

When the wilderness burns: an analysis of current fire management and the case for prescribed fire in designated wilderness in the United States

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When the wilderness burns: an analysis of current fire management and the case for prescribed fire in designated wilderness in the United States

Alyssa Worsham (corresponding author), Melanie Armstrong, Jonathan Coop, Dagny Signorelli

Abstract

Background: United States wilderness areas face increasing challenges from altered fire regimes and climate change, and land managers face ever more complex decisions about fire use. While federal policies permit various fire management strategies in wilderness, including prescribed fire, managers predominantly rely on suppression despite broad support to restore and sustain fire's natural role in these landscapes. Consequently, wilderness fire regimes continue to diverge from historical norms. To better understand wilderness fire management, we used surveys and interviews with wilderness and fire managers to assess current fire management strategies, how they differ in wilderness versus non-wilderness areas, and the rationales behind wilderness fire management decisions.

Results: Respondents identified public perception, resource availability, and administrative hurdles as primary barriers to prescribed fire and managed wildfire. Notably, these constraints stem more from implementation challenges than from wilderness policy restrictions. Though prescribed fire is rarely used in wilderness, research participants expressed strong support for its expanded application.

Conclusions: Adequate plans, policies, and practices must accompany wilderness fire management ideals. Addressing risk aversion among decision-makers and building public trust will also benefit wilderness fire management. While allowing natural ignitions to burn in wilderness might be viewed as ideal, many wilderness areas may require active management through prescribed fire to restore historical conditions before natural fire regimes could safely resume. Our research demonstrates the need for wilderness fire management that balances sustaining wilderness qualities with the realities of historical fire regimes that were shaped in part by Indigenous people and challenges posed by legacies of fire exclusion compounded by a changing climate.

Keywords

Wildland fire; wilderness management; prescribed fire; decision-making; risk-aversion; climate change.

Resumen

Antecedentes: Las áreas naturales de los EEUU enfrentan desafíos que implican alteraciones desde los regímenes de fuego al cambio climático, y los gestores de manejo se enfrentan a decisiones más complejas sobre el uso del fuego. Mientras que las políticas federales permiten varias estrategias de manejo del fuego en áreas naturales, incluyendo las quemas prescritas, los gestores confían más en las tareas de supresión a pesar del amplio apoyo que existe para restaurar y sostener el rol natural del fuego en esos paisajes. Como consecuencia, los regímenes de fuego en áreas naturales continúan alejadas de sus normas históricas. Para entender mejor el manejo del fuego en áreas naturales silvestres, usamos entrevistas y relevamientos con gestores de áreas silvestres para determinar las estrategias actuales de manejo del fuego, sobre cómo ellas difieren entre áreas naturales silvestres y aquellas no silvestres, y el criterio racional sobre en qué se basan las decisiones de manejo del fuego en cada una de ellas.

Resultados: Los respondientes identificaron la percepción pública, la disponibilidad de recursos y los obstáculos administrativos, como las principales barreras para realizar las quemas prescritas y manejar los incendios. Notablemente, esos condicionamientos se basan más en los desafíos de su implementación que en las restricciones que imponen las políticas. Como consecuencia, y aunque el uso de las quemas prescritas es raramente aplicado en áreas naturales, los participantes que respondieron a esta investigación expresaron un fuerte apoyo a la expansión en la aplicación de estas quemas.

Conclusiones: Los planes adecuados, las políticas, y las prácticas deben acompañar los ideales del manejo del fuego en áreas naturales. El desactivar la natural animadversión al riesgo entre los decisores y construir confianza pública sobre sus decisiones, podría beneficiar el manejo del fuego en áreas naturales. Mientras que el permitir que ardan aquellos fuegos iniciados naturalmente debería ser visto como lo ideal, muchas áreas naturales pueden requerir del manejo activo a través de las quemas prescritas para restaurar las condiciones históricas luego de las cuales los fuegos naturales puedan volver a reasumir su rol de manera segura. Nuestra investigación ha demostrado que la necesidad de un manejo del fuego que balancee el sostenimiento de la calidad de estas áreas naturales con las realidades de los regímenes de incendios históricos, que fueron en parte modelados por las comunidades indígenas, y los desafíos que imponen el legado de exclusión del fuego y los que componen el cambio climático.

1. Background

Designated wilderness represents the strongest level of protection of landscapes within the U.S. protected area network, yet wilderness ecosystems are increasingly vulnerable to human-induced changes. The 1964 Wilderness Act created the National Wilderness Preservation System, currently comprising 806 designated wilderness areas and almost 112 million acres of land within 44 states and territories (Wilderness Connect, 2024). Managing agencies are mandated by law to preserve wilderness character on these lands for present and future generations. However, over a century of fire exclusion has produced a fire deficit in many wilderness landscapes (Haugo et al., 2019; Marlon et al., 2012; Parks et al., 2015). Where fire has been suppressed, increased fuel density and landscape homogeneity have reduced ecosystem resilience to a range of disturbances including, ironically, inevitable fires (Boerigter et al., 2024). Compounding these shifts, climate change is accelerating fire activity and leading to anomalous fire effects in much of the United States (Abatzoglou & Williams, 2016; Parks & Abatzoglou, 2020). Consequently, contemporary and future wildfire activity bear decreasing resemblance to the historical processes that characterized wilderness landscapes prior to their political designation and may reshape many wilderness ecosystems. Wilderness and fire managers working in this context face ever more complex decisions about fire use within the wilderness system.

Multiple lines of evidence, including sedimentary records (Gavin et al., 2007), tree-ring fire scars (Margolis et al., 2022), and documented observations (Pyne, 2015), demonstrate the varied ways that wildland fire was abundant across much of the North American continent prior to European colonization. Historical fire regimes were highly variable but are generally understood to represent a fluid balance determined by interactions between ignitions, fuels, topography, and climate. Because fire reduces fuels, fire activity can be self-limiting over varying temporal and spatial scales (McKenzie et al., 2011). In many areas, some of which are now managed according to provisions of the Wilderness

Act, fire regimes were also substantially shaped by Indigenous ignitions including cultural burning practices (Klimaszewski-Patterson & Mensing, 2020; Roos et al., 2021). Fire regimes across North America were dramatically changed by European colonization, and the takeover of Indigenous lands led to the decline of Indigenous burning (Fisher, 1997). Across large areas, intensive livestock grazing also removed surface fuels and the fire regimes they supported (Fule et al., 1997). These changes were followed by aggressive fire suppression beginning in the early 1900s, which has persisted through the present (Pyne, 2015).

The advocates and legislators who wrote and passed the Wilderness Act recognized that fire regimes in many areas were already departed from historical norms (The Wildland Research Center, 1962), yet the Act did not prescribe any specific fire management policy. The definition of wilderness provided by the Wilderness Act includes five characteristics: untrammeled; natural; undeveloped; opportunities for solitude or primitive recreation; and features of scientific, educational, scenic, or historical value (Wilderness Act, 1964). While each characteristic is intended to be of equal importance, untrammeled — defined as free from human control or interference — is generally placed above the others (Boerigter et al., 2024; Landres et al., 2015). However, the Wilderness Act allows for measures to be taken “as may be necessary in the control of fire, insects, and diseases” (Wilderness Act, 1964), which has led to the widespread suppression of fire in wilderness areas despite the contradiction with the untrammeled characteristic of wilderness.

In the era when the Wilderness Act was passed, federal land management agencies adhered to a policy of total fire suppression. However, in recognition of the important natural role of fire in wilderness ecosystems, fire management programs particular to wilderness were developed in lands managed by the National Park Service and Forest Service in 1968 and 1974, respectively. These included management of both planned (i.e., manager-ignited) and unplanned (i.e., lightning-ignited)

fires on wilderness and non-wilderness lands. As the Wilderness Preservation System grew, so did the prevalence of fire management programs. Today, agency wilderness policies include a suite of wildland fire management strategies and objectives which may differ between wildfires and manager-ignited prescribed fires (Alnes, 2017). However, tension exists between the harm of ongoing fire suppression, the risk of anomalous fire behavior from unplanned ignitions burning under novel conditions, and the perceived threat of prescribed fire to wilderness values.

