Title: Outcomes of fire research: Is science used?

Running head: Outcomes of fire research

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Abstract

An assessment of outcomes from research projects funded by the Joint Fire Science Program (JFSP) was conducted to determine whether or not science has been used to inform management and policy decisions and to explore factors that facilitate use of fire science. In a web survey and follow up phone interviews, I asked boundary spanners and scientists about how findings from a random sample of 48 projects, completed between 2004 and 2010, had been applied and factors that acted as barriers or facilitators to science application. In addition, I conducted an investigation of recent planning documents to determine if products from the sampled projects were cited. All lines of evidence suggest that products and information from most (44 of 48) of these projects have been used by fire and fuels managers in some capacity. Science has mostly been used during planning efforts, to develop treatment prescriptions, and to evaluate current practices. Boundary spanners and principle investigators commonly identified lack of manager awareness as a barrier to application of science. Conversely, activities and organizations that foster interaction between scientists and managers were identified as facilitating the application of science. The efforts of the JFSP to communicate science findings and engage managers has likely contributed to the application of the fire science they have sponsored.

Introduction

Fire has long played a keystone role in many ecosystems throughout the United States, but that role has been disrupted in many systems as a result of management actions that persisted over decades.

Consequently, beginning in the later part of the 20^{th} century, the scale and magnitude of wildfires increased dramatically, particularly in the western United States, a trend that has continued to the present day (Stephens 2005; Westerling et al. 2006; Miller et al. 2009). The impacts of these fires on ecosystems, ecosystem services, and communities has prompted widespread calls for action on the part of land management agencies and communities to reduce the risk of catastrophic wildfire and bolster community protection (DellaSala et al. 2003; Keeley et al. 2004; Arno and Fiedler 2005). There is also widespread agreement that there is an important role for science to inform such actions. To that end, in 1998 the U.S. Congress directed the U.S. Department of Interior and the U.S. Forest Service to establish the Joint Fire Science Program (JFSP), with the explicit purpose of providing scientific information in support of fuel management activities. Since the inception of the program, over 150 million U.S. dollars has been competitively awarded in more than 600 projects throughout the United States. The subject matter of those research[1] projects is wide-ranging and includes such topics as effectiveness and ecological effects of fuel treatments, historical fire regimes, post-fire restoration and rehabilitation, smoke management, and social and economic aspects of fuels management, to name just a few. The research topics are very applied in nature, and are designed specifically to inform fuel management strategies. While the JFSP has sponsored projects that examine effective practices for disseminating science findings to fire and fuel managers (Barbour 2007; Wright 2010), there has never been an evaluation of the outcomes of findings from JFSP-sponsored research, specifically, whether or not science has actually informed management decisions.

As a research funding body, the JFSP is not alone in the lack of evaluation for research outcomes. In the environmental sciences, few funding organizations have thoroughly evaluated the impacts of their science on management or policy[2] decisions. The lack of empirical evaluations of environmental research outcomes is well documented in the literature (Boaz et al. 2009; Bell et al. 2015), despite calls for such work (NRC 2005). There is often a tendency for organizations to focus on outputs (e.g. number of peer-reviewed publications, number of citations) as opposed to outcomes (e.g. impacts on decision-making)

(Boaz et al. 2009; Thomas and Koontz 2011; Ford et al. 2013). There are however some notable exceptions. An assessment of research outcomes found that science has in some cases been used in decision-making in areas of coastal management (Matso and Becker 2014). A large body of work on manager use of seasonal climate forecast has shown mixed results (Rayner et al. 2005; Bolson et al 2013.; Kirchhoff et al. 2013a), which has led to criticism of some climate science programs and calls for production of more "usable science" (McNie 2007; Sarewitz and Pilke 2007; Dilling and Lemos 2011; Ford et al. 2013).

