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Using Best Available Science Information: Determining Best and Available

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Public land and natural resource management policies in the United States commonly require the use of "best available science information" (BASI) in planning and implementing management activities. However, there is little direction on what constitutes BASI and how managers should discern between science sources. While definitions of BASI vary across management agencies and within academia, most include criteria emphasizing accuracy, reliability, and relevancy. Traditional approaches to identifying BASI, such as review of peer literature sources, can be limiting for land managers and their stakeholders. We agree that the highest standards of accuracy, reliability, and relevancy are necessary in cases where there is conflicting science or disagreement on best management options. But to increase the applicability of BASI for federal land managers and their stakeholders, we suggest that a broader range of accuracy and reliability can be used as best available science, determined by the question or need of the land manager. We provide examples of specific science needs and the BASI used successfully in that particular context. By expanding potential sources of best available science beyond the most rigorous evidence-based conservation approach, managers have more options for fulfilling science needs with appropriate science information.

Keywords: best available science, land and resource management, science-based management, forest planning

The use of "the best available scientific information" (often referred to as BASI) is advised or mandated in public land and resource management by state, federal, and international environmental laws, policies, and regulations. State and federal policies with BASI components include the US Forest Service Planning Rule (36 CFR Part 219 "Planning Rule," USDA Forest Service 2012), US Forest Service Handbook (USDA Forest Service 2013), the Endangered Species Act (ESA), state directives, and programs specific to agencies including the Collaborative Forest Restoration Act (CFLRP, Omnibus Public Land Management Act 2009) and the Resilient Landscapes program (DOI 2015), which impact the management of millions of acres and a wide variety of resources across the nation. Federal agencies are held accountable to these policies by the court systems, which require demonstration of their efforts to meet BASI standards (Schultz 2008). Additionally, as the expansion of the role of collaboration in public land management has led to the inclusion of a much more diverse set of stakeholders, managers are increasingly held accountable by their external stakeholders, including elected officials, private citizens, and nongovernment organizations (NGOs). Land managers benefit from transparent use of BASI with their partners and collaborative stakeholders. Recognition of knowledge gaps and data limitations can improve relationships among stakeholders and build trust in the decision-making process (Ryder et al. 2010, Webb et al. 2010). Despite the integration of BASI mandates across land and resource management agencies, consistent and specific parameters for identifying BASI do not exist. Thus, it is unclear how land or natural resource managers should use existing available science or discern among available scientific information to identify the "best" information so that management decisions are defensible to managers and their stakeholders. The increased directives for collaborative and inclusive land management decision-making necessitates shared understanding and transparent use of BASI between stakeholders and land managers. By utilizing a flexible approach and narrowing BASI options based on our proposed framework, both managers and

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stakeholders can better understand what sources would best fit their science needs.

In this article, we examine and identify the current definitions for BASI, the range of available science sources that meet BASI criteria, and the acknowledged barriers to using BASI by public land managers. We provide a framework for determining what science is best for particular use contexts and approaches and tools for public land managers and their stakeholders for best use of the available science. This incorporation of context, or the specific resource question, is not addressed in federal guidelines for the use of BASI.

BASI Definitions

Best available science is intended to be the platform for well-informed decision-making in natural resource and land-use planning, policy, and management. Scientific inquiry provides a pathway for understanding natural systems and for tracking changes in order to better understand causative factors and potential future conditions. As pressures from climate change, large-scale disturbance, and land-use change increase, synthesizing BASI is crucial for planning and managing public lands and resources at large spatial and temporal scales, where field experiments are too costly, site-specific, and slow to produce useful results.

Attributes that define "best available" science span from what is considered academically credible or what is convenient and accessible to what is actually accurate or acceptable to support a particular position or agenda (Bisbal 2002, Ryder et al. 2010). However, there is little consensus on the meaning of "best" and "available" across state and federal agency directives. The quality of the information available, the timeframe of availability, and the management or policy question at hand are all important factors in determining BASI.