While permitting lightning-ignited fires is consistent with the untrammeled and natural characteristics legislated by the Wilderness Act, most lightning ignitions in wilderness are promptly extinguished due to perceived threats to assets both within and outside of wilderness (Parsons, 2000; Miller & Landres, 2004). Interpretations of the appropriateness of prescribed fire in wilderness vary among agencies, individuals, and the public. The Wilderness Act does not prohibit prescribed fire; it mandates that prescribed fire represent the minimum action necessary to maintain wilderness character. Policies for all four federal agencies managing wilderness also permit use of prescribed fire in these areas (Alnes, 2017). However, at present, prescribed fire is seldom implemented within designated wilderness. Consequently, wilderness fire regimes continue to diverge from historical norms, and extreme wildfires increasingly threaten a range of wilderness values, and more broadly, ecosystems and society. The purpose of this research is to better understand barriers and opportunities to improved wilderness fire management, in particular the appropriate role of prescribed fire in wilderness. We examine current fire management strategies, how they differ in wilderness versus non-wilderness areas, and what decision-making factors and rationale support wilderness fire management decisions. By analyzing the decision-making rationale of managers regarding fire in designated wilderness, this research aims to understand both the management ideals that motivate decisions and the adequacy of plans, policies, and practices to meet those ideals.

2. Methods

Our research used an explanatory sequential mixed methods approach consisting of two phases. In the first phase, we conducted a survey to collect information about current wilderness fire management. In the second phase, we conducted interviews to understand the types of fire management strategies available to wilderness managers, the interaction between wilderness and fire management policies, and the importance of different decision-making factors in land management planning and implementation.

2.1. *Survey methods and analysis*

The survey consisted of 22 questions (Appendix A), soliciting both quantitative and qualitative data. We sent the survey to current and former federal agency employees and non-federal interest groups (e.g., Tribes, non-governmental organizations, and local government officials). We relied on snowball sampling for additional survey distribution. During May and June 2022, we collected 131 responses (Table 1). Survey respondents had the option to remain anonymous, or they could provide contact information if they were interested in participating in a follow-up interview. Questions about demographic information (e.g., job title, agency/organization, length of employment, and geographical region) were included to provide context amongst responses and aid in the interview selection process.

Answers to multiple choice, rank order, and Likert scale survey questions were compiled and summarized. Short-answer survey questions produced more detailed, contextual information to provide nuance to the responses from quantitative questions, and to allow for explanations and rationale. For standalone open-ended survey questions, we assigned categories to each answer and assessed relative frequency among responses. These qualitative data also were used to develop interview questions and guide us towards case study examples.

Table 1

Affiliations for survey respondents and interview participants.

Agency/Organization	Survey		Interviews	
	Count	Percent	Count	Percent
Bureau of Indian Affairs	2	2%	0	--
Bureau of Land Management	14	11%	3	14%
Fish and Wildlife Service	3	2%	1	5%
Forest Service	70	53%	11	50%
National Park Service	21	16%	4	18%
Tribe	1	1%	2	9%
Other ¹	20	15%	1	5%

Career Category	Survey		Interviews	
	Count	Percent	Count	Percent
Agency administrator	15	11%	4	18%
Fire specialist	69	53%	10	45%
Wilderness specialist	30	23%	5	23%
Research ecologist	8	6%	3	14%
Other ²	9	7%	0	--

¹ “Other” agencies and organizations included non-profits and state/local government

² “Other” career categories included: recreation technician, forestry technician, undefined resource specialist, etc.

2.2. Interview methods and analysis

In the second phase, we bolstered the survey results with interview data. We selected interview participants based on survey participation. Of the 131 survey responses, 47 people indicated they would be willing to participate in an interview. We selected 16 interview participants to represent a range of job titles, agencies/organizations, and geographic regions, and we interviewed six additional participants based on recommendations from original interviewees (Table 1). Interview questions were semi-structured and focused on themes that emerged from survey responses to gain a deeper understanding of wilderness fire management using specific case studies where possible (Appendix B). Interviews were usually 60 minutes in duration and were conducted and transcribed via Zoom.

To analyze interview content, we used a subset of interview transcriptions to develop a codebook including parent codes and subcodes (Appendix C). We refined the codebook using an iterative process that tested the applicability of codes and inter-coder reliability amongst multiple researchers. The final codebook contained five parent codes and 17 subcodes which were used to code all 22 interview transcripts via Dedoose. Coded interview excerpts were exported from Dedoose and analyzed for frequency of identified themes.

2.3. *Limitations*

There are several limitations to our research methods including sample size and selection methods. The survey sample was relatively small ($n = 131$), and respondents were self-selected. The interview sample was also relatively small ($n = 22$), and though we attempted to select a representative sample of interview subjects, there were compounding limitations from the survey sample and additional scheduling challenges. When analyzing survey results, we frame percentages in terms of the sample size and do not suggest that the results of the survey are predictive of the opinions of all fire and wilderness managers. Similarly, when presenting findings from interviews, we indicate common themes and relative frequencies, not statistical analysis identifying central tendencies or characteristics.

3. **Results & Discussion**

The following subsections outline current fire management practices in wilderness (Section 3.1); how decisions are made regarding wilderness fire management (Section 3.2); what the ideal conditions are related to fire and wilderness (Section 3.3); and ideas for addressing gaps between current and ideal conditions (Section 3.4). In each subsection, we first present survey responses with information about current fire management strategies in wilderness, decision-making factors influencing management and implementation, and the application of both fire and wilderness policies, and then follow up with additional context and details about these topics, as well as illustrative

examples and reflections on potential paths forward for wilderness fire management, gathered during interviews. Additionally, in Section 3.5 we discuss climate change and cultural burning as they relate to wilderness fire management. These topics were not central to our original research questions; however, they add important context to our research and would benefit from further analysis and discussion. Table 2 defines terminology related to wilderness and fire management that is used throughout the results and discussion.

Table 2

Definitions and context for wilderness and fire management terminology.

Term	Description
Wilderness areas	Federal lands congressionally designated by the Wilderness Act of 1964 (Pub. L. 88-577) and subsequent statutes as part of the National Wilderness Preservation System. We also include Tribal wilderness areas, such as the Mission Mountains Tribal Wilderness (Confederated Salish and Kootenai Tribes) and Blue Lake Wilderness (Taos Pueblo), which are owned, designated, and managed by Tribes according to substantially similar provisions as in the Wilderness Act.
Wilderness character	The Wilderness Act of 1964 requires the preservation or protection of wilderness character (Pub. L. 88-577; §2(a), §4(b), §4(d)(3)), and is defined by the following five characteristics: “(1) Untrammeled—wilderness ecological systems are unhindered and free from intentional actions of modern human control or manipulation; (2) Natural—wilderness ecological systems are substantially free from the effects of modern civilization; (3) Undeveloped—wilderness is essentially without structures or installations, the use of motors, or mechanical transport; (4) Outstanding Opportunities for Solitude or Primitive and Unconfined Recreation—wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation; (5) Other Features of Value—wilderness may have unique ecological, geological, cultural or other features of scientific, educational, scenic, or historical value” (Landres et al., 2015).
Wildfire	“A wildland fire originating from an unplanned ignition, such as lightning, volcanos, unauthorized and accidental human caused fires, and prescribed fires that are declared wildfires” (NWCG, 2025).
Prescribed fire	“A wildland fire originating from a planned ignition in accordance with applicable laws, policies, and regulations to meet specific objectives” (NWCG, 2025).
Managed wildfire for resource benefit	A wildland fire ignited by lightning that is allowed to burn to meet natural resource objectives, as opposed to being managed primarily for suppression. This strategy has also been referred to as “let burn,” “prescribed natural fire,” and “wildland fire use” (van Wagtenonk, 2007), and the term is now considered to be outdated due to the 2009 fire policy update (Wildland Fire Leadership Council, 2009), which allows for multiple management objectives on a single fire.
Ignition type	Defined by two categories: natural and human. Our research uses “natural-ignition fire” and “lightning-ignition fire” interchangeably to describe wildfires (unplanned ignitions) that are started without human intervention, and it uses “manager-ignition fire” to describe prescribed fires (planned ignitions) that are intentionally lit and managed according to a burn plan. We also discuss reignition of some fires which were initially ignited naturally (via lightning-ignition) and then reignited at a later date (via manager-ignition).
Cultural burning	The Indigenous practice of intentionally lighting “smaller, controlled fires to provide a desired cultural service, such as promoting the health of vegetation and animals that provide food, clothing, ceremonial items and more” (NPS, 2025; Roos, 2020).

