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Review

Evaluating the best available *social* science for natural resource management decision-making

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ABSTRACT

Increasing recognition of the human dimensions of natural resource management issues, and of social and ecological sustainability and resilience as being inter-related, highlights the importance of applying social science to natural resource management decision-making. Moreover, a number of laws and regulations require natural resource management agencies to consider the "best available science" (BAS) when making decisions, including social science. Yet rarely do these laws and regulations define or identify standards for BAS, and those who have tried to fill the gap have done so from the standpoint of best available natural science. This paper proposes evaluative criteria for best available social science (BASS), explaining why a broader set of criteria than those used for natural science is needed. Although the natural and social sciences share many of the same evaluative criteria for BAS, they also exhibit some differences, especially where qualitative social science is concerned. Thus we argue that the evaluative criteria for BAS should expand to include those associated with diverse social science disciplines, particularly the qualitative social sciences. We provide one example from the USA of how a federal agency − the U.S. Forest Service − has attempted to incorporate BASS in responding to its BAS mandate associated with the national forest planning process, drawing on different types of scientific information and in light of these criteria. Greater attention to including BASS in natural resource management decision-making can contribute to better, more equitable, and more defensible management decisions and policies.

1. Introduction

The science relevant to natural resource management is increasingly being produced using sustainability science, social-ecological systems, and resilience thinking frameworks and approaches (Bettencourt and Kaur, 2011; Clark, 2007; Folke, 2006). These approaches recognize social and ecological sustainability and resilience as being inter-related, highlighting the importance of including social science in natural resource management decision-making. Social science can help natural resource managers (1) identify and evaluate social as well as ecological tradeoffs associated with different management options; (2) make decisions that are better for the environment *and* human well-being, given that social-ecological systems are integrated and influence one another (Liu et al., 2015); (3) make decisions that are more appropriate

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to a particular social-ecological setting; and (4) obtain information from a broad, scientifically-based sample of people to better anticipate variation in their interests, and in the effects of management decisions on human communities. Making available the best social science possible and using it in decision-making is critical for improving the credibility, defensibility, and social acceptability of management decisions, and may improve compliance with them, reducing enforcement costs. Using best available social science (BASS) in decision-making may also be a legal requirement.

Numerous laws and regulations in the USA direct natural resource managers to consider the "best available science" (BAS) in decision-making. These include the Endangered Species Act of 1973 (Section 4 [b][1][A]), the Magnuson-Stevens Fishery Conservation and Management Act of 1976 (Section 301 [a][2]), the Marine Mammal Protection Act of 1972 (Section 101 (3)(a)), and the 2012 Forest Service Planning Rule (36 CFR 219.3). Natural resources-related legislation in other countries, such as Australia (Ryder et al., 2010) and the United Kingdom (Jones, 2012) contains similar direction, as do laws in several American states (Bisbal, 2002; Francis et al., 2005; Mills et al., 2009; Murphy and Weiland, 2016). Yet rarely do these laws and regulations define or identify standards for BAS (Biber, 2012; Gerlach et al., 2013; Glicksman, 2008; Sullivan et al., 2006).

To the extent that scholars have tried to fill this gap, they have done so from the standpoint of best available *natural* science, perhaps because the role of BAS in implementing the Endangered Species Act has received so much attention (e.g., Corn et al., 2013; Doremus, 2004; Lowell and Kelly, 2016; Murphy and Weiland, 2016). Most BAS literature acknowledges the social world as a source of politics that influence management decisions (Lowell and Kelly, 2016), of economic interests vested in natural resources and their management, of social values that define management goals (Sullivan et al., 2006), and as an influence on what is accepted as BAS and its interpretation (Carolan, 2008; Ryder et al., 2010). But rarely has social science (apart from economics) been integrated into BAS definitions or endeavors to inform natural resource management decisions by agencies (Ounanian et al., 2013; Sharp and Lach, 2003); this is particularly true for qualitative social science.

For example, the Magnuson–Stevens Fishery Conservation and Management Act of 1976 is the overarching law governing fisheries management in the USA, and calls for use of the best scientific information available while allowing for eight Regional Fishery Management Councils to be responsible for overseeing fisheries management in federal waters. Each Council is advised by a Scientific and Statistical Committee (SSC). These committees are comprised of scientists internal and external to the National Marine Fisheries Service who review all scientific information brought forward to inform fisheries management, and serve as arbiters of scientific quality. However, the SSCs have lacked sufficient social science capacity, historically including one or two economists as committee members, and rarely including other social scientists as members or advisors to members. The economists are charged with leading reviews of research from all social science disciplines pertaining to fishing communities, and determining what to include as BAS − but often lack expertise to evaluate non-economic social science, especially qualitative data and analyses. This situation makes it difficult to include all of the best available social science in management decision-making by the Regional Councils and the National Marine Fisheries Service.

