

Science Informs Stewardship: Committing to a National Wilderness Science Agenda

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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. Science can help us understand the nature of the system for which we are a steward. It can help in learning how to correct human-caused perturbations in such systems. It can help in understanding how systems might be used and enjoyed without destroying them. It can help in understanding how valuable wilderness is to people and how it might enhance their lives. (Pinchot Institute for Conservation 2001, p. 14)

The National Wilderness Preservation System (NWPS) is a vital component of the national and international infrastructure for science, education, and information. The NWPS serves as an important resource for advancing research, from discovering new dinosaurs (Arbour et al. 2014, Landon 2016) to understanding human history on the American landscape (Rasic 2003). The NWPS provides invaluable records of environmental change and coverage of important types of ecosystems and natural resource systems (Aycrigg et al. 2016).

Research is also fundamentally important to wilderness stewardship and the statutory obligation to preserve wilderness character. Wilderness science has guided the management of natural resource systems, such as watersheds, forests, and rangelands. Findings with broad impacts on environmental policy and natural resource management have emerged from wilderness studies. For instance, outdoor recreation research helped to initiate wilderness science beginning in the 1950s, in response to the increasing recreation impacts on public lands (Cole 2014, 2016). Wilderness recreation studies have investigated many aspects of visitor use and resource impacts, which have directly informed management decisions such as the acceptable limit of impacts, recreation carrying capacity, and actions to prevent or minimize resource degradation (for reviews, see Marion 2016, Marion et al. 2016) (Figure 1). A second prominent example comes from wildland fire research, which has developed models and data to understand the complexity of fire as a biophysical landscape process and also investigated social factors that influence wilderness fire management. These biophysical and social science studies of wildland fire have profoundly shaped stewardship decisions regarding wildfire management both inside and outside of wilderness

boundaries (Miller and Aplet 2016) (Figure 2). These examples demonstrate the contributions of previous wilderness science to wilderness stewardship from the field unit to agency scales, but more research—and a coordinated wilderness science strategy—is needed to support the increasingly complex and contentious wilderness management issues presented in this article.

In this article, we review the evolution of wilderness research, identify the challenges of integrating wilderness science and stewardship, consider catalysts for change, and argue for the need to develop a cohesive wilderness science strategy to address NWPS management needs. We highlight the Aldo Leopold Wilderness Research Institute (ALWRI) in this article because it is the only entity focused on science to inform wilderness stewardship, but we recognize that many scientists working both inside and outside of the agencies contribute important findings that improve wilderness stewardship practices (e.g., the National Park Service [NPS] Night Skies and Natural Sounds Division, the United States Department of Agriculture Forest Service [USDA FS] National Genomics Center for Wildlife and Fish Conservation, The Wilderness Society, and university researchers).

Wilderness Stewardship Decisions Must Be Based on Sound Science

The agencies that administer the NWPS (the Bureau of Land Management [BLM], the US Fish and Wildlife Service [USFWS], the USDA FS, and the NPS) affirm that science is critical to effective wilderness stewardship. In the first interagency strategic plan for wilderness drafted in 1995, agency leaders committed to “expand the emphasis of research specifically to include natural and biological wilderness resources and psychological and social values” (BLM et al. 1995, p. 5). More recent agency documents continue to affirm their commitment to wilderness science. For instance, the 2011 Business Plan of the NPS Wilderness Stewardship Division listed four top priorities for the future, the first of which was to “increase the role of science in wilderness management” (NPS 2011, p. 16). Similarly, the USDA FS’s 2010 Strategic Plan for Wilderness Stewardship included “expanding wilderness and wild and scenic river research” as one of its goals (USDA FS 2010, p. 6). More broadly with respect to resource management, the USFWS website states that it is dedicated to basing decisionmaking on sound science, thereby providing Americans with the highest quality information possible for management of USFWS lands (USFWS 2015). Likewise, the BLM website emphasized the importance of their lands as natural laboratories, useful to both managers and scientists. This website highlights the critical role findings from research have on providing a sound foundation for management decisions on BLM-managed land (BLM 2015). Clearly, the need for science has been recognized, marked by the long history of wilderness research by the interagency ALWRI and other scientists at universities and other organizations. However, a strategy to identify and deliver wilderness research that

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Figure 1. Campsite in the Boundary Waters Canoe Area Wilderness that is heavily affected by wilderness visitors. Wilderness research on visitor use impacts resulted in management guidelines to mitigate the effects of visitor use. (Photo by Jeff Marion.)



