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A Mental Model of Science Informed by Public Lands Managers: Increasing the Chances for Management Based on Science

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Abstract: Some federal public lands have been legally protected as "wilderness areas" since 1964 in the US. A federal science program evolved first in response to a novel public lands management concept, and subsequently in response to new issues that emerged both as society changed and more knowledge about social and ecological values of wilderness accumulated. Wilderness science needs have largely been defined by government and cooperating academic scientists through identification of researchable questions which, historically, have centered on science disciplines, wilderness attributes, or threats to these attributes. Analysis of a survey of 368 federal wilderness managers demonstrates how management can inform science. From over 1200 responses, a mental map of research needs, prioritized by the purpose of the research, led to proposal of 5 major strategic science planning dimensions: (1) basic research to understand effects of various threats; (2) integrated research on "big" emerging issues that lend themselves to larger than wilderness issues; (3) applied research to evaluate stewardship effectiveness; (4) applied research to support stewardship tool development and; (5) applied research to support inventory and monitoring. A strategic science plan that identifies targets according to this mental model will increase likelihood of science being used to guide management.

Keywords: Science planning; Wilderness; Manager survey; Sustainable management
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1. Introduction

Sustainable public lands strategic management is not just a biophysical problem. According to Stead and Stead (2003), it could be described as changing how humans view things. In strategic science planning, a shift from a tempting unidimensional, disciplinary definition of priorities to an interdisciplinary, sustainable program to support management could change how we view science needs and, consequently, create long term impacts on stewardship direction and accomplishments. Public lands science planning has mostly focused on answering specific discipline-oriented questions. An alternative approach is to guide research planning with a more complex analysis of the collective purpose of multi-discipline research topics. Stead and Stead (2003) have made the argument that sustainability requires a change in our underlying mental frameworks that guide

human perceptions of the planet and our place in it. In sustainability science, these mental frameworks extend beyond truth and falsehood; they should define the relationship between humans, society and nature (Stead and Stead 2003).

This paper focuses on a national, interagency effort to obtain input from managers to consider in strategic sustainable planning for research to support the National Wilderness Preservation System (NWPS). What results is a proposed mental model to inform science through better capture of management and planning needs, which is a potentially beneficial shift in conceptualizing the science-management relationship because: (1) despite multiple efforts at wilderness strategic planning, previous plans are believed to have affected management accomplishments of the NWPS only a slight amount over the last 20 years (Ghimire, *et al*. 2015) and; (2) the rapid change in U.S. society and environmental influences, in addition to diminishing natural landscapes and expanding uncertainty about appropriate intervention to address new threats (Dawson *et al*. 2016, Watson *et al*. 2016), has motivated some to suggest a need for reconceptualization of wilderness science in a way that is more visionary (c.f., Chojnacky and Chojnacky 2016). Updating science goals and objectives require identifying today's and tomorrow's most pressing stewardship issues. A Wilderness Manager Survey (WMS) was developed and administered to managers in all four federal agencies that manage the NWPS. The emphasis of this national survey was to have managers think about the most pressing challenges likely to face wilderness stewardship in the future.

This paper next proceeds with a review of the history of wilderness management and science strategic planning. Section three describes methods of the WMS and the unique analysis and evaluation criteria that serve as the foundation of the resulting mental model. In Section four, the results of the analysis are presented, and finally, Section five concludes with a discussion of the benefits of a new mental model that could facilitate a shift in thinking from only the traditional approach of *management based on science* to include one of *science informed by management*.

2. Literature Review:

The History of Wilderness Science Strategic Planning

Our National Wilderness Preservation System, initiated with the Wilderness Act of 1964, has grown from an initial 9.1 million acre system to over 110 million acres in all but 6 states. Mapping wilderness is an exercise in attaching a set of meanings to places protected for their wilderness qualities, as determined by law or policy set by humans. It is not really the mapping of the biophysical environment itself. Carver and Fritz (2016) recently pointed out the challenges of mapping wilderness, since the beginning and ending of 'wilderness' is determined by our perception of a human modification spectrum (most to least modified). In wilderness, we have the dual responsibility of protecting naturalness (in biophysical terms, natural processes, a relatively intact ecosystem) and wildness (the relationship people define and have with wilderness, from most to least influenced by humans). Leopold insisted that a physical place protected for its wilderness character should be big enough to absorb a two weeks' pack trip, and kept devoid of roads, artificial trails, cottages, or other works of man (Leopold 1921). Leopold further described travel in wilderness by pack-train or canoe as 'American as a hickory tree' (Leopold 1949). A low percentage of people today are able to take such pack trips, but that image remains as a representation of our cultural relationship with our wild landscapes. The definition in the Wilderness Act includes some examples of attributes of areas appropriate for wilderness designation, including having outstanding opportunities for solitude or a primitive and unconfined type of recreation, and a place where the imprint of man's work is substantially unnoticeable.

Early wilderness scientists in the US, faced with the task of developing a science program to support the new job of "wilderness manager," were concerned with the post-World War II trend of

increasing recreation visitation to public lands. The Wilderness Act removed many potential threats these lands faced (e.g., roads, mechanized travel, residential development, and some commercial activities) so, as a result, early scientists focused on the remaining threat of human uses to the wilderness landscape. The primary threat to the wilderness landscape at that time was perceived to be recreation use and users (Stankey, *et al*. 1985).