In lieu of such avenues for presenting BASS to decision-makers, social perspectives are usually considered through public debate, public engagement, collaboration, or formal consultation processes. Although such processes generate information to inform decision-making, they are not grounded in scientific methods, and the information produced cannot be considered scientific, though some exceptions exist (Gregory et al., 2012). Thus, the purpose of this paper is to define and propose evaluative criteria for "best available social science" (BASS). We explore whether and how these criteria differ from those identified in the literature for the best available (natural) science. We find that evaluative criteria for BASS are consistent with many of those that have been articulated for BAS, but that they also exhibit some differences, especially for qualitative social science. We believe that BASS deserves more emphasis in natural resource management decision-making, and that the evaluative criteria for BAS should expand to include those associated with the full range of social sciences, especially qualitative social science.

Ryder et al. (2010) note that BAS 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. Other authors have written about the nature of science generally (e.g., Sullivan et al., 2006). We focus on what constitutes social science and how to assess BASS, acknowledging that there may not be one objective way of evaluating which social science findings are best. We highlight areas of commonality and contrast with existing evaluative criteria for BAS, drawing special attention to qualitative methods and data, which may be more challenging than quantitative methods and data for managers – and courts – to evaluate and use. We also describe how one federal agency in the USA – the U.S. Forest Service – has responded to its BAS mandate to illustrate how it is attempting to incorporate BASS in natural resource management decision-making. We conclude by arguing for a broader set of criteria for evaluating BAS. By articulating evaluative criteria for BASS, we hope to contribute to better, more equitable, and more legally-defensible natural resource management decisions and policies.

2. Social science

The social sciences, like the natural sciences, comprise a diversity of disciplines, including anthropology, economics, human geography, political science, psychology, and sociology. Each discipline adopts a different set of assumptions that influence the way questions are asked, the elements of society examined, and choice of research methods (Crotty, 1998; Moon and Blackman, 2014). Social scientists employ a wide range of methodological approaches (e.g., experimental, observational, and synthetic), use both qualitative and quantitative methods for data collection and analysis, and commonly combine these in mixed-methods approaches (Table 1) (Bennett et al., 2017; Bernard, 2006; Cox, 2015; Patton, 2015).

One difference between the social and natural sciences lies in how social and natural scientists approach science. Moon and Blackman (2014) identify three arenas for comparison: ontology (the nature of reality), epistemology (the nature of knowledge and means by which that knowledge comes to be known), and philosophical perspective (a set of assumptions that guide the approach to research and drive the way research is conducted). Natural scientists primarily draw upon a realist ontology (only one reality exists), an objectivist epistemology (facts about objects of study can be gathered by scientists without influencing the facts collected), and a positivist or post-positivist[1] philosophical perspective (generalizable knowledge, or truth, is acquired through unprejudiced use of the deductive scientific method). Some social scientists also share these ontological, epistemological, and philosophical approaches. For example, some anthropologists observe, record and quantify human activities in order to test hypotheses about particular environmental and social conditions that drive human behaviors involving natural resource use, seeking to predict and model these behaviors more broadly (e.g., Mulder and Caro, 1985; Paolisso and Hames, 2010; Smith, 1983). In doing so, they may draw on some of

[1] Post-positivism recognizes that some personal judgment may be unavoidable; that proving causality with certainty may not be possible although some explanations are more plausible than others; and that all methods are imperfect, so multiple methods are needed to improve understanding of how the world works and to identify valid beliefs (Moon and Blackman, 2014; Patton, 2015).

Table 1
Primary social science disciplines and a selection of common methods for data gathering and analysis.

Discipline	Focus of Study	Data gathering methods (Quantitative)	Analysis Methods (Quantitative)	Data gathering methods (Qualitative)	Analysis Methods (Qualitative)
Anthropology	Humans and their culture, both past and present	Surveys, behavioral observation, secondary data gathering	Statistical analysis, social network analysis, geographic information systems (GIS)	Ethnography, participant observation, interviews, visual methods, archival research, focus groups	Coding, discourse analysis, thick description, qualitative modeling
Economics	How people make decisions about resource allocation & implications for society	Behavioral experiments, surveys, secondary data gathering, mathematical programming	Econometrics, computer modeling, statistical analysis, behavioral modeling, economic valuation		
Human Geography	Interactions between people and their environments	Surveys, secondary data gathering	Statistical analysis, GIS, qualitative comparative analysis	Ethnography, participant observation, interviews, archival research, participatory mapping & GIS	Coding, content analysis, qualitative modeling
Political Science	The structure, distribution and exercise of power	Surveys, experiments	Statistical analysis, modeling	Interviews, ethnography	Coding, content analysis
Psychology	Mental and behavioral characteristics of individuals and groups	Controlled experiments, surveys	Statistical analysis	Focus groups, structured experiments, interviews, observations	Coding, content analysis
Sociology	Social life and institutions	Surveys, secondary data gathering, longitudinal studies	Statistical analysis, social network analysis, qualitative comparative analysis	Archival research, interviews, some ethnography, focus groups, participant observation	Coding, content analysis, qualitative modeling

the same methodological and philosophical approaches used by natural scientists.

