire, leading to concerns about treatment efficacy and return on public investment of funds spent on forest thinning (Schultz *et al.* 2018b). Although research specific to prescribed burning barriers is limited, it suggests that a range of factors constrain prescribed fire implementation and that the primary barriers to conducting prescribed fire vary by region and actor, and over time (Cleaves *et al.* 2000; Quinn-Davidson and Varner 2012; Kobziar *et al.* 2015; Melvin 2018). A general view is that the current policy environment significantly constrains the application of prescribed fire by federal land managers (USDA and USDI 2014). Cleaves *et al.* (2000), surveying Forest Service fire management officers (FMOs) about their experiences in the late 1980s and 90s, found that smoke management regulations were the most significant barrier to conducting prescribed fire; in order of subsequent importance, lack of funding, personnel shortages, narrow burn windows, concerns about liability and

other regulations were also identified as barriers. In a more recent study in northern California, [Quinn-Davidson and Varner \(2012\)](#) found similar patterns among federal land managers, with narrow burn windows, air quality regulations, lack of adequate funding and personnel, and other environmental laws among the top barriers. In the US South, [Kobziar et al. \(2015\)](#) found that federal land managers listed funding and staffing as major impediments to burning and that respondents in some agencies also said policies limited their ability to burn. Overall, these studies suggest that a combination of weather, policy and lack of capacity limit managers' ability to conduct prescribed fire.

In light of this research, some have suggested that there may be a need to reduce regulatory restrictions on smoke or generally to change federal policy so that it is more supportive of prescribed fire ([Engel 2013](#); [North et al. 2015](#); [Schoennagel et al. 2017](#)). Acting on these recommendations requires a better understanding of policy barriers and opportunities in specific terms. Policy, generally speaking, has a formal quality and exists at many levels of government. Laws (e.g. the National Environmental Policy Act and Clean Air Act), regulations (i.e. the Code of Federal Regulations, with specific sections written by administrative agencies to interpret congressional laws), state implementation plans under the Clean Air Act, and internal agency policies, such as formal accountability procedures and written guidance, all constitute policy. To identify potential barriers and solutions, it is necessary to understand where a policy barrier exists (e.g. whether it is in state or federal law or regulation). It is also important to distinguish between barriers in policy direction and those related to policy implementation, which can be influenced by a wide range of factors such as local social and political conditions, availability of capacity and funding, and the traits of individual decision-makers who implement a particular policy ([Moseley and Charnley 2014](#)). Although the literature suggests that policies constrain prescribed fire application, it is not clear where current policy barriers reside and whether some barriers are issues of policy implementation rather than policy direction. These distinctions are important, because different types of barriers present different opportunities and mechanisms for change. Changing federal law requires political action by Congress, rewriting regulations requires executive action, and changes to organisational policy and behaviour require agency action, along with effective communication, leadership and changes in incentive structures ([Fernandez and Rainey 2006](#)). Overcoming policy implementation challenges, however, may depend more on improving collaboration among agencies, local politicians and other key actors, and on providing the resources, expertise, and funding necessary to implement existing policy ([Steelman 2010](#)).

Some work has suggested that governance approaches that connect air quality regulators and land managers may be important for finding opportunities to increase application of prescribed fire ([Engel 2013](#); [Parker 2018](#)). Governance goes beyond policy and refers to the range of both formal and informal processes, policies and actors involved in influencing and responding to conditions in a complex system such as fire management. Research also suggests that increasing use of prescribed fire will require greater collaboration across land ownerships ([Quinn-Davidson and Varner 2012](#)). These observations square with a growing recognition over the last few decades that

environmental governance challenges have become too complex for any single organisation to manage alone; coordination across sectors, jurisdictions and with non-government actors has become an imperative for effective government function ([Kettl 2000](#); [Emerson et al. 2012](#); [Kamensky 2018](#)). This reality has led to an increased focus on governance approaches that are collaborative (i.e. different types of actors working together) and networked (i.e. with connections within and across different governance levels) ([Abrams et al. 2017](#)); specifically, these types of collaborative approaches involve working across multiple agencies at different levels of the system (e.g. state or federal) and different sectors within government (e.g. human health or land management), and with a combination of government and non-government actors to accomplish something no actor can achieve in isolation ([Emerson et al. 2012](#)). Importantly, the notion of collaborative governance today encompasses more than the engagement of non-state actors in formal, state-led efforts that has been the focus of much of the collaborative governance scholarship in US forest management to date ([Emerson et al. 2012](#); [Schultz et al. 2012](#)). Effective collaborative governance approaches often emerge through self-organisation of actors to respond to challenges in specific locations, but eventually policy plays a critical role in providing certainty, funding and authority to engage in collaborative governance activities ([Kamensky 2018](#)). This can involve new authorities that require or facilitate collaboration and resource sharing (see e.g. [Schultz et al. 2018b](#)), or the creation or reshaping of institutions (i.e. governance rules, structures and processes in use) to meet evolving demands ([Moseley and Charnley 2014](#); [Rutherford and Schultz 2019](#)). Collaborative and networked governance approaches also require new skills and incentives among individual agency staff members and their partners ([Kamensky 2018](#)).

With these potential barriers and opportunities in mind, we investigated policy barriers and emergent opportunities for applying prescribed fire on US federally managed public lands in 11 western US states where prescribed fire application has been limited ([Kolden 2019](#)). We sought to determine how individual laws, agency policies or aspects of policy implementation constrain the application of prescribed fire. We specifically focused on the USFS, part of the Department of Agriculture, and the Bureau of Land Management (BLM), part of the Department of the Interior. These two agencies manage the majority of US public lands – over 177 million ha nationally and nearly 50% of the land in the West. We asked the following questions: (1) what are the most significant policy barriers to prescribed fire on USFS and BLM lands in the West? And (2) what are potential opportunities and mechanisms for change? Our aim was to contribute to the applied research literature specific to fire management in the western United States and other locations where prescribed fire efforts are desirable, and generally to contribute to the dialogue around policy and policy implementation in understanding current fire and land-management challenges.

Methods

Our work began with a legal analysis of the major policies that constrain prescribed fire, including a detailed investigation of state-level air quality regulation under the federal Clean Air Act.

