

Impediments to prescribed fire across agency, landscape and manager: an example from northern California

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Abstract. Though the need for prescribed fire is widely recognised, its use remains subject to a range of operational and social constraints. Research has focussed on identifying these constraints, yet past efforts have focussed disproportionately on single agencies and geographic regions. We examined constraints on prescribed fire by surveying a wide variety of organisations (including six state and federal agencies and several tribes, non-governmental organisations and timber companies) in northern California, a fire-prone region of the western United States. Across the region, prescribed burning annually covered only 38% of the area needed to fulfil land-management objectives, and 66% of managers indicated dissatisfaction with levels of prescribed fire activity. The highest-ranked impediments were narrow burn window, regulations, lack of adequate personnel and environmental laws. Impediment ratings differed among entities, with legal and social impediments of greater concern in the private sector than in the public, and economic impediments of greater concern in the state and private sectors than in the federal. Comparisons with the south-eastern United States, where similar research has taken place, point to important regional constraints on prescribed fire activity. These findings suggest further need for research spanning geographic and ownership boundaries, as prescribed fire impediments can vary by context.

Additional keywords: air quality, burn window, constraints, fire management, Forest Service.

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Introduction

Prescribed fire is widely recognised as an important land-management tool; it offers a means to many ends, simultaneously reducing hazardous fuels and restoring natural processes, while maintaining both economic efficiency and cultural significance unrivalled by other types of treatments (e.g. Biswell 1989; Wade and Lunsford 1989; Husari and McKelvey 1996; Anderson 2005). Yet the use of prescribed fire faces a range of constraints, from operational to social, limiting land managers in their ability to effectively treat fuels, mitigate fire hazard and reintroduce fire to affected ecosystems (Cleaves *et al.* 2000; Hiers *et al.* 2003). The expansion of prescribed fire activities, and the realisation of associated ecological and social benefits, hinges on the identification and dissolution of these constraints, rendering related research critical.

Past research has explored in detail the multitude of constraints on prescribed fire activity. Ecological research has identified several limitations, including constrictions based on season of burning and its effects on flora and fauna (Knapp *et al.* 2009), legacies of past fire exclusion (Swezy and Agee 1991; Hiers *et al.* 2003; Varner *et al.* 2005) and over-arching restrictions due to fuel moisture that reduce the effectiveness of burns (Walstad *et al.* 1990; Engber *et al.* 2011). Researchers have

characterised public support for prescribed fire, emphasising the pivotal role of communication, trust and collaboration in prescribed fire planning and implementation (e.g. Shindler and Toman 2003; McCaffrey 2006), and they have also explored the role of policy (e.g. Husari and McKelvey 1996; Stephens and Ruth 2005), regulations (e.g. Craig 1990; Cleaves and Haines 1997) and economics (e.g. Husari and McKelvey 1996; Cleaves *et al.* 2000; Yoder *et al.* 2003). These diverse areas of research contribute greatly to our understanding of the issues surrounding prescribed fire, yet they do not necessarily speak about the relative influences of these constraints on management activities. A comparative approach illuminates the complexity of the issue, and may be essential to the expansion of prescribed fire use or the identification of alternatives where needed.

Though sparse, there is research that compares the relative importance of constraints on prescribed fire activity (e.g. Cleaves *et al.* 2000; Haines *et al.* 2001; Williamson 2007). These works highlight widely shared constraints, such as regulations and lack of funding, but they also reveal that the issues facing prescribed fire programs can vary by context, depending on an area's ecological, social and legal environment and on the individual values of fire managers (Cortner *et al.* 1990; Cleaves *et al.* 2000; Williamson 2007; Laband *et al.* 2008).

In their 2000 survey of USDA Forest Service (USFS) Fire Management Officers (FMOs) across the United States, Cleaves *et al.* (2000) found varying constraints in different USFS regions. For example, managers in the Northern Region identified public opinion as the biggest barrier to their prescribed burn programs, yet managers in the Pacific Southwest Region (California) rated public opinion as one of the least limiting issues in their area. This pattern of differential influence across geographic region was clear for many of the barriers on that survey; even regulations, which had the highest overall rating of any barrier on the survey, were given surprisingly low ratings by managers in one of the regions (Cleaves *et al.* 2000).

Beyond regulations, there are several legal issues that provide prime examples of regional disparities (Yoder *et al.* 2003; Laband *et al.* 2008). Liability laws, which are determined at the state level in the United States, vary substantially among regions; liability laws range from conservative strict liability laws (where the burner assumes all responsibility for escaped fire regardless of precautionary efforts) to more novel gross negligence laws (where the burner must be shown to have been grossly negligent in order to be liable for escapes) (Yoder *et al.* 2003). Many states in the south-eastern USA recognise prescribed burning as a beneficial property right, and some states (e.g. Florida) support that right with gross negligence laws (Yoder *et al.* 2003). California maintains standard negligence laws (where the burner is liable if proved negligent), and though those laws are not as conservative as the strict liability laws mentioned above, they may be more inhibitive than laws in the south-eastern USA. That said, prescribed fire managers in the USA are fortunate to have legal frameworks for burning, as the lack of legal standards and frameworks has been noted as a major regional constraint on burning in countries in the Mediterranean and other parts of Europe (Lazaro and Montiel 2010).

Though research has investigated regional influences on prescribed fire activity, one issue of context – agency affiliation – has largely been overlooked. Studies in the United States have focussed primarily on the activities and perspectives of USFS managers (Cortner *et al.* 1990; Cleaves *et al.* 2000; Williamson 2007), neglecting focus on other federal and state agencies, tribes, private landowners and non-governmental organisations (NGOs), and missing opportunities for inter-entity comparisons. Thus far, the only example of inter-entity research demonstrated differences between entities (Haines *et al.* 2001) but was restricted to the south-eastern USA, where land-ownership patterns, climate and levels of prescribed fire activity contrast with northern California and complicate generalisations outside that region. The lack of comparative research on constraints – and the limited geographic range of existing research – suggests a strong need for further investigation, particularly in the western USA, where there is incongruence between fire-prone landscapes and a comparatively limited use of prescribed fire.