Initially, wilderness management was a de-centralized process and only Forest Service areas, mostly in the West, were designated in the original Wilderness Act. Through the 1970s and 1980s, Congress expanded management responsibilities by adding wilderness across the National Park Service, the Bureau of Land Management and the Fish & Wildlife Service, and distributed them across ecosystem types and regions of the country, leading to new challenges being pursued by wilderness scientists. For example, the role of fire in large western areas of the Forest Service did not have the same history as in newly designated wilderness areas of the National Park Service or in areas closer to population centers in the east. Wilderness science began to address the new issues, such as perceptions of the threat of fire policies on recreation use and users, while maintaining a focus on understanding and testing management models for dealing with density of users in places managed for solitude opportunities and also in places where freedom and spontaneity were valued aspects of the visitor's experience.

2.1 The first wilderness management strategic plan

In 1995, the first wilderness management strategic plan emerged (BLM, *et al*. 1995). This strategic plan considered major challenges and interagency differences and, although it didn't have a specific science component, it set goals that made science needs more broad than previously evident. The goals were distributed across five major elements of the plan: preservation of natural and biological values; management of social values; administrative policy and interagency coordination; training of agency personnel; and public awareness and understanding.

This plan emphasized management of the natural component of wilderness conditions, in an era shortly following extreme turmoil over fire policies. In 1988 and immediately after the Yellowstone National Park fires, where large areas of the West burned out of control as a result of many decades of artificially manipulating natural conditions through fire suppression, restoration of natural process was widely discussed. Studies of the threat of fire, or fire suppression, to wilderness and parks had turned to larger studies of the attitudes toward fire of the general and regional populations (c.f. Manfredo, *et al*. 1990).

With this new shift in focus, several specific objectives highlighted the need for an expanded science program and shifting of priorities. For instance, the plan called for: inventory of wilderness ecosystems to collect baseline biophysical data; identification of indicators and development of monitoring standards for those elements critical to ecological integrity; development of monitoring strategies for high priority indicators and feedback for adaptive management; and where appropriate, establishment of long-term research programs. The plan further prescribed restoration of wilderness ecosystems through restoring fire to its natural role, prevention and elimination of exotic plants and animals, and retiring nonconforming use rights. Wilderness research responded by increasing allocations of funds to understand barriers to fire restoration, developing a monitoring strategy focused on understanding threats to wilderness character, and more studies to document baseline conditions on a more diverse system, across agencies, regions and ecosystems. ANILCA (the Alaska National Interest Lands Conservation Act), which passed in 1980, had extended protection to what is still about half of our entire National Wilderness Preservation System today in Alaska, where we had very little baseline information on resource conditions, use and users. Legislation in the mid-1970s had been focused on guiding more wilderness designation in the Eastern US, too, where restoration was needed, in addition to unique protection challenges.

Of course this strategic plan also reinforced several basic human values articulated in the Wilderness Act and heavily studied in the early years of wilderness science, with some implications for continued social science to provide desired social experience attributes. The plan acknowledged the need to protect spiritual and psychological values, and guarantee opportunities for solitude and primitive recreation in areas retaining their primeval character and influence.

In the area of administrative policy and interagency coordination, new science priorities were not introduced, though new methods of operation were certainly suggested. The plan emphasized the need for agencies to work together to efficiently manage the increasingly diverse National Wilderness Preservation System. Among other things, the agencies resolved to identify and coordinate research priorities for the Aldo Leopold Wilderness Research Institute, an interagency research unit created in 1993 and hosted by the Forest Service, and expand the emphasis of research to now more equally balance focus on natural and biological wilderness resources with psychological and social values.

Within the goals for increasing public awareness and understanding of wilderness, the agencies acknowledged that they had mostly focused on training wilderness visitors in low-impact camping techniques and user ethics, as well as conducting research to support these programs. Wilderness education needed to expand beyond instructing visitors to build a shared understanding of the role and value of wilderness to society. The wilderness message also needed to reach a broader spectrum of the American public. To accomplish this, the plan implied the need for research to help managers evaluate wilderness education programs to determine their effectiveness and identify strategies to communicate wilderness education messages to diverse cultural, geographical, and sociological groups, including non-recreation users. More research to evaluate visitor education programs and expand our understanding of who benefits from wilderness and how they benefit was encouraged, funded and accomplished over the next few years.

In an effort to evaluate success in accomplishing the objectives stated in the 1995 Strategic Plan, a 2014 survey found that nation-wide, wilderness managers rated accomplishment of preservation values at just under a moderate level of accomplishment (1.86 average on a scale of 0 = no accomplishment, 1 = slight accomplishment, 2 = moderate accomplishment, 3 = high accomplishment and 4 = very high accomplishment), management of social values also at just under a moderate level (average 1.78), as was administrative goals (average 1.86) and public awareness and understanding (average 1.77) (Ghimire, *et al*., 2015). Only the goal of training agency personnel exceeded the moderate level at 2.08.

2.2 The second effort at wilderness management strategic planning

In 2001, the agencies commissioned the Pinchot Institute for Conservation to investigate the effectiveness of implementation of the 1995 management strategic plan. While little evaluative content was included in this report, it did newly emphasize the term wilderness stewardship, rather than wilderness management, with stewardship implying working with Nature to perpetuate wilderness for the future (Pinchot Institute for Conservation 2001).