This law is implemented through a model of cooperative federalism, with states having primary responsibility for managing air quality within the terms of the Clean Air Act and associated regulations written by the US Environmental Protection Agency. State-level regulation is written into smoke management plans that are typically incorporated into state regulatory law; the elements of a state's smoke management program that are legally binding under the Clean Air Act also are referenced in each State Implementation Plan. We make some references to our legal analysis herein, and a detailed treatment of air quality regulatory approaches can be found in [Schultz *et al.* \(2018a\)](#) and [Quirke \(2018\)](#).

To obtain a deeper understanding of policy-related barriers and opportunities, we conducted semi-structured interviews across the 11 western states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming) between September 2017 and December 2018. Our goal was not to conduct state case studies but to obtain a broad understanding of policy barriers to prescribed fire across the West, how they might vary across the states and opportunities for improving practice. We interviewed a key informant for both the BLM and USFS in each state who was familiar with prescribed fire efforts in the state (typically state or regional fuels program leaders or directors of fire and aviation management). We also spoke to air quality or smoke management liaisons within these agencies. In states where the USFS has no regional office, we often spoke to a fire management staff person at the national forest level. We also reached out to state forestry agencies, who are key partners in this arena, and to state departments of environmental quality to hear the perspective of air quality regulators. In the six states where they existed at the time of our data collection, we also spoke to chairs of prescribed fire councils. In the end, for each state we targeted at a minimum one individual from the USFS, the BLM, the state forestry agency and air quality regulatory authority, and a prescribed fire council representative where relevant.

Our total number of interviews at the state level was 54, occasionally with more than one person participating in the interview. Our purposive sampling approach led to some state-to-state variation, due to different state institutional structures, unwillingness of some interviewees to participate or, occasionally, recommendations for additional key people to interview. Some interviewees had multiple roles (e.g. regional positions overseeing multiple states, state personnel in positions with a land management agency that is also involved in air quality regulation and positions co-funded and shared by multiple agencies). We averaged five interviews per state, ranging from four to seven per state. In addition, we interviewed five individuals working at a regional or national level, whom other interviewees recommended to us for providing broader context. Interview questions focused on: (1) goal-setting processes and progress towards goals for the land management agencies; (2) regulatory processes around air quality; (3) barriers to improving prescribed fire accomplishments, with detailed investigation of policy-related barriers; (4) strategies and suggestions for increasing use of prescribed fire; and (5) the role of partners and communication in supporting the use of prescribed fire.

We recorded and transcribed interviews, with the exception of one interview for which we took notes, at the interviewees' request. To analyse our data, we first reviewed transcripts by state and wrote state-level summaries to capture our findings on the processes for setting prescribed fire program goals and for air quality regulation. Using typical social science analytical and thematic coding procedures ([Saldaña 2015](#)), looking for both expected and emergent themes, we coded our interviews by theme and aggregated most coded themes as different types of barriers, successful strategies and opportunities for conducting prescribed fire. We then reviewed all of our coded excerpts for each theme and incorporated our analysis of barriers and strategies into our state-level summaries. As a final check, we returned to our federal land manager interviews to identify which barriers they raised most often and as being most significant, tabulating primary barriers across these interviews. To maintain confidentiality in accordance with our Institutional Review Board protocols, we do not associate any quotes with individuals. Our goal was to identify trends across the West, with input from people primarily working at the state or regional level, rather than fire managers or burn bosses working at the local level, where additional research would be useful to investigate state or local land management units as case studies to reveal additional detail about place-specific barriers and opportunities.

Results

We report on our findings across the West with regard to our two research questions, focusing on the primary themes that arose in our data regarding common barriers and opportunities. We offer examples of our data in text, with additional data provided in [Table 1](#).

What are the most significant policy barriers to prescribed fire on USFS and BLM lands in the West?

A majority of land managers indicated that lack of adequate funding and capacity (e.g. resources, knowledge and people to conduct work) were their primary barriers to conducting more prescribed fire (see [Table 1](#)). This was the most common barrier cited among our interviewees and often the primary barrier discussed in response to our open-ended question about the most significant factors constraining prescribed fire application. We often heard statements such as 'My biggest barrier right now is funding', or 'We just didn't have the resources'. Interviewees said lack of funding affects their ability to hire the staff needed to plan, prepare for and execute burns. Several interviews with both the USFS and the BLM described budgetary trade-offs with other activities that they must accomplish to meet performance targets or their agency's broader mission. Staff in the BLM noted that prescribed fire is just one among many priorities they are directed to address. In the USFS, staff in some regions indicated they focus on mechanical treatment to meet targets for both fuel reduction and timber volume, noting that mechanical treatments are a more reliable way to meet targets than prescribed fire, which may not be possible to accomplish in any given year. Several people also explained that a focus on meeting timber volume targets can compromise their ability to burn, with one person stating, 'Mechanical work is expensive.