The general scientific literature is rich with discussions and review papers on what determines whether or not science is used by practitioners and steps that scientists could take to facilitate application of science. According to Cash et al. (2003) it is critical that science be seen by intended users as credible, salient, and legitimate. In other words, research should conform to high scientific standards, be relevant to user needs, and produced in an unbiased manner that is respectful of different viewpoints. However, producing high quality, relevant, and unbiased science is often not enough to assure it will be used to inform management decisions. Many factors related to the manager or the manager's organization, such as perception of risk, availability of resources, or incentives for innovation, can play a substantial role in whether or not they value and use science (Kerns and Wright 2002; Clark and Holliday 2006; Kirchhoff et al. 2013b). There is widespread recognition that one of the most important factors that facilitates the use of science is ongoing communication between producers and users of science (Sarewtiz and Pilke 2007; Dillons and Lemos 2011; McKinley et al. 2012). An open line of communication between scientists and managers can help to assure that scientists are asking pertinent questions (increasing saliency) and establish trust between producers and users of science (increasing legitimacy).

Establishing open lines of communication between scientists and managers however is not without challenges and risk. For example, managers and scientists often use very different jargon, thus effective communication is a commonly identified barrier (Kocher et al 2012). Also, close relationships between managers and/or policy makers and scientists could lead to a perception that science findings are biased and driven by policy (reducing credibility) (Guston 2001). For these reasons and others, the work of boundary organizations, or organizations of people with expertise in both science and management and/or policy, has been seen as critical in fostering communication between scientists and managers and disseminating research findings in meaningful ways to managers (Guston 2001). Many studies have clearly shown that boundary organizations can foster the application of science findings (Rayner et al. 2005; Kirchoff et al. 2013a, 2013b). According to Cash et al. (2006), boundary organizations perform several critical functions. They convene managers, scientists and policy makers for face-to-face contact, they translate information so that it can be understood by multiple parties, they foster collaboration among different parties to co-produce knowledge, and they mediate collective decision-making when there are conflicting interests.

Recognizing the need to accelerate the application of fire science findings, the JFSP created the National Fire Science Exchange Network in 2009, a group of boundary organizations that work on a regional scale across the country (http://www.firescience.gov/JFSP_exchanges.cfm). Since that time, these organizations have communicated fire science findings, convened scientists and managers, and fostered collaboration among scientists and managers. A longitudinal evaluation of the JFSP National Fire Exchange Network has demonstrated their effectiveness in improving accessibility to and application of fire science (Sicafuse et al. 2015). However, long before this substantial investment in boundary work, the JFSP performed similar functions. For example, they translated science findings in short publications, convened managers and scientists in various workshops to inform research questions, and encouraged manager participation and endorsement of research proposals. This was all done with the assumption that it would foster the application of JFSP-funded science.

Since the inception of the JFSP, the program has funded applied fire science and made substantial steps to deliver science findings to managers. Yet, whether or not that science has been used by managers has not been evaluated, nor has the importance of the organization's various actions to produce relevant science and to communicate the findings. Thus, the purpose of this study was to determine the extent to which findings from JFSP-sponsored research projects have been used in decisions regarding fire and fuels management and policy, and to explore factors that influence application of science findings.

Methods

To address the research questions, I used multiple lines of qualitative and quantitative evidence, including a web survey conducted January - February 2014, follow-up phone interviews with a subset of survey respondents conducted March - April 2014, and a tally of citations of publications from a sample of projects in grey literature and planning documents. For each line of evidence, the focus of inquiry and analysis was a random sample of completed JFSP-funded projects. As of the initiation of this study (September 2013), the JFSP had funded 587 completed projects. Given that time would not permit an assessment of the outcomes of all of these projects, a random sample of projects meeting certain criteria outlined below were chosen for this evaluation.