Federal Agencies and BASI

The US Endangered Species Act of 1973 (ESA) created a precedent for the integration of BASI in environmental regulations and natural resource agency directives. The ESA is the law through which threatened and endangered species and the ecosystems that support them are conserved. The law mandates that the US Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA) "use the best scientific and commercial data available" in making listing decisions (16 USC § 1533(b)). Despite the emphasis on best scientific data in the ESA, the USFWS has not developed specific parameters to define what is "best" or "scientific," and a significant amount of litigation regarding the ESA and USFWS listing decisions has hinged on these issues (Joly et al. 2010, Murphy and Weiland 2016). The stipulation that science information be "available" has protected the agencies from having to generate scientific information when none is available and has also been the subject of many ESA lawsuits (Joly et al. 2010, Charnley et al. 2017).

The BASI mandate in the ESA has been widely adopted across federal land management agencies, with differing contexts and levels of detail. The National Park Service (NPS) management guidelines (2006) mandate the use of best available science in management planning and activities. The NPS defined "best available sound science and scholarship" as "up-to-date and rigorous in method, mindful of limitations, peer-reviewed when appropriate and required, and delivered at the appropriate time in the decision-making process in ways that allow NPS managers to apply its findings" (NPS Director's Order 100). The Bureau of Land Management (BLM) is encouraged to use best available science through agency strategies and plans, including the 2015 strategy for "Advancing Science in the BLM" and the 2016 Greater Sage-Grouse Land Use Plan. Additional federal agency recognition of the use of BASI includes the 2003 Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy, implemented by the US Department of Interior and the US Department of Agriculture. The strategy includes the use of best available science in Fire Management Plans and activities in its guiding principles.

The US Forest Service and BASI

The US Forest Service (USFS) has gone the furthest in providing parameters for BASI use. BASI must be used in planning, as stated in the 2012 Planning Rule (USDA Forest Service 2012):

> § 219.3 Role of science in planning. The responsible official shall use the best available scientific information to inform the planning process required by this subpart. In doing so, the responsible official shall determine what information is the most accurate, reliable, and relevant to the issues being considered. The responsible official shall document how the best available scientific information was used to inform the assessment, the plan decision, and the monitoring program as required in §§ 219.6(a)(3) and 219.14(a)(4). Such documentation must identify what information was determined to be the best available scientific information, explain the basis for that determination, and explain how the information was applied to the issues considered.

Management and Policy Implications

Federal agencies are required by law and directed through additional programmatic goals to use the best available science information (BASI) to support land and natural resource management decisions. Current guidelines for BASI lack definitions or criteria for accessing and evaluating best available science for use across the multiple contexts of land and natural resource management. There is a range of appropriate sources of science information, with varying levels of accuracy, reliability, and relevance that can cause confusion among land and resource managers and their stakeholders. We suggest assessing the specific management question and context to better determine appropriate sources of science information. Management questions with high controversy or conflicting science require high levels of accuracy, reliability, and relevance to support defensible management decisions and ensure desired management outcomes. Site-specific questions or contexts that require baseline information can be enhanced with place-based sources like traditional ecological knowledge or expert opinion. While highly accurate and reliable science sources should be integrated into land management decisions whenever possible, this level of science information is not available for all questions and contexts. Managers can use a wide array of science information options under federal agency policy. By understanding the context of the science need, managers can be more flexible and efficient in their use of BASI.