Members of the panel invited input from federal employees at all levels including wilderness managers in the field. They heard from a broad spectrum of interest groups, including those who oppose wilderness designation altogether. They concluded that stewardship must be science informed, as well as logically planned, and publicly transparent. They pointed out that science should inform wilderness stewardship as we learn more about ecological systems, individual species and their habitats, human behavior, and the successes and failures of various policies and management activities in the past. They emphasized that science can help us understand the nature of the system for which we are a steward. It can help both in learning how to correct human-caused perturbations in such systems and understanding how systems might be used and enjoyed without

destroying them. It can also help in understanding how valuable wilderness is to people and how it might enhance their lives.

This panel suggested many advantages of having a comprehensive science program to support wilderness stewardship. To be effective in stewardship activities, an understanding of the object of stewardship is necessary, and science can help in this process by uncovering the nature of the resource and the processes by which it operates. Science also can aid in understanding the perceptions and behaviors of those who use and care about the resource and how they might impact it. A strong science program should underpin our principles for stewardship and decisions that are made about appropriate policies, regulations, management actions, and other stewardship tools. Science should be a major tool in informing stewards about the state of the system and what might or might not be done, but it is not the only source of relevant information.

2.3 A wilderness science evaluation

In 2007, a panel was convened to evaluate only the wilderness science part of this wilderness stewardship responsibility. It was noted by the evaluators that only the Forest Service had wilderness research responsibilities and the Leopold Institute, in particular, was chartered for interagency purposes (Turner, *et al*. 2007). This panel of experts noted that although the FS, across many research units in the organization, had been conducting wilderness-related research for many years, there was no defined and operational wilderness research program in FS Research and Development other than the Aldo Leopold Wilderness Research Institute (ALWRI). The ALWRI was chartered to develop and disseminate knowledge to improve the understanding and management of wilderness, parks and similarly protected areas.

Nationally, they noted there was no compelling, clearly articulated vision for a wilderness research program that included other research units or more broad research issues, and thus no Service-wide mechanism for setting a wilderness research agenda at the time. The panel strongly supported development of a recognizable wilderness research program within FS Research and Development. This never occurred.

This panel felt that FS R&D leadership generally employs a narrow definition of wilderness research that emphasizes social aspects of wilderness and the definition and characterization of wilderness qualities. The external review panel recommended a broader scope for a national FS wilderness research program and offered specific recommendations for development and implementation of such a program.

They recommended that the FS create a crosscutting Wilderness Research Program Area that includes three complementary research components (Parsons 2007). Leopold (1966) had also talked of wilderness as having three complementary components: wilderness for recreation, wilderness for science, and wilderness for wildlife. This panel, however, advocated a science program focused on science for wilderness, wilderness for science, and wilderness for landscape sustainability. This panel emphasized that wilderness managers in the wilderness management agencies did not currently have a mechanism for providing input into wilderness R&D research priorities.

3. Methods: Obtaining Manager Input to Wilderness Science Strategic Planning

Research about wilderness has mostly been case studies on specific units or repeat studies at different places about individual management issues. Limited research has been conducted on stewardship and management of the entire NWPS. The Wilderness Manager Survey (WMS) was developed in 2014 (Ghimire, *et al*. 2015). This paper presents new results from analysis of data obtained through that part of the WMS focused on science information needed for stewardship. A

series of open-ended questions were asked about research needs for decision-making. Both the WMS instrument and its administration were managed on-line through Survey Monkey (www.surveymonkey.com) (Ghimire, *et al*. 2015).

Survey administration of the WMS included managers across the entire NWPS. However, implementation was hampered by not knowing the actual number of wilderness managers (survey population) nor having up-to-date identification of specific employees assigned wilderness management duties. Requests to NWPS managers to participate in the survey were sent by each of the four agencies to their respective field, regional, and national offices. Wilderness managers were broadly defined as those having responsibility in law enforcement, public information, resource and visitor management, planning and policy. Summary descriptive analysis of completed surveys was completed by the research team and reported by Ghimire *et al*. (2015).

For this article, analysis is focused on a question, asked in open-ended fashion, where managers were asked to "…identify your top 5 specific research needs for resource and visitor management in wilderness areas…" Any number of responses was acceptable (i.e. 5 or less) and order of importance was not implied. Analysis of manager responses for this paper followed the process described comprehensively by Glaspell (2002).

The first stage of data analysis was aimed at developing a thorough understanding of each individual set of responses. Even at this "first stage" of analysis, an interpretation and understanding of an individual response was influenced by what had already been noted from error checking and reading the entire data set. After a careful reading of the final proofread text of each response, predominant themes were identified in the context of all other responses and codes assigned to segments of the response that reflected those themes. *QSR NVivo* facilitated the coding process. At the first stage, and multiple attempts to reveal the most meaningful patterns of response, the themes and codes were "shallow" in nature. That is, they were not intended to reflect all the complexities inherent in the data. Instead, they served mainly as markers that provided a framework for subsequent deeper analysis. For instance, all references to conflict, crowding and rationing systems within a given response might be assigned the same general code "recreation." Or anything about fire and fuels management was only coded "fire". A second re-reading of the responses resulted in a more nuanced coding scheme. Text segments coded simply as "recreation" might have further been coded to indicate whether they referred to evaluation issues, monitoring needs or understanding experiences. Similarly "fire" codes might become coded into evaluation of fire tools, understanding the interface between climate change and fire, etc. Often, text segments were assigned several different codes.