It is well established that it takes time for science to be adopted by potential users (Rogers 2003). For this reason, older projects that were completed before 2011 were the focus of this study. It is also well established that application of science is more likely if there has been some effort to communicate the findings to managers (Guston 2001). To that end, only projects that resulted in at least one peer-reviewed publication and at least one product or science exchange activity targeted toward managers (e.g. factsheet, webinar, a meeting with managers) were included in the sample. A preliminary examination of JFSP-sponsored projects showed that a large majority of the projects that met these criteria fell under the following subject categories as identified in the JFSP project database (http://www.firescience.gov/JFSP_advanced_search.cfm): fire ecology/effects, fuel treatments, planning/risk, fire regimes, stabilization/rehabilitation/restoration, invasive species and wildlife. Since these subject areas represent a majority of the JFSP portfolio of funded research, projects were sampled only from these categories (Table 1). Finally, to represent the broad spatial scope of the JFSP portfolio of research, I randomly selected two to four projects for each region of the country, as defined by the boundaries of the 15 JFSP Fire Science Exchanges (http://www.firescience.gov/JFSP_exchanges.cfm). The number of projects selected per region was determined by the number of available projects that met the criteria. No projects met these criteria for two of the JFSP Fire Science Exchanges (the Tallgrass Prairie and Oak Savanna Fire Science Consortium and the Northern Atlantic Fire Science Exchange). Many more funded projects have been conducted in California compared to other regions (Kocher et al 2012). Thus, to better represent the pool of projects in this region they were further separated into two subcategories from which projects were chosen: those that were conducted in forested systems and those that were conducted in shrub lands. The full listing of the 48 projects in the sample are given in Appendix A.

I sent a web survey to a target population of those who specialize in fire and fuels management and could be considered "boundary spanners" (Clark et al 1998), or those who interact frequently with both managers and researchers. I targeted this specific group of individuals as a recent study has shown that they tend to act as fire science knowledge brokers in the wildland fire community and that managers often rely on them for information on relevant fire science (Wright 2010). Thus, boundary spanners are the most likely to be aware of fire science relevant to their region and to understand how research has or has not been applied by managers and why. Each participating JFSP Fire Exchange Network was asked to suggest up to ten people in their region that could be considered "boundary spanners" and the survey was sent to those individuals. These included individuals who work for federal, state, local, and non-governmental land management organizations and have some responsibility for communicating science to managers. All exchanges supplied information for fewer than ten individuals, as the boundary spanner population is relatively small compared to the broader fire and fuels manager population. The survey consisted of questions that addressed the following themes: awareness, application, and barriers/incentives to application of key findings from JFSP-sponsored projects (Table 2). A separate survey was sent to all principle investigators (PI) of the projects in the sample that addressed the following themes: number and character of interactions with managers, application of key findings of their research, and barriers/incentives to application of key findings of their research (Table 3). Since the sample of projects was the focus of analysis, I then tallied the number of projects in which a least one survey respondent selected a particular response for each question given in Tables 2 and 3.

Semi-structured phone interviews were conducted with a subset of the boundary spanners who responded to the survey. I asked boundary spanners a series of questions (Table 4) about particular JFSP projects that they were aware of, but I often deviated from the list of questions for clarifying purposes or to get more in-depth information. I recorded interviews using an application called TapeACall (© 2015 TapeACall) and hired a professional to transcribe all interviews. Transcripts were then coded using a grounded theory approach to organize and analyze the qualitative data (Charmaz 2006). Broad scale categories were predetermined based on the interview questions: use of research findings, barriers to application of science, and facilitators to application of science. Within those broad categories, I established subcategories as they emerged in reading the transcripts. I then tallied the number of projects for which a given subcategory was relevant according to the interview transcripts. This qualitative method is well suited for discovering trends and meaning, rather than testing specific hypotheses (Corbin and Strauss 2008).

To assess whether or not peer-reviewed publications from these projects were used in planning processes, I examined the references section of planning documents from each region to see if they cited peer-reviewed publications or reports from the sample of 48 JFSP projects. I examined the most recent planning documents from at least four management units in each region in the summer of 2014. These included, but were not limited to, environmental assessments, management plans, environmental impact statements, conservation plans, and fire plans from federal, state and county management units and were obtained from the management unit websites. In addition, I conducted a general internet search for at least one publication for each project to find additional planning, policy, or advocacy documents that have cited papers from these JFSP-funded projects. In total I searched the references section of 122 documents from 102 management units produced between 2010 and 2014.