Table 1. Additional data on major themes discussed in results

	Themes	Example quotes
Barriers	Funding and capacity limitations	<p>‘The other barrier is just resources... You don’t have enough people and you don’t have enough money, you just can’t burn as much as you want.’</p> <p>‘One of our big strategic issues is... when we need to burn in the summer, everybody’s fighting wildfire. Well, now the wildfires are getting longer, so we don’t have as long to burn in the summer. We just don’t have people around to burn.’</p> <p>‘[The problem is] not necessarily just [that we] need more money... availability of funding, availability of qualified staffing, [those issues] also have to do with things like timing of when staff members might be available. [It’s things like] ‘Gosh, it’s training season, and all the people who have the skills to conduct a prescribed burn during a great burn window are all at a mandatory refresher training, so that they could be ready for firefighting season during the summer.’</p> <p>‘I don’t know how many times we have air regulators who are conscious of the need for treatments and tree mortality in California suggesting that they’ve got days, and we’re in prescription, but it’s during the holidays and the seasonal fire force is off, and those that are still on [duty] have been working 60-h weeks for all summer, and now have a chance to take time off, and who would blame them? But they’re not available, and we’re losing opportunity.’</p> <p>‘One of the [challenges] is having enough qualified people. People moving around. Sometimes they have to have different [types of] qualified burn bosses... And so keeping those qualified people around makes a difference.’</p>
	Leadership, risk-aversion, incentives	<p>‘There’s always disincentive. If you have the potential for putting your whole career on the line and all your people and everything else, why would you do that? What is there that gives you points for that? Really, nothing.’</p> <p>‘While we intellectually recognise the need and value of prescribed fire, our culture is that of ‘firefighter’. And we are also pretty risk-averse organisation that really gets scared by the possibilities of a major escape. We have plenty of opportunities to draw on negative experiences of others.’</p> <p>‘I mean the personality of the person that’s talking to the burner, the person signing the permit, all the way up to the commissioner of public lands, who’s an elected official, [those things all matter]... If the elected official is extremely risk-averse, that pretty much shuts down burning. If the [decision-maker] is a very proactive, forest health-[focused person], we can have a little bit of risk, and maybe a [smoke] intrusion and learn from it moving forward.’</p> <p>‘We had the projects lined up. The burn window looked great, actually, for our region. But the politics of it... [an agency leader] asked me to cancel the event, for one because of the resource draw-down, but also just the optics of doing any kind of prescribed burning while people are losing their homes and people are losing lives and stuff. And I understood that... But I did have this feeling like... when we start cancelling the good work that needs to happen because bad things are happening somewhere else, we’re just getting farther behind.’</p>
	Air quality regulation	<p>‘I think there are a lot of other things that come into play before air quality does, to keep us from implementing prescribed burns.’</p> <p>‘The law doesn’t necessarily impede prescribed burning so much as some of the more practical realities on the ground. You don’t have enough money, you don’t have enough people, there’s too much fire danger.’</p> <p>‘There’s a misconception out there a lot of times that I hear that the air quality regulator is the barrier that’s restricting us from being able to accomplish our burns that we are required to do. I find that is an easy go-to, but the data that we have does not reflect that.’</p> <p>‘Smoke management is obviously one of those barriers... I think a lot of people kind of hang their hat on [air quality permitting] being our major implementation barrier, but when you start to look at the numbers, I don’t think it’s the major one. It’s definitely a component that restricts. Kind of narrows our windows when we can use prescribed fire... extra hoops that we have to jump through. And it’s not universal [i.e. it is different from state to state].’</p> <p>‘Air quality is something we have to consider, but it’s also just a matter of: do we have the people to burn where we want to burn? Do we have the burn windows? Is there political tolerance? I’ve heard from a number of people that they feel like air quality gets almost scapegoated as an easy excuse sometimes. I’ll say... it does get scapegoated, because it has a structure you have to follow.’</p> <p>‘Every state is different, and not just the western states, but the eastern states as well... So, if [air quality as a barrier] is something that you guys look at, you really need to read each state’s smoke management program.’</p> <p>‘Especially here in [town] there’s a lot of smoke-sensitive groups that really target our prescribed fires... There’s a lot of environmental risk activists here that really restrict a lot.’</p> <p>‘I think we are sometimes shut down, yes. I don’t think that happens very often, because our smoke coordinator is a very good negotiator for the Forest Service.’</p> <p>‘The smoke side of it – there’s days where we can’t burn because we got only into ‘fair’ or ‘poor’ air quality or our units are bigger than [we could] burn under those conditions. It does have an effect, but I think it’s minor.’</p> <p>‘We need to be able to light up a 1000 plus acres and let it do its thing day after day... Very hard to do that here... We have different challenges depending on where you are in the state.’</p>

(Continued)

Table 1. (Continued)

	Themes	Example quotes
Opportunities and successful strategies	Coordination among burners and with air quality regulators	<p>'I think there's excellent rapport between us, and I think part of that is from the land management agency. But I also think part of it is, some individuals in the [Department of Environmental Quality] have been embedded with Forest Service folks... It's not just a regulatory relationship, it's a collaborative relationship. I think it's a real positive one.'</p> <p>'We're trying to be proactive with some of our operations out there. Collecting data, building relationships with the state regulatory staff and making sure that we're proactive in addressing any issues or whatnot.'</p> <p>'I think one of my goals as a new supervisor of the [air quality regulation] unit is to keep those communication channels open with the agencies and work with them so we can both accomplish our goals. Easier said than done, but I do think clear and honest communication is the best way to go. I've received it certainly from the Forest Service, and BLM over the past year since I've become supervisor. But they've been very receptive to some of the ideas that I've had. I think that's the most productive path forward for us.'</p> <p>'We want to collaborate. We want to work together and make this work. We understand and support the need for prescribed fire, and we hope that they understand the need [...] to protect air quality.'</p> <p>'I also think part of it is some individuals in DEQ have been embedded with Forest Service offices... It's not just a regulatory relationship, it's a collaborative relationship. I think it's a real positive one, and a lot of credit goes to both Forest Service and the [Department of Environmental Quality].'</p>
	Multiparty collaboration	<p>'Once you get authority in place that says I can burn boss on your land, you can burn boss on my land, then you start opening doors. I have so many agreements in place in [this state] because [of] all these different entities, so that we can walk across our jurisdictional lines and burn on each other's land, because when we can do that, we can get this work done.'</p> <p>'We're finding out that we've got a lot of partners. [National Resource Conservation Service] is a partner with us for the ranching community. The Forestry [Division] is a partner with us for the private lands in some of these areas. It depends upon the projects and where it is as to who you end up with... We have a lot of different partners... [the Department of Wildlife] comes in and work with us on projects... We've had non-governmental types of organisations coming in working with us... A lot of this is at the district level, and we want those partnerships.'</p> <p>'There's a fairly new working group in California around prescribed fire... It's got private sector partners, Sierra [Forest] Legacy, some primary partners have signed on, the California Air Resources Board, several air districts. The whole idea is to look at efficiency [and] to increase opportunity to prescribe burn in California.'</p> <p>'We've put together a team of us from the various state agencies and federal agencies, too, where we were having daily conference calls about what was going on, how do we tell the public'</p>
	Improved monitoring	<p>'They've recognised that some of [their air quality requirements] really don't align with meeting the goals of protecting public health. We've got some of our meteorologists that work both for the BLM and for the Forest Service... we're deploying them when we do prescribed fire. And we're doing much more intensive monitoring of atmosphere conditions. And we're starting to question some of the models that have been used in the past to help determine what the ventilation index is on any given day, and therefore, how much we can burn.'</p> <p>'The next big step we can take to really improve the situation, is widespread project monitoring of smoke. As you know, monitoring is being able to take that data and develop it into forecasts that benefit the public. That really is the place that I think we stand to improve our ability in pace and scale.'</p> <p>'We've worked with [the regulators]. We've brought them out to burns... And we're doing much more intensive monitoring of atmosphere conditions... and we're kind of helping folks realise that the models previously developed maybe have some flaws in them.'</p>

So, if we're spending our money on mechanical, then we don't have money to do the final treatments of doing burning on the landscape. And, so, the constant push for new mechanical acres [to meet targets] then causes a backlog in prescribed fires.' When describing funding constraints, USFS interviewees commonly discussed the growing proportion of agency budgets devoted to fire suppression and the lack of stable funding to plan at large scales. BLM interviewees almost all mentioned the redirection of funding to conservation of sage-grouse (*Centrocercus urophasianus*), an at-risk species.

