



Current fire science research needs in the Southwest

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**SOUTHWEST
FIRE SCIENCE
CONSORTIUM**

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Cover photo: Tinder Fire, courtesy of the Coconino National Forest, 2018

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Executive summary

Overview

Fire science has advanced significantly in the past decade, yet prioritization of, access to, and use of best available scientific information (BASI) among different users remains unclear. This whitepaper presents the outcomes of a survey (informed by key informant interviews) to determine research needs in fire science across the US Southwest conducted in partnership with the Southwest Fire Science Consortium (SWFSC), a platform for science exchange between researchers and managers in Arizona and New Mexico. The objectives of this effort were to:

1. Identify the most significant research needs of fire professionals in the Southwest.
2. Determine opportunities and barriers for access to and implementation of cutting-edge research.
3. Provide recommendations to improve science exchange between scientists and managers based on findings.

Findings

Survey respondents were asked to select three fire science sub-fields (from an existing list of 18 sub-fields) that they felt most knowledgeable about. Respondents were then asked to report the current need for additional research across a range of sub-topics for each sub-field they had selected. For example, within the sub-field of fuels management and treatments respondents identified cross-boundary planning for fuels management, and the effectiveness of different fuel treatment techniques during fires as significant research needs. See pages 9-20 for a full list of research needs by subfield. SWFSC

Respondents were also asked about the barriers they experienced to accessing best available scientific information. The majority of respondents strongly agreed that “science is changing so fast that it is difficult to stay up to date,” and acknowledged conflicting opinions regarding what constitutes best available scientific information in fire science. Respondents were categorized into one of three types based on their job position: scientists, managers, and practitioners. Scientists and managers struggled to keep up with fast changing fire science and practitioners lacked access to best available scientific information because of paywalls.

Survey results indicate that participation in activities that communicate best available scientific information can be greatly increased with the use of travel stipends. For example, respondents were three times more likely to be willing to travel 300+ miles when travel funding is provided for SWFSC field trips. Most respondents identified workshops, conferences, and topical syntheses and factsheets as the most useful resources available from the SWFSC.

Recommendations

We recommend the SWFSC focus science dissemination efforts and encourage future research on the identified research needs. One core focus should be focusing on both summarizing and communicating the wealth of emerging fire science available, and proposing avenues for

accessing this science that may not be readily available for members outside of academic or federal organizations. These efforts will assist SWFSC members understand rapidly evolving areas of fire science, a central challenge for many of our survey respondents. Finally, we recommended the SWFSC increase efforts to produce conferences and workshops if the capacity is available. Detailed recommendations are available in Box 1 and in the *Recommendations and Conclusion* section of this report.

Box 1: Recommendations for the SWFSC moving forward

- **Promote significant research needs identified in this survey as future topics for Joint Fire Science Program proposal calls**, including:
 - Firefighter health, safety, and wellbeing
 - Planning for fuels treatments
 - Post-fire ecological effects
 - Strategies or factors related to increasing inclusivity in fire science
- **Provide summaries of emerging research** that help the SWFSC community keep up with emergent research. This could include:
 - An expansion of existing newsletter coverage of publications
 - Separate monthly emails highlighting recently published science based in the Southwest,
 - “Year in review” whitepapers or briefs that focus on emerging fire science based in the Southwest in the last year
- **Create a location for scientists and researchers to self-report their own published research related to the Southwest** to support both efforts above.
- **Share opportunities to access peer-reviewed fire science** that is typically hidden behind paywalls; this could include:
 - Highlighting websites and tools for accessing research without a fee (e.g., ResearchGate).
 - Featuring open access research in newsletters and other outreach
 - Providing partial financial support for open-access publishing fees to support relevant or significantly needed fire science in the form of small scholarships.
- **Continue or expand upon in-person events** such as workshops and conferences; continued or increased provision of travel funding will increase access to these resources.
- **Maintain popular virtual outreach** such as the newsletter, webinars, and topical synthesis papers and fact sheets; expansion across new social media platforms may not be as necessary as previously thought.

1. Overview

Fire science has advanced significantly in the past decade, yet prioritization of, access to, and use of best available scientific information among different users remains unclear. The Southwest Fire Science Consortium (SWFSC) was formed in 2009 with funding from the Joint Fire Science Program to improve interaction between scientists and land managers seeking best available scientific information to address wildfire. The SWFSC is headed by a board of representatives from agencies and organizations across both Arizona and New Mexico and has an extensive membership of more than 800 managers and scientists. Now that the SWFSC has been growing for more than a decade, a needs assessment for fire science in the Southwest is timely and poised to inform the next decade of best available scientific information. This whitepaper reviews the findings of a survey of SWFSC members, informed by key informant interviews, to identify current research needs among scientists and managers. The needs assessment sought to achieve three objectives:

1. Identify the most significant research needs of fire professionals in the Southwest.
2. Determine opportunities and barriers for access to and implementation of cutting-edge research.
3. Provide recommendations to improve science exchange between scientists and managers based on findings.

2. Approach

A mixed-method approach was implemented to gather information about current fire science needs in two phases: (1) semi-structured interviews with key informants, followed by (2) an online survey.

2.1 Key informant interviews

Survey design was informed by semi-structured interviews with 15 of the SWFSC's current and prior board members. The SWFSC provided a list of all past and present board members, who were then contacted via email and invited to participate in this effort. The interviewees' depth of experience in the inner workings of the SWFSC and multi-decadal tenure in varied fire science fields allowed us to ask a variety of questions about past, present, and future fire science needs, and the role the SWFSC could play in assisting these advancements.

Interviewees were also asked about SWFSC outputs and products, as well as questions on the general trajectory of the SWFSC. Finally, interviewees were asked to give input on survey topics and structure. Interviews were transcribed then analyzed using social science software QSR Nvivo to develop descriptive codes.

2.2 Online survey

Findings from key informant interviews and iterative feedback from the current SWFSC board informed the development of an online survey instrument to gather input from the broader SWFSC community. The survey and interview aimed to broadly answer the following questions:

1. What are the key research needs for fire management in the Southwest?
2. How have research needs for fire science in the Southwest changed in the last ten years?
3. Of the products and outputs the SWFSC produces, what are most useful to researchers and managers?

The survey consisted of six core sections: (1) basic background information about the respondents' experience, job position, and relationship with fire in the Southwest; (2) areas of expertise and research needs within them. Respondents were asked to select three fire science sub-fields (from an existing list of 18 sub-fields) that they felt most knowledgeable about. Respondents were then asked to report the current need for additional research across a range of sub-topics for each sub-field they had selected; (3) Respondents' use of scientific information, including the sources they use and which information they consider most useful; (4) barriers to implementing best available scientific information; (5) Respondent interactions with the SWFSC, including what products they use and how the SWFSC can better meet the need of members; and (6) demographic information.

The survey was sent to 809 email addresses and received 161 responses for a 19.9% response rate. We distributed the online survey to the entire SWFSC mailing list, used the consortium's social media to promote it, and encouraged members to share the survey. A reminder email was sent weekly during February 2022 to those who had yet to complete the survey. Survey data was compiled and analyzed using statistical analysis software SPSS to create simple frequencies and descriptive statistics.

3. Findings

3.1 Characterizing survey respondents

Survey participants were asked to self-report basic background and demographic information throughout the survey. Participants were allowed to select multiple options, so percentages may not add up to 100%. Respondents worked predominantly in Arizona (59.6%), and New Mexico (56.5%). Respondents worked primarily for federal agencies (55.9%) and universities or other academic entities (20.5%). Most survey participants described themselves as managers (47.8%) or researchers (34.2%). The most common vegetation types that participants worked in were ponderosa (73.3%), piñon-juniper (68.3%), and dry mixed-conifer (64.6%). The average participant had worked extensively in the Southwest, with a mean of 17.4 years of experience. Respondents were generally older too; 52.6% were between 45-64 years old, while around 26.7% were 18-44 years old. 65.9% of participants identified as male, and 32.6% identified as female. Participants were well educated across fields, with 31.1% holding a four-year degree, 31.1% a master’s degree, and 25.2% a doctoral degree. Demographic information is displayed below in Table 1 and respondent job characteristics are displayed in Table 2.