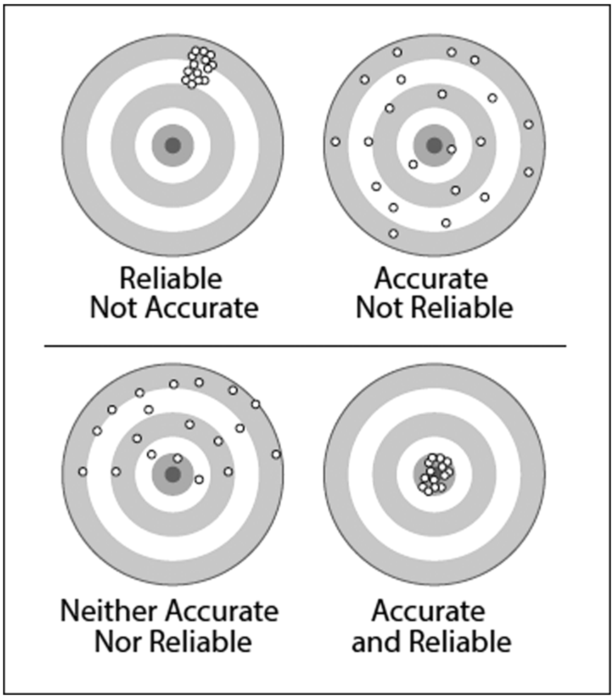

Figure 1. Reliability and accuracy (adapted from Trochim 2006).

Finalized in January 2015, the USFS Planning Directives guide the implementation of the 2012 Planning Rule and provide additional direction. The directives allow for a wide range of types of evidence to be used to meet BASI intent, including peer-reviewed publications, scientific assessments, expert opinion, observational data, and unpublished data from government agencies, academia, or public surveys. The best available information "currently exists in a form useful for the planning process without further data collection, modification, or validation. Analysis or interpretation of BASI may be needed to place it in the appropriate context for planning" (FSH 1909.12 sec 07.1). The directives further define the BASI criteria from the Planning Rule as follows:

(1) Accurate information estimates, identifies, or describes "the true condition of its subject matter" (Forest Service Handbook [FSH] 1909.12 sec 07.12, Figure 1). This can include specific measurements of conditions or estimation of trends. Accurate scientific information should be quantitatively unbiased and free of systematic error.
(2) Reliable information is precise and unaffected by random error; multiple samples represent the same condition (Figure 1). Appropriate scientific methods, including study design, assumptions, analytical approach, and conclusions, should be well-referenced and described, with citations to relevant, credible literature.
(3) Relevant information is that which pertains to the issues under consideration and relate to the appropriate temporal and spatial scales. Both accurate and reliable science need to be assessed for applicability to the management question. This includes the ability to transfer results to a management question from different systems, species, or geographies or via different methodologies.

The directives note that sometimes a clear scientific consensus might not exist, and in such cases, conflicting information can be acknowledged without necessarily choosing one "best" source of information (FSH 1909.12 sec 07.12).

Academia and BASI

The academic literature for BASI relies heavily on definitions that incorporate the scientific method, including measures of rigor, appropriate inference, and peer review to assess for bias. Ryder et al. (2010) note that BASI has three elements: a definition of what constitutes science, consideration of what scientific information is available, and an objective way of evaluating available scientific information in order to determine what is best. Effective BASI is credible, salient, legitimate, and usable (Clark et al. 2002, Cash et al. 2003). Credible information is developed according to rigorous scientific standard, salient information is relevant given the context, and legitimate information is that which has been produced in a respectful, unbiased, and fair way (Cash et al. 2003). These terms crosswalk to the USDA terms respectively: (1) Accurate/Credible, (2) Reliable/Legitimate, and (3) Relevant/Salient.

Clear and sound science adheres to scientific guidelines, includes a clear statement of objectives, a thorough review of the literature, and other relevant information, adheres to the well-established scientific process and methodology, and logical deduction of results and inferences using valid statistical analyses, with peer review (Sullivan et al. 2006, Charnley et al. 2017).

Sources of Science Information

Peer-Reviewed Literature

Peer-reviewed articles published in academic journals largely represent the highest quality sources of accurate and reliable science information, as they are reviewed by one to three anonymous experts in the field and revised accordingly. These studies can vary in rigor of experimental design and in how they are received by the scientific community after they are published, and they are subject to human error and bias (Lee et al. 2013). As such, it is appropriate to evaluate peer-review science for accuracy, reliability, and relevance to planning and management issues. Peer-reviewed studies will provide the largest source of rigorous and up-to-date science information but may not always be the most available or accessible depending on how the science was published.