Figure 2. The 2013 the Gold Pan Fire in the Selway Bitterroot Wilderness spread to more than 40,000 acres, but management decisions to allow wildfires to burn in this area over the last several decades reduced the severity of the burn. ALWRI scientists help managers by providing science describing how natural wildfires help reduce the frequency and severity of future fires. (Photo by Bob Mutch.)

addresses current and future stewardship priorities is lacking, and wilderness lands are at risk without the information to support them.

In addition to agency-level support, wilderness managers recognize the need for wilderness science, as demonstrated in the 2014 survey of NWPS managers (Dawson

et al. 2016). Based on survey results, priorities for better science-based information include (1) understanding public attitudes toward management for adapting to climate change, (2) determining public attitudes toward ecological restoration, (3) understanding what is important about wilderness to different stakeholders and to America's diversifying population, and (4) improved understanding of spiritual values and uses of wilderness. Managers also indicated that more research was needed to help them restore fire to its natural ecological role and requested more comprehensive protocols to inventory and monitor natural resources in wilderness.

The Evolution of Wilderness Science

Wilderness science has evolved dramatically since the establishment of the NWPS in 1964. Its roots can be traced to the establishment of the first federal public lands in the United States (for a review, see Cole 2014). Of course, scientific work important to wilderness stewardship has been ongoing much longer. Biophysical studies in wildlands constitute a literature base that includes both basic and applied research in fields such as forestry, wildlife and fisheries biology, and hydrology. These scientific inquiries have enhanced our general understanding of natural systems and thus benefit wilderness stewardship and protection. The first dedicated wilderness research program was the USDA FS Wilderness Management Research Unit, established in 1967 and based in Missoula, Montana. Under that program, a more systematic, long-term approach to wilderness science began, which included the following: better measurement of wilderness visitor use; an understanding of the experiences, attitudes, and preferences of wilderness visitors; and exploration of ways to manage wilderness within its carrying capacity. This program also produced wilderness studies of fire ecology, vegetation, wildlife, and economics.

Several decades later, an interagency science organization for the NWPS was chartered, which sparked an expansion in wilderness research. In the early 1990s, Congressman Bruce Vento (D-Minnesota) introduced H.R. 4325, the National Forest Wilderness Management Act (1992), which directed the Secretary of Agriculture to establish and maintain a wilderness management program within the USDA FS and to



Figure 3. Federal wilderness agencies use cameras to record the use of water installations by wildlife. Wildlife water catchments are typically installed to benefit game species such as bighorn sheep, but many wildlife species use these water installations. (Photo by USFWS.)

establish the ALWRI in or near Missoula, Montana. H.R. 4325 also directed the National Academy of Sciences to assess the status of wilderness research nationwide. Although the bill did not pass, it did spur the USDA FS to establish the ALWRI in 1993, with support from the other three wilderness management agencies. Notably, a status assessment of the NWPS has never been completed.

A 2008 charter for the ALWRI expanded on the first strategic plan from 1996 that guided the research agenda during the Institute's formative years (ALWRI 1996, 2008). The charter describes the current scope of wilderness science, which incorporates three complementary components: science for wilderness (informing effective wilderness stewardship); wilderness for landscape sustainability (improving the understanding of the roles of protected lands to the ecological, economic, and social processes, services, and integrity of larger landscapes); and wilderness for science (using wilderness as laboratories to understand the causes and consequences of environmental change, minimally confounded by other influences). Under this umbrella, a diverse array of natural and social science studies in wilderness have been conducted, addressing topics such as the values associated with wilderness, air pollution, invasive species, livestock grazing, wildlife, ecosystem services, and climate change (Cole 2014) (Figure 3). In addition, over the last 10 years, an interagency protocol to define and monitor wilderness character has been developed, which directly addresses the legal mandate to preserve wilderness character (Landres et al. 2015).

