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How Can We Span the Boundaries between Wildland Fire Science and Management in the United States?

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In 2009, the federal Joint Fire Science Program (JFSP) initiated a national network of boundary organizations, known as regional fire science consortia, to accelerate the awareness, understanding, and use of wildland fire science. Needs assessments conducted by consortia in eight regions of the United States are synthesized here using a case survey approach. Although regions used different methods based on their different ecosystems, geography, and demography, results showed striking similarities in how fire science is accessed and used, barriers to its use, and research information needed. Use of Internet-based information is universally high; however, in-person knowledge exchange is preferred. Obstacles to fire science application include lack of time, resources, and access to the most relevant information as well as communication barriers between scientists and managers. Findings show a clear need for boundary organizations to span fire science and management to (a) organize and consolidate fire science information through easily accessible websites and (b) strengthen relationships between scientists and managers to facilitate production and communication of science relevant to managers' concerns. This article contributes to boundary spanning theory by underscoring and documenting the advantages of regionally focused boundary organizations in meeting user needs and building bridges between fire scientists and managers.

Keywords: fire science, boundary organization, fire management, Joint Fire Science Program, technology transfer

Wildland fire management in the United States is becoming increasingly complex (Pence and Zimmerman 2011) as both the number of acres burned annually and development in fire-prone areas increases. Since 2000, the average number of acres burned per year has more than doubled from the 1990s total of 3.3 million to 7.0 million ac (Toman et al. 2011). A recent analysis found that, although only 9.4% of the land area in the United States is classified as wildland-urban interface where structures and human developments intermingle with wildland vegetation, 38.5% of US housing units are located in this area (Radeloff et al. 2005). Nationwide, federal fire preparedness and suppression expenditures in 2010 totaled over $1.1 billion, including $898 million spent by the USDA Forest Service and $231 million by Department of Interior agencies (Sheri Ascherfeld, pers. comm., National Interagency Fire Center, Apr. 25, 2011).

Federal managers are mandated by policy to use science to support fire management decisions, but use of science may be constrained by logistical, political, and social

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factors (Hollstedt and Swift 2000). Some obstacles include communication barriers and differences in "culture" between scientists and managers (Wright 2007). Land managers are not always aware of potentially relevant scientific information, and, in some cases, there may be too much information for managers to digest, interpret, and apply. They also may not have tools to evaluate the quality and applicability of research results to specific management projects (Cerveny and Ryan 2008). Even with improved access, research results may not be presented or integrated into a context meaningful to applied decisionmaking. Furthermore, although recent research may be of the highest quality and peer reviewed, relevance of science findings in the field is often not established (Joint Fire Science Program [JFSP] 2012).

The challenge to both scientists and managers is to make the results of scientific investigations more relevant and to apply them to policy and decisionmaking about natural and human communities (Ascher et al. 2010). This objective is of foremost importance for the fields of fire science and management (Conard et al. 2001, Franklin and Agee 2003, DellaSala et al. 2004), as well as in other fields such as climate change, sustainability, hazardous waste disposal, and medicine (Jasanoff 1990, Joyce 2003).

Role of Boundary Organizations in Facilitating Knowledge Exchange

The JFSP is deliberately addressing this challenge by creating regional boundary organizations that form a national fire knowledge exchange network. Described by Guston (2000, 2001), boundary organizations bridge the divide between scientists and nonscientists by creating tools, or "boundary objects," that facilitate collaboration (Guston 2001, p. 401). Boundary organizations are by nature prominent, visible, and on the cutting edge of communication. They serve as "information broker," "convener of forums for engagement," "translator of scientific information," "arbiter of access to knowledge," and "exemplar of adaptive behavior" (Buizer et al. 2009, p. 6). The success of boundary organizations hinges on understanding the decision context and stakeholder perspective, developing strong stakeholder relationships, and providing information that is accurate, credible, and presented at relevant spatial and temporal scales (Jacobs et al. 2005).

Spanning the chasm between "two relatively different social worlds of politics and science" (Guston 2001, p. 401) requires boundary organizations to be accountable to people and institutions in both realms (Guston 2000). Key features of successful boundary organizations are information salience, credibility, and legitimacy (Cash et al. 2003). Boundary organizations and the information they generate and communicate must have credibility and legitimacy within the social worlds of both scientists and managers or decisionmakers.