Grey Literature Sources

Grey literature is a broad category that varies from easily accessed to hard-to-find, local and specific to broadly applicable. Grey literature includes white papers, working papers, general technical reports (GTRs), government documents, theses and dissertations, and conference proceedings (Prague Definition, Farace & Schöpfel 2010), and the quality of the information can be more variable than that in peer-reviewed journals. Agency reports and publications are often peer-reviewed, meet high accuracy and reliability standards, and are more broadly available to agency managers. For example, general technical reports are peer-reviewed within the

US Forest Service by two in-house experts. Academic institutes and nonprofit organizations (e.g., The Nature Conservancy) can also be sources for working papers, white papers, and fact sheets. These sources are often produced from analyses conducted by staff scientists, are peer-reviewed, and can meet the BASI criteria of accurate and reliable information. Theses and dissertations are grey literature that may be less widely distributed but go through a process of review by the committee members, often with one or more PhD-level faculty on the committee, and can also meet BASI definitions.

Grey literature resources can represent a large body of institutional knowledge and a source of highly localized or specialized information to address issues underrepresented in the peer-reviewed literature. The synthesis of data, both published and unpublished, across broad ranges with context for land managers may not meet scientific journal publication criteria but represent important contributions to the body of literature. For example, USFS Rocky Mountain Research Station GTR 310 (Reynolds et al. 2013) summarized the natural range of variability (NRV) across two forest types in the Southwest based on a broad literature review and synopsis. The document includes management recommendations for land managers seeking to incorporate NRV into project planning. Grey literature also may be specifically geared toward a manager or specific user audience, increasing the accessibility and applicability of the scientific information for a particular purpose.

Traditional, Local, Expert, and Institutional Ecological Knowledge Sources

Widely used sources of science information defined by the USFS Planning Rule as BASI include traditional and local ecological knowledge, expert knowledge, and institutional knowledge. Traditional ecological knowledge (TEK) and local ecological knowledge (LEK) can be rich sources of scientific information. Traditional ecological knowledge is insight and knowledge about a species or ecosystem that has developed through interaction or engagement with the environment in specific places transferred over multiple generations (Berkes et al. 2000, Huntington 2000). Similarly, LEK is knowledge gained through personal interaction with local ecosystems but is more recent than TEK (Charnley et al. 2017). Traditional ecological knowledge and LEK can vary in accuracy and reliability and may not be statistically rigorous; however, these sources can provide valuable ecological information that is based on long-term observations and may be the only sources of place-based information in certain areas. Expert knowledge is information on a particular subject that is not widely known by others and often comes from an individual or individuals who are specialists in a particular field or subject (Martin et al. 2012). Experts are solicited or deferred to for interpretation and context. Institutional knowledge is knowledge within an agency, institution, research group, or area that holds information and details that are not widely known by others outside of the institution. Institutional knowledge, like local and expert knowledge, is often knowledge on a specific subject area or long-term history of a research area, plots, subject area, or landscape that is important to consider and can be used to meet BASI criteria. These sources are important when little information is available in the peer-reviewed literature for a particular landscape. These sources vary in their availability, depending on if and how the information is documented.

