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Use of Science and Modeling by Practitioners in Landscape-Scale Management Decisions

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Abstract

Scientific knowledge and tools have central roles in contemporary federal forest programs that promote restoration in large landscapes and across ownerships. Although we know much about the role of science in decisionmaking and ways that science can be better linked to practice, we know less about manager perspectives about science and science tools, and the perceived role of both in planning. We surveyed Forest Service resource managers in the western United States to address this knowledge gap. Respondents engaged most frequently with science via reading research publications; direct engagement with scientists was less common. There was widespread agreement that science was a useful input to decisionmaking. Managers believed more weight should be placed on science in decisionmaking in cases of low public consensus than in cases of high public consensus. Managers with the most frequent engagement with science generally held more positive views towards science and its role in decisionmaking.

Keywords: science use, Forest Service, decisionmaking, landscapes, modeling

Contemporary public land planning and management efforts in the western United States increasingly rely on collaborative, science-based decisionmaking approaches (Schultz et al. 2012). These are encouraged in broad-scale efforts such as the USDA Joint Chief's projects, Collaborative Forest Landscapes Restoration Program, and western sage grouse planning (Schultz et al. 2012); regional efforts such as the Forest Service's Eastside Strategy in Oregon and Washington (White et al. 2016); and Forest Service direction about the importance of collaborative processes to inform planning (Davis et al. 2017). These programs and direction emphasize managing natural resources at larger spatial scales with planning completed over faster time frames and increased attention to complexity and integration, all within a collaborative or multi-stakeholder planning framework.

Mills and Clark (2001) previously argued that science and scientists will be called on for increased engagement in decisionmaking in the face of complexity in planning over large landscapes, coupled with the engagement of diverse public values in the planning process. Current demand for science (and scientist engagement) in management and planning can be seen in comprehensive science syntheses requested by Forest Service managers (e.g., Stine et al. 2014), scientists serving as science advisors to formal forest collaborative groups (e.g., Seager and Stern 2017), the use of

Management and Policy Implications

Although Forest Service managers widely perceive science to be useful and to have a clear role in decisionmaking, managers are diverse in the degree to which they connect with science and science tools, and in their perspectives on science's role in decisionmaking. Policymakers may benefit from recognizing that those charged with implementing landscape-level planning for the Forest Service do so from a variety of perspectives and disciplinary backgrounds. This highlights the potential benefit of having less prescription in national-level restoration programs regarding the specific approaches or tools for incorporating science in landscape-level planning. Managers most frequently connected with science through the Internet or by reading science publications. This traditional model of the science–manager connection limits engagement to one direction. Managers might explore whether they can improve their benefit from science through direct connections with scientists, with two-directional flow of information, either through one-on-one discussions or perhaps in codeveloped research projects. Managers placed different weight on science in decisionmaking as public consensus about priorities increased. Given the wide range of public and stakeholder engagement approaches presently used in landscape planning, managers might reflect on how they are measuring public consensus and if that measurement captures a diversity of public perspectives.

"competing science" by stakeholders and managers to advocate for their positions (e.g., Merritt and Deibel 2011), and the development of science models to provide information for the decisionmaking (e.g., Ager et al. 2017, Spies et al. 2017).

For the US Forest Service, natural resource specialists, National Environmental Policy Act of 1969 (NEPA) planners, and line officers (specialists and planners, hereafter) are the ones charged with planning management actions in support of these landscape-scale restoration efforts. Those specialists and planners have diverse disciplinary backgrounds and education levels (Cerveny et al. 2011). There is a fairly extensive literature on defining what is best available science in the context of decisionmaking, preferences of managers for types of research reporting, barriers to science use, and observed patterns in science use among managers and science users (e.g., Ryder et al. 2010, Davis et al. 2013, Courtney and Schneider 2016, Charnley et al. 2017, Ryan et al. 2018). In this study, we add to that literature by improving our understanding of specialists and planners' perspectives towards science and science models in the context of natural resource decisionmaking.

We surveyed resource specialists, natural resource planners, and line officers working for the US Forest Service in the contiguous western states to answer four questions: (1) In what ways and how frequently do resource specialists and planners engage with science and scientists? (2) What are their perspectives on the usefulness and role of science in decisionmaking? (3) What are their views on the role of ecological models in decisionmaking and what activities increase their comfort with such models? (4) Does the frequency that specialists and planners engage with science and scientists influence the above?

For scientists, we hope this study will help inform science delivery and add to the discussion about the role and effectiveness of science engagement in policy and management. For managers and policymakers, we hope this study provides information that might be used to reflect on how interdisciplinary team members are engaging with science and how their views on the role of science, and science tools, in decisionmaking influence the outcomes of landscape-scale planning efforts.

Literature Review

Role of Science in Decisionmaking

Scientific information, and specifically "best available science," is a required component in natural resource management decisionmaking on federal lands. Ryder et al. (2010) and Charnley et al. (2017) provide thorough reviews of approaches to defining best available science, and best available *social* science, for use in natural resource planning. Charnley et al. (2017:81) note that use of the best available science "is critical for improving the credibility, defensibility, and social acceptability of management decisions, and may improve compliance with them, reducing enforcement costs." Steel et al. (2004) note the diverse views regarding the appropriate role of science (and scientists) in decisionmaking and policy development. However, the reality is that scientists (especially federal scientists) are frequently called on to directly inform management decisionmaking and policy development. Recent examples include the Sierra Nevada Science Synthesis and Bioregional Assessment (Long et al. 2014) and the Northwest Forest Plan Science Synthesis (Spies et al. 2018). As Mills and Clark (2001:190) state: "while the debate of these opposing views of science involvement is interesting, it is largely moot in any practical view." Mills and Clark (2001) provide a detailed set of "propositions" for both scientists and managers for better outcomes from engaging science in decisionmaking and policy development.