Others, however, draw upon different ontologies (e.g., relativism – multiple realities exist); epistemologies (e.g., constructionism – scientists are not wholly separate from the object of study, so facts are shaped, or *constructed*, by the scientific process); and philosophical perspectives (e.g., interpretivism – deductive scientific methods do not produce universal knowledge; all data and interpretation are contextual; and history and culture influence how information is interpreted, and meaning produced). Moon and Blackman (2014: 3) describe this spectrum of social science approaches as ranging from “knowledge acquisition is deductive, value-free, and generalizable” (compatible with natural sciences), to “knowledge acquisition is inductive, value-laden, and contextually unique” (quite distinct from natural sciences). Economics, political science, psychology, and sociology often employ a research approach based on positivism or post-positivism, although the full spectrum of approaches can be found in any of them; anthropology and human geography commonly encompass a more diverse set of approaches.

In contrast to most natural science disciplines, the social sciences also often make use of qualitative data, methods, and analytical tools, though the emphasis varies by discipline, sub-discipline, project, and practitioner (Table 1). Qualitative approaches examine the qualities and behavior of things or events in their natural settings, rather than measuring their frequency or magnitude. They explore the world of lived experience, ideas, and symbolic meanings. They also describe variation in social and cultural phenomena (e.g., people’s responses to environmental change; attitudes, beliefs, and values associated with natural resources and their management). Qualitative approaches do not seek a single or generalizable truth, but rather uncover multiple perspectives and interpretations. They enhance understanding of how social processes work, and how specific contexts are generative of specific outcomes. They can provide a basis for developing theory, and be a valuable part of mixed-methods approaches by improving the validity of quantitative methods (e.g., surveys), or offering insight regarding the variables that underlie quantitative data results. They can also provide an initial characterization or classification of topics that are new or poorly studied, and meaningful data when research findings or generalizations are too broad to be useful. Table 1S (Supplementary material) describes several common qualitative methods, their purpose, and the kinds of data they generate. For a thorough presentation of qualitative methods see Patton (2015) and Bernard (2006); for a detailed description of methods employed in the environmental and conservation-related social sciences, see Bennett et al. (2017) and Cox (2015).

3. Best available social science

Regarding *best* available science, Bisbal (2002) (working in the context of salmonid recovery in the Columbia River Basin) identifies three categories of information that may be considered as BAS: “scientific information”, “suggestive information”, and “supplementary information”. All three fall under the umbrella of science, though the terms may suggest otherwise. We adopt Bisbal’s framework because it is helpful for understanding different types of social science information and its potential use as BASS. *Available* science typically refers to that which already exists at the time a natural resource management decision process is initiated, recognizing that the information may need to be further synthesized or interpreted to make it usable by decision-makers. Available science may also include any additional scientific information that can feasibly be generated during a decision-making process (Nylen, 2011). Inherent in the concept of available science is that it is physically and conceptually accessible to the user, and directly relevant to a management issue of concern (Ryder et al., 2010). Inclusion of the term “available” in legal and regulatory language about BAS protects agencies from having to develop new

Table 2
Comparison of best available science and best qualitative social science evaluative criteria during three stages of the research process[a].