Although there is a clear need for "translation" of scientific information in environmental policy and management (Ascher et al. 2010), there is also growing recognition of the importance of "coproducing" knowledge by integrating managers throughout the research process including problem definition, research design, data collection, analysis, interpretation, and application of results (Lemos and Morehouse 2005, White et al. 2008, 2010). By engaging the direct "participation of actors from both sides of the boundary, as well as professionals who serve a mediating role" (Guston 2001, p. 401), these entities serve an important role in bridging basic and applied research and even transcending this divide to generate a new kind of coproduced science (Latour 1987) based on greater mutual understanding.

The role and effectiveness of boundary organizations has been described in agriculture, climate, and water resources sectors (Agrawala et al. 2001, Cash 2001, Feldman and Ingram 2009, Girod et al. 2009). Although existing studies analyze the effectiveness of boundary organizations that function at the regional or local scale (Jacobs et al. 2005, White et al. 2008, 2010), there are few studies that document or elaborate the advantages to a regional approach in boundary spanning. This article provides an example of regional boundary spanning developed to meet the needs expressed by fire management and science organizations.

Development of Regional Fire Science Consortia as Boundary Organizations

The JFSP was developed in 1998 to fund fire science and ensure its applicability to management problems. The JFSP is governed by five Department of Interior agencies (Bureaus of Indian Affairs and Land Management, Fish and Wildlife Service, National Park Service, and Geological Survey) and the Forest Service. During the JFSP's first 10 years, more than 450 applied research projects costing $140 million were completed by collaborators from more than 90 universities; 100 nonprofit organizations, tribal, state, county, and local governments; and resource agencies (JFSP 2010). Results have been disseminated through journal articles, dissertations, books, reports, models, conferences, workshops, posters, field trips, training, and a website. However, the Program's performance reviews noted that a gap still existed between scientific findings and the priorities, decisions, and actions of fire and fuels managers (JFSP 2011a).

To minimize this gap, the JFSP recently developed a boundary organization strategy. The program initiated a national network of regional consortia of interested management and science stakeholders working together to perform information transfer at a regional level (JFSP 2011b). The goal is to "accelerate the awareness, understanding, and adoption of wildland fire science information by federal, tribal, state, local, and private stakeholders within ecologically similar regions" (JFSP 2012). The consortia guiding principles listed in Table 1, to be inclusive, collab-

Management and Policy Implications

The awareness, understanding, and use of wildland fire science in forest management can be improved through engagement by regional fire science consortia developed by the federal JFSP. To span the worlds of fire science and management, we recommend that these consortia focus on organizing and consolidating fire science information through easily accessible websites and strengthening relationships between scientists and managers to facilitate production and communication of science relevant to managers' concerns. We recommend fire and forest managers identify their regional fire science consortium to access fire science information and to interact with fire science researchers to ensure that fire science produced is credible and more relevant to their management situation. Regional fire science consortia can be found on the JFSP website at www.firescience.gov/.

Table 1. JFSP fire science consortium guiding principles and objectives.

Guiding principles	Key objectives
Be inclusive; make sure relevant partners have the opportunity for involvement	Disseminate information and build relationships
Serve as neutral science partners	List and describe existing research and synthesize information
Be customer driven, in structure and function	Assess quality and applicability of research
Operate collaboratively, foster joint management, and science communication	Demonstrate research on the ground
Be innovative; pursue new creative ways to disseminate knowledge	Encourage/promote adaptive management
Facilitate flow of fire science information, dialogue on new science findings, and needs of managers and policymakers	Compile new research, synthesis, or validation needs

Source: From JFSP 2012.

orative, science neutral, customer-driven, and provide partners opportunities to engage, reflect a boundary spanner approach.

Eight fire science consortia were initially formed by 2011, in Alaska, Appalachia, California, Great Basin, Lake States, Southern States, Southern Rockies, and the Southwest (Figure 1). Six additional consortia were added in 2012 to serve the Great Plains, Oak Woodlands, Northwest, Northern Rockies, Pacific Island, and Eastern Tallgrass regions. The consortia were formed by academic and government scientists; federal, state, local, and tribal agencies; and stakeholders who conducted independent needs assessment to identify fire science delivery needs in their regions. This article reports on the commonalities of findings from the needs assessments conducted by the initial eight consortia between 2009 and 2010 and recommends strategies for successful fire science and management boundary organizations.