Although science is one input into federal natural resource decisionmaking and policy development, it is not the only one (Cortner 2000). Political direction can influence the weight placed on science in high-level environmental policy. For instance, Lowell and Kelly (2016) found, consistent with prior studies, that the rate of new listings under the Endangered Species Act was less during Republican administrations. Closer to the ground, Forest Service line officers make management decisions that reflect the state of science but that are also influenced by the realities of managing national forests in mixed-ownership landscapes, with competing demands for staff and funding, a diverse set of public desires about natural resource use, and a changing climate (e.g., Williamson 2007).

Use of Science Delivery Types in Planning

Science information can be reported and provided in a wealth of formats, and a number of studies have examined manager preferences for, and use of, alternative formats. In a study examining revised national forest plans completed under the 2012 Forest Service planning rule, Ryan et al. (2018) found that government documents and technical reports were the most commonly cited format of science reporting. In particular, Forest Service general technical reports, from the Forest Service Research and Development branch, were the most frequently cited type of science document. Peer-reviewed journal articles were the next most commonly cited document type. In addition, literature reviews and Internet searches, Forest Service reports and datasets, and personal knowledge were also mentioned by resource specialists as sources of science used in the forest plan revision process (Ryan et al. 2018). Davis et al. (2013) found users of fire science believed peer-reviewed journal articles (as opposed to white papers or technical reports) contained the most credible science. In a study of federal fire managers, Ryan and Cerveny (2011) found that managers obtained fire and fuels related information from a wide variety of sources, including journal articles, technical reports, and Internet searches. However, workshops, trainings, and conferences were not identified by participants in that study as ways they obtained science information (Ryan and Cerveny 2011). Those authors found that fire managers frequently looked to experts and colleagues within the respondent's own agency for science information. That pattern is consistent with the "web or network" pattern of science dissemination described by Davis et al. (2013). Courtney and Schneider (2016) asked Forest Service recreation managers about their interest in science dissemination formats, and respondents were most frequently interested in (1) a searchable database of recreation science and (2) summaries of research knowledge. In a study of fire science users, Davis et al. (2013) found that those who commonly needed to explain fire science to others desired more syntheses, briefing papers, and short summaries of fire science information.

Barriers to Use

Several studies have explored the barriers to manager use of science, and lack of time and resources are the primary barriers. For example, Courtney and Schneider (2016), in a study of recreation specialists working for the Forest Service, found that lack of time and lack of personnel were the most frequently reported barriers to using science, with study participants indicating they did not have resources to spend time searching for, learning, and implementing new recreation research (Courtney and Schneider 2016). Similarly, Kocher et al. (2012) found that lack of time was a primary barrier to fire managers searching for, and using, the latest fire science. In their study of fire science users, Davis et al. (2013: 105) found that many users simply felt "overwhelmed by (fire science's) existing volume and complexity."

Scientist–Manager Engagement

One-on-one engagement between scientists and managers has consistently been identified in the literature as a productive way for science to reach managers (Ryan and Cerveny 2011, Kocher et al. 2016) as well as to improve the actionability of science (Beier et al. 2016). Ryan et al. (2018: 168) state "engagement with scientists is particularly important for topics where little research is available." In addition to lack of time and resources (e.g., Kocher et al. 2012), identified barriers to pursuing direct scientist–manager engagement include difficulty in identifying individuals to connect with, lack of funding for joint efforts, past negative experiences, and the sometimes differing perspectives of managers and scientists (Cerveny and Ryan 2008, Kocher et al. 2012, Davis et al. 2013). However, Mills and Clark (2001: 191) note that "tension is both expected and necessary for success" in the science/manager nexus and further state "the strength of the interaction comes from acknowledging and embracing the diverse perspectives that both the scientists and managers bring."

Perceptions of Science

Studies of managers using science have consistently found generally positive views about the utility of science for planning as well as positive outcomes from engagement with scientists (Ryan and Cerveny 2011, Davis et al. 2013, Courtney and Schneider 2016, Ryan et al. 2018). Study participants have also expressed nuanced understanding of the context in which science is performed. For example, Davis et al. (2013: 106) reported that fire science users recognized fire science as "contested, complex, and dynamic" and that users "evaluate science based on its source and (believe) not all science is neutral or objective." Beyond wanting easier access to science, users have expressed desire for research that is more specific to their geographic area and raised concerns about whether "general" research or studies conducted elsewhere were locally meaningful (Davis et al. 2013, Courtney and Schneider 2016). Consistent with concerns about the "generality" of research, Kocher et al. (2012: 426) noted frustration among some managers who felt that scientists' research efforts were not informed by on-the-ground needs and that some good manager research ideas "just never get heard by the research community."

Use and Comfort with Computer Models

Computer models of ecological processes and landscape systems can be integral components of scientific studies as well as management tools that assist in decisionmaking (Ager et al. 2017). As public lands management increasingly focuses on planning for large landscape areas, computer models have the potential to help managers, decisionmakers, and stakeholders explore the potential landscape outcomes from different management strategies as well as understand the likely tradeoffs between alternative actions (Spies et al. 2017). Addison et al. (2013) reviewed the literature about views towards models for environmental decisionmaking and identified nine "common objections" raised by decisionmakers, stakeholders, and experts about the use of computer models in decisionmaking. Objections included "models focus on environmental considerations … but do not capture the social, economic, and political factors," "I don't understand the way scientists communicate," and "model outputs are too uncertain for decisionmaking." The authors identify five "practical solutions" for addressing the objections, including "present scientific outputs in brief and accessible formats," "establish frequent personal contact with decisionmakers," and "actively engage participants."