Phase 1: Research Design and Data Collection Best Science	Best Qualitative Social Science
• Clear statement of objectives • Adheres to well-established scientific process • Thorough review of literature and other relevant information • Inquiry grounded in observation and deductive hypothesis testing about the basic principles that underlie cause and effect relationships • Standardized methods for data collection • Experimental research design • There are standards for controlling the operation of the technique • Replication and repetition occur or are possible to verify results • Data gathered are objective, value-free • Addresses policy-relevant questions Sources: Bisbal (2002), Cook et al. (2013), Corn et al. (2013), Doremus (2004), Holland (2008), Lowell and Kelly (2016), Murphy and Weiland (2016), Sullivan et al. (2006), Van Cleve et al. (2004) and Wolters et al. (2016)	• Clear research purpose and questions • Justification of why chosen methods and research design (including sampling approach) are appropriate to the research questions • Relevant literature reviewed • Sufficient and appropriate theoretical constructs guide inquiry • Adequate data are gathered to identify thematic patterns and achieve saturation • Variety in types of evidence gathered; evidence comes from multiple sources • Contradictory evidence or cases are sought for comparison to understand complexity of the topic • Research conducted in a manner sensitive to the social and cultural context in which it occurs, and in an ethical manner • The research topic is relevant, timely, significant Sources: Cohen and Crabtree (2008), Elliott et al. (1999), Freeman et al. (2007), Kitto et al. (2008), Malterud (2001), Morrow (2005), Tracy (2010) and Whittemore et al. (2001)
Phase 2: Data Analysis and Interpretation • Sound logic and rigorous statistical methods used for analyzing and interpreting data and making inferences from samples • A conceptual model provides a framework for characterizing system relationships, testing hypotheses, making predictions • Other analytical models used, as appropriate Sources: Corn et al. (2013), Doremus (2004), Glicksman (2008), Joly et al. (2010), Murphy and Weiland (2016), Sullivan et al. (2006) and Van Cleve et al. (2004)	• An analytical or theoretical framework is articulated for making sense of the data • Data immersion is sufficient for understanding and providing a meaningful account of the diverse experiences, perspectives and understandings of reality that people hold • Researcher critically appraises alternative explanations, hypotheses, biases, and personal interpretations • Researcher takes steps to ensure rigor of observations and data interpretation so that they accurately reflect the meanings and experiences of research participants and the research context (e.g., triangulation, debriefing to peers, checking data and its interpretation with research participants, considering negative cases) Sources: Cohen and Crabtree (2008), Elliott et al. (1999), Malterud (2001), Morrow (2005) and Whittemore et al. (2001)
Phase 3: Data Representation in Final Products • Values and assumptions underlying the research are made explicit • Conclusions are well supported by the data • Data and information limitations, sampling biases, scientific uncertainties, known or potential rates of error are disclosed • Clear documentation of methods, results, and conclusions to provide transparency • Findings communicated in a manner that is accessible and understandable • Findings published in peer-reviewed outlets • Impact factor or stature of scientific journal in which research is published • Research is perceived as legitimate (ie, politically unbiased) Sources: Doremus (2004), Holland (2008), Lowell and Kelly (2016), Murphy and Weiland (2016), Nylen (2011), Sullivan et al. (2006) and Van Cleve et al. (2004)	• Researcher is self-reflexive about his/her values, assumptions, biases, and limitations and their potential influence on the research • Data collection techniques clearly documented, data analysis methods transparent • Multiple voices are reported to provide a meaningful account of the diverse perspectives and understandings that people hold • Writing combines researcher's interpretations and supporting quotes from participants; provides rich and evocative description, including examples, to help reader experience and understand the phenomena described • Writing is clear and coherent • Literature, research questions, methods, and findings are coherent and connected to each other in a meaningful way; research accomplishes its purpose • Ethical considerations in sharing research results are taken into account • Findings are published in peer-reviewed outlets • Research contributes to theory/scholarship, has practical application, and has value in other settings (transferability), which are specified Sources: Cohen and Crabtree (2008), Elliott et al. (1999), Freeman et al. (2007), Kitto et al. (2008), Malterud (2001), Morrow (2005), Tracy (2010) and Whittemore et al. (2001)

[a] Based on the published literature; each criterion was included in at least two sources. Not all criteria necessarily apply to all studies, depending on context.

and better science when existing science is lacking, insufficient, or inconclusive, which would prolong decision-making processes (Joly et al., 2010).

3.1. *Scientific information*

Scientific information is produced using the scientific process to understand principles governing cause and effect relationships (why and how things work) (Bisbal, 2002). Scientific information serves as the foundation for BASS. Other authors have articulated definitions and criteria associated with different stages of the research process for evaluating the best scientific information to use in providing BAS for natural resource management (Table 2, see also Ryder et al., 2010). Commonly cited criteria are: policy relevance; inquiry grounded in deductive hypothesis testing using standardized, well-documented, replicable methods; objectivity; use of analytical models; statistical analysis of results; disclosure of uncertainties and data limitations; and publication in peer-reviewed outlets. In general, social science that adopts a positivist or post-positivist approach and uses quantitative methods can be evaluated according to these best science criteria. Several of these criteria also apply to qualitative social science (Table 2), i.e., relevant topic; study design, methods, and data analysis meet standards of scientific rigor (as appropriate to the discipline) and are well-documented; use of analytical models; and research is published in peer-reviewed outlets. However, evaluative criteria for BAS that have been articulated to date in the literature do not apply to the full breadth of social science that is useful for natural resource management decision-making.

In particular, existing criteria for evaluating BAS are somewhat limited when applied to qualitative methods and data. This is so whether the approach to data collection and analysis is what is known as ‘etic’ or ‘emic’ (Kottak, 2006). The former refers to investigations based on theoretical frameworks and classifications developed by the social scientist as outside observer, and may be more generally applied across cultures or cases for comparative analysis. The latter refers to frameworks and classifications generated by the social group being studied, representing the insider perspective. Regardless of approach, the risk in not broadening BAS criteria is that scientific information that has not been developed through deductive hypothesis testing, controlled experiments, statistical analysis, modelling, or that conforms to other natural science standards may be discounted.