The majority of land management interviewees said they face capacity limitations in terms of having sufficient people available at the right time – namely, to implement a burn when environmental conditions meet the prescription. This was especially challenging where burn windows were narrow or coincided with wildfire season, when personnel with the necessary skills are often unavailable owing to the demands of wildland firefighting. Many interviewees noted that the necessary personnel capacity also can be unavailable owing to loss of seasonal workers, training activities or annual leave. As one person

explained, 'Just as burn season is gearing up, we lose most of our workforce. If that didn't happen, I think we would be in a very different position to do landscape-scale burning.'

Another aspect of capacity that almost every land management interviewee talked about was the need to share resources – in particular to have the ability to combine the resources of multiple units or organisations to conduct burns. Resource sharing is important for cross-boundary burning but also has become more necessary in the face of decreasing federal capacity, according to interviewees, because no one agency typically has the personnel and equipment needed to conduct prescribed burning. Several individuals we spoke with highlighted the challenges associated with lack of staff capacity and knowledge in writing the agreements necessary for sharing resources across organisations. As one person explained, 'We often reach out to our neighbouring agencies for assistance with resources and staffing. And that's all facilitated through agreements that we have, both with our state and other federal partners, and that process of getting those agreements in place is often cumbersome. Some of the [agreement authorities] I think are not clearly understood [by agency personnel].' A few interviewees also said declining staffing at state Departments of Environmental Quality (DEQ) and state forestry agencies is reducing the collective capacity to burn.

Another common theme that a majority of our land manager interviewees raised was the importance of personal commitment and leadership on the part of line officers (i.e. individuals with formal decision-making authority) and fire management staff. As one USFS employee explained, 'I really don't think there's a lot of incentive within the organisation to do prescribed fire. I think the incentive comes from the agency administrator [i.e. line officer] and burn boss passion for doing what's right on the landscape.' As another interviewee stated, 'I think where there's a will there's a way, and when there's not a will, there's not an incentive to find a way.' Several interviewees explained that individuals or staff members within agencies who are primarily trained for fire suppression, or not trained in fire management at all, often are less comfortable or interested in prescribed fire. As one person put it with regard to leadership, there is a need for 'fire-adapted line officers [i.e. decision makers]' who are knowledgeable about fire and willing to work with it. Individual risk tolerance and expertise also were described by many land management interviewees as playing a role in the willingness to support more prescribed fire; interviewees also said liability concerns were a barrier for some burn bosses, although not for others. Interviewees also felt that risk aversion at higher levels of the USFS, often due to concern about lack of public support or political conflict when highly visible wildfires are burning, also creates barriers to use of prescribed fire (see Table 1).

When we asked about the degree to which specific policies, including the National Forest Management Act, the National Environmental Policy Act (NEPA) and the Endangered Species Act, affected their ability to burn, the individuals we spoke with did not often indicate these as being among their primary challenges, except in specific contexts. For example, in the states where the species is present, interviewees said burning in sage-grouse habitat is difficult to accomplish owing to policy restrictions and also is not always appropriate. In western Oregon, we heard from several interviewees that protecting

northern spotted owls (*Strix occidentalis caurina*) in the Northwest Forest Plan area is a constraint that is exacerbated by fragmented landownership, creating, as one interviewee described, 'layer(s) of Swiss cheese on the [land management] map'. This person went on to say, 'And [then] you're just trying to burn all the little pieces in between that happen to be mid-slope or down in the creek, [which is] not ideal.' A few interviewees indicated that getting through the NEPA process creates a barrier to accomplishing more prescribed fire, primarily due to lack of adequate capacity for planning, and several people suggested that the federal agencies need to find greater opportunities to jointly undertake project planning and NEPA analysis. Several people noted that a lack of capacity, coupled with legal requirements to conduct archaeological and wildlife surveys and environmental analysis, can slow projects down, whereas a few others indicated this was less of an issue because they were undertaking NEPA analysis at larger and more efficient scales than in the past.

A majority of our land manager interviewees emphasised that obtaining air quality permits is not the primary barrier they face. Many people explained there are often days when air quality is acceptable, but they cannot burn owing to lack of capacity. One person expressed a sentiment we heard across approximately half the states, saying 'There are people who choose to use smoke management as an excuse not to get things done, because ... it's the scapegoat that no one questions... The problem is, we have 30 years of data to show that's just not the case.' One person explained, 'Air quality plays a role in all these things, but in my experience people like to complain about it. But I haven't seen it deemed a major barrier. Once people have all their ducks in a row and are ready to go, air quality is generally not the issue.' It also was common for people to say that air quality regulators are willing to work with them to support burning, although several interviewees indicated that air quality constraints are a restriction they accept and work within.

Although most interviewees said air quality regulation was not their biggest challenge, there were exceptions in some states (Table 1). Air quality tended to arise as a key barrier in specific locations and situations, such as being close to Class I airsheds (i.e. airsheds that receive the highest level of protection, including national parks), population centres where there are many sources of emissions that compromise air quality, or population centres that are subject to inversions. In Oregon and Washington, relatively stricter state-level regulatory approaches make air quality regulation one of the major barriers to burning, according to our interviewees. Both states often limit smoke intrusions into communities to levels that are stricter than the National Ambient Air Quality Standards (NAAQSs) under the Clean Air Act. One person explained, 'Washington really has been strict. They don't want any intrusion of any smoke into any communities at any time.' In these cases, state-level policy in state implementation plans and implementation of those policies constrain burning. Similarly, in Utah, interviewees said they were working together to address the limitations associated with having a single state-wide 'clearing index' (a ventilation measurement) that some said limited burning within the state.