Weight of the Evidence—Systematic Evaluation of Available Science

The available sources that meet BASI standards can be numerous, leading to an overwhelming amount of information that may include contradictory answers to management questions. Evidence-based conservation processes develop a comprehensive synthesis of sound, peer-reviewed science based on environmental management questions (Pullin and Knight 2003, Fazey et al. 2004, Sutherland et al. 2004). The evidence-based conservation method uses a systematic review process to assess not only the available evidence but also the quality based on rigorous criteria (Pullin and Stewart 2006). Systematic reviews differ from conventional literature reviews, which summarize studies by providing qualitative descriptions of research results without differentiating between the quality of the sources or the rigor of the experimental design. The goal in preparing a systematic review is to clearly assess and present each line of evidence, and then draw conclusions that rely most heavily on the highest quality studies (i.e., a "weight of evidence" approach). In many respects, a systematic review parallels primary research. It includes a clear definition of the problem, a design of a research methodology, a collection of data (in this case, from the literature), the analysis of those data using clearly stated and accepted procedures, and draws inferences that are supported by the analysis, and it draws conclusions that are helpful to managers and stakeholders. Because of this level of rigor, systematic reviews are particularly useful when there is conflicting peer-reviewed science, when management objectives conflict, or when the total knowledge on a subject area is needed.

In public land management, this tool is useful for assessing the effectiveness of land management approaches (e.g., does prescribed fire, thinning, or wildfire lead to higher frequency of invasive plant species?) or addressing conflicting science on land management practices. It is also useful when scientific studies with management implications contradict each other. Not all management questions lend themselves to systematic review. For example, minimal criteria for a rigorous systematic review include having a sufficient available dataset of peer-reviewed articles. Like any study, systematic reviews require a data sample that meets experimental design and data collection assumptions and occurs at the appropriate scale and distribution to allow proper evaluation and inference power. Systematic reviews are also resource-intensive; the approach requires technical expertise and investment of time to complete the extensive review process. While systematic reviews can provide a definitive source of the most rigorous science, this approach may not be the most accessible in many contexts (Supplementary Materials).

Methods and Approaches: Suggested Question-Based Scaling of BASI Requirements

We suggest that methods used to meet BASI requirements should be dependent on the management or policy issue and the value put on it by the user (Ryder et al. 2010). While evaluating the best science in a scientifically defendable way is a rigorous process (e.g., evidence-based conservation), not all management contexts call for, or allow for, this level of precision to address a science need. Land managers face significant barriers in identifying, accessing, assessing,

Table 1. Barriers to using best available science information.

Barrier	Key points	Literature
1. Differences in access, availability and preference	• Scientific journal paywalls • Limited distribution of white papers, TEK and LEK • Limited translation to management implications • Perceived bias based on authoring institution	Cleve et al. 2004, NRC 2005, Ryder et al. 2010, Van Wright 2010, Gerlach et al. 2013, Davis 2013, Colavito 2017
2. Scientific timelines, disagreement and uncertainty	• Assessment of management effectiveness needed on shorter timeline than scientific assessments • Scientist and Manager differences on communication of and comfort with uncertainty • Emergent theories and hypotheses create controversy	Van Cleve et al. 2004, Sullivan et al. 2006, Joly et al. 2010
3. Time and capacity constraints	• Limited institution capacity for systematic or literature reviews • Limited capacity for data interpretation and application	Wright 2010, Cook et al. 2013, Lowell and Kelly 2016, Murphy and Weiland 2016, Charnley et al. 2017

and synthesizing BASI, including issues of access and availability, scientific disagreement and uncertainty, and time and capacity constraints. A flexible approach to determining BASI needs that integrates management context provides land managers with a wider range of options in fulfilling BASI mandates, helping to address some of these common issues. In-depth discussion of the multiple barriers to utilizing BASI for land management decisions is beyond the scope of this article and is well-captured by other studies; see Table 1 for a summary of these barriers.

On federal lands, the use of BASI is recommended across all stages of land management activities: planning, implementation, and adaptive management. The increasing collaborative opportunities and partnership roles in federal land management create additional needs for identifying and communicating—and potentially partnering on—the BASI used in all three areas. While accuracy and reliability are factors determined by the scientific research approach (e.g., experimental design, data collection methods, methods of analysis, etc.), determining what science is best depends in part on the context—the question or intent, the data available, any knowledge gaps, and if there is controversy or debate within the scientific community on a particular subject. We have categorized the list of available science sources in Table 2, linking each to a suggested intent or need across planning, implementation, or adaptive management areas. The following section provides examples and context for BASI needs and appropriate use.