Table 1: Demographic information for survey respondents

Variable Name	Variable Definition	Frequency or Descriptive
Age	Age of respondent	<ul style="list-style-type: none"> • 18-44 -31.9% • 45-64 - 52.6% • 65+ - 15.6%
Gender	Gender of the respondent	<ul style="list-style-type: none"> • Male 65.9% • Female 32.6% • Non-binary/other 1.5%
Education	Highest level of education completed by the respondent	<ul style="list-style-type: none"> • Highschool diploma or GED 4.4% • Associate degree 2.2% • Technical or trade school 3% • Bachelor's degree or other four-year degree 31.1% • Master’s degree 31.1% • Professional degree (e.g., MD, DSS, DVM, JD) 3% • Doctoral degree (e.g., Ph.D., EdD) 25.2%

Table 2: Job characteristics of survey respondents

Variable Name	Variable Definition	Frequency or Descriptive
Experience	Number of years the respondent has been engaged in Southwestern fire management or science	<ul style="list-style-type: none"> • Mean 17.41 years • Standard Deviation 10.1 Years
Work location	The Southwestern state(s) that the respondent predominantly works in	<ul style="list-style-type: none"> • Arizona 59.6% • New Mexico 56.5% • Utah 13.7% • Texas 8.1% • No Southwest experience 3.7%
Organization	Primary organization or agency that the respondent works or volunteers for	<ul style="list-style-type: none"> • Federal Agency 55.9% • University or other academic entity 20.5% • Private business, contractor, or consultant 8.1% • Non-governmental or non-profit 7.5% • State agency 6.2% • Tribal entity 5.6% • City or county 4.3% • Community forestry or community-based collaborative 3.7% • Private landowners or community representative 2.5% • Retired 6.8%
Position	Identified current job title or position of the respondent	<ul style="list-style-type: none"> • Manager 47.8% • Researcher 34.2% • Outreach, communication, or education specialist 13% • Private contractors or business owners 3.7% • Non-governmental or collaborative employees 3.7% • Students 3.1% • Private property owners or community representatives 1.9% • Local municipality or county employees 1.9% • Politicians or policymakers 0% • Other 3.7%
Vegetation	Vegetation type that best describes the area(s) the respondent works in	<ul style="list-style-type: none"> • Ponderosa 73.3% • Piñon-juniper 68.3% • Dry mixed conifer 64.6% • Grassland 47.8% • Aspen 38.5% • Riparian 37.9% • Wet mixed conifer 37.3% • Spruce-fir 36.6% • Oak shrub 36.6% • Desert shrub 31.7% • Interior chaparral 25.5% • Sagebrush 23.6% • Alpine tundra 8.7% • Other 2.5%

3.2 Current research needs in Southwestern fire science

This survey aimed to determine the fire science research areas with the greatest need within the Southwest. First, respondents were asked to select the three sub-fields they were most familiar with in their line of work across a list of 18 sub fields within fire science. Sub-fields for this survey were identified via a combination of key informant interviews and a systematic review of abstracts for recent research related to fire science. Next, respondents were asked to indicate their current perceptions of research need for sub-topics within their areas of expertise. Respondents were allowed to add additional sub-topics that needed research in a textbox, however, few respondents chose to do so. Figure 1 below shows the distribution of respondent expertise across the 18 sub-field categories provided in the survey.

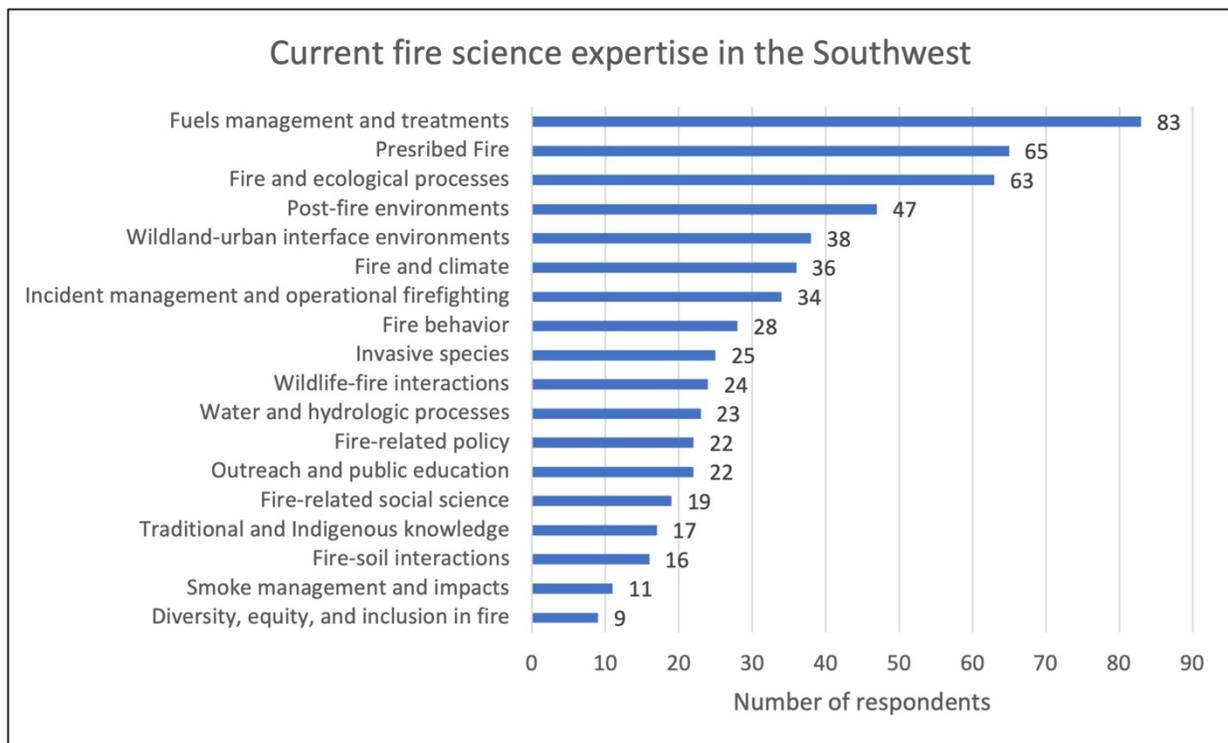


Figure 1: Respondent area of expertise across the 18 research areas. Respondents were asked to select up to three topics from the list of research areas that you are the most familiar with in your line of work.

Further information on responses related to each fire science sub-field is available in the pages below. Areas of research are ordered from respondents most selected areas to least selected. Significance of research need was calculated by averaging responses to the “significant need,” “moderate need,” and “slight need” categories. Sub-topics within the table are ordered from most significant need to least needed.

3.2.1 Fuels management and treatments

Fuels management and treatments was the largest area of expertise among survey respondents with 83 selecting this option (Table 3). There was high agreement that cross-boundary planning for fuel management is the most dominant research need, with 74.7% indicating a significant need. This was followed by the effectiveness of different fuel treatment techniques during fires, then the development and application of post-treatment monitoring programs. The least needed research in fuels management and treatments was optimizing the placement of fuels treatments.

Table 3: Fuels management and treatments research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Cross-boundary planning for fuel management	74.7%	16.0%	8.0%	1.3%
The effectiveness of different fuel treatment techniques during fires	59.5%	22.8%	16.5%	1.3%
Development and application of post-treatment monitoring programs	54.4%	29.1%	16.5%	0.0%
Optimizing the placement of fuel treatments	50.0%	35.0%	12.5%	2.5%

3.2.2 Prescribed fire

Prescribed fire was the second largest area of expertise for survey participants, with 65 responses (Table 4). Prescribed fire use on private land represented the largest research need, with 57.4% of respondents selecting significant need and 31.5% moderate need, respectively. Federal barriers to prescribed fire was the most significant research need (58.9%). Planning for prescribed fires was ranked as the lowest research need, with 5.0% of respondents selecting no research needed.

Table 4: Prescribed fire research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Prescribed fire use on private land	57.4%	31.5%	9.3%	1.9%
Prescribed fire effects	51.7%	40.0%	8.3%	0.0%
Federal barriers to prescribed fire	58.9%	25.0%	14.3%	1.8%
Non-federal barriers to prescribed fire (e.g., liability)	54.5%	32.7%	10.9%	1.8%
Smoke management during prescribed fires	45.6%	42.1%	10.5%	1.8%
Planning for prescribed fires	43.3%	45.0%	6.7%	5.0%

3.2.3 Fire and ecological processes

Approximately 63 survey respondents self-identified as experts in fire and ecological processes (Table 5). Impacts of invasive species on fire in the Southwest was the largest research need, with 58.2% of respondents selecting significant need and 0% selecting not needed. Environmental impacts of suppression was the least needed research area.