This research explored the relative influence of constraints on prescribed fire activity in northern California, USA. We included a range of entities that use prescribed fire, including four federal agencies, two state agencies, and several tribes, NGOs and timber companies. Research objectives were: (i) to characterise prescribed fire activity in northern California, including all major entities that use prescribed fire (annual area

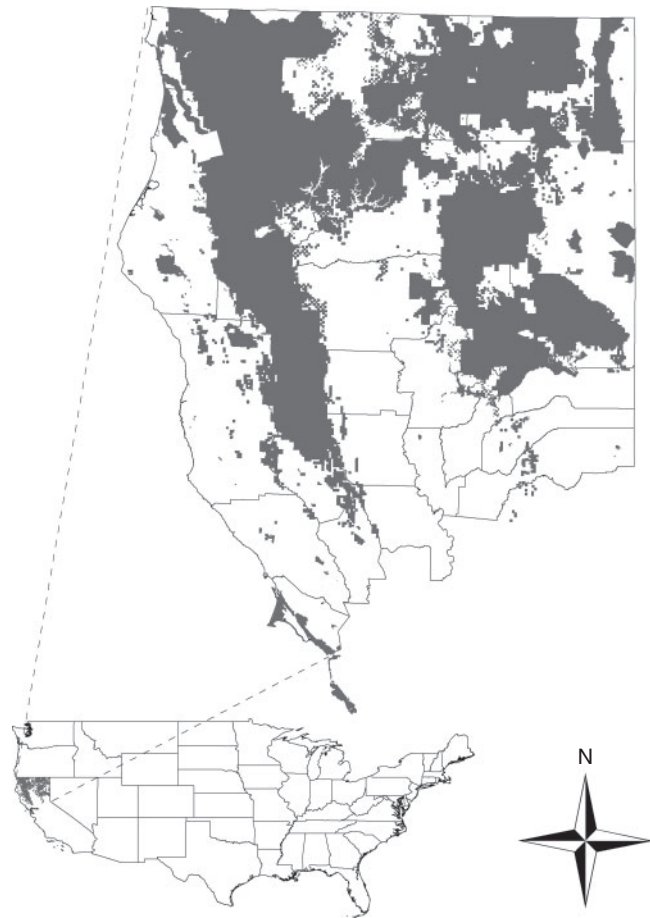


Fig. 1. Areas managed by survey respondents (in grey) (excluding timber companies), northern California prescribed fire survey, 2009.

treated, objectives of prescribed fire programs); (ii) to identify and rank impediments to the use of prescribed fire in the region, analysing differences among entities; and (iii) to enable comparisons between northern California and the south-eastern USA, where similar work has been accomplished.

Methods

In spring 2009, a survey was distributed by email to district-level fire managers across northern California. For the purposes of the survey, northern California included the area north of the San Francisco Bay Area and the Tahoe Basin (Fig. 1). Prescribed fire, as defined on the survey instrument, included only management-ignited ‘broadcast’ burns and thus did not include slash burning, pile burning, or naturally ignited wildland fires.

Survey design

Following the basic tenets of Dillman’s (2000) Tailored Design Method, we used a personalised, iterative approach to survey administration. Managers were contacted by telephone before receiving the survey, allowing explanation of the research and giving respondents the opportunity to ask questions. In order to maximise convenience and response rates, the survey was designed to be distributed, filled out and returned digitally; the

survey was emailed, with detailed instructions, directly after each telephone conversation. If the completed survey was not returned within 2 weeks, we sent a reminder email with the survey attached.

The survey included management entities for which prescribed fire is a management tool. These included state and federal agencies, including the USFS, Bureau of Land Management (BLM), National Park Service (NPS), US Fish and Wildlife Service (USFWS), the California Department of Forestry and Fire Protection (Cal Fire) and the California Department of Parks and Recreation (CDPR). The survey also included, to a more limited extent, tribes with forestry or fire-management departments, NGOs and timber companies. The distinct organisational structure of each entity dictated the number of and types of positions held by potential respondents, and though the number of respondents was limited for some entities, we felt it was important to include them; for example, we had only two respondents from the USFWS, yet those two managers represented all USFWS lands in the region where prescribed fire is utilised. This was a comprehensive effort, as agency managers from all districts in the region were surveyed.

The survey asked managers to provide the following for their management areas: (1) area treated with prescribed fire for the years 2006, 2007 and 2008; (2) management objectives for prescribed fire programs, rated on a scale of 1 (not important) to 10 (extremely important); (3) annual area of prescribed fire treatment needed to fulfil management objectives; (4) constraints to the increased use of prescribed fire, rated on a scale of 1 (not limiting) to 10 (extremely limiting); and (5) responses to statements concerning desired levels of prescribed fire use and perceptions of risk, rated on a scale of 1 (strongly disagree) to 10 (strongly agree). There was also an open-ended comment section at the end of the survey; managers' comments informed the research and this paper's discussion, but they were not systematically analysed for content.

Two of the entities surveyed – Cal Fire and NGOs – accomplish the majority of their prescribed burning on lands that are owned and managed by other groups or individuals. Cal Fire, the state's forestry and fire management agency, is responsible for fire protection on lands throughout California, but only owns and manages a small number of landholdings; the majority of Cal Fire's prescribed fire activity is accomplished on private lands or on lands owned and managed by other agencies (e.g. CDPR) through its Vegetation Management Program. Though they use prescribed fire to a much lesser extent than Cal Fire, NGOs maintain a similar pattern, assisting in the planning and implementation of burns on small, private landholdings. We were careful to account for these unique arrangements, and asked that entities only report prescribed fire acres for which they were primarily responsible.