3.1. *Current wilderness fire management practices*

When asked how frequently their agency implemented certain fire management strategies on lands managed as wilderness, most survey respondents reported using “full suppression” and “confinement” always or often, while rarely or never using “prescribed fire,” “fuels treatment,” or “managed wildfire for resource benefit” (Fig. 1). In an optional short answer response, “point protection” and “monitoring” were frequently mentioned as other management strategies. Respondents clarified how fire management strategies differed inside and outside of wilderness, particularly the use of minimum impact strategies and tactics (MIST) in wilderness, which means, according to one Bureau of Land Management National Conservation Area manager, “*without the use of [Wilderness Act Section] 4c-prohibited tools (landing aircraft, chainsaws, motorized equipment).*” Several survey respondents noted that wilderness fires are often managed using more than one strategy due to national fire policy updates in 2009, which allows for both protection and resource objectives on the same fire (Wildland Fire Leadership Council, 2009). For example, one Department of Interior wildland fire management specialist described, “*We manage every fire, every time - and most of them have multiple objectives. If we're following our land and resource management plans, they're required to balance those objectives.*”

Given that many respondents reported employing multiple fire management strategies, in interviews we sought to better understand how frequently people used these strategies on lands managed as wilderness. In line with the survey results, full suppression was the most used management strategy and prescribed fire was the least. Interviewees reported that ignition type (human or natural), geography (e.g., wilderness size, accessibility), natural environment conditions (e.g., climate/weather, forest health), built environment resources (e.g., infrastructure, recreation amenities), and

administrative considerations (e.g., crew availability) influenced the selection of management strategies.

According to interview participants, wilderness wildfires are suppressed when fires are human-caused, when fires approach geopolitical and land ownership boundaries, when fires put certain values at risk, or when administrative resources are scarce. However, when conditions allow, interviewees described a common preference to let a fire “*do what it’s going to do*” in wilderness, in combination with management tactics like tying fire control lines into natural features (e.g., waterbodies, rock outcroppings) and using point protection to protect structures and other values at risk. Geographical considerations commonly dictated the types of management strategies available in wilderness areas. For example, when lightning ignites fires in the interior of large wilderness areas, such as the 2.3-million-acre Frank Church-River of No Return Wilderness in Idaho, managers have more physical space to let a fire burn before feeling the pressures of adjacent landownerships and nearby communities.

Prescribed fire and fuels treatment were the two least frequently used fire management strategies in wilderness according to survey responses (Fig. 1) and confirmed by interview participants; however, wilderness and fire managers alike expressed support for prescribed fire if it was determined to be the minimum required action to achieve wilderness objectives. For example, a National Park Service wilderness manager noted that “*the discussion should... not [be] the validity of prescribed fire as a tool. It’s the only tool we have. ...You just can’t do enough acres with mechanical.*” In contrast, a Forest Service wilderness manager expressed disapproval based on the perception of prescribed fire as a “trammeling” action to be avoided in wilderness: “*Prescribed fire would be inappropriate in wilderness. ...I think it’s a pretty large trammeling effect on wilderness.*”

Several managers pointed to longstanding and ongoing wilderness prescribed fire programs, such as the Illilouette Basin in Yosemite National Park, the Bob Marshall Wilderness Complex on the Flathead and Helena-Lewis and Clark National Forests, or North Cascades National Park, to exemplify current wilderness fire management practices. Yosemite National Park has one of the oldest wilderness fire management programs in the country. Since 1972, natural ignitions have been allowed to burn within wilderness – especially in rocky, high elevation areas which have natural control lines and are otherwise hard to access – and they have also been supplemented with prescribed fires. According to the park’s fire management officer, these longstanding management practices have created a system that effectively limits fire escape:

In the last two years while everyone around us was burning... we were sitting here in between them managing our little lightning fires. ...And the reason our fires are staying so small is because they're high elevation, we're blessed with an abundance of rock ... so we can have some control lines. But because we have a history of all these little fires for so many years, there's a self-limit.

Similarly, a district ranger who manages part of the Bob Marshall Wilderness Complex discussed the mix of prescribed fire and managed natural ignitions over the past few decades that have created self-limiting fire behavior and landscape resilience thanks to second, third, and even fourth-entry fires throughout the wilderness. In North Cascades National Park, the Fire Management Plan allows for reignition, after initial suppression, of natural-ignition wildfires in predetermined fire zones – some of which include wilderness – later in the season during more favorable fire conditions. This approach addresses the dilemma of otherwise “good” fires (depending on their fire zone location) that occur at the wrong time (i.e., the height of summer when lightning strikes are most common, but fuels are most dry).

Such cases demonstrate that prescribed fire is currently being used in wilderness areas, in compliance with federal policy and with at least some level of social support. Thus, while prescribed fire is used less frequently, it is not because its use is prohibited by policy or otherwise. Indeed, its effectiveness has been demonstrated in iconic wilderness landscapes. Still, managers are largely deciding to suppress and not to introduce fire in wilderness. Accordingly, we next sought to understand the decision-making processes that guide the use of prescribed fire and its possible application in the wilderness landscape.

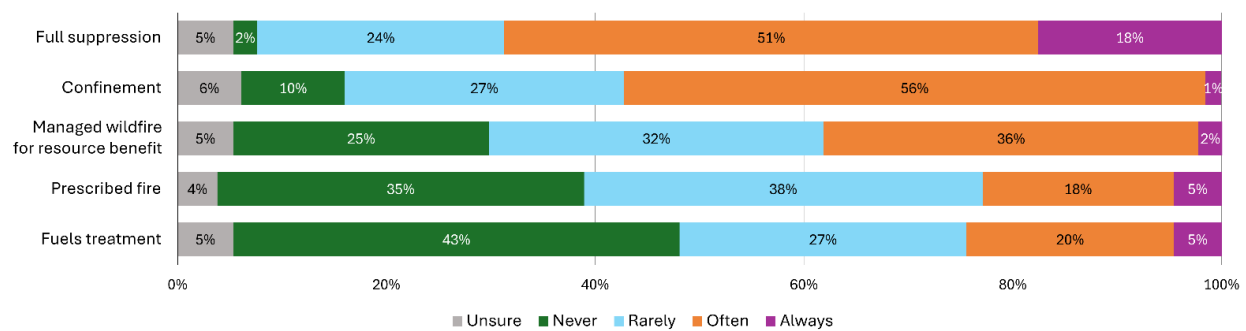


Fig. 1. Frequency of survey responses to question about current use of wilderness fire management strategies. Definitions: (1) Full suppression: the most aggressive fire management strategy with the goal of rapidly extinguishing a fire; (2) Confinement: allowing a fire to burn for a longer period within a set area; (3) Managed wildfire for resource benefit: the use of naturally ignited fire to achieve resource management objectives; (4) Prescribed fire: direct application of fire to wildland fuels under specified conditions to attain resource management objectives; (5) Fuels treatment: reducing the amount of vegetation or changing the arrangement of fuels in the environment using hand thinning, mechanical thinning, or other treatment tactics.