Table 5: Fire and ecological processes research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Impacts of invasive species on fire in the Southwest	58.2%	36.4%	5.5%	0.0%
Range management and fire interactions	43.6%	34.5%	20.0%	1.8%
Grazing and fire interactions	39.3%	35.7%	23.2%	1.8%
Environmental impacts of suppression (e.g., dozers, retardant)	38.9%	31.5%	22.2%	7.4%

3.2.4 Post-fire environments

Post-fire environments was an area of expertise for 47 respondents (Table 6). Vegetation type conversions was the largest research need, with 75.6% of respondents selecting significant need and 19.5% selecting moderate need. Post-fire landscape management and risk mitigation efforts are the next highest areas of research need. The least needed research was related to Burned Area Emergency Response assessment and implementation, with only 36.6% of respondents selecting significant need and 22% selecting slight need.

Table 6: Post-fire environments research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Vegetation type conversions	75.6%	19.5%	4.9%	0.0%
Post-fire landscape management	72.1%	25.6%	2.3%	0.0%
Post-fire risk mitigation efforts	69.8%	25.6%	4.7%	0.0%
Flooding, debris flows, mudflows, and other secondary hazards in post-fire environments	60.0%	32.5%	7.5%	0.0%
Cause and effects of reburns	46.3%	41.5%	12.2%	0.0%
Restoration and slope stabilization	46.2%	33.3%	20.5%	0.0%
Burned Area Emergency Response assessment and implementation	36.6%	39.0%	22.0%	2.4%

3.2.5 Wildland-urban interface environments

Wildland-urban interface environments were an area of expertise for 38 respondents (Table 7). Successful planning and zoning or development policy was the largest research need, with 73.5% of respondents indicating that it presented a significant need. Community recovery after wildfire was also highly ranked, with 73.5% of respondents selecting significant need. Firefighting strategies in the WUI and fire-resistant landscaping were the least needed areas.

Table 7: Wildland-urban interface environments research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Successful planning and zoning or development policy	73.5%	20.6%	5.9%	0.0%
Community recovery after wildfire	73.5%	17.6%	8.8%	0.0%
Evacuation planning and communication	60.0%	28.6%	8.6%	2.9%
Home ignition zone management and best practices	50.0%	35.3%	14.7%	0.0%
Hazard mitigation in the WUI	50.0%	26.5%	20.6%	2.9%
Firefighting strategies in the WUI	38.2%	47.1%	5.9%	8.8%
Fire-resistant landscaping	35.3%	38.2%	23.5%	2.9%

3.2.6 Fire and climate

Fire and climate was an area of expertise for 36 respondents (Table 8). Managing fire regime changes posed the greatest research need, with 75% of respondents indicating there was a significant need for more science on this topic. Most of the respondents (71.4%) also agreed that applications of adaptation strategies had a significant research need. Experimental management (e.g., assisted migration) was the most divided subtopic, with 50% selecting significant need while simultaneously the largest number of not needed (3.8%) selected. Historic climate-fire relationships was the least needed research area, with only 41.4% selecting significant need and an equal number selecting moderate need.

Table 8: Fire and climate research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Managing fire regime changes	75.0%	21.4%	3.6%	0.0%
Applications of adaptation strategies	71.4%	25.0%	0.0%	3.6%
Climate change impacts on vegetation	50.0%	42.9%	7.1%	0.0%
Fire-monsoon-climate interactions	65.5%	31.0%	3.4%	0.0%
Climate change impacts on fire behavior and occurrence	56.7%	40.0%	3.3%	0.0%
Climate change impacts on wildlife and habitats	50.0%	42.9%	7.1%	0.0%
Experimental management (e.g., assisted migration of species)	50.0%	42.3%	3.8%	3.8%
Carbon dynamics	48.1%	33.3%	14.8%	3.7%
Historic climate-fire relationships	41.4%	41.4%	13.8%	3.4%

3.2.7 Incident management and operational firefighting

Incident management and operational firefighting was a topic of expertise for 34 respondents (Table 9). Firefighter health and wellbeing was the most significant research need (65.5%). Incident management and operational firefighting and several other topics presented a more even distribution of opinions on research need. Minimum impact suppression techniques/tactics (MIST) was the least needed research area, with only 23.3% of respondents indicating that it was a significant research need.

Table 9: Incident management and operation firefighting research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Firefighter health and wellbeing	65.5%	27.6%	6.9%	0.0%
Managed or resource objective fires	54.8%	22.6%	12.9%	9.7%
Firefighter safety	40.0%	43.3%	13.3%	3.3%
Techniques and approaches to hazard and risk assessment	35.5%	51.6%	9.7%	3.2%
Use of technology to inform suppression	41.9%	38.7%	16.1%	3.2%
Potential Operational Delineations (PODs)	33.3%	48.1%	11.1%	7.4%
Effective suppression techniques	26.7%	50.0%	23.3%	0.0%
Decision support systems	22.6%	51.6%	25.8%	0.0%
After Action Reviews	33.3%	30.0%	36.7%	0.0%
Minimum Impact Suppression Tactics (MIST)	23.3%	26.7%	43.3%	6.7%

3.2.8 Fire behavior

Fire behavior was a topic of expertise for 28 respondents (Table 10). Fire-weather interactions was the largest research need (42.9%). While fire-weather interactions was not the highest significant need, it had a high percentage of moderate need (51.4%), low percentages of slight need (2.9%), and few identified it as not needed (2.9%). Fire behavior modeling and climate influence on fire behavior were the least needed research areas.

Table 10: Fire behavior research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Fire-weather interactions	42.9%	51.4%	2.9%	2.9%
Changes in fire behavior over time	45.8%	33.3%	20.8%	0.0%
Fuel treatment impacts on fire behavior	50.0%	25.0%	25.0%	0.0%
Fire behavior monitoring	41.7%	37.5%	20.8%	0.0%
Climate influence on fire behavior	45.8%	29.2%	25.0%	0.0%
Fire behavior modeling	40.0%	36.0%	20.0%	4.0%

3.2.9 Invasive species

Invasive species was a topic of expertise for 25 respondents (Table 11). Invasive species management was the largest research need, with 77.3% of respondents indicating a significant need – one of the higher percentages throughout the survey. Changes in the geographic extent of invasive species was also a prominent research need, with 73.9% of respondents agreeing there was a significant need. Human influence on the presence of invasive species had the lowest research need of the subtopics within invasive species.

Table 11: Invasive species research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Invasive species management	77.3%	18.2%	4.5%	0.0%
Changes in the geographic extent of invasive species	73.9%	13.0%	13.0%	0.0%
The effect of invasive species on fire behavior	60.9%	30.4%	8.7%	0.0%
The effect of invasive species on fire return intervals	56.5%	34.8%	8.7%	0.0%
Human influence on the presence of invasive species	60.9%	26.1%	8.7%	4.3%

3.2.10 Wildlife-fire interactions

Wildlife-fire interactions was a topic of expertise for 24 respondents (Table 12). Fire impacts to threatened and endangered species was the largest research need, with 65.2% of respondents indicating a significant need and none selecting slight need or not needed. The effects of fire on species migration was the least needed research area, with 38.1% of respondents selecting significant need.

Table 12: Wildlife-fire interactions research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Fire impacts to threatened and endangered species	65.2%	34.8%	0.0%	0.0%
Impacts of fire severity patterns and mosaics to wildlife	68.2%	27.3%	4.5%	0.0%
Habitat fragmentation and degradation	68.2%	22.7%	9.1%	0.0%
Fire impacts to wildlife	47.8%	43.5%	8.7%	0.0%
Effects of fire on species migration	38.1%	42.9%	19.0%	0.0%

3.2.11 Water and hydrologic processes

Water and hydrologic processes were a topic of expertise for 23 respondents (Table 13). Secondary hazards in burned areas (e.g., debris flows, flooding) was the largest research need, with 61.1% of respondents selecting significant need and none selecting slight need or not needed. Watershed health and fire was the second most needed research area, with 61.1% of respondents selecting significant need. Fire effects on water quality was the least needed research subtopic.