To allow comparisons, management objectives were roughly modelled after those included in previous studies (Cleaves *et al.* 2000; Haines *et al.* 2001). In some cases, previously used categories were combined; for example, wildlife habitat enhancement represented only one objective on this survey, whereas it was broken into three separately rated categories (habitat for non-game species, threatened and endangered species, and game species) in the Cleaves *et al.* (2000) survey. The importance of cultural landscapes and uses of fire in

northern California called for the addition of an objective not included on previous surveys: cultural resources.

The constraints included on the survey were also modelled after those used in previous studies (Cleaves *et al.* 2000; Haines *et al.* 2001). As in previous studies, not all categories were mutually exclusive; for example, regulations (e.g. air quality) are a component of narrow burn windows, yet there was value in preserving regulations and narrow burn window as separate categories; collapsing regulations into the narrow burn window category would have provided a more coarse, and less useful, description of two of the most influential issues in the region. Likewise, it was important to distill the relative influence of regulations (including air quality) and environmental laws (including laws that protect water quality, endangered species, archaeological sites and other resources); this distinction was made clear on the survey instrument, and ultimately allowed more acute analyses. Ratings of these impediments (narrow burn window, regulations and environmental laws) were only moderately correlated with one another (Pearson correlation coefficients (R) 0.34–0.45), justifying retention of the categories included on the survey.

Before the survey was administered, it was reviewed by an NPS Prescribed Fire Specialist; he recommended the addition of one constraint: burn unit preparation. An 'other' category was also provided on the survey instrument to ensure inclusion of constraints that were unaccounted for; however, respondents did not identify any major additions.

Data analysis

This survey consisted of a census rather than a sample of agency managers in northern California; therefore, inferential statistics were not employed. District-level burn data were aggregated for each entity, producing the following, by entity, for the survey region: (1) total area under management; (2) area treated with prescribed fire each year from 2006 to 2008; (3) average area treated annually with prescribed fire from 2006 to 2008; (4) percentage of managed area treated annually with prescribed fire (using average value from 2006 to 2008); and (5) percentage of burned area needed to fulfil management objectives. Overall mean ratings (all entities) were calculated for each management objective ($n=8$) and impediment ($n=13$) included in the survey. Mean ratings were also calculated by individual entity, by federal, state and private ownership, and by public and private ownership.

Results

Prescribed fire activity in northern California

The survey was completed in spring 2009, with a response rate of 92% among agency managers ($n=51$) and 84% among all surveyed ($n=70$). Survey respondents managed a total of 5 929 343 ha in northern California (Table 1). Of these lands, 602 375 ha were private, 16 997 ha were tribal, 5 207 474 ha were federal and 102 497 ha were managed by the State (does not include areas under Cal Fire jurisdiction, as Cal Fire largely plans and implements projects on private or other lands and does not act as a primary land manager in most cases). An annual average of 20 915 ha ($\sim 0.004\%$ of the total area) was treated

Table 1. Size of areas under management and areas treated with prescribed fire, by entity, northern California, 2006 to 2008 (as reported by survey respondents)

USFS, USDA Forest Service; BLM, Bureau of Land Management; NPS, National Park Service; USFWS, US Fish and Wildlife Service; Cal Fire, California Department of Forestry and Fire Protection; CDPR, California Department of Parks and Recreation; NGO, non-governmental organisation; TC, timber companies

	Area under management (ha)	Average annual area burned, 2006 to 2008 (ha)	Annual area needed to achieve objectives (ha)	Percentage burned of managed area	Percentage burned of area needed to achieve objectives
USFS	3 435 847	7848	24 403	0.23	32.16
BLM	1 532 967	722	5281	0.05	13.67
NPS	178 693	2155	3064	1.21	70.32
USFWS	59 967	8293	11 250	13.83	73.71
Cal Fire	–	1721	2206	–	78.04
CDPR	102 497	43	5322	0.04	0.81
TC	602 375	112	2657	0.02	4.22
Tribes	16 997	0	0	0	–
NGOs	–	20	324	–	6.25
Total all	5 929 343	20 915	54 506	0.35	38.37

Table 2. Mean ratings (with standard deviations) of management objectives for prescribed burning programs, by entity, northern California
Scale of 1 to 10, with 1 being 'not important' and 10 being 'very important.' See Table 1 for entity definitions

Management objective	All (n = 59)	USFS (n = 20)	USFWS (n = 2)	NPS (n = 6)	BLM (n = 6)	Cal Fire (n = 7)	CDPR (n = 6)	TC (n = 7)	Tribes (n = 2)	NGOs (n = 3)
Wildfire hazard reduction	8.5 (2.1)	9 (1.2)	3 (1.4)	7.8 (2.8)	9.3 (0.8)	9.3 (1.5)	6.8 (1.2)	9.1 (1.2)	5.5 (6.4)	10 (0.0)
Ecosystem management and restoration	7.8 (2.2)	8.2 (1.4)	8 (2.8)	9.5 (1.2)	8.8 (1.2)	6.1 (2.6)	8.7 (1.2)	5.4 (1.7)	5.5 (6.4)	9.3 (0.6)
Vegetation management	7.8 (2.1)	8 (1.7)	8.5 (2.1)	8.8 (1.3)	6.5 (1.9)	9.3 (1.1)	6.7 (2.7)	7.1 (2.0)	4 (4.2)	8.7 (1.2)
Wildlife habitat enhancement	7 (2.2)	7.2 (1.4)	10 (0.0)	6.5 (2.8)	8 (1.3)	6.1 (3.0)	7.3 (1.2)	5.3 (2.0)	4.5 (5.0)	8.7 (1.2)
Cultural resources	5.1 (3.2)	5.5 (2.8)	1 (0.0)	5.7 (3.8)	5 (2.2)	6.3 (2.4)	3.7 (2.9)	2.9 (3.3)	9.5 (0.7)	7.3 (4.6)
Insect and disease management	4.9 (2.8)	5.4 (2.1)	2.5 (0.7)	5.2 (2.8)	4.2 (2.6)	5.6 (3.6)	3.2 (2.8)	4.7 (3.3)	5.5 (6.4)	6 (4.0)
Rangeland improvement	4.4 (3.0)	4.1 (2.4)	6.5 (5.0)	2.5 (3.2)	5.5 (3.2)	7.3 (2.8)	2 (2.0)	4.7 (2.7)	3 (2.8)	6 (4.0)
Site preparation for reforestation	4.2 (3.1)	5.4 (2.8)	1 (0.0)	1.8 (2.0)	2.8 (1.8)	3 (2.5)	1.3 (0.5)	7.7 (2.4)	9 (0.0)	3 (2.0)

with prescribed fire by all surveyed entities in the region (Table 1).