3.2. *Wilderness fire management decision-making*

When making decisions regarding fire management in designated wilderness areas, land managers use wide-ranging rationale that are sometimes unrelated to supporting wilderness qualities. In

a survey question ranking the importance of decision-making factors, respondents most selected “perceived risk” and least selected “fire outcomes” as the most important factor (Fig. 2). Survey respondents explained that perceived risk is often interwoven among all other decision-making factors: risk is top of mind for public perception and local politics (i.e., sociopolitical factors), risk affects staffing and funding decisions (i.e., operational considerations), and risk tolerance depends on agency leadership and policies such as the National Wildland Fire Preparedness Levels (i.e., institutional influences). The prevalence of risk in decision-making narrows the list of management options. As explained by one Forest Service fire management officer in their survey response: *“There are many negative outcomes possible... There is little incentive, reward, or recognition for managers or agency administrators taking on this risk especially when compared with the myriad negative outcomes.”*

Interviewees further explained that risk-averse agency leaders and line officers making decisions based solely on political pressure or potential negative outcomes – like *“getting reprimanded by the public or the threat of litigation”* – continue to rely on full suppression as the dominant management strategy. While fear of reprimand affects all fire management decisions, it is especially prohibitive for manager-ignited prescribed fires, both inside and outside of wilderness areas. For example, one Forest Service interviewee hypothesized that the 2022 Hermits Peak-Calf Canyon fire, an escaped prescribed fire in New Mexico that grew to be the largest wildfire in the state’s history, would cause a setback nationwide for future prescribed fires due to the fire’s destructive impacts and consequent loss of public trust. In fact, the Forest Service temporarily paused all prescribed fires in 2022, even with a 99.84% success record for prescribed fires going as planned (Forest Service, 2022).

Survey and interview participants alike noted that risks to life and property are considered first when managing any fire. Interagency policies name public and firefighter safety as the number one priority for all fire management, followed by the role of wildland fire as an “essential ecological

process and natural change agent” (Wildland Fire Leadership Council, 2009). The prioritization of public and firefighter safety shapes fire management in non-wilderness areas, and it also forms the basis for letting lightning-ignited fires burn in remote wilderness areas. As one Forest Service fuels planner explained in their survey response:

Wilderness (and other remote) fires rank lower in terms of immediate threat to human values and are frequently managed using a monitoring strategy...we are directed to keep costs commensurate with values at risk and ensure exposure of firefighters is commensurate with the values being threatened.

To help control for risk and justify management decisions in the face of public outcry and potential litigation, managers rely on systematic processes for decision making. Such tools in turn shape management priorities, implementation, and outcomes. Interviewees discussed using formal and informal processes, including the Wildfire Decision Support System (WFDSS), Minimum Requirements Decision Guide (MRDG) (recently replaced by the Minimum Requirements Analysis Framework [MRAF]), along with decision-making criteria or mobilization guidelines developed locally. Such tools and systems help fire managers, wilderness specialists, and agency administrators document their rationale and have the larger effect of consistently defining “appropriate” management responses using familiar criteria such as risk, safety, ecological effects, and wilderness character. However, two interviewees deemed these frameworks as inadequate and sought to create additional guidance. One National Park Service wilderness specialist reported developing a 12-step set of criteria for wilderness management decisions, which included fire management; another Forest Service district ranger implemented a briefing form tied to designated fire management areas.

Though “institutional influences” was not commonly a top decision-making factor in the survey (Fig. 2), interview participants frequently talked about the effects of agency history and culture on

interpretation of wilderness and fire policies. Notably, interviewees with experience at multiple agencies commented on differing interpretations of the Wilderness Act and its effect on internal agency policies and guidelines. While these interviewees noted both pros and cons of agency-specific management strategies, they concurred that the Forest Service has the narrowest interpretation of the Wilderness Act for all wilderness management, including fire. This is summarized by a Forest Service fire ecologist discussing prohibited uses and minimum requirements:

Each of the federal agencies that manage wilderness [has] always had their own particular flavor and how they interpret the Wilderness Act – how they set their own internal policies to meet those guidelines and objectives... Each agency uses the same process, we've standardized it across all the four agencies, but the Forest Service tends to have the narrowest view of what is justified.

Wilderness qualities (e.g., naturalness, untrammeled, solitude) were frequently cited as ideals that influence decision-making when responding to fires. According to interviews, wilderness and fire managers alike prefer allowing natural (lightning-ignited) fires to burn in wilderness because of the “naturalness” quality. As described by a Forest Service fire management specialist, *“In wilderness you'd have to have a really good reason to not allow fire to play its natural role, and then outside the wilderness, you have to have a really good reason to let fire play its natural role.”* However, interviewees also explained that wilderness values are more likely to influence *how* fire management strategies are implemented, as opposed to *which* strategies were chosen – meaning, managers may have little decision space to choose managing a fire over suppressing it, but they can choose to use less invasive tactics (i.e., MIST) instead of prohibited uses like bulldozers and fire retardant which are often temporarily exempted during wildfire suppression. This is often because operational considerations, such as the National Wildland Fire Preparedness Level, outweigh wilderness considerations. As described by another Forest Service interviewee, *“I would say the values internal to the wilderness*

would probably be on the lower end of things towards bottom after the other values have been considered.”

Lastly, interviewees discussed collaboration as a critical component of decision-making. Internal collaboration, including discussions among agency administrators, resource specialists, and incident management teams, informs immediate decision-making for wildfire emergencies. External collaboration, which for prescribed fire generally occurs during planning phases, includes coordination with other federal and state partners, local jurisdictions, commercial interests, private landowners, and advocacy groups. Cross-boundary collaboration is especially important when managing wildland fire because, according to a survey participant in county government, “wildfire never stops at a fence.” Decision-makers use collaboration to determine values at risk and additional fire management considerations; however, several interviewees mentioned the need for earlier and more robust collaboration outside required procedural collaboration, as exemplified by one Forest Service fire program manager: “It takes longer on the front end but then you don’t have to go to court to implement on the back end.” Collaboration helps to build social license – or general approval among community members and agency partners – for a broader suite of fire management tools, which in turn increases the decision space – or range of choices – available to managers.

Our research shows that while managers ultimately choose fire management strategies within the range of decision space available to them, perceived risk, the fire environment, sociopolitical context, and operational considerations are more influential than particular fire outcomes, such as restoration of historical forest structure. Whereas wilderness policies may function as operational considerations, wilderness values are more likely to influence the sociopolitical arena and perceived risk. Additionally, decisions about managing fire are least influenced by the desire to create a particular ecological outcome, which creates difficulty in articulating the need for fire actions to be taken in

wilderness areas. Formalized decision-making processes, like WFDSS, are meant to aid fire management decisions using data and modeling to systematically evaluate risk, but these tools may still be overridden by the influence of risk averse decision-makers.

This survey of the decision-making landscape shows that the potential to transform the formal and informal protocols through which fire is managed in wilderness may be realized by addressing the barriers of perceived risk, as well as sociopolitical and operational influences. Decision space is expanded by collaboration, policy flexibility, and proactive fire management, and it is reduced by risk aversion, public mistrust, and changing climate conditions.

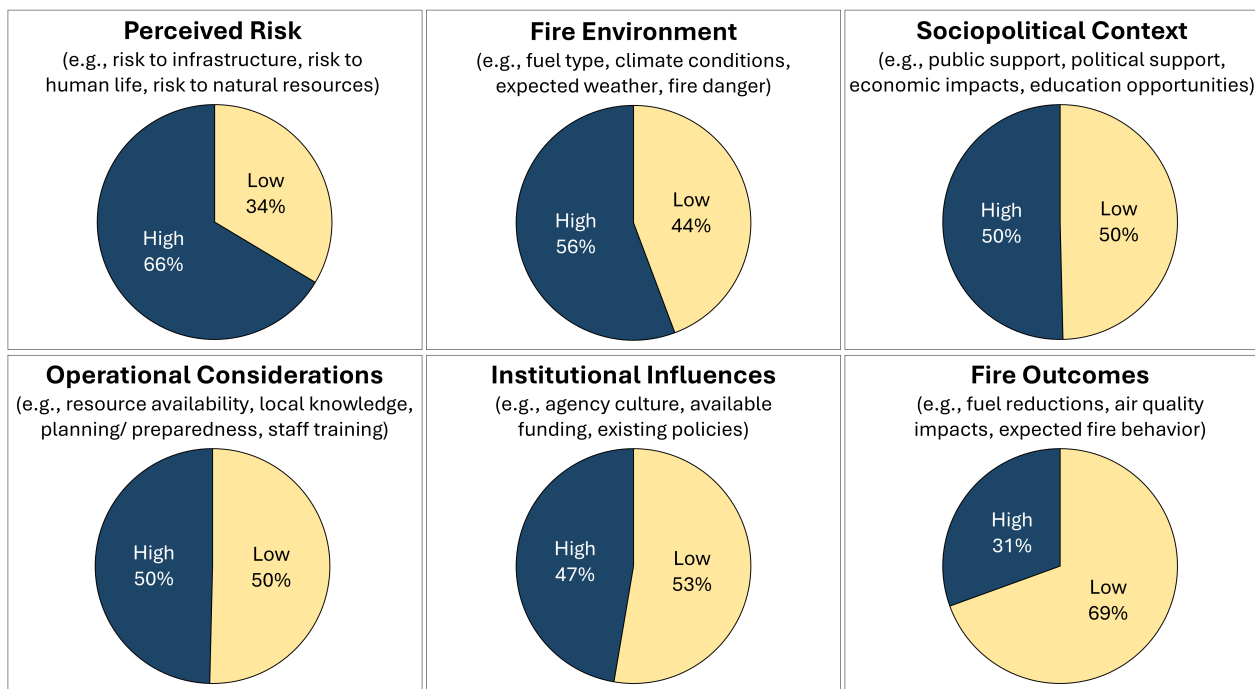


Fig. 2. Relative rankings of six decision-making factors for wilderness fire management. “High” ranking includes ranks 1-3; “Low” ranking includes ranks 4-6.