Table 13: Water and hydrologic processes research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Secondary hazards in burned areas (e.g., debris flows, flooding)	61.1%	38.9%	0.0%	0.0%
Watershed health and fire	61.1%	33.3%	5.6%	0.0%
Hydrologic changes in burned areas	55.6%	27.8%	16.7%	0.0%
Fire impacts and behavior in riparian areas	42.1%	42.1%	15.8%	0.0%
Fire effects on water quality	36.8%	47.4%	15.8%	0.0%

3.2.12 Outreach and public education

Outreach and public education was a topic of expertise for 22 respondents (Table 14). Public education was the largest research need, with 76.5% of respondents selecting significant need. Skill development for residents in fire-prone areas (e.g., chainsaw certification) and the formation and efficacy of collaborative groups were the least needed research areas within outreach and public education.

Table 14: Outreach and public education research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Public education on fire	76.5%	17.6%	5.9%	0.0%
Public communication about fire risk and impacts	68.4%	21.1%	10.5%	0.0%
Fire science outreach to private landowners	61.1%	27.8%	11.1%	0.0%
Skill development for residents in fire-prone areas (e.g., chainsaw certification)	50.0%	27.8%	22.2%	0.0%
Formation and efficacy of collaborative groups	37.5%	50.0%	6.3%	6.3%

3.2.13 Fire-related policy

Fire-related policy was a topic of expertise for 22 respondents (Table 15). Barriers and opportunities for policy change was the largest research need, with 62.5% of respondents indicating a significant need and 31.3% indicating a moderate need. The next greatest research need is funding for forest health, restoration, and hazardous fuels reduction. The least needed research area is funding for fire suppression and management, with 29.4% of respondents perceiving it as a significant need.

Table 15: Fire related policy research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Barriers and opportunities for policy change	62.5%	31.3%	6.3%	0.0%
Funding for forest health, restoration, and hazardous fuels reduction	52.9%	41.2%	5.9%	0.0%
State policies for prescribed fire	43.8%	50.0%	6.3%	0.0%
Carbon policy	58.8%	23.5%	11.8%	5.9%
Coordination across jurisdictions (e.g., Joint Chiefs' Partnership, CFLRP)	43.8%	43.8%	12.5%	0.0%
Funding for fire suppression and management	29.4%	58.8%	11.8%	0.0%

3.2.14 Fire-related social science

Fire-related social science was a topic of expertise for 19 respondents (Table 16). Matching communities with adaptation strategies was the largest research need, with 60% of respondents selecting it as a significant need. Social dimensions of post-fire recovery and public perceptions of wildfire risk reduction was the next greatest research need. Support or opposition for risk mitigation techniques is the lowest research need.

Table 16: Fire-related social science research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Matching communities with adaptation strategies	60.0%	33.3%	6.7%	0.0%
Social dimensions of post-fire recovery	60.0%	26.7%	13.3%	0.0%
Public perceptions of wildfire risk reduction strategies	56.3%	31.3%	12.5%	0.0%
Public perceptions of fire management	62.5%	18.8%	18.8%	0.0%
Risk communication about wildfire	62.5%	18.8%	18.8%	0.0%
What extent research need for social vulnerability to fire	46.7%	40.0%	13.3%	0.0%
Organizational approaches to fire (e.g., collaborative groups, community organizations)	37.5%	56.3%	6.3%	0.0%
Creating fire adapted communities	56.3%	18.8%	25.0%	0.0%
Human behavior and decision-making about fire (e.g., evacuation behavior)	50.0%	25.0%	25.0%	0.0%
Economic impacts of fire	46.7%	26.7%	26.7%	0.0%
Impact on local fire practitioners (e.g., burnout, resource needs)	43.8%	31.3%	25.0%	0.0%
Relationships between fire events and insurance	35.7%	42.9%	14.3%	7.1%
Citizen-agency conflict	31.3%	37.5%	31.3%	0.0%
Engagement in mitigation programs (e.g., Firewise)	30.8%	15.4%	53.8%	0.0%
Media coverage and communication of fire management and mitigation	37.5%	25.0%	37.5%	0.0%
Support or opposition for risk mitigation techniques	40.0%	26.7%	20.0%	13.3%

3.2.15 Traditional and indigenous knowledge

Traditional and Indigenous knowledge was a topic of expertise for 17 respondents (Table 17). Preserving cultural knowledge about fire was the most significant research need (76.9%). The next three subtopics – the impact of Indigenous fire use on fire regimes, application of cultural burning, and facilitating support for Indigenous fire use and management–were all identified as having equal research need, with 78.6% of respondents indicating a significant need. The least needed subtopic within traditional and Indigenous knowledge is effectively supporting cultural fire use via policy, although this was still prioritized by 69.2%.

Table 17: Traditional and indigenous knowledge research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Preserving cultural knowledge about fire	76.9%	23.1%	0.0%	0.0%
Impact of Indigenous fire use on fire regimes	78.6%	14.3%	7.1%	0.0%
Application of cultural burning	78.6%	14.3%	0.0%	7.1%
Facilitating support for Indigenous fire use and management	78.6%	14.3%	0.0%	7.1%
Knowledge exchange between Indigenous and non-indigenous populations	71.4%	21.4%	0.0%	7.1%
Effectively supporting cultural fire use via policy	69.2%	23.1%	0.0%	7.7%

3.2.16 Fire-soil interactions

Fire-soil interactions was a topic of expertise for 16 respondents (Table 18). Erosion in burned areas was the largest research need, with 69.2% of respondents indicating a significant need. Soil hydrology followed closely behind, with 61.5% selecting significant need. Biocrusts was the least research need, with 18.2% of respondents selecting significant need.

Table 18: Fire-soil interactions research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Erosion in burned areas	69.2%	23.1%	0.0%	7.7%
Soil hydrology	61.5%	30.8%	7.7%	0.0%
Burn severity	46.2%	46.2%	7.7%	0.0%
Postfire stabilization	46.2%	38.5%	7.7%	7.7%
Biocrusts	18.2%	63.6%	18.2%	0.0%

3.2.17 Smoke management and impacts

Smoke management and impact was a topic of expertise for 11 respondents (Table 19). Smoke impacts to firefighters was the most urgent research need, with 75% of respondents selecting significant need, 25% moderate, and no responses for slight or no need. Public communication about air quality and smoke impacts to the public followed as the second and third greatest research needs. Smoke mitigation during prescribed burns was the least needed research subtopic within smoke management and impacts.

Table 19: Smoke management and impacts research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Smoke impacts to firefighters	75.0%	25.0%	0.0%	0.0%
Public communication about air quality	62.5%	25.0%	12.5%	0.0%
Smoke impacts to the public	37.5%	62.5%	0.0%	0.0%
Policy and planning for air quality related to fire use and management	62.5%	12.5%	25.0%	0.0%
Household and community efforts to mitigate smoke impacts	37.5%	62.5%	0.0%	0.0%
Air quality research	37.5%	50.0%	12.5%	0.0%
Smoke mitigation during prescribed burns	25.0%	50.0%	25.0%	0.0%

3.2.18 Diversity, equity, and inclusion in fire

Diversity, equity, and inclusion in fire was a topic of expertise for nine respondents (Table 20). The top subtopics were inclusion of underrepresented groups in conversations and decision-making about fire and risk mitigation, gender equity and inclusion in fire-related fields, and equitable distribution of grants, funding, and resources for community risk reduction, identified by all participants as a significant research need. Equity and allocation of suppression resources was the least needed research area.

Table 20: Diversity, equity, and inclusion in fire research needs

Subtopic	Significant Need	Moderate Need	Slight Need	Not Needed
Inclusion of underrepresented groups in conversations and decision-making about fire and risk mitigation	100.0%	0.0%	0.0%	0.0%
Gender equity and inclusion in fire-related fields	100.0%	0.0%	0.0%	0.0%
Equitable distribution of grants, funding, and resources for community risk reduction	100.0%	0.0%	0.0%	0.0%
Access to and availability of materials in multiple languages	50.0%	50.0%	0.0%	0.0%
Environmental justice issues related to wildfire	33.3%	66.7%	0.0%	0.0%
Access to and geographic distribution of fire practitioners	20.0%	80.0%	0.0%	0.0%
Equity and allocation of suppression resources	25.0%	50.0%	25.0%	0.0%

3.3 Use of, and access to, scientific information

Most survey respondents (n=102) answered that the use of best available scientific information is a requirement of their current job or position. This is reflected in the frequency with which respondents access best available scientific information to inform fire-related decision-making at work (Figure 2, Figure 3).