Prescribed fire activity varied widely by entity. The USFWS reported the highest levels of prescribed fire activity, with an annual average of 8293 ha treated between 2006 and 2008 (40% of the entire regional total), and CDPR reported the lowest levels of activity of any agency, with an annual average of only 43 ha (0.2% of regional total) treated each year over the same period (Table 1). Levels of prescribed fire activity were generally lower and less evenly distributed in the non-governmental sector. For example, timber companies reported treating an average of 112 ha per year with prescribed fire (0.5% of regional total), but burning by this entity was disproportionately spread; only three of the seven companies surveyed were responsible for that activity. The two tribes that responded to the survey reported no prescribed fire activity, and only one of the three responding NGOs reported any activity – an annual average of 20 ha treated between 2006 and 2008 (0.1% of regional total).

Of the entities surveyed, Cal Fire treated the highest percentage (78%) of the annual area needed to satisfy management objectives of its prescribed fire program. The USFWS and the NPS followed closely, treating annual averages of over 73 and 70% of the area needed to fulfil management objectives of their programs. The USFS treated an annual average of 32% of its needed area, BLM treated almost 14% and CDPR treated 0.8%. Timber companies treated more than 4% of the annual area needed to fulfil their objectives and NGOs treated just over 6% (Table 1).

Management objectives for prescribed fire programs

On a scale of 1 to 10, with 1 being 'not important' and 10 being 'extremely important', northern California managers identified wildfire hazard reduction (average rating: 8.5), ecosystem management and restoration (7.8) and vegetation management (7.8) as the most important objectives of their prescribed fire

Table 3. Mean ratings (with standard deviations) of impediments to prescribed fire, by entity, northern California
Scale of 1 to 10, with 1 being 'not limiting' and 10 being 'extremely limiting.' See Table 1 for entity definitions

Impediment	All (n = 59)	USFS (n = 20)	USFWS (n = 2)	NPS (n = 6)	BLM (n = 6)	Cal Fire (n = 7)	CDPR (n = 6)	TC (n = 7)	Tribes (n = 2)	NGOs (n = 3)
Narrow burn window	8.2 (1.7)	8.2 (1.1)	7.5 (3.5)	8.7 (1)	6.7 (3.3)	9.3 (1)	8 (2)	8.7 (1.3)	9 (0)	7.3 (2.1)
Air quality regulations	7.2 (2.7)	6.6 (3.1)	6.5 (0.7)	7 (3)	6.3 (2.9)	8 (2)	7.2 (1.2)	9.6 (0.8)	9 (1.4)	5.7 (4)
Lack of adequate personnel	6.2 (2.7)	5.6 (2.7)	9 (1.4)	6.2 (2.6)	4.8 (3.7)	6.7 (2.4)	7.8 (3)	5.8 (2.3)	6.5 (3.5)	7 (1.7)
Environmental laws	6.1 (2.7)	6.7 (2.1)	4 (1.4)	3.7 (2)	4.8 (2.3)	7.7 (1.7)	5.2 (3.4)	8.7 (2.1)	6.5 (5)	4 (1.7)
Residential area near burn	6 (3.1)	5.5 (3.2)	3.5 (2.1)	5.8 (3.2)	6.7 (3.1)	8.1 (2.1)	6.2 (3.1)	6.9 (3)	2 (1.4)	5.3 (4)
Lack of adequate funding	5.6 (3)	4.7 (3.1)	7 (2.8)	3 (2.2)	4 (2)	7.7 (1.9)	8 (3.2)	5.5 (2.7)	9 (1.4)	8 (1)
Liability	5.5 (3.1)	4.9 (2.7)	3.5 (2.1)	4.2 (3.6)	4.5 (2.9)	6.9 (2.6)	4 (3.1)	8.9 (1.5)	6.5 (5)	6.3 (4)
Fuel loading	5.4 (2.6)	6.1 (2.6)	2 (1.4)	5.5 (1.4)	4 (1.7)	6 (2.7)	5 (3.4)	6.1 (3.1)	5 (2.8)	4.3 (2.5)
Planning costs	4.9 (2.8)	4.8 (2.8)	4 (2.8)	3.5 (1.5)	3 (1.7)	6 (2.5)	7.3 (3.3)	5.2 (3.3)	7 (2.8)	4.7 (4)
Public opinion	4.6 (2.5)	4.1 (2.5)	4 (1.4)	4 (2.6)	3.7 (1.5)	5.7 (2.3)	3.5 (1.9)	7 (2.7)	5.5 (6.4)	5.3 (2.3)
Preference for alternative strategies	4.3 (2.6)	4.8 (2.6)	3.5 (2.1)	2.3 (1)	4.7 (2.1)	4.9 (3.3)	4.5 (3.8)	3.3 (1.9)	5 (2.8)	4 (2.7)
Burn unit preparation	4.2 (2.5)	3.8 (2.5)	5 (1.4)	3.7 (2.5)	3.8 (1.3)	5.3 (2.9)	5.5 (2.8)	4.5 (3)	3 (2.8)	2.7 (2.1)
Insurance limitations	3.5 (2.8)	2.8 (1.9)	1.5 (0.7)	2 (1.7)	2 (0.9)	4.9 (2.9)	1.2 (0.5)	6.7 (3.7)	5 (2.8)	6.3 (4)

programs (Table 2). Wildlife habitat enhancement (7.0) and cultural resources (5.1) received moderate ratings, and insect and disease management (4.9), rangeland improvement (4.4) and site preparation for reforestation (4.2) received relatively low ratings.