3.3. *Ideal conditions for wilderness fire management*

Beyond understanding how and why fire is managed in wilderness areas, as discussed in the previous sections, this research sought to characterize ideal conditions for wilderness fire management.

According to both survey and interview participants, fire should be allowed to play its “natural role” on the landscape to the maximum extent possible without threatening public and firefighter safety. However, many research participants agreed that current fire management falls short of this ideal.

Most survey respondents indicated that to enhance wilderness resources, full suppression should be used less often and strategies that involve more fire on the ground should be used more often (Fig. 3). Notably, 65% of survey respondents believed that full suppression should be used less often, while respondents thought that managed wildfire for resource benefit (73%) and prescribed fire (75%) should be used more often. There is strong support among those who manage these landscapes for the use of prescribed fire in wilderness areas.

Survey respondents used phrases like “the natural role of fire” and “returning fire to the landscape” to justify such wilderness fire management strategies and decisions. Nineteen unique respondents used the term “natural role” in 25 total instances across all survey responses. To explore this idea in detail, we asked each interview participant to describe their view of ideal conditions (including both biophysical and social conditions) for fire management in wilderness. Again, fire’s “natural role” came up often (7 of 22 interview participants). Generally, interviewees agreed that fire belongs in wilderness areas as an ecological process, as explained by one Forest Service interviewee:

Wildfire belongs in wilderness. Wild things belong in wild places, so one of the most quintessential things you can experience in a wilderness area is a burned landscape or see fire and smell smoke and know that that’s an important ecological and cultural process that managers are allowing to occur....Thinking about fire as not just a disturbance, but something that’s so elemental, so necessary, it’s as important as sunshine or rain or snow or anything else you’d expect to experience on a wilderness adventure.

Interview participants expressed that ideally, lightning ignitions would be allowed to burn and play their “natural role” in wilderness with as little management as possible. However, participants recognized that in many western U.S. wilderness areas, naturally ignited wildfires would devastate wilderness resources due to fuel build-up from over 100 years of fire suppression and changing climate trends. As described by a National Park Service interviewee, it is becoming ever more challenging to let natural-ignition fires burn in some wilderness areas:

If we could allow more lightning strikes to burn in wilderness, we could see fire regimes adapting to climate change a lot better – so that is the ideal. It’s a lot of work to thin and do prescribed fire and do all the compliance, and you ideally want to let nature be in charge. I think we’re past the tipping point in some places where it’s probably too darn dangerous to let lightning strikes burn.

Despite the labor and compliance efforts, interviewees discussed the possibility of first employing active management strategies, like fuels treatments and prescribed fire, to address hazardous conditions, reduce high fuel loads, and then eventually allow natural ignitions to play a larger role in maintaining those conditions. A Forest Service fire ecologist describes this shift from active to passive management:

The ideal scenario is... a future scenario where within these wilderness areas we’ve done enough active management, in the sense of doing some prescribed burning, that we have very resilient wildernesses. Then we can start becoming more passive and allowing more lightning fires to do more. It’s a scenario where we have reintroduced fire under appropriate terms and with enough degree of success, where now we can sit back and just allow it to maintain itself over time.

This idea of “self-regulation” of fire in the wilderness was expressed by several interviewees, particularly where new fires would run into the boundaries of older fires that function as a fuel break. Interviewees also expressed that a function of self-regulating fire regimes in wilderness is a

heterogenous landscape mosaic, termed “pyro-diversity” by one Forest Service district ranger, which means that landscape is characterized by patches of unburned and burned areas of varying ages, severity, and extent. Achieving these ideal conditions, as described by managers, requires knowledge of historical fire regimes, assessment of current wilderness conditions, intentional application of fire to the landscape (where necessary), and patient management of natural ignition fires. It also requires a cooperative sociopolitical atmosphere.

Interviewees identified social change as another critical component of an ideal future condition, particularly in increasing the visibility of beneficial fire effects. Interviewees agreed that fire is a natural disturbance that belongs in wilderness, and they saw public understanding of this as critical for effective wilderness fire management. To sway public perception, beneficial fire effects must be made apparent. If the public can see increased open space and improved hunting conditions, for example, or more water in rivers due to less canopy interception and transpiration, an appreciation of the complex effects of fire could grow. In the aforementioned cases at Yosemite and North Cascades National Parks, public outreach was critical during prescribed burns. Signage and public-facing educational staff helped prevent confusion and explain the benefits of what otherwise could be perceived as “dangerous” smoke or “ugly” burned areas. While such outreach particularly aligns with the visitor-serving mission of the National Park Service, the need for effective public communications for all managed fire was noted by respondents from all agencies.

Interviewees also supported engaging a diversity of voices in fire management, including co-stewardship with Tribes and collaboration with wilderness advocacy groups. For example, a Forest Service district ranger discussed attempts to add a Tribal representative to the forest unit’s WFDSS team and discussed the possibility of including wilderness advocates as well. This participant wondered, *“how do we open up our decision-making process to include those voices that are more*

supportive of fire on the landscape? You can either do it during the fire, or you can start doing the FOIAs [Freedom of Information Act] and the litigation after the fires, and I guess I'd rather have them at the table, skin in the game." This sentiment was expressed by other research participants in their survey and interview responses, indicating broad support for collaboration between agencies and external partners.

Finally, several interviewees discussed ideal social conditions within agency staffing and leadership. In all agencies, participants desired cross-training for resource specialists in both wilderness and fire management. One Bureau of Land Management fire specialist suggested that hiring "from the ground up," or hiring and promoting agency leaders who have worked in the field, would help increase the risk tolerance of future decision-makers. Additionally, risk today reduces risk tomorrow, according to another Forest Service district ranger, who further explained that current line officers who are willing to take risks can lay the groundwork to reduce risk and increase decision space for their successors in the future. Research participants indicated that these steps are crucial for creating a workforce that will be better prepared to face the increasing challenges associated with fire management – both within and outside of wilderness – in a changing climate.

Overall, our research identifies strong agreement among land managers from a variety of agencies, organizations, and geographies about ideal fire conditions in wilderness areas: fire should be allowed to play its natural role on the landscape to the maximum extent possible, in ways that are characteristic of historic fuel and fire conditions, and so that they do not harm people, property, or other values at risk. To achieve these ideals, managers need more than fire management tools and resources; they need changes to the social context in which fire is understood and managed.

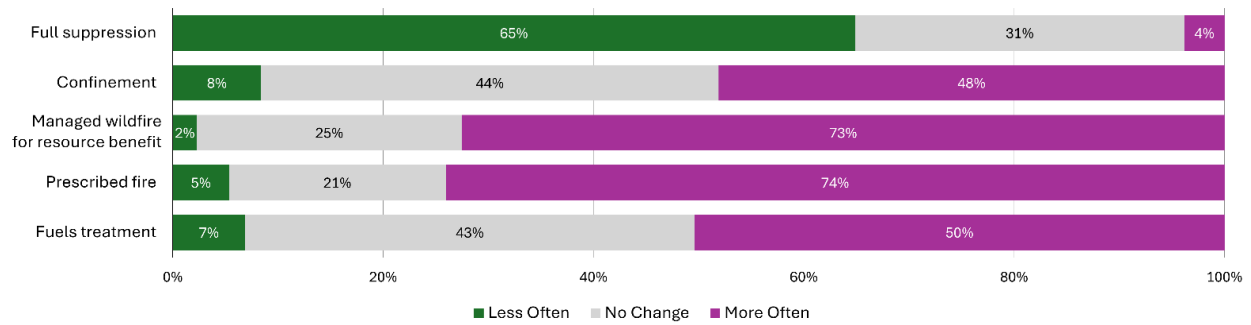


Fig. 3. Frequency of survey responses to question about ideal changes to wilderness fire management strategies. Management strategies are defined in Fig. 1.