Study Methods

This study focused on members of interdisciplinary planning teams (IDTs), specifically NEPA natural resource planners, resource specialists, and Forest Service line officers (e.g., district rangers) working in Forest Service project and forest planning in Forest Service regions 1 through 6. These regions cover the 11 western contiguous states extending from Montana, Wyoming, Colorado, and New Mexico west to the Pacific Ocean. A comprehensive list of individuals in this category does not exist (the study population). We developed our list of survey recipients from (1) online listings of IDT members, where available, for individual Forest Service units, (2) contacts with line officers and IDT leaders on Forest Service units, (3) Forest Service e-mail distribution lists, and (4) contacts with planning coordinators in Forest Service regional offices. Ultimately, we identified 455 unique contacts.

Personalized e-mails were sent from a Forest Service scientist member of the research team to each contact beginning in June of 2017. The e-mails included information about the project and a unique link to an online survey. Two more e-mail contacts, approximately 10 business days apart, were sent to those who had not completed the survey and had not requested to be removed from the study. The survey took about 15 minutes to complete and consisted mostly of closed-ended, multiple-choice questions. The majority of the survey questions had been tested in a related study of forest collaborative participants' attitudes towards landscape management and the use of models in natural resource planning (http://gbgh.forestry.oregonstate.edu/). The survey and methods received clearance through the Oregon State University Institutional Review Board (IRB Number 7408).

We received 205 usable responses for a response rate of 46 percent. Natural resources planners (i.e., NEPA planners) contributed 70 responses, with the remaining responses coming from resource specialists and line officers (Table 1). Resource specialists in fire and fuels management, wildlife, and silviculture/timber contributed the greatest numbers of responses.

Table 1. Number of respondents by discipline specialty/position and Forest Service region.

Position/specialty	Region 1—Northern	Region 2—Rocky Mountain	Region 3—Southwestern	Region 4—Intermountain	Region 5—Pacific Southwest	Region 6—Pacific Northwest	Total
National Environmental Policy Act of 1969 coordinator/natural resource planner	14	12	13	11	8	12	70
Silviculturalist or timber program	11	1	0	4	1	5	22
Wildlife specialist	10	0	3	4	3	1	21
Fire/fuels specialist	7	0	0	8	2	3	20
Recreation specialist	3	0	0	4	1	0	8
Botany specialist	2	0	1	0	2	3	8
Hydrology specialist	1	0	0	2	2	2	7
Fish biologist	3	0	1	2	0	1	7
Soils specialist	2	0	1	0	1	2	6
Others with up to five responses	*7*	*4*	*1*	*9*	*9*	*6*	*36*
Sum	60	17	20	44	29	35	205

All six of the Forest Service regions within our study area were represented in the sample. Because the numbers of specialists and planners across the Forest Service regions are unknown, we did not weight the sample to be representative by Forest Service region. Further, our sample was not designed to test for differences between resource specialties or Forest Service regions. Survey data were exported from the Qualtrics survey platform to SPSS 25 and cleaned. Respondents who left a question blank were excluded from analyses for that question. Descriptive statistical analyses were completed in SPSS.

In this article, we focus on responses to survey questions about engagement with science and scientists, perspectives on the use of science, and use and comfort with models (Table 2). In the survey, we defined scientists as "someone external to the National Forest System whose primary job is to do research." For this study, we adopt the broad view of Bisbal (2002) that best available science knowledge includes the formal and traditional peer-reviewed "scientific information," as well as the output of models which, in some cases, would be considered "suggestive information," and the expert opinions of scientists providing "supplemental information" in cases where data and/or research is limited. We view the process of science knowledge generation in natural and social sciences consistent with

Table 2. Analysis of respondent views about science.

Research theme	Survey components	Statistical analysis
Engagement with science	• Frequency of engagement with science and scientists via five mechanisms	Descriptive statistics
Perspectives on science and the role in decisionmaking	• Agreement with six statements about science and the use of science findings • The relative weight placed on science vs. public priorities in decisionmaking under low and high public consensus	Descriptive statistics
Use of models in decisionmaking	• The relative weight in decisionmaking placed on ecological models vs. other technical information and knowledge • Importance of seven actions aimed at increasing the comfort of using ecological model information in decisionmaking	Descriptive statistics
Engagement frequency	• Comparing the above for those with the most and least-frequent engagement with science	Logistic regression