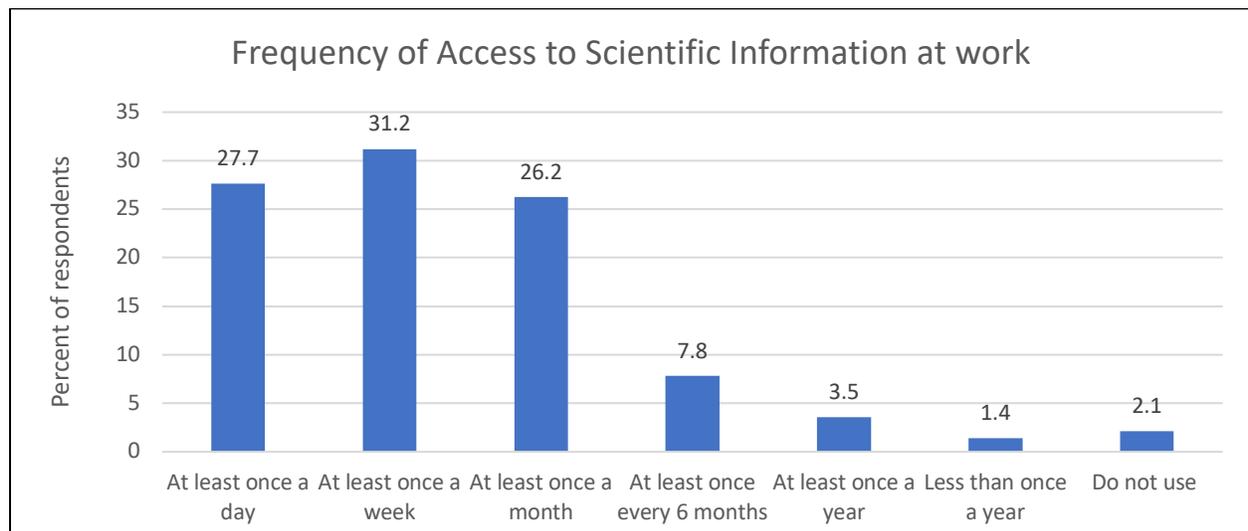


Figure 2: Response to the question “how often do you use fire science research to inform the work you conduct in your current job position?”

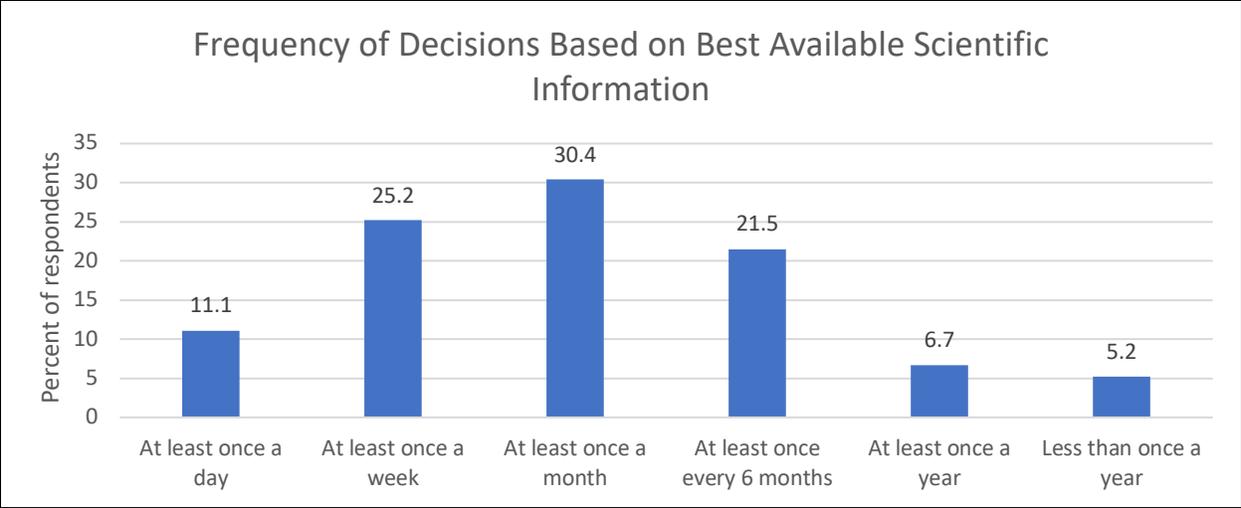


Figure 3: Response to the question “how often do you actively seek best available scientific information to inform fire-related decision-making?”

Respondents accessed best available scientific information from a variety of sources. We assessed use of different sources of information across four types of resources: academic (Table 21), specialized (Table 22), personal (Table 23), and organizational (Table 24). The sources within the tables below are ordered from most frequently accessed to least frequently used. Frequency of access was calculated and organized by mean response for each source.

Table 21: Frequency with which respondents used academic resources to locate best available scientific information. The response with the highest percentage of respondents for each question is shown in bold.

Source	At least once a day	At least once a week	At least once a month	At least once every 6 months	At least once a year	Less than once a year	Do not use
Scholarly search engines (e.g., Google Scholar, science.gov, Refseek, WorldWideScience, etc.)	19.9%	22.7%	25.5%	14.9%	5.0%	5.0%	7.1%
University library search engine or website	6.6%	16.9%	22.8%	16.9%	9.6%	11.0%	16.2%

Table 22: Frequency with which respondents used specialized resources to locate best available scientific information. The response with the highest percentage of respondents for each question is shown in bold.

Source	At least once a day	At least once a week	At least once a month	At least once every 6 months	At least once a year	Less than once a year	Do not use
SWFSC website or resources	0.7%	4.3%	30.5%	36.9%	10.6%	14.2%	2.8%
Firescience.gov (Joint Fire Science Program Website)	0.0%	2.9%	23.7%	33.1%	12.9%	18.0%	9.4%
US Forest Service Treesearch database	1.4%	7.1%	12.9%	25.0%	13.6%	13.6%	26.4%
Fire Effects Information System (FEIS)	0.0%	2.9%	15.8%	25.2%	12.2%	18.0%	25.9%
Fire Research and Management Exchange System (FRAMES.gov)	0.7%	1.5%	15.3%	21.9%	13.9%	16.8%	29.9%
Wildland Fire Library	0.7%	3.6%	9.5%	21.9%	10.9%	20.4%	32.8%

Table 23: Frequency with which respondents used *personal resources* to locate best available scientific information. The response with the highest percentage of respondents for each question is shown in bold.

Source	At least once a day	At least once a week	At least once a month	At least once every 6 months	At least once a year	Less than once a year	Do not use
Colleagues at your workplace	11.6%	36.2%	28.3%	13.0%	4.3%	2.9%	3.6%
Colleagues from a partner organization, agency, or institution	7.3%	21.2%	37.2%	19.7%	7.3%	7.3%	0.0%
Direct communication with SWFSC staff	0.0%	3.6%	10.2%	10.9%	16.1%	22.6%	36.5%

Table 24: Frequency with which respondents used organizational resources to locate best available scientific information. The response with the highest percentage of respondents for each question is shown in bold.

Source	At least once a day	At least once a week	At least once a month	At least once every 6 months	At least once a year	Less than once a year	Do not use
Internal folders or databases (e.g., google drives, share points)	9.4%	18.7%	23.0%	18.0%	9.4%	10.8%	10.8%
Local or regional collaborative groups	2.9%	12.9%	25.9%	26.6%	13.7%	12.2%	5.8%
Other regional fire science consortia or science exchanges outside the Southwest	0.0%	4.3%	20.9%	25.2%	15.8%	16.5%	17.3%

Respondents tended to agree that the more place-specific and topic closeness to their research, the better (Table 25). Local and vegetation-specific research is important in their work, highlighting the importance of regionally based science-focused organizations like the SWFSC (Figure 4).

We also found that survey respondents share best available scientific information with a diverse range of other collaborators or colleagues. Figure 5 shows the most frequent recipients of shared best available scientific information from survey participants.

Table 25: Considerations for accessing fire science. The response with the highest percentage of respondents for each question is shown in bold.