Although overall ratings provide a general sense of the relative importance of management objectives in the region, ratings varied greatly among entities for all management objectives except insect and disease management (Table 2). Wildfire hazard reduction was the most important objective for the USFS, BLM, Cal Fire, timber companies and NGOs; ecosystem management and restoration was the top objective for the NPS and CDPR; wildlife habitat enhancement was the top objective for the USFWS; and cultural resources were the top objective for the tribes. In general, there was minimal variation in ratings among respondents from the same entities, indicating general internal agreement on objectives. Tribal respondents represented the one major exception, with high variance in ratings of five of the eight objectives (not including cultural resources and site preparation for reforestation, their two top objectives, for which variance was low).

Impediments to the use of prescribed fire – which are most limiting?

Of the 13 impediments listed on the survey, northern California managers identified narrow burn window (average rating = 8.2) and regulations (7.2) as the greatest hurdles to their use of

prescribed fire (Table 3). Lack of adequate personnel (6.2) and environmental laws (6.1) were also identified as major constraints on prescribed fire activity in the region. Other impediments included, in order of descending importance, residential areas near burn (6.0), lack of adequate funding (5.6), liability (5.5), fuel loading (5.4), planning costs (4.9), public opinion (4.6), preference for alternative strategies (4.3), burn unit preparation (4.2) and insurance limitations (3.5).

Though ratings were consistent across entities for several of the impediments (e.g. narrow burn window and regulations), there were differences among groups. For example, the NPS and timber companies differed substantially in their ratings of environmental laws, with timber companies identifying laws as very limiting (average rating: 8.7) and NPS managers identifying laws as not limiting (3.7). There were also differences between ratings of lack of adequate funding by the NPS and the CDPR; the NPS identified funding issues as not limiting (3.0), whereas the CDPR classified funding issues as very limiting (8.0).

Though differences were found between individual entities (Table 3), patterns were also illuminated in comparisons among federal, state and private entities (Table 4) and between entities that manage public versus private lands (Table 5). Comparisons among federal, state and private entities highlighted disparate funding for prescribed fire programs, namely between federal and state agencies. Ratings differed substantially between federal and state agencies for both lack of adequate funding and planning costs, with federal agencies rating funding concerns as

not limiting (4.4 and 4.2) and state agencies rating those concerns as limiting (7.9 and 6.7).

Comparisons between public and private land managers illuminated several dissimilarities. Interestingly, private land managers consistently identified impediments as more limiting than public land managers did; ratings differed greatly between the two groups for regulations, environmental laws, liability,

Table 4. Ratings of impediments to prescribed fire by federal, state and private entities in northern California, 2009

Impediment	Federal (<i>n</i> = 34)	State (<i>n</i> = 13)	Private (<i>n</i> = 12)
Narrow burn window	7.9	8.7	8.4
Regulations	6.6	7.6	8.5
Lack of adequate personnel	5.8	7.2	6.3
Environmental laws	5.7	6.5	7.0
Residential areas near burn	5.6	7.2	5.7
Lack of adequate funding	4.4	7.9	6.8
Liability	4.6	5.5	7.8
Fuel loading	5.4	5.5	5.5
Planning costs	4.2	6.7	5.4
Public opinion	4.0	4.7	6.3
Preference for alternative strategies	4.3	4.7	3.8
Burn unit preparation	3.8	5.4	3.7
Insurance limitations	2.5	3.3	6.3

Table 5. Mean ratings of impediments to prescribed fire by public and private lands managers in northern California, 2009

Impediment	Public lands (<i>n</i> = 40)	Private lands (<i>n</i> = 19)
Narrow burn window	8.0	8.7
Regulations	6.7	8.3
Lack of adequate personnel	6.1	6.4
Environmental laws	5.6	7.3
Residential areas near burn	5.7	6.6
Lack of adequate funding	4.9	7.2
Liability	4.5	7.5
Fuel loading	5.3	5.7
Planning costs	4.7	5.6
Public opinion	3.9	6.1
Preference for alternative strategies	4.3	4.2
Burn unit preparation	4.1	4.3
Insurance limitations	2.3	5.8

Table 6. Percentage of responses (*n* = 59) in each rating category for given statements, northern California prescribed fire survey, 2009
Scale of 1 to 10 with 1 being 'strongly disagree' and 10 being 'strongly agree'

	Disagree (1–4)	Neutral (5–6)	Agree (7–10)
'I am generally satisfied with the amount of prescribed burning achieved in my management area each year.'	76%	9%	15%
'I wish that we could treat more acres in our management area with prescribed fire.'	0%	5%	95%
'Managers must take personal risks in order to get prescribed fire on the ground.'	26%	9%	65%
'I am willing to take personal risks in order to use prescribed fire in my management area.'	35%	10%	55%

insurance limitations, lack of adequate funding and public opinion, with higher ratings given by private land managers in all cases.

Satisfaction with programs and perceptions of risk

Responses to statements concerning satisfaction with prescribed fire programs and perceptions of risk revealed two themes: (1) there is widespread agreement among managers on the need for expanded application of prescribed fire, and (2) managers are somewhat divided in their perceptions of the risks associated with prescribed fire and in their willingness to take risks if needed (Table 6). A total of 76% of respondents indicated dissatisfaction with the amount of prescribed burning accomplished in their management areas, and almost all (95%) agreed that they would like to increase their use of prescribed fire. Responses to questions about risk-taking were less consistent – 65% of respondents agreed that managers must take personal risks in order to use prescribed fire, but only 55% agreed that they are personally willing to take risks.