Each of the regions has a unique combination of forest and grassland ecology, fire regime, population demographics, and fire management and research institutions. These regions also, have unique histories of fire research and use for management. An analysis of the JFSP's project database shows the number of projects funded by JFSP between 1998 and 2011 in the initial 8 consortia regions ranged from 51 in California to 12 in the Lake States (see Figure 2). Unique regional conditions, including this historical legacy of fire research, are important in understanding the differences discussed in this article.

Methods

Each consortium designed and conducted a needs assessment to best match the region's management, demographic, and ecological features. As shown in Table 2, assessment methods included qualitative, quantitative, and mixed approaches. Qualitative methods were used to gather input from workshops, meetings, focus groups, and phone and in-person interviews. Quantitative methods included online, phone, and in-person surveys. Mixed approaches included both types of methods to take advantage of the strengths of each.

Quantitative and qualitative methods differ in their strengths and limitations (Creswell 2009). Quantitative methods allow data to be collected using consistent question and response formats across a broad sample of the population. Depending on the sampling design, inferences can be drawn to the broader population (Creswell 2009). Questions included in needs-assessment surveys often consisted of a closed-choice format, enabling participants to respond to a predetermined set of responses and allowing data to be analyzed statistically. In a complementary approach, qualitative interviews and focus groups typically use open-ended questions to explore the depth of particular topics by gathering responses outside of the predetermined categories provided by researchers (Creswell 2009). As is typical, qualitative approaches used had smaller sample sizes and selected participants purposively rather than randomly.

Methods of inviting stakeholders to participate in assessments varied by region, so reported findings incorporate the views of various combinations of federal and state fire and resource managers, conservation organizations, private landowners, associations, and consultants, as well as university and government scientists (Table 2). The number of participants varied from 84 in the Southwest to nearly 1000 in the Southern region. Regions vary in configuration from encompassing a single state in Alaska and California, to 13 states in the Southern consortium. Questions asked in survey, interview, and focus groups varied by region. Nonetheless, there was general topical consistency because findings were intended to help structure consortia programs.

This synthesis was developed by collecting assessment data and results from each region and analyzing them using the case survey method (Yin 1989). Using this secondary analysis technique, each needs assessment was treated as an individual case and common findings across cases were synthesized. Because assessment approaches were not standardized, no statistical generalizations can be drawn. Instead, the case survey method allows for identification of overall patterns common to individual case study findings. This synthesis increases the reliability of the individual needs-assessment findings and makes them available to a broader audience of managers and scientists who are engaged in building networks and exchanging information about wildland fire as well as other forest and environmental management issues.

Findings

Fire science stakeholders in each region were queried to identify research needs, how fire science is currently used and accessed, barriers to effective science delivery, and to gauge the potential role of fire science boundary organizations. When reviewing these findings, it is important to note that differences in assessment protocols preclude drawing statistical comparisons between regions. Differences in participant demographics as well as regional ecology, climate, demography, and landownership also likely led to differences in responses among regions.

Regional Research Needs

Seven of the eight initial consortia asked participants about fire research needs by selecting or ranking a predefined list of research topics or by listing needs in their own words. Topics ranked in the top five or chosen or listed by at least 50% of participants were compiled. Participants in five assessments identified the need for more research on fire effects on vegetation, fauna, soil, and water. Fuels and prescribed burning best practices research was identified in four assessments. Three assessments prioritized research on smoke modeling and air quality, fire ecology and behavior, and re-

Figure 1. Map of the JFSP fire knowledge exchange consortia regions in 2012.