In California, people described the large number of population centres and competition in some airsheds from other pollution sources; interviewees noted that these conditions

create challenges for burners in some parts of the state. As one person put it, ‘The air regulations are going to be an impediment [...] but I feel like there’s a little bit of change happening. Some of our air districts have had year after year of really large, catastrophic wildfires, and the science shows that prescribed fire [...] produces significantly less smoke per acreage than those wildfires [...] I feel like the air regulators are really working with us, but we are going to continue to comply with the statutes, as they exist.’ However, no one suggested a current need for air quality policy in California to change or said this was their primary barrier to burning. All our interviewees in California emphasised that their priorities for increasing the use of prescribed fire included better monitoring of smoke impacts to inform air quality protection, addressing capacity issues, and planning more strategically to capitalise on burn days when they are available. Several individuals across states noted that air quality regulation for landscape or multiday burning presents a conundrum that will require future attention, and that potentially stricter future regulation around particulate matter standards would present new challenges.

What are potential opportunities and mechanisms for change around policy-related challenges?

When we asked about strategies for success and opportunities for improvement, a common theme was the importance of communication, partnerships and collaborative forums. These were important for coordinating among burners and with air quality regulators to manage competition in airsheds, build trust and understanding, share resources, and capitalise on opportunities for burners with restrictive burn windows and prescriptions. Dedicated positions and processes to bridge across land managers and air regulators were often said to be essential; for instance, in most states the USFS now has a dedicated liaison that works directly with air quality managers to find opportunities to burn and track planned burns in airsheds. A majority of interviewees emphasised that this type of practice helps both land and air quality managers understand each agency’s goals, concerns and constraints (see Table 1). One example is the Montana–Idaho Airshed Group, which is run by burners to coordinate burning activities and streamline communication with regulators. As one person explained about this group, ‘I think that we can work with what we have, which has been built by burners and has been iterated by burners [...] to be as unobtrusive a smoke management approval process, and we can figure out how to build [our programs].’ Another interviewee in a different state noted, ‘I find that for our federal partners and for me [...] having a strong relationship with our air quality districts, like a personal relationship, has been so important to getting projects done.’

Interviewees also commonly described the role multiparty collaborative forums play in developing creative solutions to getting more prescribed fire on the ground as it facilitates

place-specific problem solving, identification of resource sharing opportunities and development of coordinated communication strategies (see Table 1). Many land management interviewees emphasised in particular the importance of relationships among state and federal land management agencies. As one person explained, ‘Those working under [that fire manager] are very integrated and [on a] first-name-basis with their [state agency] counterparts on the fire side. In the areas where we’ve had the biggest challenge, [that] is where either one or both of those relationships are not as strong.’ A few interviewees noted that such partnerships also can have benefits beyond prescribed fire. One USFS interviewee said, ‘It’s the working relationships during the prescribed fire season that jump over into the suppression season, and you already know each other, and suppression goes easily because of having those relationships in fire and fuel management already.’

A majority of land managers described the importance of efforts to streamline resource sharing. Interviewees stated that for basic or short-term items, there are fairly straightforward ways around inter-agency agreement limitations, such as ‘If you just need an engine for a day or two, most folks are more than willing to say, ‘Yeah... we’ll just kind of do a handshake.’ However, interviewees consistently said this was more challenging for high-cost items or longer-term endeavours. In some states, such as Arizona and California, the land management agencies are using a statewide master agreement to support resource sharing among the state and federal agencies for prescribed fire. Several regional and state offices said they are working with units to coordinate agreements to create efficiencies. Interviewees in all but a couple of states said they were utilising the ‘Good Neighbor Authority’ or ‘Wyden Authority’¹ to share resources with the states and conduct cross-boundary burning, and people indicated these were useful policy tools for burning in complex, mixed-ownership landscapes. However, most land managers said they needed more grants-and-agreements capacity and expertise to make these kinds of initiatives and processes more efficient.

Several interviewees suggested creating structures for prescribed fire parallel to those that exist for wildfire suppression to facilitate resource sharing, including a shared resource-ordering system. Several people said they would benefit from having a single, interagency charge code that all federal agencies could utilise for ordering resources, as exists for wildland fire events, for prescribed fire to obviate the need for multiple interagency agreements. One person in California said that a national agreement to share resources between the USDA and USDI would be ‘the single biggest breakthrough’ that would allow their staff to get more fire on the ground; several people at the state and regional levels, when we asked how this could work, indicated they could still track resource sharing locally to maintain accountability but without the need to enter into multiple formal agreements.

¹The ‘Good Neighbor Authority’ (16 USC § 2113a) allows the US secretaries of Agriculture and Interior to enter into cooperative agreements or contracts with states pursuant to which state agencies can perform ‘forest, rangeland, and watershed restoration services’ (including ‘activities to reduce hazardous fuels’) on USFS and BLM land. The ‘Wyden Authority’ (16 USC §§ 1011 and 1011a) allows the departments of Agriculture and Interior to enter into ‘cooperative agreements’ with other federal agencies, tribal, state and local governments, and private and non-profit entities and landowners for the protection, restoration, enhancement of fish and wildlife habitat ‘and other resources on public or private land’ and for ‘the reduction of risk from natural disaster where public safety is threatened.’

Several land manager interviewees said there is a need for dedicated prescribed fire capacity. Interviewees noted that firefighting resources can be held on reserve during wildland fire season, preventing personnel from being available to participate in a prescribed burn. Individuals said despite the need to address wildland fire, somehow more personnel need to be made available for multiple days at a time to conduct prescribed fire even during times of heightened wildfire activity. Suggestions included creating dedicated prescribed fire teams, either within the federal government, or at the state level, or with the help of non-governmental organisations. Several land managers also noted that hazard pay and overtime pay create financial incentives that draw fire-qualified personnel to wildland fire events; they suggested exploring possible incentives for fire-qualified personnel to work on prescribed fire.

Finally, in places where air quality was more of an issue, several efforts are under way to create more room to manoeuvre. Both Oregon and Washington are in the process of revising their smoke management plans with the intent to expand the decision space around approving prescribed burns; Oregon's revised plan was adopted in spring 2019. In California, interviewees indicated regulators are working actively with land managers to find more opportunities to burn. In addition, a coalition of actors in California is working together to problem-solve, seeking to understand why more available burn days are not utilised and what the potential solutions might be (see https://www.sierraforestlegacy.org/CF_ManagingFire/FireMOU.php, accessed 9 August 2019). In addition, several interviewees noted that federal Clean Air Act regulations now allow prescribed fire events, when they are consistent with land management plans, to be considered as exceptional events (i.e. with air quality exceedances potentially excluded from assessments of NAAQS attainment); to date, no state has utilised this provision, which was revised in 2016 by the Environmental Protection Agency in coordination with federal land management agencies (see 81 FR 68216 and [Quirke 2018](#)).