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
The more place-specific a research study is, the more helpful I find it	20.0%	42.9%	30.7%	6.4%	0.0%
It is easy to find new research that is relevant to my line of work	12.9%	47.1%	23.6%	15.0%	1.4%
There is enough research about my local area to inform my work	4.3%	33.1%	36.0%	23.0%	3.6%

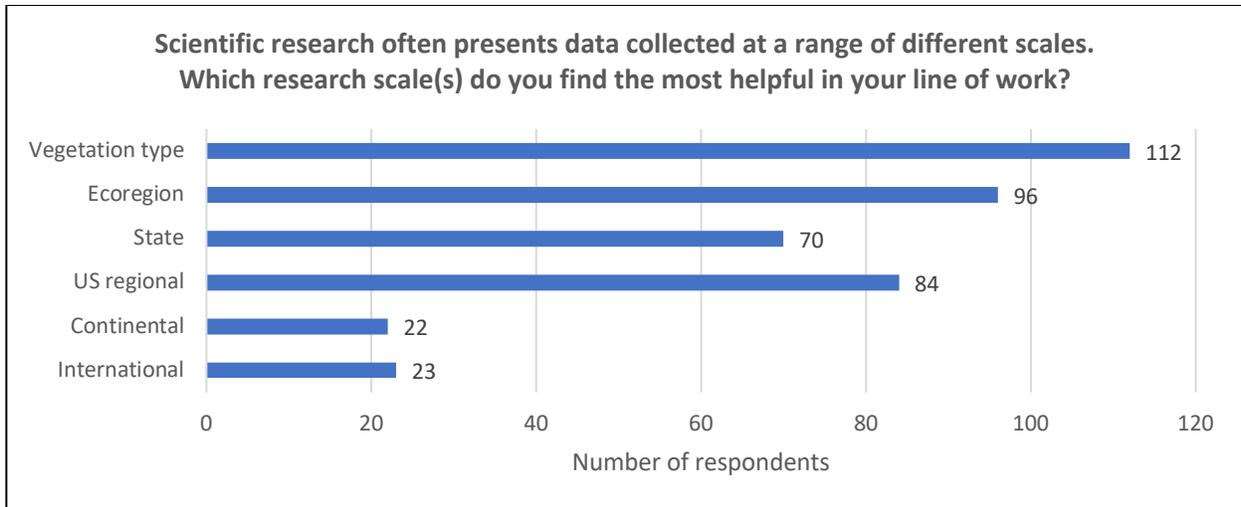


Figure 4: The scales of research that are most helpful to respondents in their line of work. Respondents were allowed to select multiple scales.

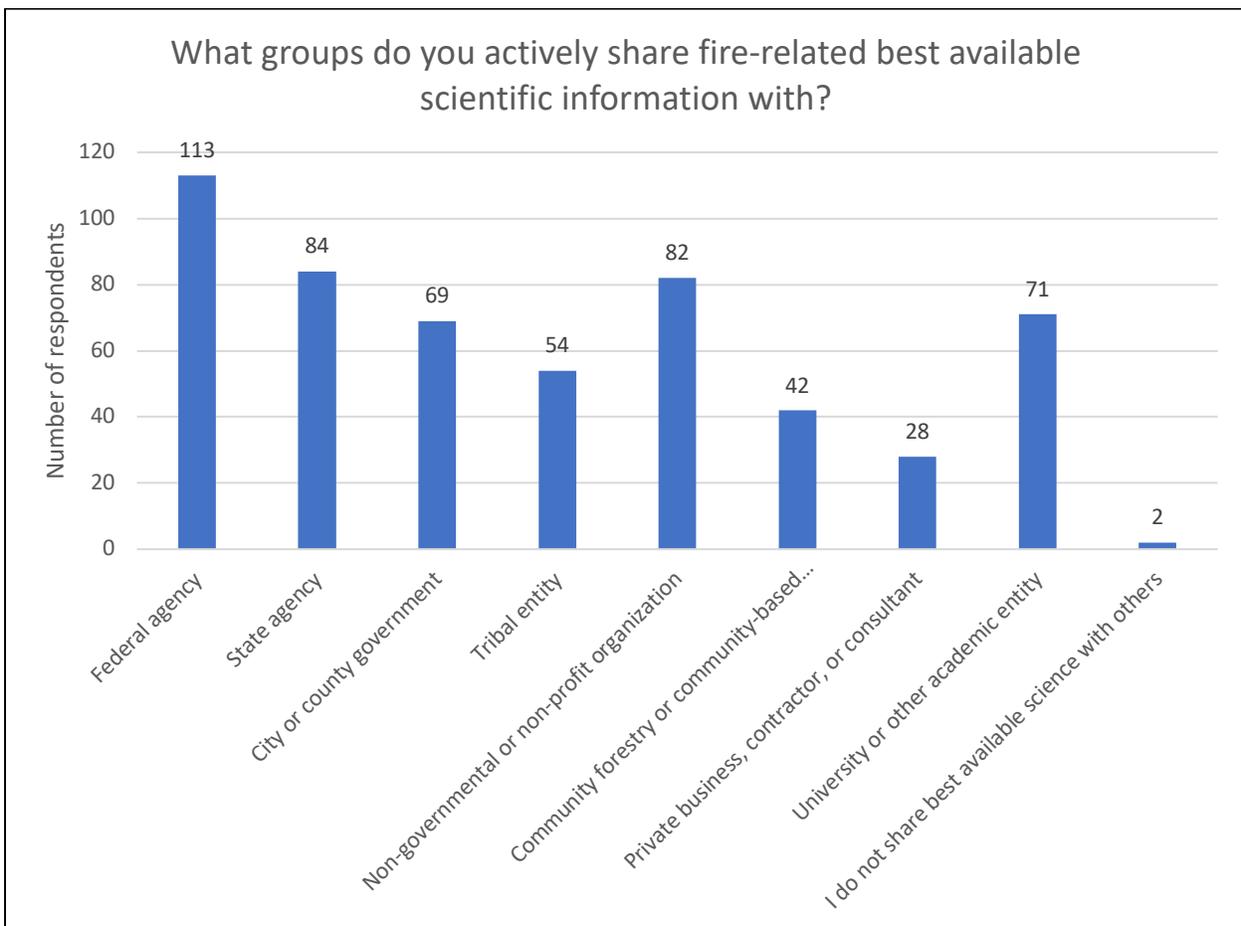


Figure 5: The different groups and agencies that respondents share fire-related best available scientific information with. Respondents were allowed to select multiple groups.

3.4 Barriers to implementing best available scientific information

SWFSC members are presented with various barriers to implementing best available scientific information in their positions. We aimed to understand where these barriers are present, how they correlate with job positions, and the role the SWFSC can play in encouraging the use of best available scientific information. Respondents were asked to indicate the extent to which they agreed or disagreed with a set of statements about barriers to accessing and using scientific information. Barriers are listed in Table 26 from highest to lowest agreement.

Table 26: Barriers to using best available scientific information (BASI) across all disciplines.

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Science is changing so fast that it is difficult to stay up to date	9.5%	29.9%	29.2%	27.7%	3.6%
Conflict of opinions between management organizations and research entities about what constitutes BASI	5.1%	27.7%	36.5%	21.9%	8.8%
There is a lack of public support for BASI	8.8%	22.6%	33.6%	27.0%	8.0%
I don't have enough time to implement BASI	6.6%	27.2%	30.1%	28.7%	7.4%
A lack of interaction means that emergent research isn't relevant to me	7.4%	19.9%	38.2%	28.7%	5.9%
The BASI I want to use is hidden behind paywalls	5.8%	26.3%	30.7%	27.7%	9.5%
Academic language and unfamiliar terminology make the science difficult to understand	5.1%	18.4%	30.1%	34.6%	11.8%
The educational resources available to me are not up-to-date (i.e., professional courses, internal training)	3.0%	12.1%	41.7%	37.1%	6.1%
Current scientific information is contradictory	0.0%	8.8%	41.6%	43.1%	6.6%
I am not sure how to locate BASI	1.5%	17.6%	24.3%	36.8%	19.9%
Organizational barriers at my current workplace prevent me from using BASI	5.1%	8.1%	27.2%	36.0%	23.5%
There is no new scientific information available on topics that I need	2.2%	8.8%	23.4%	49.6%	16.1%
I am concerned about litigation or other consequences from BASI	1.5%	9.6%	25.2%	44.4%	19.3%
I do not agree with the current best available science in my field	0.0%	2.9%	23.4%	48.2%	25.5%

To best understand how to overcome these barriers and who to communicate these solutions to, it is useful to examine the data in Table 26 by job position. Respondents' job positions were placed under one of three categories for further analysis: scientists, managers, and practitioners.