Results

The first web survey was sent to 93 boundary spanners and between one and nine individuals per region (47 total or 51%) responded. This resulted in at least some information for each of the 48 projects in the sample. At least one boundary spanner was aware of 37 of the projects in the sample and for those projects, more information was gathered on application of the research through the survey. The second survey was sent to the 48 principle investigators of the sample projects and 21 individuals (44%) responded. A subset of boundary spanners (10) who responded to the survey also agreed to participate in phone interviews, in which 25 JFSP-sponsored projects in the sample were discussed.

There was general agreement between the boundary spanner and PI surveys regarding manager awareness of research, use of research and barriers to research. For most projects, both boundary spanners and PI's agreed that some (not most) managers were either aware of or well versed in many aspects of the research (Table 5). Boundary spanners and PI's also stated that the most common uses of research were in planning processes, to inform treatment prescriptions and in evaluation of current practices (Table 6). It was less common for projects to have been used in development of models/decision support tools or to inform policy. The most common barriers to use of research from these projects was lack of manager awareness, lack of resources/time, uncertainty in the science, and political barriers (Table 8). For both boundary spanners and PI's, lack of relevance or compatibility of the science with management practices was not as common of a barrier. There was also agreement in terms of most important forms of science delivery, with personal communication among researchers and managers as most important (Table 8). Other important sources of information were peer-reviewed publications, factsheet/reports, JFSP Science Exchange events/products, and personal communication among managers.

Phone interviews were conducted with a subset (10) of the boundary spanners that responded to the survey. Through these interviews 25 of the projects in the sample were discussed. Results from the coded interview transcripts are presented in Tables 9 – 12. According to the interviews, 14 of the 25 projects discussed were used to inform fire and fuels management actions or decisions by the boundary spanner or the managers that they interact with (Table 9). For three projects, boundary spanners indicated that they had not used information from the project, but it is likely used by others. For two projects, boundary spanners indicated that they had not yet used information from the projects, but were likely to use the findings in the future. For six projects, boundary spanners indicated that to the best of their knowledge, information from the project had not been used.

According to the interviews, a common way in which projects had been used was to inform/support existing treatment prescriptions. In other words, information from the project tended to provide support for practices that managers were already implementing on the ground (Table 10). To that end, studies from these projects were often used in planning efforts. Many boundary spanners indicated in interviews that these studies have been particularly helpful when management plans have been challenged with litigation. Many of the projects (8 out of 25) also led to changes in treatment prescriptions based on their findings (Table 10). Some of these changes were subtle, such as leading to changes in how fire is managed on different mountain slope aspects or changing the type of seed used in post-fire rehabilitation efforts. Some of these changes were substantial, such as applying prescribed fire to landscapes where this was not previously a common management practice.

In the interviews boundary spanners also discussed factors that facilitated or acted as a barrier to use of information from these projects. The most commonly identified facilitators were the fact that the studies were highly relevant to managers and that there was good outreach to managers (Table 11). In many cases, interviewees highlighted the importance of personal communication in facilitating science exchange, either between researchers and managers, among managers, or facilitated by boundary spanners (Table 11). For three of the studies, people mentioned the importance of the fact that the study was conducted in their area, giving them strong backing for their practices (Table 11). For the six studies identified as not being used, the most common factors that acted as barriers to application of research findings was that managers didn't have the time/resources to implement it and the fact that other studies or sources of information are more commonly used (Table 12). Other identified barriers included institutional/bureaucratic barriers, lack of trust between managers and researchers, and lack of research relevance.