Aside from these actions, several interviewees across different states noted that improved monitoring data and smoke modelling efforts within the land management agencies could provide much-needed information to refine air quality assessments. Currently, many states' air quality measures are made on a statewide or regional basis. Improved monitoring and modelling of smoke would enable regulators and burners to assess air quality at a more local level, which could create more room for increased burning (e.g. allowing burning at higher elevations above an inversion even when the air quality below is poor) (see [Table 1](#)). In a few places, people said that individual regulators within a state sometimes would allow different levels of burning; improved data from land managers and transparency in decision-making from air quality regulators both could be useful for understanding how permitting decisions can be better tailored to local conditions. Here, too, trust and relationships matter. As one person said, when discussing this, 'That goes back to their relationship and trust' built between land managers and local air quality regulators, emphasising that some burn bosses who get more acres approved by regulators 'really work on that relationship and communicate what they're trying to do'.

Discussion

Through interviews across the western US states, we investigated barriers and facilitating strategies for prescribed fire application on USFS and BLM lands. The barriers that were identified most frequently by our interviewees were lack of adequate capacity and funding for accomplishing prescribed fire, along with a need for greater leadership direction and incentives to apply prescribed fire. Barriers related to policy requirements tended to be significant only in specific locations or situations, such as smoke regulations in the Pacific Northwest or protecting specific threatened and endangered species. Although more investigation would be needed to determine whether more policy flexibility is desirable in these cases, no one suggested a need for changes to federal law or that any single policy at the national level was acting as a major barrier. The most common barriers we identified were more a result of factors that influence policy implementation, such as leadership direction and resource availability, rather than problems associated with policy requirements in law or regulation. Although this was not a focus in the present work, interviewees also discussed other barriers to burning, like drought conditions, short burn windows and the presence of challenging landscape conditions, such as the presence of invasive cheat grass (*Bromus tectorum*), that limit their ability to conduct prescribed fire.

Our findings provide support for previous survey work that found that capacity is a major limitation for applying prescribed fire ([Quinn-Davidson and Varner 2012](#); [Melvin 2018](#)). We found less support for previous findings that air quality regulation is consistently a significant barrier ([Cleaves et al. 2000](#); [Quinn-Davidson and Varner 2012](#)). There are several potential reasons for the latter difference. Most of the cited work comes from surveys where it can be more of a challenge to distinguish the nuances of responses and how variables interact; it also may reflect the point several of our interviewees made that air quality is an easy barrier to point to. Another possibility is that our sample includes relatively more people in leadership positions, rather than individual burn bosses, who may have different perceptions of barriers to achieving prescribed fire. It could also reflect other organisational changes: over time, agency efforts to address air quality regulation may have helped decrease the relative importance of that barrier, while changes in agency staffing levels may have increased the capacity challenge. Compared with 2000, federal agency capacity, particularly in the USFS, has decreased substantially. The agency estimates it now has ~11 000 employees in the National Forest System compared with 20 000 in the year 2000 ([USFS 2015](#)). This loss of 45% of individuals may have exacerbated the capacity issue, with less people available to support planning for prescribed fire, public outreach, entering into agreements and implementation of prescribed fire. At the same time, efforts put into building relationships between land managers and air quality regulators, through dedicated positions, processes and other collaborative processes, may have reduced the relative significance of air quality regulation as a challenge. Our interviews indicated that greater coordination through air quality liaisons with the land management agencies, active communication with air quality regulators and a desire on the part of regulators to create flexibility, based on a growing understanding of the importance

of prescribed fire for mitigating wildland fire behaviour, all are leading to a more flexible regulatory environment around air quality. Air quality regulation was a significant challenge in some places, and some interviewees said regulation might become more of a challenge in the future if land managers were burning as much as they needed to. Although many other factors currently are constraining the size of burn programs, this is an issue that will need ongoing attention into the future.

Our findings highlight the critical role collaborative governance plays in increasing the use of prescribed fire, particularly in light of the fact that the challenges and opportunities are unique from place to place. Efforts to manage complex social–ecological systems, like those of US fire management, depend on the capacity of communities of practice to support learning and adaptation, leverage diverse knowledge sources and capacities, and share power across diverse actors through collaboration (Armitage 2005). Challenges and solutions will often be specific to the partners and social–ecological conditions in any given place, and this necessitates collaborative problem solving.

Collaborative and networked approaches are increasingly essential to effective government function today – a reality that necessitates other institutional adjustments, including potentially new policies, positions and processes to support improved governance (Kettl 2000; Emerson *et al.* 2012; Abrams *et al.* 2017; Kamensky 2018). Collaborative governance forums in our data were important for working across sectors (e.g. land and air quality management) and coordinating among federal, state and non-government partners to share resources, problem-solve and improve communication. In particular, we heard that forums at the state level are important for bridging across land and air quality managers, among state and federal agencies, and leveraging the problem-solving and capacity-building skills of non-profit partners. Continuing to invest in positions for staff members who act as liaisons between agencies, and to support processes for coordinating among burners and regulators likely will be critical to future success. Given the prominence of capacity as a barrier in our findings and the fact that declining capacity to conduct prescribed fire has been identified as far back as the 1995 Federal Fire Policy Review, increased support for collaborative governance policies, processes and structures to support resource sharing and capacity building will be essential going forward (USDA and USDI 1995). Agencies may want to investigate ways to create state and national-level master agreements that would allow more nimble resource sharing for prescribed fire, obviating the need for individual regions or units to enter into multiple agreements with other local land management entities. Staff members specialised in entering into partnerships and cost-sharing agreements may need to be added. Agencies and partners may also want to continue exploring how to create more dedicated prescribed fire capacity, both within the federal government and among state and non-governmental partners, to avoid the problem of losing key personnel during burn windows to wildfire suppression.