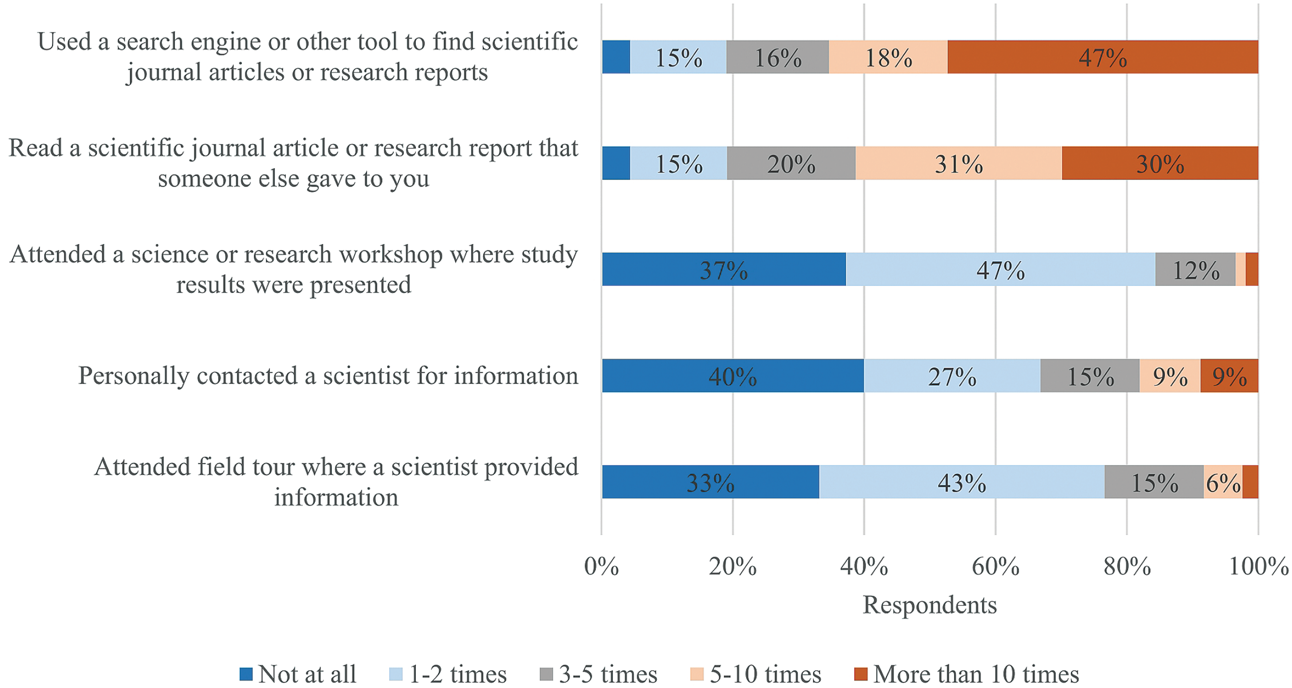

Figure 1. Engagement with science and scientists by resource specialists and planners in the past year.

the descriptions of Ryder et al. (2010) and Charnley et al. (2017).

We examined differences in the attitudes of respondents reporting the *most*- and *least*-frequent engagement with science/scientists towards the utility of science, the role of science in management decisions, and the application of models. The science/scientist engagement frequency for each respondent was created by summing their responses for the five science-engagement types considered in this study (e.g., searching for science journal articles or research reports) that are described further in the Results section. For each engagement type, respondents selected one of five categories of how frequently they had done that science-engagement activity in the last year: "not at all," "1 to 2 times," "3 to 5 times," "5 to 10 times," and "more than 10 times." Summed respondent scores for the science/scientist engagement frequency ranged from 5 (did not engage in any of the five activities in the last year) to 25 (engaged in each of the five activities more than 10 times in the last year). Respondents were then divided into the most-engaged and least-engaged groups based on obvious breakpoints in the summed frequency of engagement. The most-engaged group was defined as the upper 25 percent of respondent engagement frequency (a combined score of 17–25, inclusive). The least-engaged group was defined as the lower 30 percent of respondents, with a combined engagement score of 5–11. Tests of the relationships between science-engagement intensity and manager perspectives were done via a series of ordered logistic regressions in SAS 9.4 (proc surveylogistic) using a generalized logit model. Models were estimated with the dependent variable being the ordinal responses and the independent variable being the engagement classification of the respondent (i.e., least or most).

Results

Engagement with Science and Scientists

Planners and specialists frequently engaged with science through searches for science publications or by reading science products but less frequently had direct engagement with scientists (Figure 1). Nearly half of respondents stated they used a search engine or tool to find journal articles or research findings more than 10 times in the last year; about 30 percent of respondents reported the same response for "read a journal article or research report someone else had given you." Conversely, fewer than 10 percent of respondents reported similar levels of engagement (one on one or in group settings) with scientists. In aggregate, nearly all respondents reported that they had either searched online for a journal article or report or read a journal article or report that someone had provided to them at least one time in the last year. In contrast, 14 percent of respondents stated that they did *not* participate in any of the three direct engagement activities with scientists (i.e., attending a workshop, contacting a scientist, or attending a field tour with a scientist) in the last year. When it did happen, direct engagement with scientists was most commonly on field tours or in a workshop.

Usefulness and Role of Science in Planning

Resource specialists and planners had generally positive views about science. The vast majority of respondents (96 percent) agreed or strongly agreed that "if science is only able to tell us the most likely outcomes of forest management, that is still useful information" (Figure 2). Further, a majority (76 percent) of specialists and planners disagreed or strongly disagreed with the statement "scientific research takes too long to be useful."

There were few clear patterns in the views of planners and specialists about bias in science, the implications of contradictory science findings, and the connection between science and management decisionmaking. Almost 40 percent of respondents disagreed or strongly disagreed with the statement "scientific knowledge is inherently unbiased," but slightly less than a third agreed or strongly agreed with the statement. Similarly, there was no predominant belief about what contradictory findings imply about scientific consensus about an issue. Roughly a third of respondents disagreed, agreed, or neither agreed nor disagreed with that statement. Finally, a plurality (37 percent) of respondents agreed with the statement "science can tell us which forest management actions are the right ones." However, a similar share (34 percent) chose the neutral response to that statement, and an additional 20 percent of respondents disagreed with that statement.