3.4. Barriers to ideal conditions

Current fire and wilderness management policies are flexible enough to allow for varied fire management strategies in wilderness areas, according to survey and interview responses, though prescribed fire is by far the most difficult strategy to implement. Participants indicated policy implementation, administration, and public perception as the main barriers to effective fire management in wilderness areas.

In the survey, participants evaluated the relationship between fire and wilderness management in questions about (1) the impact of fire management policy on wilderness resources (Table 3) and (2) the impact of wilderness management policies on fire objectives (Table 4). For both questions, many participants noted a discrepancy between fire or wilderness policy as written and its implementation. As expressed by a Forest Service fuels specialist, “*policy is often not implemented in a way that leads to positive fire management outcomes. Suppression strategies often prevent the opportunity to realize wilderness characteristic goals.*”

When discussing how fire policy shapes wilderness resources (Table 3), survey respondents mentioned the “natural role” of fire and other ecological benefits as examples of fire enhancing

wilderness, and they most often described the trammeling effects of fire suppression tactics (e.g., use of mechanized equipment) when describing how fire management policies degrade wilderness resources. Table 3 shows low consistency among managers regarding the perceived effects of fire management on wilderness outcomes, for managers equally perceive fire policy as enhancing or degrading wilderness resources. Responses indicate that managers see complexity in the ways that fire management affects wilderness outcomes, as management decisions can be accompanied by tradeoffs and unintended consequences. Respondents see high potential, however, for new fire management policies that enhance, rather than degrade, wilderness qualities.

When discussing how wilderness policy helps or hinders fire objectives (Table 4), survey respondents who thought wilderness policy helped fire management objectives often mentioned the importance of fire as a natural process, especially related to natural ignitions. However, participants who described wilderness policy as hindering fire management objectives were likely to state that management options were more limited in wilderness due to restrictions on equipment and treatment types. Additionally, managers indicated that beyond wilderness policy, fire management strategies and outcomes are closely tied to on-the-ground considerations, like wilderness size and ecological conditions, and the sociopolitical atmosphere, including local leadership priorities. Again, the mixed perceptions of wilderness policy helping and/or hindering fire management indicates an opportunity to create new or employ existing wilderness policy in ways that allow positive ecosystem effects of fire to be realized in wilderness areas.

The survey also asked participants to describe specific barriers and opportunities to achieving more prescribed fire and managed fire for resource benefit in wilderness, which were then categorized and ranked by relative frequency (Fig. 4). More barriers than opportunities were described. Public perception was the top barrier for both strategies, followed by resource availability, planning, smoke

and air quality, geography, politics, and fuel conditions. Barriers specific to managed fires for resource benefit included general fire management considerations, such as risk aversion, lack of experience, and drought and climate conditions. In contrast, barriers for prescribed fires were more specific to wilderness management requirements (e.g., restrictive wilderness policies, impacts to wilderness values, and prohibitions on mechanized equipment). While managed fires for resource benefit face general fire management challenges, introduction of prescribed fire in wilderness is instead constrained by wilderness values and policy interpretation. The perception that wilderness policy disallows prescribed fire or otherwise creates inappropriate circumstances for prescribed fire as a resource management tool is likely to impact when and how often prescribed fire is used.

When asked how to achieve “ideal conditions” for wilderness fire management, interview participants discussed many of the same barriers, including public perception, prohibitive policy language, administrative hurdles, and planning challenges. Like survey respondents, interviewees frequently identified public perception as a barrier to improving fire management outcomes, due to the lack of trust and social license afforded to agencies. According to participants, public understanding has improved in the last several decades but continues to be limited by complexities introduced by climate change, negative media coverage, and concerns about smoke and air quality. Without social license from the public, agencies are hamstrung by liability concerns and will remain risk averse. A National Park Service wilderness specialist explained the layers of trust that must be built with the public and others in order to work towards desired wilderness conditions:

In terms of fire on the landscape, the ideal is all natural conditions are allowed to burn freely until they burn out in the wilderness.... Getting to that point requires that change in perception by the public, by the politicians, by those in the agency. It's going to take greater acceptance within the wilderness community of doing those manipulations to get those fuel levels down.

Other interviewees echoed this warning that gaining even minimal support for managed fire for resource benefit has been hard-won, and building similar support for prescribed fire in wilderness presents a significant challenge. Though they had mixed opinions on the trajectory of social support, several interviewees agreed that fire policy has gradually become more flexible over time and highlighted the importance of the 2009 fire policy update which granted the ability to concurrently manage fires for multiple objectives. Interview participants from the Forest Service discussed prohibitive language in the agency's fire management guidelines (e.g., Forest Service Manual 5140.31 [Forest Service, 2020]) that limits the circumstances in which managers can use prescribed fire in wilderness to reduce unnatural buildups of hazardous fuels. Based on published research (Alnes, 2017) and interviews with participants from other federal land management agencies, this limitation is unique to the Forest Service. Other survey and interview participants mentioned confusion surrounding the interpretation of different kinds of directives, such as policies and guidance documents, which has the potential to create misaligned objectives between and within federal agencies. A Forest Service interviewee described this uncertainty:

What gets in the way of fire playing its natural role is that there isn't a universal understanding of what natural is...there isn't consensus on what natural is. And so, how can we possibly be working towards something that is supposed to be defined clearly in goals and objectives when we can't even agree on what the benchmark is?

Agency policies are distinct by design, due to their varied histories, divergent individual mission statements, and different implementing regulations; however, universally understood definitions would contribute positively toward common management goals. Along with policy, interviewees identified agency funding, staffing, and leadership, as significant barriers to effective fire management inside and outside of wilderness. Of these barriers, staffing and funding were the most

mentioned. For example, a National Park Service fire management officer noted staffing challenges for implementing prescribed burns:

Most of our prescribed burns we do in the shoulder seasons when we pretty much laid off our seasonal workforce. So, trying to get people who have been responding to suppressing these large fires all summer long, ... the last thing they want to do is pick up the drip torch and go burn, go see more fire and smoke.

As fire seasons get longer, staffing for prescribed fire will increasingly have to compete with staffing for wildfire suppression activities. In a similar vein, several interview participants discussed limitless funding for these suppression activities, but challenges for acquiring funding for other types of management strategies, especially during high National Wildland Fire Preparedness Levels. However, as stated by one Forest Service interviewee, funding alone will not solve the fire problem: “*We cannot buy fewer fires. We can buy better fires, but we cannot buy less fires.*”

Both survey and interview participants also discussed barriers associated with out-of-date resource management plans and lengthy National Environmental Policy Act (NEPA) processes for new approvals. Resource management plans, including forest plans and more specific fire or vegetation management plans, dictate local objectives and lay the groundwork for fire management decision-making when using tools like WFDSS. Generally, NEPA itself wasn’t seen as a barrier; rather, interviewees expressed frustrations related to inadequate stakeholder engagement and litigation threats during the NEPA process.

To remedy some of the barriers described above, interviewees suggested new and improved practices within current wilderness fire management policy. Responses followed prominent themes of increasing planning, coordination, and proactive management to expand the decision space for future fires. Other specific recommendations included: integrating fire into wilderness management by

incorporating fire stewardship as a routine task for wilderness specialists; designating fire monitors in wilderness areas; requiring after-action review to evaluate efficacy and impacts of suppression activities in wilderness; and promoting active management on the perimeter of wilderness areas with fuels treatments and prescribed fire.