Consider the Body of Science: Assessing Quality of Evidence

Management and planning issues that are supported by strong scientific consensus and low levels of conflict do not require a great deal of additional assessment. When the relevant peer-reviewed literature meets accuracy and reliability criteria and provides consistent answers, resource managers can easily justify the incorporation of that science into their management needs. Given the breadth of science knowledge made available to land and resource managers, BASI users may face a deluge of science information and should use accuracy, reliability, and relevance criteria to refine what is available. Evaluating a single study for these characteristics is not the same as evaluating the body of science on a topic, which requires looking across the body of evidence on a particular subject. For many resource management issues, synthesis of relevant science may already be available in the form of evidence-based systematic reviews. Sources with high accuracy, reliability, and relevance should be prioritized.

When Uncertainty and Controversy Are High, Use a Rigorous Evidence-Based Approach

When addressing contentious management issues, the BASI utilized should meet the highest level of accuracy and reliability; both peer-reviewed journals and GTRs are appropriate. Contradictory scientific outcomes also require a more rigorous weight-of-evidence process. Systematic reviews are the most rigorous way to determine the "best" component of BASI and provide a clear assessment of available science on management questions, providing a highly reliable and accurate source of science information for managers. Conflicts in proposed management can occur when the current status or condition of a resource is

Table 2. Approaches to meet BASI requirements.

Management Scenario	BASI Source	Access	Tools
Conflict of peer-reviewed science; potential risk to resource objectives; high risk of litigation	Peer-reviewed evidence-based conservation	Select: Academic, research agencies	Systematic Reviews
Legally-defensible planning documents; project implementation design; conflict of stakeholder interests	Peer-reviewed literature, including journals and GTRs	Select: Academic, research agencies, agency	Literature search
Agency and stakeholder learning; conflict of stakeholder interests	Grey lit (e.g., agency or NGO reports, white papers, working papers, research briefs, thesis, dissertations)	Select: Agency, academic. Grey lit can be difficult to find.	Web search, literature search, TREESEARCH
Initiating planning, stakeholder learning; and effectiveness monitoring	Expert Opinion, Institutional Knowledge & TEK	ALL	Field Trip, Presentation Seminar
Agency and Stakeholder learning; gap assessment;	Local Knowledge	ALL: Agency, stakeholders and partners	Field Trip, Citizen Science

Table 3. Guidelines for use of science to meet BASI standards.

BASI Factors	If…	If…
State of the Scientific Knowledge	Body of literature is well developed and supported. Science findings are professionally recognized.	Science and technology is emerging. Findings and interpretations are inconsistent.
Data Availability	Data is well developed. Techniques are well accepted.	Data gaps exist. The data or collection techniques are highly insufficient.
Controversy	Little to no controversy exists. General scientific consensus exists.	The issue is highly disputed and controversial. There is little to no scientific consensus.
Management Risk	Risk is low.	Risk is high.
	Then, available science is adequate	**Then, further lines of evidence are needed**

Table 3 is adapted from the 2012 planning rule directives (USDA Forest Service 2012).

unknown or when proposed management activities are controversial and management actions that have not been assessed for effectiveness may be challenged by recent science findings. Similar situations occur in implementation; assessments and adaptive management for best management practices may show conflicting results. Many of these guidelines were identified in the USDA planning rule directives. Table 3 (adapted from USDA Forest Service 2012) identifies similar guidelines and provides potential triggers for when a higher quality of science is needed to meet BASI requirements.

An example of an evidence-based review is a study by Kennedy and Fontaine (2009), who summarized the effects of fire and fire surrogates in dry forests of the US West. The Kennedy and Fontaine systematic review addressed specific knowledge gaps and sought to synthesize multiple findings across wildlife taxa to inform land management decisions related to fire and wildlife. The questions Kennedy and Fontaine sought to address included:

1. What information exists on the response of wildlife species, community, or species guilds in fire and fire-surrogate project areas to the proposed treatments?
2. Is there information on the species-specific response to a treatment that is consistent (positive, negative, or no response)?
3. Is the response to the treatment or wildfire event short-term (less than five years) or long-term (more than 10 years)?