Another finding, one not clearly identified in the previous work on prescribed fire, is the importance of agency leaders and fire personnel who are committed to conducting prescribed fire to support successful burn programs, particularly in the absence of clear direction or incentives to undertake prescribed burning. In conversations since our data collection, USFS leadership in

multiple regions has indicated it is working to give leaders at the National Forest level clearer direction to undertake prescribed fire, holding staff members more accountable for meeting prescribed fire targets and rewarding units who meet targeted accomplishments accordingly. These types of internal policy changes, with new incentives from the agency, along with communication from regional and national leadership about the importance of prescribed fire would be valuable. There may also be opportunities to address this issue in leadership training and in hiring practices to support the notion of a larger cadre of ‘fire-adapted line officers’. More research will be needed to understand how such efforts develop going forward. Clearer incentives and direction for fire managers to actively work to apply prescribed fire and rewarding effective leaders with the staff and resources they need would likely increase the number of active burn programs.

This research has broader implications for fire and natural hazard management more generally. First, it is important in a complex governance system to continue to assess where barriers lie and how they can be addressed; challenges typically do not exist as inflexible barriers in a strict sense and will change over time, requiring a nuanced and ongoing contextual approach to understanding impediments to improving practice (Biesbroek *et al.* 2017). These can rest not just with policy direction, but also in matters of policy implementation at the field level, related to details like resource availability and leadership direction. Although substantive policies can set goals for policy implementers, it is equally important to have the processes and resources in place to translate policy goals into action (Howlett 2009). Improved policy implementation may rely on adequate knowledge, skills and resources, as well as new governance structures and processes, like the land manager–air quality positions and state-level collaborative forums that we found to be critical for success.

In addition, our findings highlight the importance of multi-level governance approaches in fire management. National-level collaboration can facilitate resource sharing and address high-level policy challenges where they exist, while state-level coordination is critical for addressing air quality regulation, sharing resources with state agencies and engaging state-level political actors. Local collaboration is also important for planning, resource sharing and generally building agreement to engage in fire management activities (Schultz *et al.* 2018b). Actors at all levels bring comparative advantages for addressing a variety of issues in the governance system (Crona and Parker 2012), and bridging organisations or forums are essential to connecting among levels (Cash *et al.* 2006; Schultz *et al.* 2019).

Our observations align with the National Cohesive Wildland Fire Management Strategy’s assessment that ‘the ultimate success of the Cohesive Strategy effort depends on how strategic direction and national priorities can be translated into on-the-ground, local actions of agencies, organisations, governments, and individuals that can produce meaningful cumulative effects’ (WFEC 2014b, p. 7). Recent research on wildland fire response similarly highlights the importance of collaborative forums and interagency communication as key determinants of success under the Cohesive Strategy (Steelman and Nowell 2019). Although there may not be a ‘silver bullet’ to getting more prescribed fire on the ground, the opportunities and activities we

identified in our research reveal that there is substantial room to improve practice in the current policy context, although meaningful progress will require active problem-solving at multiple levels of the governance system.

Conflict of interest

The authors declare no conflicts of interest.