After both rounds of coding, specific themes based on the purpose of the research were identified through narratives that were relevant across several responses. The goal of the analysis was to achieve a deeper level of understanding of why the managers needed this research. Interest was not so much in the fact they mentioned fire or recreation, but what purpose they identified for the research needed. We selected a heading for each dimension based on the narratives that emerged and knowledge of past wilderness strategic planning activities. The language used by participant managers was important to maintain, therefore sub-themes are all in the words of respondents. Their specific wording from open-ended responses were included in all analysis. No data were truncated.

A variety of authors have suggested various alternative methods for evaluating qualitative research (Lincoln and Guba 1985; Patterson 1993; Spiggle 1994; Thompson 1990). Patterson (1993) suggests that three useful evaluative criteria are persuasiveness, insightfulness, and practical utility. Persuasiveness refers to a reader's ability to come to the same conclusion as the researcher. This does not mean that a reader must agree with the researcher's interpretation, only that they can see how the interpretation was derived. This requires that sufficient data are presented to justify an interpretation. Spiggle (1994) suggests a parallel criterion in "adequacy." In evaluating the

adequacy of qualitative research, a reader asks, "Is there sufficient basis presented for assessing how grounded in the data the representation is?" (p. 503).

According to Patterson (1993), insightfulness results from creative interpretation that results in a new, holistic understanding. It involves more than merely organizing data into constituent parts or common themes. Spiggle (1994) describes three related criteria that reflect different aspects of insightfulness: innovation, integration, and resonance. Innovation refers to newness: Does the interpretation provide a new way of looking at a concept; in this case wilderness science needs? A recent theme issue of a peer reviewed journal, that focused on summary articles presenting knowledge gained from 50 years of wilderness science, was criticized for not presenting a new approach or demonstrating an evolving body of knowledge, particularly that it did not reflect a body of knowledge desired by wilderness managers and wilderness users (Chojnacky and Chojnacky 2016). This paper demonstrates the potential to respond specifically to that criticism. Integration refers to the coherence of an interpretation. Does the interpretation fit well within previous knowledge about science priorities or newly exposed trends in issues? Resonance is closely related to innovation; it refers to the contribution of research: Does the interpretation enrich understanding of the phenomenon? In order for this analysis to be regarded as insightful, it must be more than grouped into very general categories, such as provided by Ghimire, *et al*. (2015), and it must also be more than an in-depth case study of a few responses. It should demonstrate a creative new understanding of wilderness science needs, with applicability to the broader fields of science and strategic planning.

The criterion of practical utility is somewhat self-explanatory: Does the research answer the questions that motivated it? Also, does the research address issues or problems that are of concern in the appropriate field of inquiry (Spiggle, 1994)? A second dimension of practical utility is "trustworthiness." According to Patterson and Williams (2002), trustworthiness refers to the degree to which the concepts and procedures employed in a study are used or have been used by other researchers. Thus, the value of the results of this research might be partially evaluated based on the procedures that guided the study. While analysis procedures of qualitative data is common in the social science literature, analysis of manager perceptions of science needs is not common and has never previously been systematically collected or analyzed for wilderness stewardship science planning. In this case, instead of a typical focus on "science should inform wilderness management" as emphasized by Fox and Hahn (2016) to illustrate the positive benefit of science to stewardship decision-making, the focus here becomes on an innovative, persuasive, insightful and practical mental model of science informed by management.

4. Results

Between February 24 and May 19, 2014, responses to the manager survey were received from 368 wilderness managers of the NWPS in the Forest Service (FS), Bureau of Land Management (BLM), National Park Service (NPS) and Fish and Wildlife Service (FWS).

4.1 Who were the responding managers?

The largest percentage of respondents (30%) was from the FS, followed by the FWS (26%), NPS (22%), and BLM (21%). While responding managers worked at different levels in their respective agencies, the majority (80 or more percent in each agency) worked at local field levels. Responding managers reported they had been in their current positions an average of eight years; however, 55 percent had been in their positions five or fewer years. Considering both current and previous positions, on average, respondent managers had about 12 total years of experience with some level of wilderness stewardship responsibility.

4.2 What did the managers say about science information needs?

Just over 1220 individual responses (not all managers listed as many as five needs) were coded into 22 sub-nodes of 5 major strategic planning themes (nodes). The science needs questions were not asked for a specific time frame. From initial data set compilation and reading, it was first evident that many science questions listed were applied, based on existing issues managers were facing now, and some were basic science-oriented, looking off into unknown future issues they were likely to face. Some were things that might show substantial progress in 5 years; and some, if pursued, would take time to initiate (most likely in need of some informative basic science or consideration of other fields of inquiry) and even longer before answers and tools might emerge. Some suggested just packaging (or re-packaging) existing information, or updating it and getting it into the hands of managers (who have changed with agency turnover) or evaluating the success of some tools that emerged from much earlier research.