Discussion

This research, which is unique in both its level of inclusion and its geographic focus, demonstrates the importance of context in prescribed fire management. This work highlights regional influences, pointing to the opportunities and limitations posed by land-ownership patterns, climate and other region-specific factors. Yet it also reveals the influence of management entity, showing that managers who share a geographic region do not necessarily share all objectives for or constraints on prescribed fire use.

Regional patterns

As the results of this study show, prescribed fire activity in northern California is concentrated on public lands; federal agencies manage a large proportion of the landscape and were responsible for ~92% of prescribed fire activity between 2006 and 2008. This pattern contrasts with that documented in the south-eastern United States, where burning is concentrated on state and private lands; only 12% of prescribed fire activity documented in that region between 1985 and 1994 occurred on national forest lands, the only federal lands included in the study of Haines *et al.* (2001). These contrasting patterns of prescribed fire activity indicate major differences in the ways that lands are organised and burning is accomplished between the south-eastern and western United States. This regional contrast may

limit our ability to extend results beyond areas where these data have been collected, an important caveat for past and future work.

In northern California, prescribed fire programs are severely limited by both operational and regulatory issues. Operational concerns (narrow burn window and lack of adequate personnel) comprised two of the three most important constraints on prescribed fire activity in the region. Narrow burn window clearly stood out as the most important constraint, earning the highest rating of all impediments listed on the survey. Though narrow burn window has been identified as an important constraint in previous research (e.g. Cleaves *et al.* 2000; Haines *et al.* 2001), its status as top impediment is shared only by a handful of regions, as it is often trumped by regulatory and funding constraints.

The importance of narrow burn window in northern California reflects the relationship between weather patterns, topography, air quality, environmental laws and regulations present in the region. With its Mediterranean climate (Sugihara and Barbour 2006), northern California experiences limited periods in which prescribed burning is either feasible (long wet winters make burning difficult in many areas) or safe (hot, dry summers make spring and summer burning more risky). Appropriate conditions tend to fall between the two extremes, when the weather is mild enough to permit burning but fuels are still dry enough to render burns effective at meeting objectives. In some parts of the region, these windows of opportunity are brief, often lasting only 2 to 3 weeks. For example, oak woodland and grassland burning in Redwood National Park was severely affected by lack of sufficient burn windows during fall (autumn) 2009 (J. McClelland, pers. comm. 2009). Though the Park successfully implemented several burns, other well-planned burns were cancelled because conditions – such as relative humidity and wind speed – exceeded prescription. Just days after those cancellations, a Pacific storm drenched burn units to the point where many woodlands were too wet to effectively burn. Weather-based constraints are familiar to prescribed fire managers in other Mediterranean regions (e.g. Fernandes and Botelho 2004), yet the south-eastern USA, where burning is concentrated seasonally but accomplished throughout the calendar year, is less restricted by these narrow windows (Wade and Lunsford 1989). These regional disparities in burn windows limit prescribed fire differentially and may temper attempts to increase burned area.

Though burn windows are related to weather, it is the social and legal context within which weather is framed that defines acceptable ‘windows’ of opportunity. Regulations play a large part in defining acceptable weather, and they are therefore an instrumental component of burn windows. Regulations dictate acceptable air quality conditions, relative humidity levels and wind speeds. Thus, it is not surprising that regulations were identified in this study as the second most important constraint on prescribed fire activity in northern California, and they were previously identified as the top constraint on USFS programs in the south-east (Haines *et al.* 2001) and nationwide (Cleaves *et al.* 2000).

In northern California, additional restrictions are placed on prescribed fire activity owing to the presence of the Northern Spotted Owl (*Strix occidentalis caurina*) and other seemingly

fire-sensitive protected species (through the Endangered Species Act). This species-level constraint contrasts sharply with most threatened animal and plant species in the south-eastern USA that prosper in frequently burned landscapes and often facilitate the use of prescribed fire (Brennan *et al.* 1998; Hiers *et al.* 2003). In spite of much argumentation (e.g. Hanson *et al.* 2009; Spies *et al.* 2010), little data exist to clarify the effects of fire on threatened species in northern California, an important research need that could facilitate the increased use of prescribed fire regionally and elsewhere in the USA (e.g. Keyser and Ford 2006).

Given this background, ratings of environmental laws are intuitive for the two regions: low in the south-eastern USA (Cleaves *et al.* 2000; Haines *et al.* 2001) and high in northern California; however, ratings of liability – another important legal constraint – are surprising. In the south-eastern USA, an area that identifies prescribed fire as a property right and protects its use with gross negligence liability laws in some states (Yoder *et al.* 2003), managers identified liability as one of their biggest constraints (Cleaves *et al.* 2000; Haines *et al.* 2001). In contrast, managers in California (both in the survey of Cleaves *et al.* (2000) and in the present study), which maintains more conservative, less burner-friendly negligence laws, did not identify liability as a primary constraint. Though private land managers in the current study did give liability high ratings – a point discussed below – the constraint still ranked only seventh overall (of 13) and ninth for public lands managers. This unexpected contrast may be explained by differences in property sizes and arrangements between the two regions; comparatively high ratings of both public opinion and residential area near burns in the south-eastern USA (Cleaves *et al.* 2000; Haines *et al.* 2001) imply more social pressure in that region than in northern California, where burn units are often embedded in large tracts of public land (e.g. national forests, national wildlife refuges and national and state parks) and risk of liability may be comparatively low. Public support for prescribed fire in wildland settings like these has been shown to be high in some regions (Knotek *et al.* 2008), and may assuage the management concerns that arise in more widely populated areas like the south-eastern USA. However, climate change and land-use pressures promise to shape future fire regimes and management strategies (McKenzie and Littell 2011; Miller *et al.* 2011), and may further complicate prescribed fire use in northern California and beyond.