While our research indicates that many barriers exist to fire management in wilderness, most of these barriers are not strictly tied to wilderness policy prohibitions and therefore are not specific to the wilderness system. Rather, they are barriers that plague fire management across agencies and geographies, stemming from resource limitations and perceived risk by decision-makers and the public. Prescribed fire, in particular, is constrained by these barriers, yet most research participants indicated support for the expanded use of manager-ignited fires in wilderness, so long as it is the minimum action necessary to maintain wilderness qualities. While wilderness requires additional consideration of minimal tools and intervention, it also provides opportunities for fire's "natural role" to be realized in ways not available to lands outside the wilderness system (e.g., wildland urban interface [WUI], timber production areas).

Table 3

Survey response categories, frequencies, and examples for the question, "Does fire management policy at your agency/organization enhance or degrade wilderness resources?" Percentages add up to 98%, as 2% of responses were categorized as N/A (e.g., "What are you really wanting to know?").

Response Category	Percent	Example Quote
Enhance	39%	"Fire is a part of the natural ecosystem and process. Thus the current fire management policy fortifies wilderness value."
Degrade	30%	"Fires are nearly all directly suppressed regardless if the ignition was natural or human caused. Wilderness managers are not consulted on suppression techniques and/or alternatives to suppression"
Both	19%	"Fire management may directly manipulate the biophysical environment of a wilderness and degrade the untrammelled or undeveloped qualities of wilderness character."

		However, fire management may also increase the natural quality of wilderness character.”
Neither	4%	“Fire playing a natural role in wilderness enhances wilderness character when conditions allow. Resource availability often times does not allow such management and fire management actions taken are contrary to wilderness values.”
Other	6%	“Depends on your definition of enhance/degrade wilderness resources. Wilderness resources by default will have less available options for resource management than other lands.”

Table 4

Survey response categories, frequencies, and examples for the question, “Does wilderness management policy at your agency/organization help or hinder broader fire management objectives?” Percentages add up to 96%, as 4% of responses were categorized as N/A (e.g., “I don't know enough about fire management objectives to answer this”).

Response Category	Percent	Example Quote
Help	34%	“Allowing for fires to play a role on the landscape breaks up fuel continuity and modifies fire behavior when burning into or out of the wilderness from adjacent lands managed for multiple use.”
Hinder	31%	“The wilderness designation limits, or complicates, the district’s ability to aggressively pre-plan or pre-treat areas that will promote or support large fires that would threaten the infrastructure that is ours to protect.”
Both	9%	“Wilderness management helps fire management objectives by asking fire managers to take a deeper look at fire impacts and how actions/impacts may impact other resources and managed public lands. Wilderness management hinders fire management objectives by requiring more red tape and management time to examine, discuss, and think about impacts and protocols.”
Neither	8%	“Wilderness management policy neither helps nor hinders broader fire management objectives, but rather allows for different considerations when managing fire.”
Other	15%	“I would say Wilderness management policy is usually ignored when it comes to fire, with only occasional lip service paid to Wilderness management.”

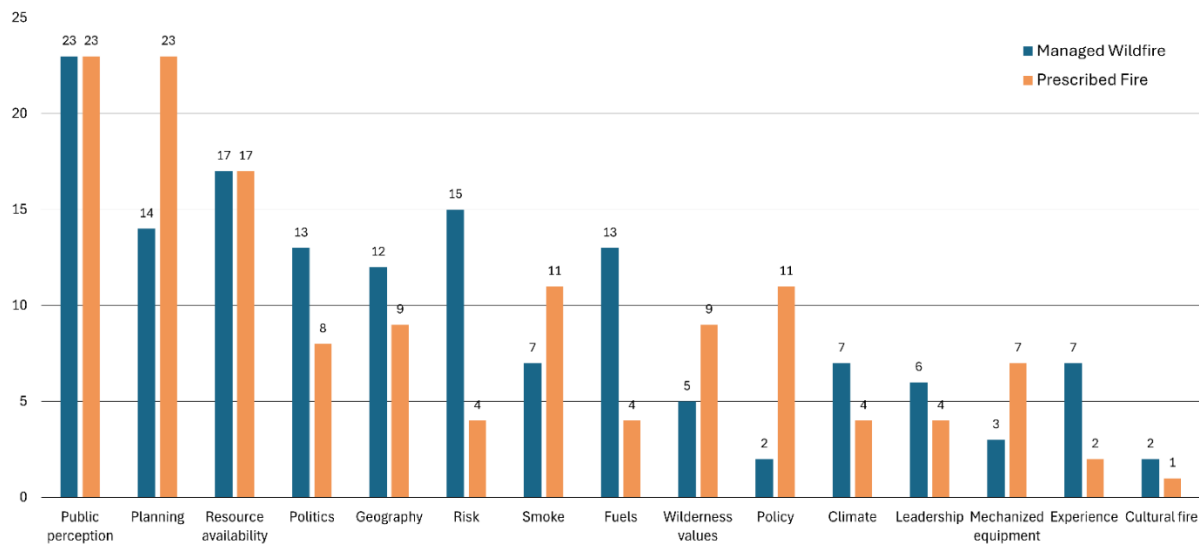


Fig. 4. Categories of barriers to achieving more prescribed fire and wildfire managed for resource benefit in wilderness.

3.5. Additional findings and areas for further research

Climate change and Indigenous cultural burning emerged as important topics throughout the survey and interview responses. While we did not explicitly ask participants about climate change in relation to wilderness and fire management, it was mentioned frequently in response to questions about ideal conditions and barriers to meeting those conditions. Many participants described the need to change fire management practices – especially in wilderness areas – but also expressed uncertainty in how to do so because, as stated by a National Park Service fire planner, “*climate change is not a natural process*” and is instead “*a fundamental trammeling of wilderness.*” Research participants discussed the already noticeable effects of climate change in wilderness areas they manage, including hotter, drier conditions, tree mortality caused by insect and disease outbreaks, and longer wildfire seasons and subsequently shorter shoulder seasons ideal for manager-ignited fires. These challenges, compounding over a century of fire exclusion, are creating additional constraints on fire management options in wilderness. As discussed previously, some wilderness areas are perceived as not ready for

prescribed or managed fire because current conditions would promote extreme burning and likely lead to vegetation type conversions and degraded wilderness qualities. Most participants expressed a strong sense of urgency to adapt management practices to address these challenges. As stated by a National Park Service survey participant, *“The environment around us is changing so rapidly in this era of climate change that science, policy and management are not keeping up.”* Though climate change is creating fire conditions which are poised to produce increasingly negative impacts on ecosystems (Parks & Abatzoglou, 2020), it also provides opportunities for innovative wilderness fire management.

Indigenous cultural burning was another topic that was not specifically asked about in survey and interview questions, outside of interviews conducted with Tribal representatives. However, research participants frequently acknowledged the extent to which Indigenous land management, including intentional fire use, shaped our wilderness areas as we now experience them. As described by a cultural fire practitioner in an interview, *“for tens of thousands of years native people managed their homelands with fire, and when Europeans arrived two hundred years ago, what they described in their journals was park-like landscapes.”* These “park-like landscapes” became some of the wilderness areas we know today. In their survey and interview responses, participants spoke of support for the use of Indigenous cultural burning as a fire management strategy, both inside and outside of wilderness. They also discussed the importance of using a combination of Western science and Indigenous knowledge for effective fire management in accordance with co-stewardship and co-management principles. However, the reasons for burning are notably different between federal agency and Indigenous cultural fire practitioners. While agency-affiliated managers most often cited hazardous fuels reduction as justification for manager-ignited fires, cultural fire practitioners discussed the importance of maintaining culturally significant plant and animal species and habitats (e.g., hazel bush, blueberry patches, moose habitat). Perhaps these are all “values at risk.” Tribal members also noted the ways in which wilderness designation and policy limits their management options, yet there was no consensus

on how policies or practices could be revised to effect change. Recent scholarship attempts to answer these questions around the importance of cultural burning for the landscape and other benefits (Long et al., 2021; Greenler et al., 2024); however, this remains an area for further research and development.