The authors performed an extensive survey of the published, peer-reviewed, scientific literature on wildlife response to fire and fire-surrogate treatments, utilizing articles that presented empirical, quantifiable data on wildlife population and community-level responses (e.g., abundance, vital rates, and distribution) to wildland fire or management treatments. This approach addressed multiple species, including birds, small mammals, herpetofauna, ungulates, mesocarnivores, and carnivores. Of the more than 150 studies reviewed, a total of 90 studies met systematic review criteria, resulting in 4,937 records of 313 vertebrate species.

Important conclusions from this large review maintain that fire has both positive and negative impacts on wildlife species depending upon the severity of the burn, spatial extent, post-fire structural and compositional elements, and the resulting habitat mosaic. Overall, the impact of fire as a disturbance agent on wildlife habitat and consequently species abundance and density is species-specific. To translate this to specific land management needs, the authors provided detailed tables summarizing published studies and individual species responses from each region in the appendices (Kennedy and Fontaine 2009). The authors also acknowledge where large knowledge gaps existed, illuminating where systematic reviews can work and where limited data exist for a systematic review methodology. The results of this study and consecutive journal articles (see Fontaine and Kennedy 2012) detail species-specific responses to fire and fire-surrogate treatments. These findings support management decisions by providing information on the effects of disturbance, such as fire and mechanical treatments, on wildlife abundance, density, distribution, and habitats.

Systematic reviews are dependent on available and existing research, so this assessment approach is not possible for all management issues. Where sufficient research does exist, conducting a systematic literature review requires a high level of expertise and a significant investment of resources. This may be more investment than can be expected of land and natural resource managers (Cook et al. 2013, Lowell and Kelly 2016, Murphy and Weiland 2016, Charnley et al. 2017), who typically work near capacity. In these cases, partnering with individuals or organizations that have the capacity and resources to do systematic reviews is necessary to produce meta-analyses that can address relevant management questions.

Utilize Specific and Localized Knowledge Sources for Local Knowledge Gaps

Expert opinion and local and institutional knowledge can provide highly relevant science information for the right questions, although not all sources may meet accuracy or reliability standards based on the USDA Planning Rule definitions. Local and expert knowledge is often place-based and can be helpful to inform both manager and stakeholder learning for locally relevant "status of knowledge" information. Information can be delivered via field trips or workshops with local experts on particular land management issues.

For example, the Deschutes Forest Collaborative, a collaborative stakeholder group working on USFS landscapes in Oregon, enlisted local and expert knowledge to answer stakeholder-developed questions relevant to their local landscape (Waltz, pers. commun., 2017). This USFS landscape included multiple forest vegetation and fire regime types, including frequent fire–adapted ponderosa pine and dry mixed-conifer forests, mesic to wet mixed-conifer forests, and high-elevation spruce fir, where historic fires were infrequent and often high in severity (Simpson 2007). In 2011, the collaborative group developed restoration principles for each forest type, including mixed-conifer forests. Stakeholders had high uncertainty regarding active management in mixed-conifer forests and developed the following questions for the land manager: 1) What defines mixed conifer—how do wet and dry mixed-conifer forests differ? and 2) What are the restoration needs, if any, in all mixed-conifer forests?

The land manager (USFS) enlisted the help of an agency ecologist to develop parameters for identifying dry and wet mixed-conifer forests in the field (Simpson 2007); the local USFS silviculturists planned for field visits that were indicative of both types, with and without active management (e.g., thinning treatments). After field visits, a stakeholder group identified additional data gaps, and a literature review was solicited by a working group of the collaborative. The Nature Conservancy staff took on the task of addressing specific issues using grey and peer-reviewed literature to address the stakeholder questions, producing a literature review internal to the collaborative, but which was developed and reviewed by multiple stakeholders (Waltz & Caligiuri, pers. commun., 2017).