The five major themes, and their associated narratives, were: 1) Basic research on understanding – it includes mostly basic science needs to understand how phenomena that have not been studied much in the past can influence wilderness benefits and how to assess these influences; 2) Integrated research on "big" emerging issues – this narrative revolved more around "bigger than wilderness" issues that are novel and could be considered "integrated science" questions, basic science in these larger issues, but with applied science from other disciplines, and long-term in both knowledge building and impacts; 3) Applied research on stewardship effectiveness – moving more toward applied science, with medium term application value, and with implications for evaluating success of existing science that is aimed at sustaining wilderness within larger social and ecological systems; 4) Applied research on stewardship tools – very short term needs for science to support decision-making that is testing management –implemented solutions; and 5) Applied research to support inventory and monitoring, which is also a compilation of issues managers identified as applied and will likely produce useful knowledge in the short term, though with long term wilderness conservation benefits (Table 1).

Table 1. Overall interpretation of strategic aspects of research priorities identified from the Wilderness Manager Survey (n=1,220 responses from 368 managers).

Major themes	*Narrative summary*	*Basic or Applied*	*Short-term, Medium-term or Long-term*
Research on Understanding	Science for wilderness	Basic	Long-term
Research on "big" emerging issues	Wilderness for science	Integrated Basic	Long-term
Research on stewardship effectiveness	Science to sustain wilderness in larger systems	Applied	Medium-term
Research on stewardship tools	Science to develop and test tools	Applied	Short-term
Research to support inventory & monitoring	Science to produce baseline data and guide monitoring protocol	Applied	Short-term

In Table 2, the sub-themes for the major themes are listed. Within each node (or theme), sub-nodes (or sub-themes) were defined until there were no more than 20 specific statements that defined that sub-node, sometimes to a lower number. All statements, arranged by the remaining sub-nodes not further examined, exist in a coded data set for further examination at a later time if needed. Presenting the specific statements within each sub-node does not make up a problem analysis. It only shows how managers tried to define the problem. Review of the relevant literature, agency missions and initiatives and interaction with other scientists and managers would likely need to take place once this mental model, or an adapted one for strategic research planning, is selected.

Table 2. Themes and sub-themes of research needs, with number of times listed in wilderness manager survey responses

Theme	*Sub-theme*	*Number of responses*
(1) Research on understanding	Climate change effects	56
	Workforce development	50
	Relevance	32
	Conflict	29
	Adjacent land use	23
(2) Research on "big" emerging issues	Technology	85
	Scientific information	56
	Ecosystem and landscape integrity	29
	Tribal consultation	20
(3) Research on stewardship effectiveness	Invasive species	88
	Visitor management	43
	Partnerships	38
	Visitor impacts	33
	Fire restoration	32
	Use allocation	31
(4) Research on stewardship tools	Communication & education	77
	Leave No Trace	37
(5) Research to support inventory and monitoring	Visitor use, preferences and impacts	126
	Ecological resources	37
	Air and water quality	12

(1) Those potential sub-themes with less than 20: funding, benefits, water connectivity, wildlife connectivity, hydrology, naturalness, legal direction
(2) Those potential sub-themes with 10 or less: archeological resources, intervention, beyond recreation
(3) Those potential sub-themes with 20 or less: restoration, livestock grazing, visual resources, commercial uses, fish & wildlife, pack stock, fire planning, cultural resources
(4) Those potential sub-themes with 5 or less: Limits of Acceptable Change, minimum tool, minimum requirement decision guide, best practices, co-management
(5) Those potential sub-themes with 8 or less: invasives, cultural resources, sound scapes, naturalness, tools.

4.2.1 Basic science needs: a focus on understanding particular issues

Of the 56 people who listed some aspect of climate change as an important research need, 7 people ONLY said "climate change." Although this is a consistent response and helps define the node, it doesn't contribute very much to articulating science questions. The vagueness of the response, however, also reveals the basic science aspect of the question and the fact that great uncertainty exists among managers as to how it relates exactly to wilderness stewardship. Twenty-two more respondents only said the "effects (or impacts) of climate change" was an important information need, which similarly show vague perceptions of how climate change will influence their stewardship responsibilities. Statements about sea level rise are more specific concerns expressed about climate change and pose one set of "understanding" needs. Adaptation and understanding climate change at the intersection with invasive species issues and fire regime changes expand this understanding topic into one of high importance.

Understanding the managers' expression of need for information about how changes in the modern workforce will affect wilderness could be easily dismissed as a bureaucratic issue. However, "workforce development" was indicated as a major information need as often as "climate change" and "effects/impacts of climate change" and, in addition, the more detailed responses suggested an important understanding challenge. Working in wilderness often requires expertise in using primitive tools or applying primitive skills. As society speeds toward more technological

solutions in almost every aspect of our lives, a workforce interested in primitive skills becomes more scarce. Understanding the role of primitive skills in wilderness stewardship and how the values associated with these skills are changing across time are researchable questions. Will workforce attributes also follow societal trends or can we develop recruitment and training tools that capitalize on the contrast between wilderness values and the increasing emphasis in society on electronic access, technological solutions and convenience?