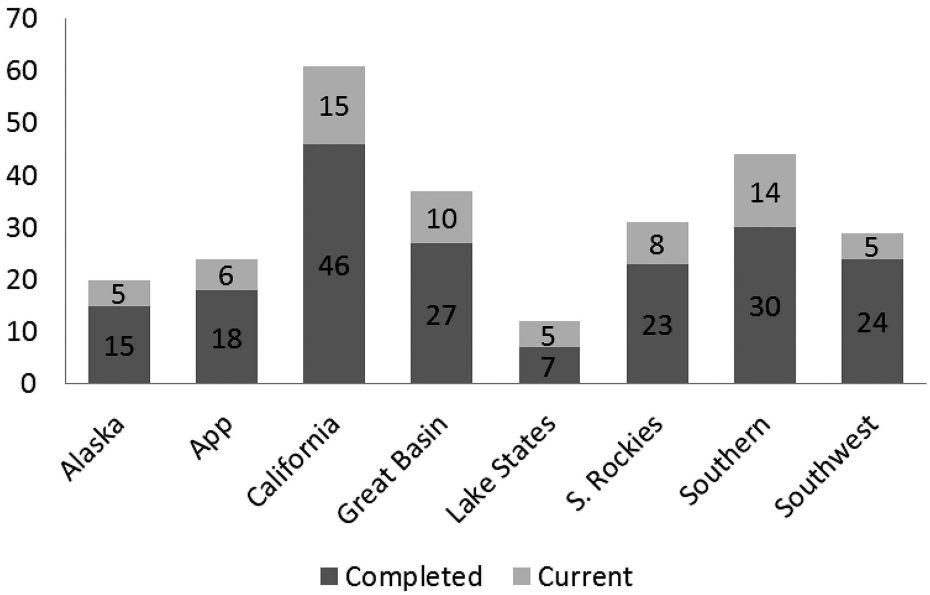

Figure 2. Current and completed fire science and delivery projects funded by the JFSP by region, 1998–2011.

gionally specific fire information. Having regionally specific information was described as being very important by many, including this California manager who said, "The biggest need I see is to have a better understanding of the local fire ecology. I have come to appreciate (and respect) that the fire ecology in our area is extremely complex. Having a greater understanding about the different historical fire regimes would greatly assist me in matching the right treatments to the right landscapes."

Table 3 lists topics identified in each region. Note that it identifies which research needs are held commonly in various regions and is not a national ranking of science needs.

The Use and Accessibility of Fire Science

In the Southwest, California, Lake States, and Alaska, investigators asked participants how likely or how often fire science is to be used in their work. Overall responses showed that fire managers use fire science frequently; however, responses varied by region. More than four of five participants in the Southwest said it was very or somewhat probable that fire science was applied to their units' work. In California, over one-half said they use science to help guide the design and implementation of land-manage-

Table 2. Regional consortium needs-assessment methods and participants.

Consortium approach	Methods	Sample size	Respondents/participants
Alaska—mixed	Workshop	60	Federal resource managers, state fire managers, tribal organizations, and university scientists
	Survey	41	
Appalachian—qualitative	Meetings	79	Fire managers and fire scientists
California—mixed	Interviews	75	Federal resource managers
	Focus groups		
	Online survey	160	
Great Basin—mixed	Focus groups	111	Federal resource managers
	Interviews		
Lake States—mixed	Interviews	12	Federal resource managers, state resource managers, and scientists
	Online survey	81	
Southern Rockies—qualitative	Meetings	200	Federal, state, and local agency resource managers; local NGOs/collaboratives; ski association members; and federal and academic researchers
Southern—mixed	Focus groups	65	Federal, state, and local agency resource managers; private landowners/associations; NGOs; cooperative extension; and scientists
	Online survey	976	
Southwest—quantitative	Phone survey	84	Federal fire managers, state fire managers, and NGOs, scientists

NGOs, nongovernmental organizations.

Table 3. Needs-assessment summary of research information needs.[a]

Topic for which more information is needed	Number of consortia finding that the topic was in the top five or was selected or listed by at least 50% of respondents (consortium abbreviation)
Fire effects (flora, fauna, soil, and water)	5 (AK, AP, CA, GB, and SE)
Fuels/modeling	4 (AK, CA, GB, and SR)
Prescribed burning best practices[b]	4 (CA, GB, SE, and SR)
Smoke modeling (air quality)	3 (AP, SE, and SR)
Fire behavior and fire ecology	3 (AK, CA, and SR)
Regionally specific information	3 (CA, SE, and SR)
Threatened and endangered species	2 (CA and SW)
Weather assessment and forecast	2 (AK and SE)
Resilience/insect and disease	2 (GB and SR)
Monitoring and adaptive management	2 (GB and SE)
Risk management, climate/environmental change, and fire danger[c]	1 (AK)
Mapping and imagery	1 (SE)
Invasive species, ecosystem restoration, and safety	1 (SW)
WUI treatments/community protection	1 (SR)

[a] The Lake States region did not include this in their assessments and so are not included in this table.
[b] This also includes growing season burns as reported in the Southern region.
[c] This also includes seasonal fire danger as reported in Alaska.
AK, Alaska; AP, Appalachian; CA, California; GB, Great Basin; LS, Lake States; SE, Southern; SR, Southern Rockies; SW, Southwest; WUI, wildland-urban interface.

ment projects on at least a monthly basis. However, only one-quarter of fire managers in the Lake States said the scientific community has a great or moderate influence on restoration and fuel-management decisions. Instead, participants said management decisions were more likely to be affected by budgets, competing agency interests, and wildland-urban interface constraints.