We asked respondents how much weight should be placed on scientific knowledge versus public priorities when making forest-management decisions, first in low- and then in high-public-consensus situations. When there was a low level of public consensus around management priorities, 81 percent of respondents believed that either "more" or "much more" weight should be placed on science compared to public priorities when making management decisions (Figure 3a). An additional 15 percent of respondents believed there should be equal weight between science and public priorities when public consensus was low. When public consensus about management priorities was high, the share of respondents believing "more" or "much more" weight should be placed on science fell to 45 percent. Further, 36 percent of respondents believed, when public consensus was high, that equal weight should be placed on science and public priorities, and 19 percent believed that more weight should be placed on public priorities compared to science.

Slightly more than half of respondents gave different responses on the relative weight that should be placed on scientific knowledge versus public priorities when questioned about the two hypothetical levels of public

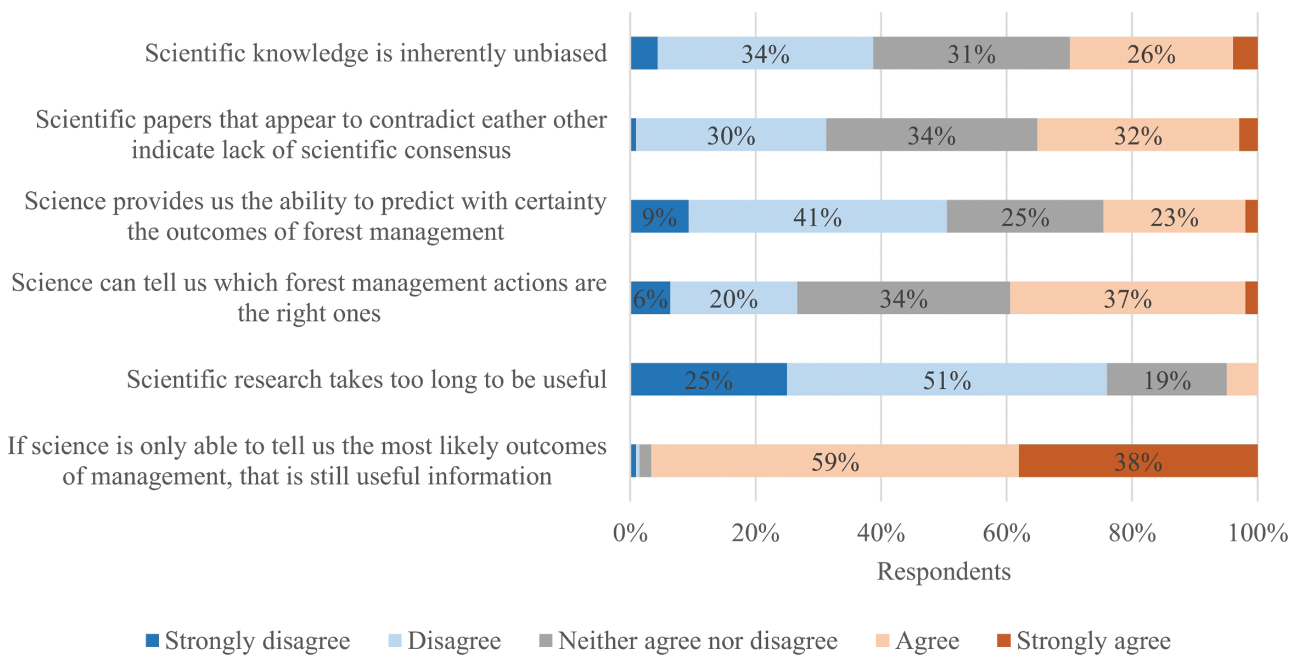

Figure 2. Perspectives on science by resource specialists and planners.