While not many managers specifically used the term "relevance," the term has taken root in current concerns about changing demographics of wilderness users (Watson 2011). Managers are interested in understanding how perceived changes in social values are related to the priorities of the organizations managing wilderness and the purpose of wilderness stewardship practices (Potts 2007). Better understanding of public support among the silent population would be helpful, as well as some insight into the relevance of nature protection to the next generation of voters in the U.S. Elsewhere in the wilderness manager survey, managers identified "lack of political and financial support for wilderness protection and management" as the highest threat to accomplishing their wilderness stewardship responsibilities, with 74% of all managers agreeing this threat is high or very high (Ghimire, *et al*. 2015).

Interpersonal conflict in wilderness was an important and popular research topic from the late 1970s to the mid-1980s and then experienced a resurgence due to clamoring by managers about increasing and unresolved conflict issues in the early 1990s. Scientists studied the relationship between conflict and crowding, impact on wilderness experiences, how to monitor conflict and how to evaluate success of solutions of conflict management. By the beginning of the 21st century, this conflict research had expanded to the study of societal or cultural differences among users of wilderness (e.g., recreation and subsistence) and competing demands (e.g., crowding and commercial uses). These contemporary wilderness managers consider conflict as an issue worthy of additional research effort, which could be caused by changes in users, user activities, user past experiences, changes in management, or even changes in society and technology. Visitor to visitor conflicts and conflicts between wilderness purposes and other purposes warrants new research to understand how we have managed conflict in the past, how we are managing it now, managers' role in managing conflict, and the extent we are understanding it, monitoring it and addressing it.

Almost half (44%) of the managers who took the quantitative survey indicated that "adjacent land management and use" was a high or very high threat to their ability to protect wilderness in the future (Ghimire, *et al*. 2015). The twenty-three managers who identified this as an "understanding" issue defined it fairly specifically. The threats of energy development, fragmentation, herbicide use, and urban encroachment pose threats to water quality, air, noise and light pollution and visitor experiences. Increased efforts to understand the role of adjacent land use on restoration efforts, protection efforts and decisions about intervention are needed. There is also a component of the "effectiveness" node that describes the need for more evaluation of the effectiveness of monitoring and managing visitor intrusions from adjacent lands in the forms of trespass on all-terrain vehicles (illegal access).

4.2.2 Big research questions: thinking beyond wilderness boundaries

"Big" research questions extend beyond the wilderness boundary in application. Although these "bigger than wilderness" issues may be confronted by non-wilderness public land managers, also, they are potentially more complex for wilderness managers. For example, emerging technology issues may not be particularly troublesome to non-wilderness managers, but they are still relevant. Recent research by Martin and Blackwell (2016) and others are developing baseline understanding of how technology is changing behaviors of visitors to wilderness, but the changes in technology are occurring faster than the research. The managers need science to facilitate decision-making about what is acceptable, as well as what may or may not be legal in wilderness. Emerging

technologies for communication also challenge managers, with uncertainty about adequacy of the typical methods used to communicate with the public. Simultaneous study of differential influences of technology inside and outside of wilderness would contribute substantial amounts of knowledge about how technology is changing our relationships with nature.

Managers recognize that there is potential for studying many biophysical issues within wilderness to the benefit of science beyond wilderness, and that recent advances in ecology can influence how they look at the integrity of wilderness ecosystems. A thorough analysis to determine ecosystem health, the integrity of specific areas, and the system as a whole is crucial. The NWPS extends across many ecosystem types, which likely supports threatened and endangered species; the role of the NWPS in broad ecosystem science should be advocated, recognized and protected.

While not every manager identified research questions related to tribal issues, this topic emerged with more specificity than other "relevance" or "public support and communication" issues. Partly due to the emphasis on the importance of tribal consultations and government to government relations between the US public agencies and tribes (Obama 2009), this is an area that managers, as well as scientists, are exploring with regard to expectations, processes and potential outcomes. Managers know that scientists and other managers have developed strong relationships with tribal entities, and most managers are sincerely interested in addressing tribal interests in wilderness lands they manage. Generally, managers are interested in thoughtful analysis related to successes and pitfalls in these government to government consultations, as well as research on the diversity of native perspectives, including those beyond the more "traditional" orientation toward wilderness.

4.2.3 Stewardship effectiveness

Managers identified "invasive species" as the second most agreed upon threat (56% across all agencies) to their task of protecting wilderness character in the future (Ghimire, *et al*., 2015). However, this conclusion does not provide much insight into the research needs. The open-ended response format provides more insight, even though most managers (70%) who indicated research needs in this area only said "invasive species management." Managers were primarily interested in research that evaluated the effectiveness of our applications of existing knowledge to meeting invasive species management needs. For instance, if we proceed with prescribed burning and grazing in wilderness, do we have safeguards to accomplish our invasives management objectives while also trying to restore fire and meet special provision direction for commercial activities? We are using a variety of containment and elimination strategies in different places for different species, but information on effectiveness of these practices or the general evaluation of how these techniques support or impact wilderness character protection is lacking.