All consortia asked how fire science is currently accessed, including queries on the use of Internet, print-based, and interpersonal communication. Internet searches were the most commonly used means in all regions (see Table 4). In California, over one-half of respondents said they accessed written fire science information through web searches at least monthly. Across regions, most respondents said they use written scientific information on a regular basis, particularly materials developed for managers such as technical reports and research briefs. The type of material preferred and frequency of access varied (Table 4). In Alaska, at least one-half of respondents had used technical reports, fact sheets, brochures, and magazines within the last month. In California, one-half said they had read journal articles in the same period. However, many respondents said that finding what they needed could be a problem, including this California manager: "I would like to emphasize that knowing what and where information is available is difficult. Data overload. . . ."

Notably, there was agreement across regions on the high value of in-person communication about fire science. In Alaska, over one-half of the respondents had talked to agency or staff specialists in the last week or had attended a teleconference, academic lecture, or workshop in the last month. In the Lake States, more than three-quarters of the respondents said they talked to management colleagues either often or always as a source of information, and 70% sought information directly from agency scientists. In general, fewer Lake States managers had contact with University scientists; only 29% considered scientists as one of their two most preferred science sources.

Most assessments noted the usefulness of in-person courses, meetings, and networking for information exchange, with high percentages of respondents in the Southern assessment indicating that in-person courses, and meetings and networking were "very useful," and this was the easiest way to find needed fire information. Participants in Appalachian focus groups recommended more face-to-face networking, including small group meetings and field trips with managers and researchers.

Barriers to Accessing, Interpreting, and Applying Fire Science

Five consortia (California, Great Basin, Lake States, Southern Rockies, and Southern) asked about challenges to accessing, interpreting, and applying research to fire and fuels management. Although barriers were expressed differently across regions, many commonalities were noted. Across regions, lack of time was consistently identified as a barrier. Of the 1,000 respondents to a web-based survey from the Southern consortium, 46% identified lack of time to review literature as a very significant barrier. Sixty-eight percent of survey respondents in the Lake States agreed that they do not have the time to look for the latest information to help achieve fire and restoration objectives. As one focus group participant in the Lake States remarked, "I'm looking to get information quickly because I don't have enough

Table 4. Needs-assessment findings on how fire science is accessed.

Science dissemination method	Number of consortia finding that over half the respondents use these frequently (consortium abbreviation)
Web/internet based[a]	
Internet searches	6 (AK, CA, GB, SE, SR, and SW)
National databases/state/federal agency web portals	5 (GB, LS, SE, SR, and SW)
E-mail alerts	3 (AK, LS, and SW)
Agency in-house databases	2 (GB and SE)
Teleconference/webinar	2 (AK and LS)
Print-based information[b]	
Technical reports	5 (AK, CA, GB, LS, and SW)
Research briefs/newsletters/fact sheets	4 (AK, LS, SE, and SW)
Journal articles	4 (AK, CA, GB, and SE)
In-person based method[c]	
Communicating with management colleagues	5 (CA, GB, LS, SE, and SW)
Local/regional conferences	5 (AP, CA, LS, SE, and SW)
Communicating with local agency experts/researchers	3 (AK, GB, and LS)
Prescribed fire councils	2 (AP and SE)
One-on-one communication with academics	2 (AK and SE)
Lectures/courses/workshops	2 (AK and SE)
Field days	2 (LS and SE)
Professional societies	1 (SE)

[a] Appalachian consortium did not ask this question.
[b] Appalachian and Southern Rockies consortia did not ask this question.
[c] Southern Rockies did not ask this question.
AK, Alaska; AP, Appalachian; CA, California; GB, Great Basin; LS, Lake States; SE, Southern; SR, Southern Rockies; SW, Southwest.

time in my day. Time is the biggest challenge to the information exchange process." Another in California stated, "Everyone is too busy doing the status quo and there is no time to reflect and adapt to new information."

Part of the time crunch issue arose from the challenge of understanding the context of available information and whether it is locally relevant. Many managers doubted that available research was applicable to their specific location and ecosystem. This sentiment was expressed in each region, although most strongly in the Lake States where proportionally less fire research has been completed (35% of Lake States participants agreed that available fire science was not applicable to their situation; another 35% provided a neutral response).