The Challenge of Integrating Science into Wilderness Stewardship

Although the NWPS agencies recognize and endorse the need for sound science as the basis of good wilderness stewardship, there are many barriers. These include (1) different mandates and missions between NWPS agencies, (2) the past reorganization of US Department of Interior (USDOI) research programs and scientists, (3) chronic underfunding of wilderness science, (4) lack of effective information exchange, and (5) lack of agency accountability metrics to link wilderness science and stewardship. These impediments are significant and cannot be ignored, but they can be resolved to ensure that science is better coordinated to improve wilderness stewardship. Overcoming these barriers will require cooperation and coordination among NWPS agencies and with external partners and the public.

The NWPS agencies have distinctive missions and mandates and operate under different sets of regulations and policies, such as multiple-use management for the USDA FS and BLM, primary refuge purposes for the USFWS, and an emphasis on recreation and tourism for the NPS. As a result of these disparate agency missions, science programs have developed within each agency to address specific management information needs. As the wilderness system grew and stewardship issues became more complex, however, there was little effort to coordinate science between the NWPS agencies. Thus, opportunities to leverage scientific collaborations and to increase inference from coordinated research sites, by involving multiple agencies and wildernesses, have been lost.

Another barrier to coordinated wilderness science emerged in 1993, when the USDOI wilderness agencies lost their scientists and science funding to the newly created National Biological Survey; just 3 years later, all of these scientists were transferred to a new US Geological Survey (USGS) branch, the Biological Resources Division. These organizational changes were highly controversial and disruptive and weakened the link between science and natural resource management decisions for the NPS, BLM, and USFWS (Parsons 2004). Twenty years later, the repercussions of these DOI science reorganizations still have an impact on wilderness science: the USGS conducts some wildland studies but lacks a wilderness science program.

Coordinated, interagency funding for wilderness science remains elusive, which exerts a strong influence on the type and scope of wilderness studies that are undertaken. Since 1993, base funding to the ALWRI has been provided primarily by USDA FS Research and Development (86%), with smaller portions from the BLM, USFWS, and the NPS, and no base funding from the USGS. To meet research needs, NWPS agencies provide the ALWRI with project funding that is usually site specific and short term and does not allow for longer-term, networked investigations that can be leveraged to more powerfully inform resource management at multiple scales. The funding challenges for wilderness science at the ALWRI are also experienced by university and nongovernment organization scientists, and the piecemeal approach to science funding restricts the ability of wilderness science to inform stewardship.

Information exchange continues to be an area for improvement (Roux et al. 2006). Technology transfer between managers and scientists most often occurs through peer-reviewed literature, formal presentations, and occasional training courses. Scientific literature and presentations are outstanding vehicles for delivering research results to scientists but may not effectively reach wilderness managers. Publications may be too specific and too technical and not translated into usable information or metrics that are applied in field operations, such as specific thresholds for wildfire management or wildlife habitat. Managers need useful summaries of science findings across disciplines and a description of how these findings can be best applied to the stewardship problems.

Across all the NWPS agencies there is a strong need to explicitly integrate wilderness science into wilderness management plans, stewardship decisions, and performance accounting. Connecting wilderness science and wilderness stewardship in agency accountability metrics and annual reports would demonstrate a solid commitment to meeting the objectives outlined on agency websites and business plans and to fulfilling our legal mandate to preserve wilderness character (Sutherland et al. 2004). Currently, there are no requirements to integrate wilderness science into planning, projects, and reporting; as a result, the prospects for current wilderness science to inform wilderness stewardship may be reduced.

Potential Catalysts for Change

The NWPS agencies have used a variety of internal and external assessments to evaluate their management effectiveness, including the use of science. Here, we focus on two reviews that consider the NWPS and wilderness science. In 1999, the most thorough external assessment of the state of wilderness stewardship was commissioned by all four NWPS agencies, 35 years after passage of the Wilderness Act. The Pinchot Institute for Conservation was asked to convene a panel of experts to examine the critical management issues facing the four agencies and to develop a common set of wilderness management priorities to ensure the future integrity of the NWPS (Pinchot Institute for Conservation 2001). This Wilderness Stewardship Panel included members with significant experience and expertise and also reflected a diversity of wilderness values and perspectives. Perry Brown, then dean of the School of Forestry at the University of Montana, chaired the group.