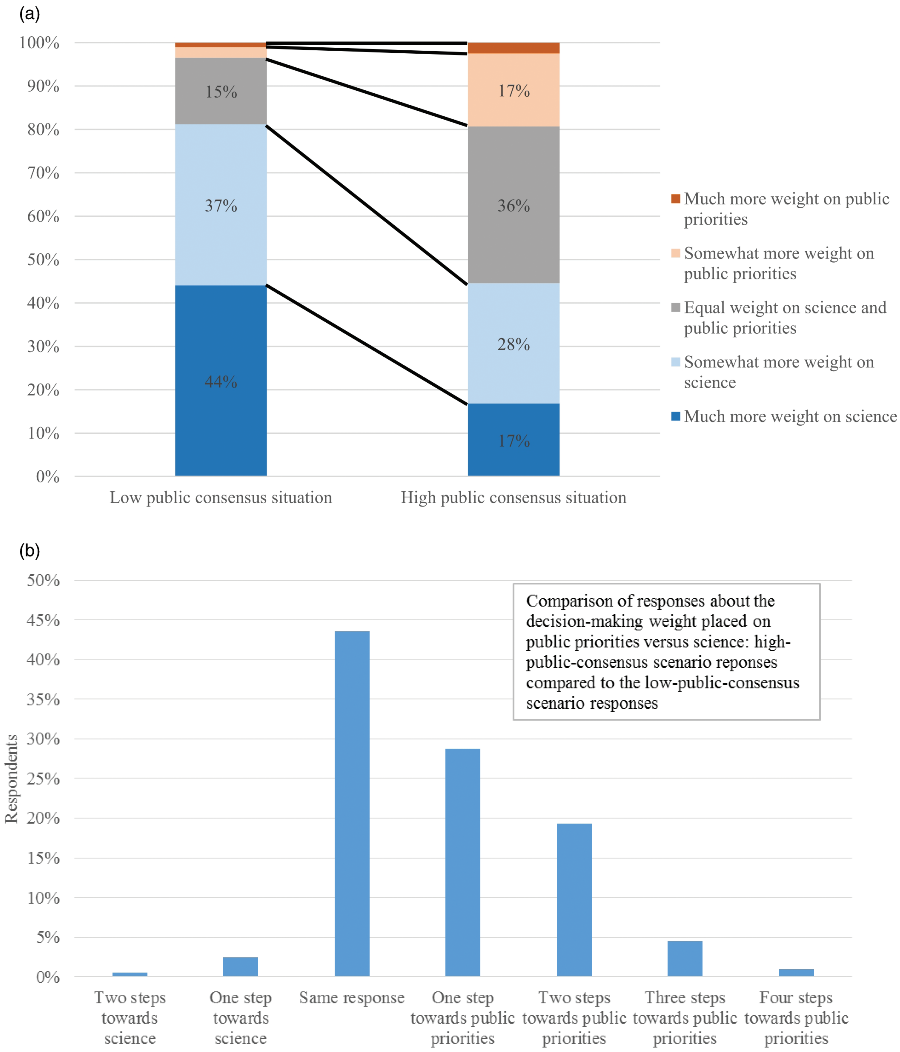

Figure 3. (a) Respondents' perspectives about "how much weight should be placed on scientific knowledge versus public priorities" in situations of low and high public consensus. (b) Degree of difference, in responses categories, across low- and high-consensus contexts.

consensus (Figure 3b). Those providing different relative weights for science/public priorities under the two hypothetical levels most frequently differed by one position towards placing more weight on public priorities, for example, providing a response of placing "somewhat more weight on science" when public consensus about management priorities was low and selecting a response of placing "equal weight on both science and public priorities" when public consensus was high. However, 19 percent of respondents differed by two positions towards placing greater weight on public priorities, such as from "much more weight on science" to "equal weight between both science and public priorities." Most striking were those individuals whose response changed from placing more weight on science in low-consensus situations to placing more weight on public priorities in high-consensus situations. Fifteen percent of respondents supported science being the primary influence on management decisions with low public consensus yet supported public priorities being the primary influence in situations of high public consensus. This group of shifters most commonly changed to placing "somewhat more weight on public priorities" when public consensus was high.

Use of Ecological Models

The output of ecological computer models is one potential source of information for landscape-scale decisionmaking. When asked about how much weight should be placed on information from computer models versus other pieces of information (such as stand survey data, remotely sensed imagery, or experience/intuition) when making landscape management decisions, about half of respondents stated that equal weight should be placed on both sources of information when making management decisions. However, nearly half of specialists and planners stated that either "somewhat more weight" (36 percent) or "much more weight" (12 percent) should be placed on other information. Just 4 percent of respondents thought models should have a greater role in decisionmaking than other sources of information.

Specialists and planners were asked to rate the importance of several individual and group activities related to enhancing their comfort with using ecological computer models "to inform forest management decisions." "Understanding how the model operates and its key assumptions" and "access to output for review at your convenience" were the activities rated as most important to improving comfort with an ecological computer model (Figure 4). Statements of model validity and appropriateness by scientists and managers were the next two most important activities. In contrast, less than half of respondents thought "personally running the model and being able to alter assumptions" and "seeing the model run in real time" were important activities for improving comfort with an ecological model.

Influence of Science-Engagement Frequency

Respondents exhibited a range of frequencies for engaging with science and scientists (i.e., Figure 1). Wildlife specialists, silviculturalists/timber program managers, and fish biologists were consistently among those reporting the most-frequent engagement with science and scientists. The respondents commonly reporting the least-frequent engagement with science or scientists were NEPA planners, fire/fuels management specialists, recreation specialists, and archaeologists. We compared perspectives about science, the use of science, and the use of models between the least-frequent ($n = 65$) and most-frequent ($n = 52$) engagement groups and focus on unique patterns below.

Perspectives on Science

Membership in the most- or least-engaged group was a statistically significant predictor of response to the statement "scientific knowledge is inherently unbiased" (Wald $F = 2.96$, P-value = .023). Specifically, the least-engaged-with-science group was less likely than their most-engaged colleagues to "agree" with the statement (40 percent compared to 16 percent; parameter estimate −0.9497, t-statistic −3.35, P-value = .001). Members of the least-engaged group most frequently (43 percent) indicated that they neither agreed nor disagreed with that statement; members of both groups disagreed with that statement with about the same frequency (about 35 percent of respondents).

Beyond bias in science, the most-engaged and least-engaged groups also showed differences in their perspective about uncertainty in science (Wald $F = 273.19$, P-value < .001). Although most specialists and