3.4.1 Best available scientific information barriers for scientists

Scientists were categorized as respondents who are researchers and students; 46 respondents fell under this group. The most prominent barriers to implementing or understanding best available scientific information for this group are:

1. Science is changing so fast that it is difficult to stay up to date
2. There is a lack of public support for best available scientific information
3. I don't have enough time to implement best available scientific information
4. The educational resources available to me are not up to date (i.e., professional courses, internal training)
5. The best available scientific information I want to use is hidden behind paywalls

3.4.2 Best available scientific information barriers for managers

Managers were categorized as respondents who are land managers, private contractors or business owners, and federal, state, county, and local municipality employees; 70 respondents are included in this group. The most prominent barriers to implementing or understanding best available scientific information for this group are:

1. Science is changing so fast that it is difficult to stay up to date
2. Conflict of opinions between management organizations and research entities about what constitutes the best available scientific information
3. A lack of interaction between researchers and managers means that emergent research isn't relevant to me
4. I don't have enough time to implement best available scientific information
5. There is a lack of public support for best available scientific information

3.4.3 Best available scientific information barriers for practitioners and outreach positions

The practitioner/outreach group were categorized as respondents who are outreach, communication, or education specialist, private property owners or community representatives, politicians or policy makers, and non-governmental or collaborative representatives or employees; 21 respondents are included in this group. The most prominent barriers to implementing or understanding best available scientific information for this group are:

1. The best available scientific information I want to use is hidden behind paywalls
2. There is a lack of public support for best available scientific information
3. Conflict of opinions between management organizations and research entities about what constitutes the best available scientific information

4. A lack of interaction between researchers and managers means that emergent research isn't relevant to me
5. I don't have enough time to implement best available scientific information

3.5 Southwest Fire Science Consortium products

The SWFSC produces a number of outputs aimed at science communication, including webinars, maintaining a website, and developing videos. Respondents indicated the outputs they most frequently interacted with, shown in Figure 6. Survey respondents also ranked which of these products are most useful. Respondents selected two in-person products, workshops, and conferences, as the most useful (Table 27). We did not count the votes of respondents who said they did not use a product in the usefulness ranking.

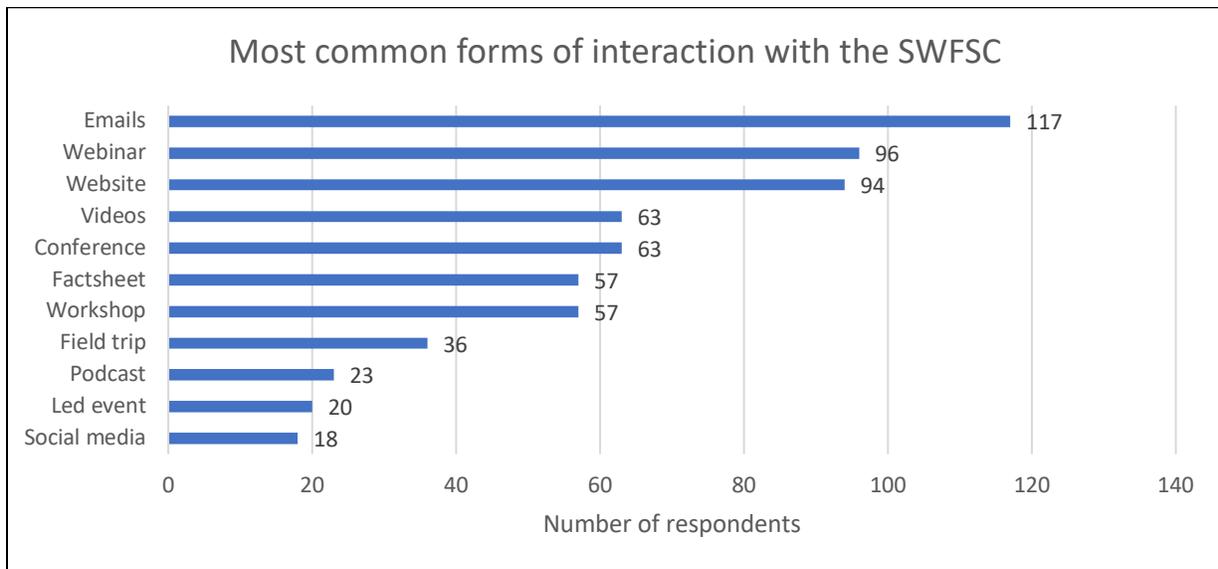


Figure 6: Response to the question “What ways have you engaged with the SWFSC the past five years?” Respondents were allowed to select multiple options.

Table 27: The products of the SWFSC are listed from most useful to least useful. Response to the prompt “Please select one answer for each product.”

Product	Extremely useful (5)	Very useful (4)	Moderately useful (3)	Slightly useful (2)	Not at all useful (1)	Do Not Use	Mean
Workshops	20.9%	37.2%	6.2%	4.7%	0.0%	31.0%	4.08
Conferences	24.6%	35.4%	11.5%	4.6%	0.0%	23.8%	4.05
Topical synthesis papers and factsheets	20.3%	36.1%	23.3%	3.8%	0.0%	16.5%	3.87
Networking	21.5%	29.2%	19.2%	6.2%	0.0%	23.8%	3.87
Field trips	11.5%	32.3%	7.7%	3.1%	2.3%	43.1%	3.84
Webinars	15.9%	53.8%	12.9%	9.1%	0.8%	7.6%	3.81
Website	16.5%	39.1%	30.8%	4.5%	0.8%	8.3%	3.72
YouTube Videos	12.3%	30.0%	24.6%	3.8%	0.8%	28.5%	3.69

Field trips were a valued product of the SWFSC. Respondents were willing to travel further distances if financial support could be provided to participate in these trips. Nearly 70% of the people surveyed were willing to travel 300+ miles if the SWFSC provided a travel stipend; less than 20% would participate in the same event without financial support (Figure 7).

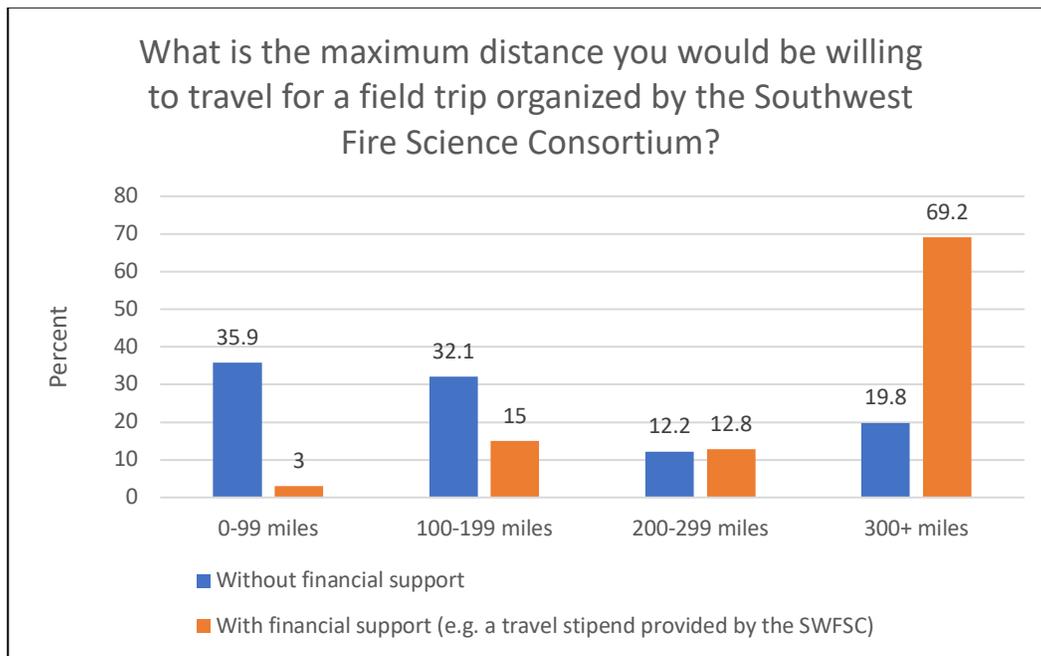


Figure 7: The distance respondents were willing to travel with and without financial support. Respondents were only allowed to select one distance for financial support and one without.

4. Recommendations and conclusion

4.1 Research priorities

This survey aimed to determine the research areas with the greatest need related to fire science within the Southwest. First, respondents were presented with 18 sub-fields within fire science and asked to select three that they were most familiar with. Then respondents were asked to indicate whether there was a significant research need for each sub-topic. The single top research need for each of the 18 areas of fire science are displayed in Table 28. We suggest that the SWFSC can play a significant role in supporting future efforts and products related to these significant research needs below; recommendations are provided below and summarized in Box 1.