The Brown Report's extensive recommendations affirmed that, without significant action, the very existence of the wilderness system could be at risk. The panel proposed that stewardship be science informed, logically planned, and publicly transparent. They urged that science programs be enhanced and focused to provide information, professional expertise, and public support for wilderness stewardship. As science expands our understanding of the complexity of ecological processes and functions in wilderness, stewardship becomes necessarily more complex. Wilderness stewardship challenges are further complicated by the diverse social pressures and values as-

sociated with these resources. They concluded that "the scale of the system requires a substantial investment of resources" (Pinchot Institute for Conservation 2001, p. 6). Based on panel recommendations, a new Wilderness Policy Council was created, consisting of senior executives from each of the four federal agencies whose task was to coordinate more closely than in the past on NWPS management. Although consistent agency policies for wilderness stewardship have not been completed (Cordell et al. 2016), the Wilderness Policy Council has expressed increased interest in science, and these leaders have agreed to work toward building base funding for the ALWRI in the coming years.

In 2006, the USDA FS convened an external panel for a Strategic Program Area (SPA) Review of the agency's wilderness research. Because the ALWRI conducts research on the interagency NWPS but is administered by the USDA FS, the SPA Review addressed research for the wilderness system to some extent, but did not evaluate wilderness science efforts in the DOI agencies. The group included high-caliber scientists, educators, and science managers whose major charge was to describe wilderness research needs, opportunities, and priorities and to provide recommendations to USDA FS research leadership on what the wilderness research program should encompass (Turner et al. 2007). The SPA Review team identified the ALWRI as the sole entity with an integrated, coherent wilderness research program that has been effective, despite the modest investment of resources in staff and operational funding. The review noted that ALWRI researchers have articulated a range of threats to the NWPS and the associated science priorities, but limited resources have hampered progress.

Looking toward the future, the SPA panel strongly supported the development of a clearly defined, national USDA FS research program in wilderness research with a compelling vision addressing purpose, goals, objectives, and expected outcomes. The SPA panel also endorsed the need for more funding support for wilderness research in general, and for the ALWRI in particular, by the BLM, USFWS, NPS, and USGS.

There is a resounding consensus—from both the NWPS agencies and external review panels—on the need for science as the foundation for wilderness stewardship. Now we must commit to the development of a

cohesive wilderness science strategy and secure the resources to implement the strategy.

The Importance of Science to Future Wilderness Stewardship

Looking toward the next 50 years of the NWPS, we expect that managing wilderness lands will become more complex, more contentious, and more litigious, highlighting the need for robust research to inform management decisions. There are many challenges facing the NWPS agencies, and a closer relationship between wilderness science and stewardship can help to address these issues.

The ecological issues challenging the stewardship of NWPS natural and cultural resources are extensive, such as biodiversity loss, invasive species, and air, noise, and light pollution. Climate change already affects many natural and cultural resources in wilderness, and these impacts are accelerating in ways that are not fully understood. Although our scientific knowledge of the interrelationship between natural disturbances, human-caused threats, and wilderness resources has dramatically expanded over the last 50 years, we recognize that our understanding of both system complexity and management responses is incomplete (e.g., wildlife reviewed in Schwartz et al. 2016). As a consequence of these dynamic and complex changes, wilderness managers must rely on science to aid decisions in the face of novel ecosystems, threats, and risks to the NWPS both now and in the future.

In addition to ecological complexity, changes in the American public will shape wilderness stewardship and demand new science to support stewardship decisions (Schwartz et al. 2016, Watson et al. 2016). For instance, one challenge facing wilderness managers is the increasingly diversified, urbanized, and aging America population. Scientists can help wilderness managers and agencies understand the trajectories of those changes and identify how different stakeholders value wilderness. Researchers can also describe the economic values and benefits of wilderness to help make this important resource relevant to diverse populations (Holmes et al. 2016). NWPS managers must balance public demand for access with the requirement that we preserve wilderness character: the untrammeled, natural, undeveloped, and solitude qualities (Figure 4). Science can play a key role in finding this balance by assisting wilderness managers to



Figure 4. Describing the character of wilderness areas—their untrammelled, natural, primitive, and solitude qualities—is important to protect it over time as required by the Wilderness Act. Gates of the Arctic in Alaska in one of a number of wildernesses where ALWRI scientists have described and mapped wilderness character.

understand both the pressures on wilderness (e.g., visitor impacts) and the values and benefits (e.g., ecosystem services). Social media and new technologies are also affecting wilderness resources. For example, social media is changing the way people communicate about wilderness and can concentrate visitation to particular sites in wilderness. Likewise, the increased use of powered hang gliders and newer technologies such as drones to fly over wilderness has diverse effects on wilderness resources such as wildlife populations and visitor experiences (e.g., Wick 2016). Understanding the full range of impacts to wilderness character from these technologies is needed.