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References

- Abrams J, Huber-Stearns HR, Bone C, Grummon CA, Moseley C (2017) Adaptation to a landscape-scale mountain pine beetle epidemic in the era of networked governance: the enduring importance of bureaucratic institutions. *Ecology and Society* **22**, 22. doi:10.5751/ES-09717-220422
- Armitage D (2005) Adaptive capacity and community-based natural resource management. *Environmental Management* **35**, 703–715. doi:10.1007/S00267-004-0076-Z
- Biesbroek R, Dupuis J, Wellstead A (2017) Explaining through causal mechanisms: resilience and governance of social–ecological systems. *Current Opinion in Environmental Sustainability* **28**, 64–70. doi:10.1016/J.COSUST.2017.08.007
- Burrows N, McCaw L (2013) Prescribed burning in south-western Australian forests. *Frontiers in Ecology and the Environment* **11**, e25–e34. doi:10.1890/120356
- Cash D, Adger WN, Berkes F, Garden P, Lebel L, Olsson P, Pritchard L, Young O (2006) Scale and cross-scale dynamics: governance and information in a multilevel world. *Ecology and Society* **11**, 8. doi:10.5751/ES-01759-110208
- Cleaves DA, Martinez J, Haines TK (2000) Influences on prescribed burning activity and costs in the national forest system. USDA Forest Service, Southern Research Station, General Technical Report SRS-37. (Athens, GA, USA)
- Crona B, Parker J (2012) Learning in support of governance: theories, methods, and a framework to assess how bridging organizations contribute to adaptive resource governance. *Ecology and Society* **17**, 32–50. doi:10.5751/ES-04534-170132
- Emerson K, Nabatchi T, Balogh S (2012) An integrative framework for collaborative governance. *Journal of Public Administration: Research and Theory* **22**, 1–29. doi:10.1093/JOPART/MUR011
- Engel KH (2013) Perverse incentives: the case of wildfire smoke regulation. *Ecology Law Quarterly* **40**, 623–672.
- Fernandes PM, Davies GM, Ascoli D, Fernández C, Moreira F, Rigolot E, Stoff CR, Veja JÁ, Molina D (2013) Prescribed burning in southern Europe: developing fire management in a dynamic landscape. *Frontiers in Ecology and the Environment* **11**, e4–e14. doi:10.1890/120298
- Fernandez S, Rainey HG (2006) Managing successful organizational change in the public sector. *Public Administration Review* **66**, 168–176. doi:10.1111/J.1540-6210.2006.00570.X
- Howlett M (2009) Governance modes, policy regimes, and operational plans: a multilevel nested model of policy instrument choice and policy design. *Policy Sciences* **42**, 73–89. doi:10.1007/S11077-009-9079-1
- Kalies EL, Kent LL (2016) Tamm Review: are fuel treatments effective at achieving ecological and social objectives? A systematic review. *Forest Ecology and Management* **375**, 84–95. doi:10.1016/J.FORECO.2016.05.021
- Kamensky JM (2018) Becoming collaborative. In ‘Government for the future: reflection and vision for tomorrow’s leaders’. (Eds MA Abramson, DJ Chenok, JM Kamensky) pp. 111–137. (IBM Center for the Business of Government: Washington, DC, USA)
- Kettl DF (2000) The transformation of governance: globalization, devolution, and the role of government. *Public Administration Review* **60**, 488–497. doi:10.1111/0033-3352.00112
- Kobziar LN, Godwin D, Taylor L, Watts AC (2015) Perspectives on trends, effectiveness, and impediments to prescribed burning in the southern US. *Forests* **6**, 561–580. doi:10.3390/F6030561
- Kolden CA (2019) We’re not doing enough prescribed fire in the western United States to mitigate wildfire risk. *Fire* **2**, 30. doi:10.3390/FIRE2020030
- Melvin MA (2018) 2018 National prescribed fire use survey report. Coalition of Prescribed Fires, Inc., Technical Report 03–18. Available at <https://www.stateforesters.org/wp-content/uploads/2018/12/2018-Prescribed-Fire-Use-Survey-Report-1.pdf> [Verified 9 August 2019]
- Moritz MA, Batllori E, Bradstock RA, Gill AM, Handmer J, Hessburg PF, Leonard J, McCaffrey S, Odion DC, Schoennagel T, Syphard AD (2014) Learning to coexist with wildfire. *Nature* **515**, 58–66. doi:10.1038/NATURE13946
- Moseley C, Charnley S (2014) Understanding microprocesses of institutionalization: stewardship contracting and national forest management. *Policy Sciences* **47**, 69–98. doi:10.1007/S11077-013-9190-1
- North M, Collins BM, Stephens S (2012) Using fire to increase the scale, benefits, and future maintenance of fuels treatment. *Journal of Forestry* **110**, 392–401. doi:10.5849/JOF.12-021
- North MP, Stephens SL, Collins BM, Agee JK, Aplet G, Franklin JF, Fulé PZ (2015) Reform forest fire management. *Science* **349**, 1280–1281. doi:10.1126/SCIENCE.AAB2356
- Parker UL (2018) Reducing impediments to prescribed burning opportunities: the importance of collaborative relationships between land managers and air quality regulators. Unpublished Master’s Thesis, California State University, Chico, CA, USA. Available at <http://csuchico-dspace.calstate.edu/handle/10211.3/205899> [Verified 9 August 2019]
- Quinn-Davidson LN, Varner JM (2012) Impediments to prescribed fire across agency, landscape and manager: an example from northern California. *International Journal of Wildland Fire* **21**, 210–218. doi:10.1071/WF11017
- Quirke D (2018) Legal appendix: an overview of the Clean Air Act and state-level air quality regulation. Ecosystem Workforce Program Working Paper 86. (Eugene, OR, USA). Available at <https://ewp.uoregon.edu/publications/working> [Verified 9 August 2019]
- Rutherford TK, Schultz CA (2019) Adapting wildland fire governance to climate change in Alaska. *Ecology and Society* **24**, 27. doi:10.5751/ES-10810-240127
- Ryan KC, Knapp EE, Varner JM (2013) Prescribed fire in North American forests and woodlands: history, current practice, and challenges. *Frontiers in Ecology and the Environment* **11**, e15–e24. doi:10.1890/120329
- Saldaña J (2015) ‘The coding manual for qualitative researchers.’ (Sage Publications: London, UK)
- Schoennagel T, Balch JK, Brenkert-Smith H, Dennison PE, Harvey BJ, Krawchuk MA, Mietkiewicz N, Morgan P, Moritz MA, Rasker R, Turner MG (2017) Adapt to more wildfire in western North American forests as climate changes. *Proceedings of the National Academy of Sciences of the United States of America* **114**, 4582–4590. doi:10.1073/PNAS.1617464114
- Schultz CA, Jedd T, Beam RD (2012) The Collaborative Forest Landscape Restoration Program: a history and overview of the first projects. *Journal of Forestry* **110**, 381–391. doi:10.5849/JOF.11-082
- Schultz CA, Huber-Stearns H, McCaffrey S, Quirke D, Ricco G, Moseley C (2018a) Policy barriers to prescribed fire: a diversity of challenges and opportunities across the west. Ecosystem Workforce Program Working Paper 86. (Eugene, OR, USA) Available at <https://ewp.uoregon.edu/publications/working> [Verified 9 August 2019]

- Schultz CA, McIntyre K, Cyphers L, Kooistra C, Ellison A, Moseley C (2018b) Policy design to support forest restoration: the value of focused investment and collaboration. *Forests* **9**, 512–532. doi:10.3390/F9090512
- Schultz CA, Timberlake TJ, Wurtzebach Z, McIntyre KB, Moseley C, Huber-Stearns HR (2019) Policy tools to address scale mismatches: insights from US forest governance. *Ecology and Society* **24**, 21. doi:10.5751/ES-10703-240121
- Steelman T, Nowell B (2019) Evidence of effectiveness in the Cohesive Strategy: measuring and improving wildfire response. *International Journal of Wildland Fire* **28**, 267–274. doi:10.1071/WF18136
- Steelman TA (2010) 'Implementing innovation: fostering enduring change in environmental and natural resource governance.' (Georgetown University Press: Washington, DC, USA)
- USDA and USDI (1995) Federal Wildland Fire Management Policy and Program review. (Washington, DC, USA). Available at https://www.forestsandrangelands.gov/documents/strategy/foundational/1995_fed_wildland_fire_policy_program_report.pdf [Verified 9 August 2019]
- USDA and USDI (2014) 2014 Quadrennial fire review: final report. (Washington, DC, USA). Available at <https://www.forestsandrangelands.gov/documents/qfr/2014QFRFinalReport.pdf> [Verified 9 August 2019]
- USFS (2015) The rising cost of wildfire operations: effects on the Forest Service's non-fire work. (Washington, DC, USA). Available at <https://www.fs.fed.us/sites/default/files/2015-Fire-Budget-Report.pdf> [Verified 9 August 2019]
- WFEC (2014a) A National Cohesive Wildland Fire Management Strategy. (Washington, DC, USA). Available at https://www.forestsandrangelands.gov/documents/strategy/reports/1_CohesiveStrategy03172011.pdf [Verified 9 August 2019]
- WFEC (2014b) The National Strategy Summary: the final phase in the development of the National Cohesive Wildland Fire Management Strategy. (Washington, DC, USA). Available at <https://www.forestsandrangelands.gov/documents/strategy/strategy/communications/National-StrategySummary.pdf> [Verified 9 August 2019]
- Wurtzebach Z, Schultz C (2016) Measuring ecological integrity: history, practical applications, and research opportunities. *Bioscience* **66**, 446–457. doi:10.1093/BIOSCI/BIW037