Criteria for evaluating the quality of qualitative research have been developed in the social sciences as well as in the fields of medicine and education. Although these may vary among qualitative research approaches and evolve over time, common criteria associated with different stages of the research process (which may be iterative) include elements not mentioned in existing BAS frameworks (Table 2). For example, in the research design and data collection phase, evaluating methodological rigor includes seeking appropriate justification for the selection of samples (rarely random), sample size (not standardized), research sites, and/or information sources. How were research sites (as exemplars of the phenomena in question) selected? Are persons interviewed legitimate holders of local knowledge (e.g., locally-recognized experts), or do they embody a unique perspective due to their position or history in a group? It is important to gather sufficient data to identify key themes, patterns, and achieve sampling saturation (when data gathering ceases to reveal new information). For instance, when conducting interviews, it has been found that the full range of thinking on a topic tends to plateau after approximately 30 interviews; thereafter similar ideas tend to be repeated and relatively few new ideas emerge (Morgan et al., 2002). It is also important to collect data that represent multiple perspectives and come from multiple sources, including contradictory evidence. "Against-the-grain" or non-conventional examples or data sources ensure as full a range of perspectives as possible. Deductive hypothesis testing is not emphasized; "grounded theory" approaches, whereby theory about a phenomenon under study is built inductively by developing and revising hypotheses during the research process through iterative data collection and analysis during fieldwork – to ground it in the real world – is common (Corbin and Strauss, 2015).

Evaluating quality of data analysis and interpretation depends on the data collection approach. Qualitative data analysis often requires sorting or coding information into ideas and categories. Best practice involves two or more researchers coding the same material to ensure consistency (Bernard, 2006). Coding can be done using a priori (deductive) coding schemes (e.g., a scheme that is etic, where the categories of analysis are derived from theories generated outside or beyond the research site or group itself). When an a priori coding scheme is used, it should be explicitly disclosed and justified. When coding is conducted in an emic or inductive fashion, the organization of categories is such that the ideas are grounded in the language and constructs that people use, or in reference to the context or site studied. Analysis then proceeds using a variety of potential strategies to identify patterns, themes, and relations in the data, and commonalities and differences across a range of perspectives; and to gradually develop generalizations that are related to a body of knowledge or theory (see Corbin and Strauss, 2015; Miles and Huberman, 1994). The researcher typically uses an analytical framework to guide this process.

During data analysis and interpretation, it is important to ensure that interpretation accurately reflects the meanings and experiences of study participants, and has been checked using methods such as triangulation or obtaining feedback from participants. This step helps ensure internal validity – i.e., the researcher's interpretation of a causal relationship reflects as accurately as possible a causal relationship that exists between two or more variables (Cox, 2015). Internal validity may also be demonstrated through the use of counterfactuals (i.e., if event A had not occurred, would linked event B still have occurred?); or, a theoretical/mechanistic explanation of why a particular causal relationship occurs, taking into account possible alternative explanations (Cox, 2015).

There is wide variation across the social sciences in data representation at the stage of writing. Approaches range from strongly narrative framing of evidence with a distinct literary signature, to highly didactic reporting with clear distinctions between data and findings. To some extent, this variation results from different disciplinary or journal conventions, or target audiences. Clear, richly descriptive, evocative writing to help the reader understand the phenomena under study is often important. While the final form of research outputs varies across social science disciplines, the quality of these outputs can be assessed by evaluating to what extent the wording and interpretation are supported by the data and the analysis. Clear evidence should be provided, whether through supportive quotes from interviews, examples, qualitative comparative analysis, or qualitative models. It is important for the researcher to be self-reflexive, acknowledging personal or cultural values, biases, and agendas that may have influenced the research process. Because social science research is about people, sensitivity to the social and cultural context in which it occurs, and ethical conduct to protect human subjects throughout the research process, should be evident. Additionally, it is important to assess the external validity of research findings – that is, the degree to which they may be applicable and transferable to settings beyond the study area.