The public will continue to question wilderness management decisions in court, and litigation will influence NWPS stewardship. Recent case law reviews offered some interesting patterns. Feller (2014) and Appel (2010) reviewed the cases since 1965 in which NWPS agencies were taken to court. In cases in which plaintiffs sought more protection for wilderness, they won 68% of the time, whereas those in which less protection for wilderness was sought, plaintiffs won 32% of the time. With climate change increasingly altering ecosystem function, the agencies will face more decisions on whether to take restoration actions such as assisted migration, which may result in litigation (Nie and Barns 2014). Ensuring that restoration is based on solid ecological science will be essential to informing court decisions (Long and Biber 2014).

The Way Forward

The identification of wilderness science priorities continues to evolve. In 2013, the NWPS Wilderness Policy Council asked the ALWRI to conduct a survey of wilderness managers and staff (Dawson et al. 2016). The survey served two main purposes: to inform the development of a new strategic plan for the NWPS and to articulate the science needs of wilderness managers to develop a new science strategy. The Policy Council used survey results to draft the *2020 Vision: Interagency Stewardship Priorities for America's National Wilderness Preservation System* (BLM et al. 2014). In 2015, the ALWRI is developing a comprehensive 10-year strategic plan for wilderness science informed by the wilderness manager's science needs, the strategic goals for the NWPS laid out in the *2020 Vision* document, and research needs for wilderness as defined by scientific experts from relevant fields.

As the ALWRI helps to develop a new science strategy, we invite feedback and collaboration from agency, university, and nongovernment organization partners and the public. The ALWRI will continue to use the criteria established when it was founded to inform a wilderness science agenda: the priorities of wilderness managers and agency wilderness leaders; the conduction of similar or related work elsewhere; and the match between research needs and the expertise of current ALWRI staff and our collaborators (ALWRI 1996). We are continuing to de-

velop a network of affiliated scientists for funding and science partnerships to address the priority research needs of managers using a cost-effective, flexible approach (Roux et al. 2015). The new science strategy for the ALWRI needs to define how we can improve information exchange. We plan to do the following: present wilderness science findings in regional and national wilderness training courses; produce more syntheses of science findings; and participate in the development of new wilderness management plans.

Implementing a strategic wilderness program will require additional funds from diverse sources and greater commitment from the NWPS agencies. To conduct the most critical science research needed by the NWPS, we must expand financial support for research and applications. Building capacity and broadly applicable research requires the commitment to fund a strategic wilderness science program. One way of addressing the need for consistent and adequate long-term funding is to develop financial endowments to fund research. While we are working with all of the NWPS agencies to build consistent base funding support, we are also working to establish an external endowment with the outdoor recreation industry and private investors that can also provide the fiscal foundation for a comprehensive wilderness research program. In the next phase of our science program we will also work with agency wilderness leaders to develop performance measures for wilderness stewardship that require the integration of science as a component of agency accountability. When science is a part of stewardship planning and accomplishments reporting, then it will be truly integrated into NWPS goals.

The future is promising for the extraordinary natural and cultural resources of the National Wilderness Preservation System. In 2014, the NWPS agencies used the 50th anniversary of the Wilderness Act to work on solutions to a host of challenges. The *2020 Vision* report seeks “to inform wilderness stewardship decisions using the most current and credible science” (BLM et al. 2014, p. 4). The legacy of wilderness deserves protection, and the NWPS agencies are on track to deliver on that promise with a cohesive wilderness science strategy. The need for wilderness science—to understand how the natural and cultural resources of the NWPS function and change over time, to monitor the impacts of these changes on wil-

derness character, to inform agency managers and their stewardship decisions, and to enrich public appreciation of wilderness values—has never been greater.

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