Responses from several assessments revealed barriers in culture and communication between scientists and managers. Scientists and managers sometimes have different priorities and perceptions of the science delivery and application process. In the Southern Rockies, some scientists expressed concern that their research results would be improperly interpreted and applied by managers, and some managers reported difficulty evaluating conflicting scientific information or in "believing" some results. Scientists also noted that science delivery or outreach is not formally part of their job. One Appalachian scientist said, "I do not have time to meet and greet every land manager to sell my science."

Managers across regions identified communication problems as a hurdle. As one Appalachia manager noted, "I am uncomfortable calling a scientist that I do not know." Other managers said barriers reduced the applicability of fire science produced by the research community. One California manager commented, "The direction of fire science research too often comes from university and research station scientists without on the ground land management input." Another from the Lake States remarked, "No, the questions that I need answered are not being answered. Fire managers' questions, specifically, are not being addressed." Some managers also expressed a preference for technical assistance over new research information through development of expert "help desk" systems for addressing specific questions or problems. As one said, "We need technical assistance with the models we have, not new models."

Regional Boundary Organizations for Fire Science Communication

When asked to describe what functions the new fire science consortia could serve in their respective regions, respondents identified two primary opportunities: to consolidate fire science information and improve communication between managers and scientists. These needs were identified in all regions and are classic boundary spanning activities in a trading or sharing network (Hsiao et al. 2012).

Consolidate Fire Science Information. Participants in all regions expressed the desire to access fire science in one, easily accessible location. They consistently noted that while substantial fire science information exists, the amount of information available from multiple sources makes it challenging to identify the best available research for their particular management situation. As one participant in the Appalachian needs assessment, expressed, "We have a lot of information but it is scattered and too difficult to find."

To address this need, respondents overwhelmingly called for development of a comprehensive website that could be updated with emerging research and management findings. One Appalachian participant said, "We need one website or one publication that has it all." Many referred to this as an Internet-based "one-stop-shop" of information that would include brief summaries of projects and the ability to link to full reports where possible. Moreover, by setting standards for inclusion, managers suggested the website could provide an assessment of the quality of reported findings.

Improve Connections between Managers and Scientists. There was also agreement on the need for stronger connections and communication between scientists and managers to improve the use and applicability of fire science. This is not only consistent with existing research on boundary organizations, but is critical in the "coproduction" of science and policy (Lemos and Morehouse 2005). One participant from California remarked, "… creating professional relationships with researchers and land managers at workshops and conferences is invaluable. The leadership on both sides do not put near enough importance on this interaction." Another from the Lake States commented, "There needs to be some way for managers to engage. There are lots of good ideas that just never get heard by the research community."

To address these challenges, managers called for a more active role in the research process through increased interactions with scientists. They wanted to increase informal communication with management and research colleagues, have regional workshops where best practices and emerging findings

could be discussed, and develop demonstration sites to allow discussion of the planning, implementation, and outcomes of practices in particular locations. Participants described several potential benefits of increased two-way communication: managers could more actively participate in developing the research agenda and scientists could gain a valuable network to communicate with on research findings. This could improve the application of research results to fire planning and management.

Discussion

Although methods, assessment questions, and participant groups varied across regions, striking similarities emerged from the eight needs assessments conducted by the initial JFSP consortia. Assessments in all regions confirmed that managers want to use fire science in management, planning, and decisionmaking and actively search for research information. Web-based and printed materials were found to be effective forms of communication, and improvement of in-person communication was identified as a critical need to improve science delivery and adoption of research results. This is consistent with findings elsewhere that suggest learning is a dynamic process requiring more than simple exposure to information (Long 1998, Rogers 2003). Because fire managers already have a high level of fire knowledge and experience, they will interpret new information in relation to their prior understanding and specific situation. New information is more likely to be adopted when it is recognized as relevant to current problems (Wlodkowski 1999, Rogers 2003). The interactive exchanges offered through personal communication are better suited to problem-centered learning and improve the ability of managers to integrate and apply new information (Merriam and Caffarella 1999, Lemos and Rood 2010). Perhaps most importantly, the give and take of such exchanges offers opportunities to build relationships that can have far-reaching effects from increasing confidence in scientific information to improving the relevance and application of scientific findings.