3.2. Suggestive information

Suggestive information consists of empirical data, detailed observations, outputs from modelling or other simulation exercises, and estimates that are gathered using scientific methods (which should be clearly articulated and evaluated for their scientific rigor), that can contribute substantively to the knowledge base (Bisbal, 2002). Unlike scientific information, however, it does not explain cause-effect relationships or offer in-depth understanding of complex interactions and processes. It is often used when there is insufficient scientific information relevant to a particular management question (Glicksman, 2008). Often suggestive information is quantitative, but it may also be qualitative. Examples are inventory and monitoring data (e.g., the US Census of Population and Housing, annual number of recreation visitors to a national forest); indicator measurements (e.g., the number of people having commercial fishing licenses); modelling outputs (e.g., projections of the production of goods and services under different forest management options, predictions of future population growth); and some archival data (e.g., written descriptions by past agency personnel documenting historic natural resource use practices of a Native American tribe). Although such information may be available and accessible, alone it often fails to answer scientific questions or exist at relevant scales for informing management decisions. Social data should not be conflated with social science ("scientific information"). Social science requires sufficient human and other resources to rigorously analyze, synthesize, and interpret suggestive data; or, sufficient resources to collect original data using scientific methods. Nevertheless, suggestive information may "suggest" priorities for future scientific research (Bisbal, 2002) and can be used by social scientists to build and test hypotheses or to develop research approaches that inform natural resource management, resulting in scientific information (see for example Colburn and Jepson, 2012; Cutter et al., 2003).

3.3. Supplementary information

Supplementary information is that which does not fall into the "scientific" or "suggestive" categories, and is generally used when both are scant, but management decisions must nevertheless be made (Bisbal, 2002; Martin et al., 2012). The main type is "expert opinion" or "expert knowledge". Expert knowledge has been defined as "substantive information on a particular topic that is not widely known by others" (Martin et al., 2012: 30). Expert judgment is when experts make predictions based on their knowledge about what may happen in a given situation (Martin et al., 2012). Experts gain knowledge through personal experience, training, research, and skill development; their expertise is legitimized by factors such as their background, accomplishments, publication record, reputation among peers, and ability to communicate effectively (Bisbal 2002; Martin et al., 2012; Wolters et al., 2016). Examples in which the expert knowledge of social scientists was used for natural resource management decision-making are scant in the literature. Although evaluative criteria for assessing the quality of supplementary information arising from expert knowledge and opinion are not generally applied, Martin et al. (2012) developed one approach for eliciting this information and associated criteria for assessing the elicitation process in order to evaluate the rigor with which it was obtained, minimize bias, and improve its scientific accuracy.

3.4. Traditional and local ecological knowledge

Bisbal (2002) considers traditional and local ecological knowledge as supplementary information; we disagree that traditional and local ecological knowledge *a priori* fall into the "supplementary information" category. Instead, this knowledge can be scientific, suggestive, or supplementary, depending on how it was acquired and the content. It is also not an information source of last resort when others are limited; traditional and local ecological knowledge can provide a rich source of scientific information to consider in any best available natural or social science effort.

Traditional ecological knowledge (TEK) constitutes a body of knowledge and insight about species or ecosystems that has developed through engagement with the environment in specific places and been transferred over multiple generations (Berkes et al., 2000; Huntington, 2000). Like TEK, local ecological knowledge (LEK) includes knowledge regarding species or ecosystems that is gained through extensive personal observation of and interaction with local ecosystems, and is shared; but it is more recent (Charnley et al., 2007). These unique forms of knowledge are not simply "anecdotal", but rather can provide valuable ecological information based on long-term observations of and interactions with natural resources for which there may be no other long-term data sets. TEK and LEK are fundamentally tied to the place-based individuals and communities who hold and transmit this knowledge, and as such, are often excluded from BASS that seeks to generalize information for wider application. There are many methods (both quantitative and qualitative) for producing robust and reliable information about TEK and LEK; this information should be subjected to the same standards for BASS as information on other topics, depending on which of the three categories (scientific, suggestive, supplementary) it falls under.

The most useful integration of TEK and LEK into BASS is likely to occur through collaborations between conventional scientists, natural resource managers, and TEK/LEK knowledge holders in which the latter are included at the start of the process, and are treated as equal participants in the effort. Although it may take considerable time to build relationships of trust, expertise to navigate cultural differences, and a willingness to transform standard practices of collecting BASS, the potential outcome is likely to be more equitable and inclusive science-based management. There are several examples of such collaborations in the USA that combine different forms of knowledge for a more complete understanding of natural processes and phenomena (e.g., Beaudreau and Levin, 2014; Finlayson and McCay, 1998; Knapp and Fernandez-Gimenez, 2009; Vellucci, 2007). Of course, the TEK and LEK held by different groups, and western scientific knowledge, may also be quite different or contradictory. Such cases call for collaborative processes to vet differences and find productive ways of moving forward. When attempting to include TEK and LEK as a source of BASS, it is important to recognize that some TEK and LEK is sacred or proprietary; and, that use and engagement with TEK or LEK and its knowledge holders should follow established local protocols for free, prior, and informed consent (c.f. Harding et al., 2012; Williams and Hardison, 2013).