The references section of 122 documents were searched and citations from the sample of 48 JFSP-sponsored projects were found in 86 (71%) of the documents. Citations of papers from a majority of projects in the sample (41) were found in at least one planning or policy document, confirming that information from these projects has been used in planning processes. For a majority of those projects (26), citations were found in more than one planning document, indicating that the sources were used often. For 13 projects, citations were found in planning documents in more than one region, indicating a broader scope of use. Publications from three projects were cited in documents produced by advocacy organizations. Only one publication was found in a policy-related document.

Discussion

While research on science outcomes has been commonly addressed in other fields (i.e. medicine, industry), this study addresses a well-recognized gap in environmental sciences, which is a lack of empirical evaluations of research outcomes (Boaz et al. 2009; Bell et al. 2011). While many studies have examined the value and use of climate science by managers in a general sense, none link manager awareness or decisions to specific science products or projects (Rayner et al. 2005; Bolson et al. 2013; Kirchhoff et al. 2013a). More recently, case studies of science outcomes have provided important findings but have focused on a limited number of projects (one to three) (Hart and Calhoun 2010; Matso and

Becker 2013). This study is unique in the field of natural resources in that the outcomes of a large number of research projects sponsored by a funding body were evaluated, representing roughly 10% of the research portfolio at the time of the study. Studies like this are critical for informing the strategic direction of science programs and effective strategies for dissemination of science.

Considering all the methods used in this study to evaluate the outcomes of research funded by the JFSP (boundary spanner and principle investigator surveys, boundary spanner interviews, and assessment of publication citations) for only four projects out of the 48 in the sample was there no evidence that findings from the study has been used in management. This supports the notion that science funded by the JFSP is indeed used to inform decision-making in fire and fuels management. Compared to other studies which show limited (Rayner et al. 2005; Bolson et al. 2013) or some (Matso and Becker 2013) use of science in decision-making, a large majority of the research projects funded by the JFSP in this sample seems to have been used by managers in some capacity. It should be noted however that the assessed usage of JFSP-sponsored studies may be artificially high as this study did not evaluate projects for which there was no manager outreach and/or no peer-reviewed publication. However, the sample of randomly-selected projects is likely representative of the entire population of JFSP projects as a majority of them have had resulted in outreach products/activities (81%) as well as peer-reviewed publications (64%) (Table 1).

The surveys and interviews suggest that managers are mostly using science during the planning process and to inform treatment prescriptions. This finding was confirmed with the analysis of planning documents. This is consistent with another study that showed fire and fuels managers tend to seek out science during large-scale planning efforts and when considering changes in management practices (Barbour 2007). Boundary spanner interviews suggested that availability of relevant and credible scientific studies is key for supporting current management actions, especially when those actions are challenged by external organizations. In a few cases, findings from JFSP-studies led to changes in management practices on the ground, such as altering the timing or frequency of prescribed fire, types of seed applied after fire, and where prescribed fire is implemented on a landscape.

According to the boundary spanner interviews, research in these projects was utilized by managers because the information provided was highly relevant to management needs, a finding supported by another study (Barbour 2007). Boundary spanners also indicated that use of science from the JFSP-sponsored projects was facilitated by communicating the findings in products and outlets for managers, direct interaction between scientists and managers, and manager engagement with boundary organizations, including the JFSP Fire Science Exchange Network. This finding is consistent with a large body of work that highlights the importance of communication between scientists and managers in assuring that science is used to inform decisions and the importance of boundary organizations in facilitating those interactions in a manner that preserves legitimacy (Guston 2001; Cash et al. 2003, 2006; McNie 2007). A separate evaluation of the JFSP Fire Science Exchange Network also demonstrates the importance of boundary organizations and the effectiveness of this particular network in conducting boundary work within the fire management community (Sicafuse et al. 2015).