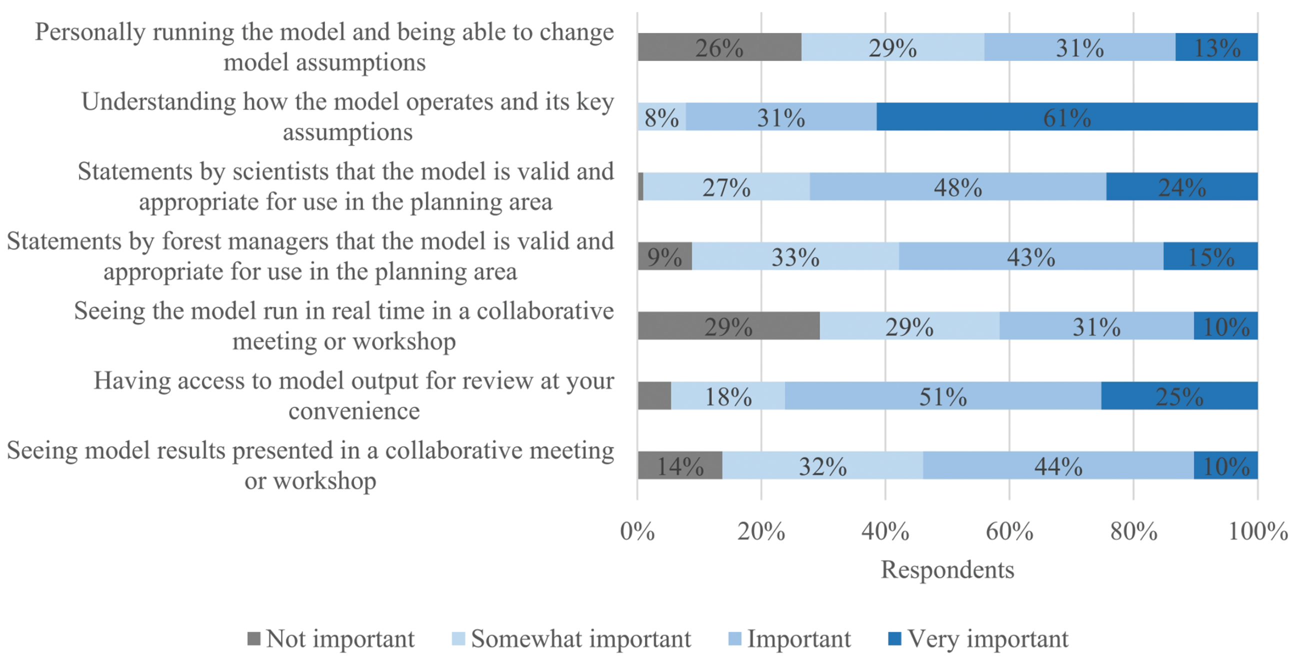

Figure 4. Importance of activities aimed at increasing comfort with use of ecological models.

planners agreed or strongly agreed that "even if science can only identify the most likely outcomes from management that is still useful information for management," those least-engaged with science were less likely than their most-engaged colleagues to strongly agree with that statement (44 percent compared to 23 percent; parameter estimate –0.4619, *t*-statistic –2.18, *P*-value = .031).

Role of Science in Decisionmaking

The two engagement groups were similar in their belief that more weight should be placed on science (than public priorities) in making management decisions when public consensus around management priorities was *low*. However, in *high*-public-consensus situations, the most-frequently-engaged-with-science group was more likely (50 percent) than the other group (32 percent) to continue to believe that science should receive more weight in decisionmaking. This pattern emerges because the group of specialists and planners least-frequently engaged with science was more likely than the other group to have different responses to the hypothetical low- and high-public-consensus questions (Wald F = 32.70, *P*-value < .001). Just 36 percent of the least-frequently engaged group (compared to more than half of the most-engaged group) gave the same response under the two consensus scenarios. In particular, the least-engaged-with-science group was statistically more likely to provide responses that differed by two places towards putting more weight on public priorities as public consensus increased (23 percent to 12 percent; parameter estimate 0.5194, *t*-statistic 1.77, *P*-value = .080). A two-place difference in relative weight generally resulted in a transition *from* placing slightly more weight on science *to* placing slightly more weight on public priorities in decisionmaking.

Improving Comfort with Models

In regard to improving comfort with models for decisionmaking, the least-frequently engaged-with-science group tended to rate any activity as "very important" less frequently than their most-engaged counterparts. Statistically significant differences in reporting an activity as "very important" were found for: (1) "understand model operation and the key assumptions" (73 percent to 54 percent; Wald F = 2.60; *P*-value = .078; parameter estimate –1.0808, *t*-statistic = –1.96, *P*-value = .053), (2) "have access to model output to review on their own time" (30 percent to 16 percent; Wald F = 186.01; *P*-value < .001; parameter estimate –0.6264, *t*-statistic = –1.92, *P*-value = .058), and (3) "hear statements by scientists about model validity and appropriateness" (31 percent to 20 percent; Wald F = 57.62; *P*-value < .001; parameter estimate –0.5203, *t*-statistic = –1.91, *P*-value = .059).

Discussion

Engagement with Science and Scientists

Our finding of the popularity of traditional formats for science delivery and the relative infrequency of direct engagement in workshops or one-on-one communication is consistent with the findings of Ryan and Cerveny (2011) in their study of federal fire managers. Despite general low direct engagement with scientists, 30 percent of respondents did report frequent direct engagement with individual scientists (five or more instances in the last year). Although we did not ask if the contacts were with the same scientist, it appears that a subset of managers and planners are highly engaged with scientists in the course of their work. Ryan and Cerveny (2011) propose that federal agencies may be able to increase manager–scientist relations by incentivizing such interactions and providing additional resources for engagement. Davis et al. (2013) describe several models of science delivery and use of fire science by practitioners that take advantage of direct engagement between scientists and practitioners.

With specialists and planners relying on the ever-increasing number of peer-reviewed articles and research reports disseminated in a growing and diversifying set of outlets as their primary sources of information, it seems natural they would feel "overwhelmed" (Davis et al. 2013) by the sheer extent of science information. The popularity of engagement with science in this written and formal "science information" format (Bisbal 2002) highlights the importance of science syntheses and briefing papers that are readable and accessible by nonscientists. Such summaries are likely more useful for decisionmaking when they respond to the needs expressed by managers (Kocher et al. 2012). Although synthesis and briefs can be useful for managers and policymakers, the length of time required to produce some syntheses (the recent Northwest Forest Plan science synthesis took more than two years to complete), the lack of interest among some scientists to participate in writing syntheses and briefing papers, and the complexity of synthesizing research knowledge are some likely challenges to producing more science summaries.