4. BASS at the U.S. Forest Service

The preceding sections have sought to articulate evaluative criteria for BASS used to inform natural resource management decision-making. A related issue is, how might natural resource management agencies seek to incorporate BASS when responding to BAS mandates? Here we provide an example from a federal agency in the USA, the U.S. Forest Service (USFS), in which one of the authors (Charnley) participated, to illustrate one approach. This USFS example entails inter-disciplinary panels of scientists tasked to provide BAS to inform planning and management of national forest lands and occurs prior to the assessment phase of plan revision (not the only model the agency uses).

The USFS manages 154 national forests and 20 national grasslands in 43 states and Puerto Rico, or 78,104,329 ha (193 million acres) of federal land in the USA.[2] The National Forest Management Act of 1976 calls for development of land and resource management plans to guide management of each national forest and grassland, to be revised at least every 15 years. The USFS 2012 National Forest System Land Management Planning rule (36 Code of Federal Regulations Part 219)[3] contains guidance for revising these plans. Section 219.3 of the rule states: "The responsible official shall use the best available scientific information to inform the planning process required by this subpart." Forest Service Handbook FSH 1909.12[4] states that BAS may come from a number of different sources and should be evaluated based on three criteria: accuracy, reliability, and relevance (Table 3).

Following release of the 2012 Planning Rule, eight national forests, including three located in California's southern Sierra Nevada Range became pilots for plan revision under the new rule. At the request of a collaborative group engaged with national forest management in the Sierra Nevada Range, the agency's Pacific Southwest Regional Office and Pacific Southwest Research Station assembled an inter-disciplinary team of mostly internal agency scientists to develop a synthesis of BAS to inform plan revision on these three national forests under the new rule (Long et al., 2015). The team was comprised of 22 scientists, three of whom were social scientists representing different disciplines. Team members were directed to assemble and synthesize peer-reviewed, published literature ("scientific information") relevant to forest management issues of concern in the Sierra Nevada Range. In 2015, a similar effort was initiated in the Pacific Northwest to inform forest plan revision on 17 federal forests located within the range of the Northern Spotted Owl *(Strix occidentalis caurina)* (the Northwest Forest Plan area) (Spies et al. In Review). This science synthesis was requested by USFS regional managers, who identified a long list of questions (including questions relating to social and economic issues) they hoped the synthesis would address. An inter-disciplinary team of mostly internal agency scientists was tasked by the Pacific Northwest Regional Office and Pacific Northwest Research Station of the USFS to synthesis the relevant BAS, with strong emphasis on peer-reviewed, published literature. Of the 10 lead scientists on this team, two were social scientists (anthropologists). Each lead scientist assembled a group of other scientists (internal and external to the agency) to help synthesize the science and coauthor chapters relevant to the specific topics addressed. The purpose of these science synthesis documents is to provide forest managers with a foundation of best available scientific information relating to key topic areas and management issues of interest to inform the forest plan revision process. For social science, these topics include socioeconomic well-being in forest communities and its links to federal forest management, the socioeconomic impacts of forest management actions, human uses of national forests (ranging from timber harvest to recreation), environmental justice implications

[2] https://www.fs.fed.us/about-agency.

[3] Federal Register Vol. 77, No. 68, April 9, 2012, pp. 21162–21276.

[4] Land Management Planning Handbook 2013, Chapter 40–Key Processes Supporting Land Management Planning, Section 42–Use of Best Available Scientific Information to Inform the Land Management Planning Process.

Table 3
Standards for BAS at the US Forest Service.

Accurate	• Scientific information must estimate, identify, or describe the true condition of its subject matter
	• Statistically accurate information is near to the true value of its subject matter, quantitatively unbiased, and free of methodological error
	• Findings are based on supporting evidence that identifies the relative accuracy or uncertainty of the findings
	• Reliable statistical or other scientific methods are used to establish accuracy or uncertainty of the findings
Reliable	• Scientific methods have been applied appropriately
	• Results are consistent with established scientific principles
	• Appropriate study design and well-developed scientific methods are used and clearly described
	• Assumptions, analytical techniques, and conclusions are well referenced
	• Conclusions are based on reasonable assumptions or are logically and reasonably derived from the data
	• Information gaps and inconsistencies with other relevant scientific information are explained
	• Quantitative analysis having known and quantifiable rates of error improves reliability
	• Quality control standards are applied to the scientific information, e.g., peer review or publication in a refereed scientific journal
Relevant	• Information must pertain to the issues under consideration and to the planning area, and be at the appropriate spatial and temporal scales

of forest management, and collaborative processes for forest management.