4. Conclusion

This research shows there is broad support among fire and wilderness specialists alike for fire in wilderness. However, current approaches to managing fire in our nation's wilderness areas, including policies that aim to ensure lightning-ignited fires can burn, are not achieving desired conditions. Our findings highlight how presently it is nearly impossible to let fire play a "natural role" in wilderness areas because of geographic factors (e.g., wilderness size, location), ecological factors (e.g., fuel loads, vegetation type conversions), and risk factors (e.g., safety, values at risk). In the absence of fire, tree densities and fuel loads in many wilderness ecosystems continue to increase beyond historical levels (Stephens et al., 2022). Increased fuels burning under longer, drier, and more extreme conditions can lead to fire behavior and effects that are historically anomalous (e.g., Parks & Abatzoglou, 2020; McClure et al., 2024). These changes may represent a fundamental "trammeling" of wilderness in addition to departures from natural conditions (Boerigter et al., 2024). Beyond the conflict this represents to the legal designation of wilderness, altered wilderness fire regimes, particularly under a changing climate, are increasingly likely to overcome the resilience of wilderness ecosystems. Protected areas like wilderness are critical for sustaining biological diversity and ecosystems services (Mittermeier et al., 2003; Ellison, 2009), and in an era of global environmental change, vulnerability of many wilderness ecosystems presents a wide array of risks. Accordingly, both fire and wilderness management strategies must acknowledge and respond to this shifting context.

Effective use of prescribed fire has high potential to shrink the gap between existing and ideal ecological conditions in wilderness. The Wilderness Act does not prohibit prescribed fire and the

policies of the four federal agencies that manage wilderness also allow the use of prescribed fire in wilderness areas (Alnes, 2017). In fact, the 2009 national fire policy update, cited by many of our research participants, offers this guiding principle: “*Wildland fire will be used to protect, maintain, and enhance resources and, as nearly as possible, be allowed to function in its natural ecological role*” (Wildland Fire Leadership Council, 2009). Thus, the constraints for using prescribed fire in wilderness are not policy-driven and do not differ significantly from the barriers that constrain fire management outside wilderness areas. Some barriers can immediately be addressed, such as by revising agency guidance documents and other policies that shape implementation. For example, passage of the Inflation Reduction Act (IRA) significantly increased funding for agencies to complete fuels reduction work; however, the legislation includes specific language which precludes the use of IRA appropriations for projects in wilderness or wilderness study areas (Inflation Reduction Act, 2022). Other barriers must be overcome by addressing trickier issues like risk aversion which are engrained in public perception and agency leadership.

Under changing climate and disturbance regimes, land management is a moving target. As discussed by our research participants, there is no “one size fits all” approach to managing fire in wilderness. Managers will need a diverse set of tools in their toolbox to make informed, context-dependent decisions for wilderness fire management and to prevent degradation of these special areas in an era of growing flammability and enhanced fire effects (Abatzoglou & Williams, 2016). In the words of a wilderness advocacy organization’s state director, “*If we have wilderness, we should have fire and we will have fire. That’s, to me, the whole purpose of the wilderness.*”

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Declarations*Funding Declaration*

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Human Ethics and Consent to Participate Declarations

This study was approved by the Human Research Committee (HRC) under the Institutional Review Board (IRB) of Academic Affairs at Western Colorado University (approval number HRC-2021-02-05-R38). Informed consent was obtained from all research participants, and documentation is available upon request.

Clinical Trials

Clinical trial number: not applicable

APPENDIX A. Survey questions

No.	Survey Question
Survey Consent	
1	I acknowledge that I am at least 18 years old, have read the above information, and provide my consent to participate under the terms above.
Your Background	
2	Within your agency/organization, do you participate in fire and/or wilderness management, policy, or research?
3	What is your current job title, as it relates to fire and/or wilderness management?
4	What is the current agency or organization that you work for?
5	How many years of professional experience do you have in fire and/or wilderness management?
6	In what geographic area of the United States do you have the most professional experience?
Management Policies and Strategies	
7	Does fire management policy at your agency/organization enhance or degrade wilderness resources?
8	Does wilderness management policy at your agency/organization help or hinder broader fire management objectives?

No.	Survey Question
9	For lands your agency/organization manages as wilderness, how often do you use the following fire management strategies? • Full suppression: Never; Rarely; Often; Always; Unsure • Confinement: Never; Rarely; Often; Always; Unsure • Managed wildfire for resource benefit: Never; Rarely; Often; Always; Unsure • Prescribed fire: Never; Rarely; Often; Always; Unsure • Fuels treatment: Never; Rarely; Often; Always; Unsure
10	For lands your agency/organization manages as wilderness, what changes in fire management strategies would most enhance wilderness resources? • Full suppression: Less often; No change; More often • Confinement: Less often; No change; More often • Managed wildfire for resource benefit: Less often; No change; More often • Prescribed fire: Less often; No change; More often • Fuels treatment: Less often; No change; More often
11	Are there any other fire management strategies that we missed in the questions above?
12	Please describe any opportunities or barriers that would need to be considered in order to achieve more wildfires managed for resource benefit in wilderness.
13	Please describe any opportunities or barriers that would need to be considered to achieve more prescribed fire in wilderness.
14	Please rank the importance of the following factors (Fillmore et al., 2021) that affect decision-making regarding fire management in areas your agency/organization manages as wilderness. • Fire environment (e.g., fuel type, climate conditions, expected weather, fire danger) • Fire outcomes (e.g., fuel reductions, air quality impacts, expected fire behavior) • Institutional influences (e.g., agency culture, available funding, existing policies) • Operational considerations (e.g., resource availability, local knowledge, planning/preparedness, staff training) • Perceived risk (e.g., risk to infrastructure, risk to human life, risk to natural resources)
15	Please provide any details regarding your answers to the questions above.
Fire Management Plan	
16	Is there a current fire management plan for the specific lands that your agency/organization manages as wilderness?
17	Please briefly describe the current fire management plan for lands that your agency/organization manages as wilderness.
18	What are some items in this plan that you consider innovative or particularly effective?
19	What are the shortcomings of this plan?
Any Other Burning Thoughts? (Optional)	
20	Would you be willing to participate in an interview for this study?
21	Are there any particular experiences you have had with managed fire or prescribed fire in wilderness that would provide a good case study or learning opportunity for researchers, managers, or policy makers?
22	Any additional questions and/or comments for the research team?

APPENDIX B. Interview questions

No.	Interview Question
1	Describe your former/current work experience as it relates to designated wilderness or fire management.
2	How does your organization make fire management decisions on lands managed as wilderness? How does your job/role fit into the process?

No.	Interview Question
3	How does fire management contrast between wilderness areas and non-wilderness areas on lands that your agency manages? Are you able to use prescribed fire in wilderness areas? Why or why not?
4	Does public perception influence decision-making? Has public perception changed throughout your career? What would you like the public to better understand about wilderness fire management?
5	Survey participants discussed differences in how policies are written and how they are implemented in the field. Have you experienced this in your organization?
6	One of our survey questions asked if wilderness policy helped or hindered fire management objectives. There was an even split among survey responses: 30% answered “help”, 30% answered “hinder”, and the remaining 40% was split among both/neither/other. In what ways does wilderness policy help fire management in wilderness? In what ways does wilderness policy hinder fire management in wilderness?
7	Survey respondents ranked “perceived risk” as the most important factor affecting decision-making for fire management in wilderness areas. “Fire outcomes” were ranked as the least important factor. a. Do you agree with these rankings? Why or why not?
8	More than 25% of survey respondents mentioned the “natural role of fire” in ecosystems. How is fire able or not able to play its “natural role” in wilderness areas you manage? Are there certain fire management strategies that affect this?
9	Describe any specific examples of fire management projects, decision-making processes, and results/impacts within wilderness areas.
10	<u>Required question</u> : Imagine the ideal scenario for fire and wilderness management. What does it look like and how do we get there?
11	<u>Required question</u> : Is there anyone else you think we should interview?

APPENDIX C. Major themes from interview coding

Parent Code	Subcode
Considerations in management approaches	Administrative Geographic Natural environment Built environment
Foundations for decision-making	Agency culture, history, and policy interpretation Tools/systems Wilderness qualities Collaboration Risk/safety
Need for change	Plans/policies Implementation/practices Administrative barriers Public communication
Ideal conditions	Natural/biophysical Social
Case studies	Reasons why research is necessary Examples of innovative management