The lack of adequate personnel to conduct burns is a wide-ranging issue, affecting agency managers in both northern California and the south-eastern United States. In California, this constraint is reflected not only in a lack of trained staff to implement burns, but also in a lack of qualified burn bosses to compose and sign off on burn plans, and on conflicting fire needs and concerns within different regions of California. For example, one manager argued that ‘prescribed burn plans have become increasingly more difficult to process... less qualified people are able or willing to sign them, [and] many are not willing to risk liability in an ever-increasing litigious environment’ [Survey comment 2009] and another commented that there has been a ‘depletion of qualified Type I and II burn bosses, due to a backlog of quality training assignments for trainees’ [Survey comment 2009]. Likewise, wildfire season in

southern California coincides with fall prescribed fire season in northern California, absorbing personnel and other resources and further limiting prescribed fire activity. As one Cal Fire manager articulated:

When my small burn window occurs in the late fall of the year (September–November), Southern Cal [California] suffers from Santa Ana wind events and subsequent large catastrophic fires. All the fire suppression personnel from up north ‘bump down the State’ to assist our brethren in southern California, leaving me with no personnel to conduct burns. By the time they return (when the weather turns cold and wet in So. Cal. [southern California]), we have cold temperatures, high humidity and I am out of prescription and physically unable to conduct successful broadcast burns. [Survey comment, 2009]

Inter-entity patterns

Prescribed fire programs are clearly shaped by the ecological, social and legal environments within which they operate; this concept has been shown previously (Cleaves *et al.* 2000) and is reiterated in the present research. Yet the experiences of different prescribed fire users in the same regions have largely been overlooked, complicating efforts to increase or improve prescribed fire activity in specific locales. This research identifies shared objectives and constraints among prescribed fire managers in northern California, yet it also highlights the diverse and often disparate experiences of the many prescribed fire practitioners in the region.

The major constraints on prescribed fire in northern California – narrow burn window, regulations, environmental laws and lack of adequate personnel – are widely shared by managers from all entities. However, other constraints affect groups differentially, illustrating the range of financial, legal and social settings within which prescribed fire is accomplished in the region. Generally speaking, economic constraints are felt more in the state and private sectors than in the federal, and legal and social impediments are more limiting in the private sector than in the public.

Though California’s tenuous economy explains financial constraints in the state and private sectors, reason for the disproportional influence of legal and social constraints on private-sector burning is less clear. In the south-eastern USA, Haines *et al.* (2001) documented a similar pattern, where liability issues and public perception influence burning on private lands much more than they do on government-owned lands. In northern California, ratings of environmental laws, regulations, liability, insurance limitations and public opinion were substantially higher in the private sector than in the public, raising interesting questions about the unbalanced reality of these constraints and suggesting a need for increased sensitivity and attention to private-sector prescribed fire programs. Though the private sector is responsible for relatively little prescribed fire activity in the region, timber companies and other private landowners have shown interest in increasing their use of fire; their efforts may require increased collaboration with and support from federal and state agencies, which maintain more

robust burn programs and, at least ostensibly, enjoy a level of confidence not shared by their private counterparts.

Perceptions of risk

Interestingly, perceptions of risk varied greatly by individual manager but not by entity. This variability points to the importance of individual perspective, identified in previous research as a primary influence on management decisions (Williamson 2007), yet it also reveals a general lack of agreement on the personal risks associated with the use of prescribed fire. This ambiguity does not inspire confidence in managers; 65% of respondents agreed that managers must take personal risks in order to use prescribed fire, yet only 55% were willing to take those risks, indicating a direct connection between perception and action. As one manager wrote on his survey, ‘only those individuals within a program that are proactive and willing to operate outside of a comfortable cushion can or will succeed’ [Survey comment 2009]. Although it is outside the realm of this research, the clarification of risks – which may also vary by region and by entity – may be an important area for future investigation.

Conclusion

Prescribed fire is constrained by factors specific to each region and entity. In northern California, all entities share in a struggle with weather, air quality regulations and shortages of personnel. Yet other factors, such as funding and liability concerns, affect entities differentially and promise to continually reshape and redefine prescribed fire in the region. California’s faltering economy will continue to be reflected in the burn programs of state agencies, and federal agencies will likely maintain their role as the primary users of prescribed fire. However, inter-entity efforts to discuss and address prescribed fire impediments, like the nascent Northern California Prescribed Fire Council, are under way, and managers from all entities are eager to increase their application of prescribed fire, as the opportunities for its use continue to outweigh the constraints on it.

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References

- Anderson MK (2005) ‘Tending the Wild.’ (University of California Press: Berkeley, CA)
- Biswell H (1989) ‘Prescribed Burning in California Wildlands Vegetation Management.’ (University of California Press: Berkeley, CA)
- Brennan LA, Engstrom RT, Palmer WE, Hermann SM, Hurst GA, Burger LW, Hardy CL (1998) Whither wildlife without fire? In ‘Transactions of the Sixty-third North American Wildlife and Natural Resources Conference,’ 20–24 March 1998, Orlando, FL. pp. 402–414. (Wildlife Management Institute: Washington, DC)
- Cleaves DA, Haines TK (1997) Regulation and liability risk: their influence on the practice and price tag of burning. In ‘Environmental Regulation and Prescribed Fire, Legal and Social Challenges.’ (Ed. D Bryan) pp. 165–183. (Florida State University: Tallahassee, FL)