As a social scientist participating on both teams, Charnley and her social scientist coauthors used the following approach to provide BASS relevant to the issues of concern:

- Assemble, review, and synthesize all relevant "scientific information" from published, peer-reviewed outlets across a range of social science disciplines – including literature using quantitative and qualitative methods, and employing a variety of ontological, epistemological, and philosophical perspectives. None of this literature was excluded owing to a general shortage of relevant publications.
- Where none such information was available, assemble and review information from the gray literature and reference or include it as appropriate, indicating the source.
- Include "suggestive information" when specifically requested or needed (e.g., demographic data, timber harvest data, recreation use data) from sources widely regarded as being the best.
- No "supplementary information" (expert knowledge) was included.
- Include information based on TEK and LEK from the literature where appropriate, or discuss the role that TEK and LEK could play in further informing the forest planning and management process.
- Weigh the research findings from different sources, identify consistencies and contradictions, evaluate what might be reasonably concluded from the evidence.
- Point out uncertainties, limitations, and research gaps associated with the BASS.
- Address transferability of findings.
- Identify management implications based on the BASS synthesis.

The BASS included in the synthesis documents largely met USFS evaluative criteria for BAS, although many qualitative studies were included, which did not undergo quantitative analysis using statistical or quantitative methods.

Before final publication, draft versions of the science synthesis document underwent several rounds of review, including by invited peers internal and external to the USFS; through an external peer review process similar to that undertaken by refereed journals; by interested members of the public, who could both comment and suggest additional science for consideration; and a management and policy review by regional agency leadership. These steps were designed to ensure that all of the pertinent BAS was considered, and the integrity of the final science synthesis publication.

The USFS planning rule states that, "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' (§219.3). To date it is unclear how BASS has been or will be used to inform decision-making because the Sierra Nevada forest plan revision process has not yet been finalized, and the Northwest Forest Plan process has just begun (science synthesis is the first step). However, BASS from the Sierra Nevada science synthesis informed the national forest-level assessments conducted as part of the forest plan revision process, and the associated Environmental Impact Statement. Should a particular management decision arise in the future that generates public concern and for which BASS is needed, the relevant scientific information could be subject to closer scrutiny using the evaluative criteria articulated in Table 2.

5. Conclusions

Increasing recognition of the human dimensions of conservation and natural resource management issues, and of social-ecological system sustainability and resilience as goals of natural resource management, highlights the importance of incorporating social science into natural resource management decision-making. Additionally, a number of laws and regulations require natural resource managers to consider the "best available science" when making decisions, including social science. In this article we have articulated evaluative criteria for BASS, highlighting some of its unique qualities that call for expanding the evaluative criteria set out to date for BAS by those focused on the natural sciences. Although we found that evaluative criteria for BASS and BAS share many elements in common, they also exhibit some differences, especially where qualitative social science is concerned. For example, credibility is an important standard for both; but whereas natural scientists emphasize credibility in the eyes of the scientific community, social scientists also emphasize credibility in the eyes of research participants to ensure that their experience is accurately represented. Natural scientists tend to use an objectivist epistemology, emphasizing the importance of objective, value-free, unbiased science while documenting assumptions, data limitations, and uncertainties. Social scientists often employ a constructionist epistemology, emphasizing the importance of presenting multiple perspectives and voices, and personal reflexivity to acknowledge how researcher biases, assumptions, and experiences may influence the research process. Natural scientists stress deductive hypothesis testing and statistical analysis, which may or may not be undertaken by social scientists who also employ inductive hypothesis testing, or grounded theory, approaches. Thus, our argument is *not* that wholly different evaluative criteria should be applied for best available natural and social science; rather, some criteria used to evaluate BAS will not always be appropriate for evaluating BASS, while other standards not typically applied to BAS may better serve to evaluate BASS. Given this, we argue that the evaluative criteria for BAS should expand to include those associated with diverse social science disciplines, particularly qualitative social science, which existing BAS definitions and criteria have neglected to date.

As Lowell and Kelly (2016) point out, there is a difference between best available science and best use of available science. The best use of available science once it has been produced, synthesized, or compiled and considered by natural resource management agencies may be impeded by lack of institutional capacity to use it effectively (e.g., insufficient staff expertise to interpret and apply it, lack of resources to implement it, short time lines for decision-making) (Cook et al., 2013; Lowell and Kelly, 2016; Murphy and Weiland, 2016). Moreover, managers and policy makers consider many variables, of which science is but one, in natural resource management decision-making (Biber, 2012; Doremus, 2004; Francis et al., 2005; Jennings and Hall, 2011; Karl et al., 2012; Lowell and Kelly, 2016). Ultimately, as in the USFS case described here, social scientists will be tasked with producing BASS to comply with BAS mandates, and will be responsible for finding the "best available" amidst the good and the better. But BASS efforts do not end once the science has been produced or synthesized. More focus is needed on ways to present and transfer BASS to decision-makers to help them use it in a meaningful and ongoing way. Natural resource management has evolved to embrace a philosophy of "nature and people" (Mace, 2014), and this evolution requires greater emphasis on social science in BAS endeavors, and incorporating the full plurality of social science into the science tool chest. In doing so, applying the evaluative criteria we propose here should help ensure that the best available social science is used to inform decision-making about natural resources.

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