Only a few respondents to the boundary spanner and PI surveys indicated that research funded by the JFSP has influenced policy. In addition, influences to policy were not mentioned in any interviews, and citations of publications from JFSP-sponsored research were found in only one national level policy document. This all suggests that JFSP research has not influenced policy in the same way it has influenced regional to local level planning efforts. However, the methodology used in this study was probably not adequate for assessing effects of JFSP sponsored research on policy. This study focused on regionally applicable studies in order get a broad view of the outcomes of JFSP sponsored research. The sample did not include projects that were national in scope, synthesis studies, or development of decision support tools that are more likely to inform policy. In addition, the boundary spanners and principle investigators that were invited to take this survey would likely not have been engaged in efforts to craft policy.

The focus on boundary spanners in this study was intentional, as these individuals tend to have deep knowledge of fire science in their region (Wright 2010). This notion is supported in this study by the fact that in the survey most boundary spanners indicated that they learn about fire science from the peer-reviewed literature (Table 8). However, because this study did not include a large survey of managers, the results cannot be used to determine the number of managers across the U.S. that are using JFSP-funded fire science. Although the analysis of citations in planning documents does indicate that these 48 JFSP-funded studies have been widely used during that process. Results from surveys seem to indicate that there is room to improve upon manager awareness of science, as both boundary spanners and PI's identified lack of manager awareness of science as a common barrier to the application of science. It may be that JFSP funded science is being utilized by "innovators" or "early adopters", essentially those more open to new ideas, but not utilized by other managers who are more resistant to change (Rogers 2003). Additional study would be needed to determine the number and characteristics of managers using fire science.

It should be mentioned that the outcome evaluated in this project was whether or not science has been used in decision making by managers. The project did not address outcomes in terms of effects on environmental or socioeconomic factors, as some have suggested is needed (Conley and Moote 2003; Koontz and Thomas 2006; Mandarano 2008; Rogers and Weber 2010). Of course, such outcomes are more difficult to address, require longer time frames, and data that may or not be available (Bellamy and MacLeod 1998). Thus, this project focused on a more intermediate-term outcome, application of science information (Bellamy and MacLeod 1998; Thomas and Koontz 2011). Whether or not that science has resulted in positive societal or ecological outcomes would need to be assessed in a different manner and over a longer period of time.

While this study did not examine effectiveness specific JFSP activities, it is worth reflecting on practices the program has adopted that may have contributed to the perceived credibility, legitimacy, and relevancy of the science the program has sponsored. Such reflections are key if funding bodies are to advance the application of science (Matso and Becker 2014). Long before the establishment of the JFSP Fire Science Exchange Network, the organization made multiple steps to assure the projects they funded were relevant to management needs and that research findings were communicated to managers. For example, both managers and scientists are represented on the JFSP governing board and in peer-review panels that evaluate research proposals. Research proposals that involve managers or show support from managers are generally weighted higher than proposals that do not. In addition, manager input has always been solicited in development of research questions used in requests for research proposals. When projects have been completed, JFSP has worked with scientists to produce short publications, electronic newsletters, and other products that are designed to communicate findings to managers. The fact that a large majority of examined projects completed before the establishment of the JFSP Fire Science Exchange Network had products designed for managers is probably a testament to these efforts (Table1). Many of these activities were mentioned specifically by boundary spanners in interviews as contributing to the relevancy and application of the science. In future studies, it would be fruitful to examine the effectiveness of such activities in accelerating the application of science findings.

Conclusion

This study shows that the JFSP is perceived by many in the wildland fire community as credible and legitimate and has been effective in sponsoring relevant science that has been used by managers to inform decision-making. Thus, the JFSP has been successful in meeting its mission of providing credible research tailored to the needs of fire and fuel managers. Boundary organizations can play an important role in mediating interactions between scientists and managers and the JFSP is currently investing heavily in this work through the Fire Science Exchange Network.

Footnotes

[1]The terms 'research' and 'science' are used interchangeably in this paper and are defined as a systematic study of natural phenomena through observation and experiment.

[2]For the purpose of this paper, 'policy' includes regulatory measures, laws, and funding priorities as they relate to fire and fuels management.

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