Table 28: Most significant research in fire science for the US Southwest, listed by sub-field.

Sub-field	Most significant research need
Fuels management and treatments	Cross-boundary planning for fuel management
Prescribed fire	Prescribed fire use on private land
Fire and ecological processes	Impacts of invasive species on fire in the Southwest
Post-fire environments	Vegetation type conversions
Wildland-urban interface environments	Successful planning and zoning or development policy
Fire and climate	Managing fire regime changes
Incident management and operational firefighting	Firefighter health and wellbeing
Fire behavior	Fire-weather interactions
Invasive species	Invasive species management
Wildlife-fire interactions	Fire impacts to threatened and endangered species
Water and hydrologic processes	Secondary hazards in burned areas (debris flows, flooding)
Outreach and public education	Public education on fire
Fire-related policy	Barriers and opportunities for policy change
Fire-related social science	Matching communities with adaptation strategies
Traditional and Indigenous knowledge	Preserving cultural knowledge about fire
Fire-soil interactions	Erosion in burned areas
Smoke management and impacts	Smoke impacts to firefighters
Diversity, equity, and inclusion in fire	Inclusion of groups in conversations and decisions

This list of research needs may act as an agenda for outreach efforts, particularly topics for webinars or white papers and briefs that overview the current state of science under each subfield. These topics may also provide direction for future Joint Fire Science Program proposal calls; for example, multiple subfields prioritized the need for research related to firefighter health, safety, and wellbeing. Another overarching need across these sub-fields is investigation related to fuels treatments planning, ranging from cross-boundary work to prescribed fires and

the ways in which policy interacts with these efforts. Post-fire ecological effects also emerged as an important area for future research in the Southwest. Lastly, we note a growing interest in identifying strategies and approaches for more inclusive fire science in decision making and planning for wildfire, and suggest that identifying factors that contribute to more inclusive efforts among Southwest-specific groups and cultures is needed across all sub-fields.

4.2 Barriers to best available scientific information

Most survey respondents answered that the use of best available scientific information is a requirement of their current job or position. More than 60% of respondents used best available scientific information to inform management decisions more than once a month. We found that scientists, managers, and practitioners each face different barriers to implementing best available scientific information in their positions. Providing products that help managers and scientists keep up with rapidly evolving scientific information should be a continued focus of the SWFSC moving forward. This could include monthly emails highlighting recently published science based in the Southwest, or “year in review” whitepapers that focus on emerging fire science based in the Southwest in the last year. These could be similar to the fire season reviews the SWFSC has historically published. Creating a form on the SWFSC website for researchers to self-report new publications that they feel are relevant to the Southwest may accelerate these efforts while reducing the workload of SWFSC staff.

All three groups, especially the practitioner group, struggle to access best available scientific information because of paywalls. The SWFSC can play an important role in alleviating this challenge by highlighting open access materials and websites where available (e.g., ResearchGate), and providing brief summaries of publications where that option is not available. These sources could be highlighted in a section of the website outlining the best areas to access free fire based best available scientific information. Other more costly options may include connecting scientists with funding opportunities that offset costs associated with open access publishing, particularly in instances where the publication may address one or more of the most significant needs identified for the Southwest.

4.3 Southwest Fire Science Consortium products

Our survey investigated which of the SWFSC’s products were most useful. The three most common ways respondents interacted with the SWFSC were emails from the mailing list, attendance at a SWFSC webinar, and visiting the SWFSC website. While the three most used products were all virtual, respondents largely identified face-to-face interactions as most useful, highlighting the value of workshops and conferences. The pandemic limited the consortium’s ability to host workshops and conferences; however, they remain as the two most useful products. Engagement with in-person opportunities could be further increased with higher access to travel stipends or funding where possible. In instances where funding is not possible, focusing efforts as close to target audiences as possible will increase the likelihood of attendance. This survey indicates that there is enough interest for the SWFSC to expand its field trip, workshop, and conference offerings if the capacity for organizing these events is available.

Social media was ranked as the least used SWFSC product, and our analysis of sources for best available scientific information leads us to believe respondents look to other areas to find fire science. Continued presence on twitter may be valuable but we do not believe spreading to other platforms such as TikTok will meaningfully increase engagement.

The overall perception of the SWFSC in both key informant interviews and comments provided in the survey was positive. Respondents were generally pleased with the consortium's products and efforts and saw a few small opportunities to improve its reach and effectiveness.

5. Appendices

5.1 USGS research comparison

In 2021 USGS conducted a survey of members across all 15 exchanges within the Joint Fire Science Program exchange network (see Meldrum et al. 2022). This included 810 SWFSC members, of which 100 responses were received. The USGS survey covered 16 areas of fire science and asked respondents to rate the SWFSC based on its performance in that specific area. The survey worked to understand what areas of science the consortium was failing to provide adequate information on. The USGS study found that the SWFSC was perceived as performing poorly in five areas: smoke, air quality and health, invasive plant species, wildlife, economic impacts, social science, and human dimensions. Our survey included very similar categories of science and the subtopics within these categories allow us to further understand where to focus efforts through the SWFSC. The following displays the five areas of research need identified through the 2021 USGS survey supplemented with additional information learned during our survey.

5.1.1 Smoke, air quality, and health

The survey allowed participants to select "*smoke management and impacts*" as a research area they were most familiar with in their work, and 11 survey respondents selected it. We had seven subtopics in the area of smoke management and impacts. Listed below are the seven topics, ranked from significant research need to least needed.

1. Smoke impacts to firefighters
2. Public communication about air quality
3. Household and community efforts to mitigate smoke impacts
4. Smoke impacts to the public
5. Policy and planning for air quality related to fire use and management
6. Air quality research
7. Smoke mitigation during prescribed burns

5.1.2 Social science and human dimensions

The survey allowed respondents to select "*fire-related social science*" as a familiar research area in their line of work. 19 respondents selected it and answered the questions. There were 16 subtopics in the area of fire-related social science. Below are the 16 subtopics listed, from the most significant research need to the least needed.

1. Matching communities with adaptation strategies
2. Social dimensions of post-fire recovery
3. Public perceptions of fire management
4. Risk communication about wildfire
5. Public perceptions of wildfire risk reduction strategies
6. Social Vulnerability to fire
7. Organizational approaches to fire (e.g., collaborative groups, community organizations)
8. Creating fire adapted communities
9. Human behavior and decision-making about fire (e.g., evacuation behavior)

10. Economic impacts of fire
11. Impact on local fire practitioners (e.g., burnout, resource needs)
12. Relationships between fire events and insurance
13. Citizen-agency conflict
14. Engagement in mitigation programs (e.g., Firewise)
15. Media coverage and communication of fire management and mitigations
16. Support or opposition for risk mitigation techniques

5.1.3 Economic impacts

Our survey did not use economic impacts of fire as a potential area of work. However, we did ask respondents to rate the level of research needed for the economic impacts of fire as a subtopic. We found that 46.7% selected significant need, 26.7% selected moderate need, 26.7% selected slight need, and 0% selected not needed. When ranked against other topics from the fire-related social science area, economic impacts of fire was in the middle of the significance of research needed. While our survey could not provide more detail on subtopics within the economic impacts of fire, our results concur with USGS that the area could use more research in the Southwest.

5.1.4 Wildlife

The survey allowed respondents to select "*wildlife-fire interactions*" as a familiar research area in their line of work. 24 respondents selected it and answered the questions. There were five subtopics in the area of wildlife-fire interactions. Below are the five subtopics listed, from the most significant research need to the least needed.

1. Fire impacts to threatened and endangered species
2. Impacts of fire severity patterns and mosaics to wildlife
3. Habitat fragmentation and degradation
4. Fire impacts to wildlife
5. Effects of fire on species migration

5.1.5 Invasive plant species

The survey allowed respondents to select "*Invasive Species*" as a familiar research area in their line of work. 25 respondents selected it and answered the questions. There were five subtopics in the area of invasive species. Below are the five subtopics listed, from the most significant research need to the least needed.

1. Invasive species management
2. Changes in the geographic extent of invasive species
3. The effect of invasive species on fire behavior
4. The effect of invasive species on fire return intervals
5. Human influence on the presence of invasive species

The five categories identified during the 2021 USGS survey can provide researchers and the SWFSC a starting point for research. In addition our survey can provide more detail and supplemental information for these five research areas.