Science application requires a substantial time commitment for managers and scientists alike. However, as noted here, one of the greatest barriers to effective science application in fire management is lack of time. This widespread finding is consistent with other recent assessments of barriers to the use of science (Hohl 2007, Wright 2010, Jacobi et al. 2011). Managers and researchers already have a full or in many cases overloaded slate of responsibilities with limited time for additional commitments. These findings underscore the challenge for the JFSP consortia to facilitate access to relevant fire and fuels science and improve science application for time-strapped managers and researchers.

These results confirm the need for boundary organizations to develop appropriate forums, effective tools, and opportunities to build relationships between scientists and managers at an appropriate scale. With their regional foci, the consortia are well positioned to identify the managers and scientists who are most active within their ecologically and socially defined regions and bring them together to not only facilitate information exchange, but to communicate the information needs of managers to scientists and help communicate key findings and management implications to managers.

By consolidating available information useful for specific geographic regions, the consortia can reduce the search time of managers and facilitate more prompt access to relevant findings. This will also benefit scientists, who are increasingly being asked to show research impacts, by providing an effective way to communicate results with interested users and to gain input to the design and framing of future research.

Although there was substantial agreement on information needs, preferred communication methods, and challenges to science application across the regions, the ecological, social, and institutional differences between locations suggest the need to tailor science delivery methods and content to regional needs. For example, the large-scale differences in the availability of regionally relevant information (see Figure 2) and existing networks of scientists and decisionmakers among regions suggests different emphases for each consortium. In regions such as California, the consortium may serve to bring together existing networks and provide a means to organize the large amount of already available fire science information. In other areas, such as the Lake States, the consortium may need to work at a more foundational level to develop initial connections between managers and scientists and inform development of future research.

This synthesis of regional fire science needs assessments underscores the importance of a regional approach in boundary spanning and in the creation and application of boundary objects and decision-support tools. Although regions found similar information needs, meeting these needs calls for development of regional boundary organizations. This is because regions have characteristic ecosystems and fire regimes that need fire science information relevant to their ecoregion to be salient, credible, and legitimate. Fire science that applies in the boreal forest of Alaska, e.g., will be less salient for managers in the pine forests of the Southeast or Southwest. Creating a "one-stop-shop" for managers to meet fire information needs, providing relevant online information databases, and generating salient decision-support tools, such as Internet resources, fact sheets, and technical reports, all require focus on the regional context of fire science and management. Across regions, the topics most often cited in the needs assessments were fire effects and fuels modeling, both of which require ecosystem and regionally specific products to be relevant for fire managers.

This analysis highlights the importance of in-person communication in spanning the boundary between fire scientists and managers. Regionally based boundary organizations are uniquely positioned to build long-term, trusting relationships with stakeholders, an essential step in building credibility and legitimacy in science communication and coproduction of knowledge (Cash et al. 2003). Regionally based boundary organizations are also uniquely positioned to relate directly to the regional context of management decisions and to facilitate one-on-one communication between scientists and managers both of which contribute to the salience, credibility, and legitimacy of their work.

Future of the Regional Knowledge Exchange Network

This needs-assessment findings synthesis shows a clear need for boundary organizations to facilitate communication, collaboration, and relationship-building between fire scientists and managers. Major obstacles to fire science application are lack of time to find and access to the most relevant information and communication barriers between scientists and managers. Managers prefer active communication through face-to-face interactions, which provide opportunities for enhancing mutual understanding and the coproduction of knowledge. Passive communication through online "help desks" or web-based repositories, fact sheets, and research summaries is also effective but should be a complement to more active in-person communication techniques. There-

fore, fire science boundary organizations will need expertise in both interpersonal communication and current technology for science communication.

To become effective boundary organizations, we recommend that the JFSP Knowledge Exchange Network focus on (a) organizing and consolidating the fire science through easily accessible websites and (b) strengthening relationships between scientists and managers to facilitate production and adoption of science relevant to managers' concerns. JFSP and the regional knowledge exchange consortia are committed to program evaluation that includes iterative assessment of user needs and how they are being met by consortia efforts.

This synthesis contributes to boundary organization literature by showing how a regional approach can be used to span the boundary between science and management. Results also point to a need for more research on how to span the cultural divide between scientists and managers; develop a process of coproducing knowledge to support management; and identify the characteristics of scientists, managers, and organizations that foster boundary spanning.

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