- 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. (Asheville, NC)
- Cortner HJ, Taylor JG, Carpenter EH, Cleaves DA (1990) Factors influencing forest service fire managers' risk behavior. *Forest Science* **36**, 531–548.
- Craig JN (1990) Regulation of prescribed fire. In 'Natural and Prescribed Fire in Pacific Northwest Forests'. (Eds JD Walstad, DV Sandberg) pp. 261–267. (Oregon State University Press: Corvallis, OR)
- Dillman DA (2000) 'Mail and Internet Surveys: the Tailored Design Method.' (John Wiley & Sons: New York)
- Engber EA, Varner JM, Arguello LA, Sugihara NG (2011) The effects of conifer encroachment and overstory structure on fuels and fire in an oak woodland landscape. *Fire Ecology* **7**, 32–50. doi:10.4996/FIRECOLOGY.0702032
- Fernandes P, Botelho H (2004) Analysis of the prescribed burning practice in the pine forest of north-western Portugal. *Journal of Environmental Management* **70**, 15–26. doi:10.1016/J.JENVMAN.2003.10.001
- Haines TK, Busby RL, Cleaves DA (2001) Prescribed burning in the South: trends, purpose, and barriers. *Southern Journal of Applied Forestry* **25**, 149–153.
- Hanson CT, Odion DC, DellaSala DA, Baker WL (2009) Overestimation of fire risk in the Northern Spotted Owl Recovery Plan. *Conservation Biology* **23**, 1314–1319. doi:10.1111/J.1523-1739.2009.01265.X
- Hiers JK, Laine SC, Bachant JJ, Furman JH, Green WW, Compton V (2003) Simple spatial modeling tool for prioritizing prescribed burning activities at the landscape scale. *Conservation Biology* **17**, 1571–1578. doi:10.1111/J.1523-1739.2003.00381.X
- Husari SJ, McKelvey KS (1996) Fire-management policies and programs. In 'Sierra Nevada Ecosystem Project: Final Report to Congress (Volume 2)'. pp. 1101–1114. (University of California, Davis, Centers for Water and Wildland Resources: Davis, CA)
- Keyser PD, Ford WM (2006) Influence of fire on mammals in eastern oak forests. In 'Fire in Eastern Oak Forests: Delivering Science to Land Managers.' pp. 180–191. USDA Forest Service, Northern Research Station, General Technical Report NRS-GTR-P1. (Newtown Square, PA)
- Knapp EE, Estes BL, Skinner CN (2009) Ecological effects of prescribed fire season: a literature review and synthesis for managers. USDA Forest Service, Pacific Southwest Research Station, Research Paper PSW-GTR-224. (Albany, CA)
- Knotek K, Watson AE, Borrie WT, Whitmore JG, Turner D (2008) Recreation visitor attitudes towards management-ignited prescribed fires in the Bob Marshall Wilderness Complex, Montana. *Journal of Leisure Research* **40**, 608–618.
- Laband D, Hussain A, Gonzalez-Caban A (2008) The impact of forest service litigation success on administrative appeals of proposed fuels reduction actions. *Forest Policy and Economics* **10**, 444–449. doi:10.1016/J.FORPOL.2007.12.003
- Lazaro A, Montiel C (2010) Overview of prescribed burning policies and practices in Europe and other countries. In 'Toward Integrated Fire Management – Outcomes of the European Project Fire Paradox.' (Eds J Sande Silva, F Rego, P Fernandes, E Rigolot) pp. 137–150. (European Forest Institute: Joensuu, Finland)
- McCaffrey S (2006) Prescribed fire: what influences public approval? In 'Fire in Eastern Oak Forests: Delivering Science to Land Managers.' pp. 192–199. USDA Forest Service, Northern Research Station, General Technical Report NRS-GTR-P1. (Newtown Square, PA)
- McKenzie D, Littell J (2011) Climate change and wilderness fire regimes. *International Journal of Wilderness* **17**, 22–27.
- Miller C, Abatzoglou J, Brown T, Syphard AD (2011) Wilderness fire management in a changing environment. In 'The Landscape Ecology of Fire (Ecological Studies Vol. 213)'. (Eds D McKenzie, D Falk, C Miller) pp. 269–294. (Springer, London)
- Shindler B, Toman E (2003) Fuel reduction strategies in forest communities: a longitudinal analysis of public support. *Journal of Forestry* **101**, 8–15.
- Spies TA, Miller JD, Buchanan JB, Lehmkuhl JF, Franklin JF, Healey SP, Hessburg PF, Safford HD, Cohen WB, Kennedy RSH, Knapp EE, Agee JK, Moeur M (2010) Underestimating risks to the Northern Spotted Owl in fire-prone forests: response to Hanson *et al.* *Conservation Biology* **24**, 330–333. doi:10.1111/J.1523-1739.2009.01414.X
- Stephens SL, Ruth LW (2005) Federal forest-fire policy in the United States. *Ecological Applications* **15**, 532–542. doi:10.1890/04-0545
- Sugihara NG, Barbour MG (2006) Fire and California vegetation. In 'Fire in California's Ecosystems.' (Eds N Sugihara, J Van Wagtendonk, KE Shaffer, J Fites-Kaufman, AE Thode) pp. 1–9. (University of California Press: Berkeley, CA)
- Swezy DM, Agee JK (1991) Prescribed-fire effects on fine-root and tree mortality in old-growth ponderosa pine. *Canadian Journal of Forest Research* **21**, 626–634. doi:10.1139/X91-086
- Varner JM, Gordon DR, Putz FE, Hiers JK (2005) Restoring fire to long-unburned *Pinus palustris* ecosystems: novel fire effects and consequences for long-unburned ecosystems. *Restoration Ecology* **13**, 536–544. doi:10.1111/J.1526-100X.2005.00067.X
- Wade DD, Lunsford JD (1989) A guide for prescribed fire in southern forests. USDA Forest Service, Southern Research Station, General Technical Report SRS-11. (Asheville, NC)
- Walstad JD, Radosevich SR, Sandberg DV (1990) 'Natural and Prescribed Fire in Pacific Northwest Forests.' (Oregon State University Press: Corvallis, OR)
- Williamson MA (2007) Factors in United States Forest Service district rangers' decision to manage a fire for resource benefit. *International Journal of Wildland Fire* **16**, 755–762. doi:10.1071/WF06019
- Yoder J, Tilley M, Engle D, Fuhlendorf S (2003) Economics and prescribed fire law in the United States. *Review of Agricultural Economics* **25**, 218–233. doi:10.1111/1467-9353.00055