Perspectives on Science

The stated greater reliance on science when there is low consensus on the public's priorities for management may indicate that science is relied on as an arbiter of what actions are best when there is little consensus about priorities. That use of science is somewhat consistent with the finding that 37 percent of respondents agreed with the statement "science can tell us which management actions are the right ones" (although, about one-fourth of respondents disagreed or strongly disagreed with that statement). This reliance on science in low-consensus situations potentially offers a ripe setting for devolution into trading of competing science (such as that described by Mills and Clark 2001) as those engaging in formal collaborative planning processes push forward science they believe shows their preferred action is most appropriate.

Our finding that greater weight may be placed on public priorities when public consensus about management priorities is high raises the question of how scientific findings that are at odds with public priorities are (or are not) incorporated in management decisions. But, perhaps more importantly, this finding also raises the question of how Forest Service specialists and planners engaged in landscape-level planning and management are gauging the degree of public consensus around management priorities. Renewed reflection on this question by managers, policymakers, and researchers seems especially pertinent, given evolving practices of public engagement, the increased reliance on formal collaborative groups as part of landscape-level management planning, and heightened discussion about the relative importance of local and nonlocal perspectives in management decisionmaking.

Use of Models

Managing and planning at the landscape-level likely necessitate the use of models to properly account for the complexity in landscape-scale conditions and potential management outcomes over long time frames (Spies et al. 2017). Specialists and planners in this study indicated that information from ecological models was best combined with other, more traditional, information when making management decisions. There was little interest among specialists and planners in placing primary decisionmaking weight on models. This finding is consistent with the observation of Bisbal (2002) that managers preferred to rely on multiple sources of scientific information (what Brisbal labeled scientific, suggestive, and supplementary) in plan development for anadromous fish in the Columbia Basin. Many of the "practical solutions" for overcoming concerns about using models in decisionmaking that are proposed by Addison et al. (2013) rely on direct engagement activities with scientists. That may be difficult given the low propensity for such engagement among Forest Service planners and specialists. Overcoming the barriers to direct engagement is important, given that the landscape-scale and multiownership planning at the core of many current policies likely necessitates increased reliance on information from models.

Influence of Engagement Frequency

Those planners and specialists engaging most frequently with science and scientists often had different perspectives about science and the role of science in decisionmaking than those engaging less frequently. Of particular note was the consistency in placing greater weight on science in decisionmaking, regardless of the level of public consensus around management priorities. However, it is unclear if those perspectives resulted from greater exposure to science and scientists, or if those most-engaged practitioners had more positive views about science and the role of science and therefore chose greater engagement. Nevertheless, the science/manager engagement best practices highlighted by Mills and Clark (2001) and Addison et al. (2013) are aimed at obtaining better outcomes between science and managers; adopting them may help increase, or sustain, science/manager engagement.

Those specialists and planners in our most-engaged-with-science group reported participating in the sorts of direct engagement with scientists that are part of science coproduction and improved manager–scientist engagement. Coproduction of research (Meadow et al. 2015) and improved linkages between science and managers (Beier et al. 2016, Ryan et al. 2018) are expected to result in better outcomes for both management and science. Although this study was not designed to test for a causal relation, we did find some evidence of a link between exposure to science/scientists and positive attitudes towards science and the utility of science for management, consistent with what might be expected from greater science/manager engagement. The specialists and planners in this study who participated in more direct engagement tended to be specialists in physical science disciplines. Additional efforts to promote direct engagement by specialists in other resource areas, such as suggested for recreation specialists by Cerveny and Ryan (2008), may be useful for expanding the benefits of direct science/manager engagement.

Conclusions and Future Research

Forest Service resource specialists, planners, and line officers have diverse opinions about science, the role of science in decisionmaking about management, and the use of models in that decisionmaking. Although not necessarily surprising, this finding highlights the need to recognize that those charged with implementing landscape-level planning for the Forest Service do so with a variety of perspectives. National-level programs focused on promoting landscape-level planning and management may do well to recognize that diversity of views towards science in the implementation of those programs rather than using a one-size-fits-all approach.

This study focused on Forest Service regions in the western contiguous states. Forest Service resource specialists and planners working in the eastern US or Alaska may have perspectives not captured here. Forest Service managers in those areas could be the focus of future studies. Because there is not a comprehensive, current listing of individuals in the positions considered in this study, we had to construct our sample based on existing partial lists of individuals and information provided by key contacts, and some individuals may have been missed. That lack of a comprehensive listing also precluded assessment of sample representativeness. Further research is needed to ascertain the relative influence of disciplinary background, position tenure, organizational norms, and other factors on the formation of manager perspectives.

Landscape-level planning and management, including across diverse ownerships, likely require increased engagement between resource managers and science. Continued pursuit of coproduction of research—where scientists and managers partner throughout the scientific process—may be a promising avenue for such engagement. However, scientists can likely continue to facilitate use of science knowledge by ensuring results are communicated in accessible formats, creating scientific tools, including models, that have clear application for landscape-scale management, and directly providing scientific knowledge in collaborative management processes.

For the science engagement questions, the "5-10 times" response category erroneously overlapped with the "3-5 times" response category in the survey. We completed a sensitivity analysis on the most-and least frequent science engagement portion of this manuscript by treating the two response categories equivalent. Based on that analysis, we concluded this error did not influence the study results.

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