A great deal of wilderness research focuses on understanding and suggesting visitor management techniques (Watson, *et al*. 2016). Managers require evaluative research, however, to enhance understanding of how well currently used practices are meeting visitor management objectives. Recreation fees were introduced in the 1990s, and the implementation of new policies generated a great deal of research in wilderness and across the landscape spectrum (Watson 2001). Apparently past fee research has not adequately addressed all concerns. Further research evaluating long-term effectiveness of impact and experience protection tools could be implemented. Along with adjacent lands issues covered earlier, more monitoring to determine the extent of trespass and illegal use is needed as well as effectiveness of constraining efforts.

With decreasing budgets and increased reliance on partnerships, volunteers, outside funding and in-kind donations to accomplish workloads, managers are trying to determine how to measure success. A balance between gaining benefits from outside partners and protecting the professionalism of employees is needed. Clear communication with partners about the purpose of

wilderness, methods of operation to protect both wildness and naturalness, and dealing with safety and health are important. Research to document the successes, failures and both resource and social benefits of partnerships could be helpful in decision-making by managers.

Managers seem to differentiate between needs for evaluating effectiveness of visitor management and the specific need for research to assist visitor management to control impacts. Visitor impacts are both social and biophysical. In terms of overall land extent, some impacts may be minute, though to other visitors they can be alarming because they occur in areas of high visitor traffic. Illegal or unauthorized uses can be particularly alarming to both visitors and to non-visitors. Visitor-created trails or climbing routes must be monitored and evaluations of success at curbing proliferation must be developed and evaluated for success.

Just over one-third of managers in the quantitative survey indicated wild-land fire suppression and management is a high or very high threat to protection of wilderness values in the future (Ghimire, *et al.* 2015), and only about one-fifth felt science-based information on fire and fuels management was not adequate or only somewhat adequate. A substantial number, however, indicated there is a need for research about the effectiveness of current efforts to restore fire in wilderness ecosystems. Managers are particularly interested in having more knowledge to judge effectiveness of prescribed fire to encourage the natural role of fire and the level of consistency with wilderness values. Managers are interested in evaluations of how our policies have changed conditions and what we have learned about effects of policies on wildlife, vegetation and water benefits.

Recreation use allocation research has been a focus of wilderness research for many years. There is a large amount of research and opinion, as well as foundational frameworks developed specifically to address carrying capacity issues. In most cases, the agencies use indicator-based planning systems (Cole, *et al.* 2005) to determine the levels of impacts that would suggest user behavior or numbers were unacceptable departures from the pristine. Several allocation systems have been developed and evaluated in the past as potential ways to limit numbers of people, influence timing of use, intensity of use, group sizes, camping or traveling behaviors and user density (Cable and Watson 1998). Currently, managers are wondering if travel patterns have changed due to changing demographics, whether importance placed on aspects of the experience have changed over time, and whether allocation systems put into place after the first or second round of wilderness planning in the 1970s and 1980s are still accomplishing the original objectives, or even whether the original objectives are the correct ones. Public response may have changed as new visitors have begun visiting specific places. In addition, expectations could have changed based on newly developed appreciation or ignorance of wilderness values by the public. A fresh look at the effectiveness of use allocation systems is desired by managers.

4.2.4 Stewardship tools

A small number of tools were identified by managers as in need of research to support implementation, divided into communication tools and primarily sanitation and human waste management tools. Managers recognize the need for communication methods to improve relationships with an increasingly diverse public. There must be some principles that can guide them in developing messages, some creative approaches to engaging in discussions to allow two-way sharing of information and even on specific methods of transfer of information, electronically or otherwise. And sharing information may be different from persuasive information. If more knowledge is gained through greater understanding of the relevance of wilderness to different segments of the population, managers may find themselves in a situation of trying to convince the public that even though they don't visit wilderness, they are receiving many benefits they value highly.

While Leave No Trace (LNT) techniques are heavily based on the most basic of recreation ecology (Cole, *et al.* 2005), managers perceive the need for more evaluation of recommended techniques across a greater variety of environments. They are asking about the best sanitation method in different situations and as visitor behaviors have changed, how have their human waste impacts changed? More research to advance tools needs to take place.

4.2.5 Support for inventory and monitoring

Watson, *et al.* (2000) published the only comprehensive technical guide to inventory and monitoring of wilderness visitor use and preferences, and Cole (1989) has provided the primary reference on monitoring physical impacts in wilderness with broad application in other areas. Although these guides exist and are heavily used and referenced, managers see the need for research to update them. Sometimes research just needs to replicate previous studies so trends can be described and methods explained. Cole, *et al.* (1995) and Watson, *et al.* (2013) have focused on a small number of areas to provide some understanding of trends at these areas, but only hypotheses exist for many areas, due to limitations on funding and personnel. Cole (2013) has tracked physical impact changes at a number of areas. However, changes in use patterns, technology used to measure impacts and count visitors, and knowledge about wilderness values are understood by managers. As a result, there is a desire for further analysis of the systems we have been using, the type of knowledge we have generated, and evaluation of potential alternatives for improvement in our inventory and monitoring methods used to understand human use and impacts in wilderness.

Managers did express concern about biophysical monitoring beyond the impacts of recreation users. Sometimes there are specific populations of birds or animals that they are uncertain about how to monitor, or they are simply uncertain if they are using the methods of monitoring and inventory that reflect the latest technology and purposes. As with the social science monitoring needs, there is also a need for replication of ecological studies to establish trends. Sometimes managers cannot produce these replication studies due to limitations on funding and personnel, or because of lack of knowledge about methods and instrumentation. These concerns extend to the water and air components of the wilderness environment.