The goal of this process was to increase stakeholder learning on their local forest vegetation type where there were acknowledged gaps. Both stakeholders and USFS managers contributed to the learning, but as science needs increased, stakeholders provided the extra capacity to synthesize available science and produced a final issue paper (Waltz 2017, pers. commun.). The process had a few unintended benefits. First, while it is acknowledged that disagreement can be a driver of specific science needs (Davis et al. 2013), the Deschutes Forest Collaborative stakeholders saw disagreement as an opportunity to work together to synthesize available science and increase the trust in a collaborative process. Second, collaborative stakeholders, like those found in the Deschutes and other funded CFLRPs, often access scientific information primarily from university-based organizations and federal agencies through oral modes of delivery (Colavito 2017). The land managers welcomed the added capacity and access to additional peer-reviewed sources (Caligiuri, pers. commun., 2017).

Local, site-specific assessment may help identify where broad consensus exists for management needs and goals or can identify where gaps or conflict exist that may require BASI with higher levels of accuracy and reliability. For BASI related to implementation needs, institutional knowledge or local knowledge can be highly relevant and applied in best management practices. Guidelines for wildlife mitigation, weather impacts on travel, or operational feasibility are incorporated regularly in land management. Adaptive management is also informed by continued acquisition of local knowledge, traditional ecological knowledge, and expert knowledge and can inform changes in implementation methods or treatment practices. By collecting and assessing place-based science information, BASI users can reduce uncertainty and increase relevance of science-based approaches to land and resource management questions. Collaboratively derived BASI can also meet multiple stakeholder needs, reduce preference bias, and disperse the work of developing and assessing BASI across a group, which eases the burden on managers.

Develop Coalitions for Production of Science Outcomes Relevant to Management and Policy Making

Coproduction of science—the process of developing specific questions, the approach to addressing those questions, and the resulting research, analysis, and application of findings—is being used more frequently as an all-inclusive approach to developing strategies and solutions to large-scale resource and land management issues (Beier et al. 2016). This approach could be further utilized in land and resource management to fill local knowledge gaps and broad, pressing, scientific issues. Additional interaction of researchers and managers helps to ensure that scientific research is relevant to fields of applied science, while also bolstering the usability of research outcomes. Coalitions, such as the Fire Science Consortia, bring scientists and land managers together to identify and prioritize pressing management issues on public lands. Boundary organizations often act as intermediaries, or "knowledge transfer entities," and can interpret and communicate science for a range of users and needs (McNie 2007, Davis et al. 2013). These organizations can be academic institutions or NGOs, such as the Climate Impacts Group at University of Washington, or advisory committees or commissions, such as the State of Washington Climate Advisory Committee, formed to address a specific issue. Coproduction of science, through collaboration or partnership, with individual researchers or boundary organizations, provides managers with an opportunity to provide input on what science information will be most helpful in addressing management issues, ultimately leading to actionable science outcomes.

Conclusion

Scientific research provides the baseline information that land and resource managers and policy makers consider in natural resource–management decision-making (Doremus 2004, Jennings and Hall 2011, Biber 2012, Lowell and Kelly 2016). Use of best available science information by public land managers is required, but agency guidance can be vague and difficult to apply in practice. Multiple potential information sources of varying quality contribute to confusion in finding and applying appropriate BASI, and determining objectively "best" science can require rigorous methodology and capacity that is beyond most BASI users. Embracing variation in BASI sources and looking beyond the traditional peer-review sources for additional science expertise and resources can provide a wider range of science information options and additional flexibility for land managers. BASI requirements that incorporate the management context and resource management questions can make land management use of BASI more accessible and defendable for both managers and collaborative stakeholders.

Supplementary Materials

Supplementary data are available at *Journal of Forestry* online.

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