5. Discussion

A sustainable science program should not simply be opportunistic, responding to new issues as they arise, as the wilderness science program has largely been defined in the past, and assume managers will apply the research. Sustainable science planning should invite opinion from those who use it, particularly those with the greatest stake in the science, and strive to ground science planning in reality. Adoption of a mental model that embraces those facts will likely increase sustainability of the resource and the science that supports it.

From this analysis of past wilderness stewardship and related science strategic planning, it is first of all apparent that wilderness managers have not previously been systematically included in developing a mental model of wilderness science. Most strategic planning was accomplished by agency scientists and administrators with input from some stakeholders and academic panels. In-depth analysis of manager-generated science needs to support wilderness stewardship was long overdue.

Qualitative assessments allow a great deal of in-depth response, but requires a certain amount of interpretation. A mental model can emerge, however, that helps us see the research topics from another view point; one different from expert panels or the scientists themselves. Although it may appear that some items of traditional focus in wilderness research, such as visitor management, planning, forest and vegetation protection, fish and wildlife management and fire and fuels management research are not high on priority lists of managers (Ghimire, *et al.* 2015), a new mental

model, a new conceptualization of wilderness science, if trustworthy, can be used to understand remaining science needs associated with these topics. Emphasis has transitioned from knowledge development in many of these areas, to needs for science to evaluate effects of implementation of that knowledge.

From this survey of managers, a new conceptual organization, or the way we look at wilderness science, wilderness stewardship and the role of wilderness in larger systems, has emerged. Managers have some large basic questions about how to protect wilderness (science for wilderness). There is a desire to understand how to meet climate change uncertainty, how changes in the work force are influencing their ability to protect wilderness, and how the relevance of wilderness today might be different from the past. They are also suggesting new conflict issues are on the horizon, including conflict related to issues on adjacent lands. As society changes, surrounding land issues change and the environment changes. We need to look at science for wilderness in a new context. In the early days of wilderness research, recreation visitors were seen as the major threat to wilderness protection, whereas now, some of the major threats may be our own lack of understanding of how threatening forces will impact wilderness attributes and values in the future.

After 50 years of managing and studying wilderness issues, managers are expressing support for science on emerging issues with larger applications for science – wilderness for science. The largest issue, and one that is uniquely related to the concept of wilderness in many ways, is emerging technology. Managers realize the changing role of technology. Many of the purposes of wilderness, however, seem strangely in contrast with efficient, rapid, complex technological solutions being used in our everyday civilized lives. Wilderness is a great laboratory for studying how technology use and dependence is affecting user behaviors, their experiences in nature, and the way they value wild nature, a place they commonly go to get away from modern technology.

Similarly, while wilderness science was initiated to address a seemingly narrow spectrum of issues to contribute to management of recreation threats (Watson, *et al.* 2016), this scientific study has expanded to more complex issues with the need for frameworks to guide incorporation of new knowledge into stewardship practices. While the social sciences have provided increased understanding of an evolving set of issues managers and scientists have identified in the past (Watson, *et al.* 2016), the increasing complexity of ecosystems and landscape integrity science is providing new frameworks for assessing the role of wilderness and its important contributions to quality of the environment and quality of life.

Current federal administrative policy and society's emphasis on the importance of tribal consultations offer opportunity for managers to explore the meanings of wilderness to tribal entities that may well guide issue solving outside wilderness. Cultural landscapes are full of meanings to indigenous people, not empty of them, as they might be to non-indigenous people (Watson, *et al.* 2011). More thorough exploration of how protected nature contributes to quality of life for American Indian and Alaska Native communities can contribute to many issues much larger than wilderness.

Wilderness is part of larger ecosystems and societal interests in public lands use issues. Managers need to integrate their management policies with policies elsewhere on invasive species, visitor management, partnerships, impact control, restoration of fire and use allocation. While research and opinions have been published on the best ways to accomplish these tasks in both wilderness and the larger sustainability literature, specific research is needed to evaluate the effectiveness of these tools to sustain wilderness in larger social and ecological systems.

Communication tools and sanitation guidance tools have been developed, but additional research is needed to refine application of these or other tools, useful in educating visitors and

controlling impacts. Of course managers need to have continuing scientific engagement in measuring and monitoring baseline and changing conditions of visitor use and users, their impacts on experiences and ecological resources and air and water quality. More scientific contributions to understanding what to monitor, how to monitor it and how to integrate monitoring data can contribute to wilderness protection.

A new mental model for planning sustainable wilderness science is possible and grounding it in the needs of the managers of the protection process is one way to do it. Other influences may affect future science programs, such as individual scientist interests or initiatives, funding, and new issues, but a comprehensive framework based on current manager perceptions is highly likely to engulf most potential topics and the more responsive science is to manager perceptions of importance, the more likely management is going to be responsive to science. Managers are the stewards of not only the wilderness resource, but also of the relationships the American public have with that wilderness resource. Clearly visioning wilderness science needs within the topics of understanding, emerging issues, landscape sustainability effectiveness, stewardship tools development and improvement, and research to support inventory and monitoring is indicative of how we as a society have evolved to respect nature on our planet and define our role in protecting it.

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