Title

Wildlife working group: 10-year strategic plan for wilderness research

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Introduction

At the National Wilderness Conference, convened in 2014 to celebrate the 50th anniversary of The Wilderness Act, the chief of the U.S. Forest Service and the directors of the Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Geological Survey signed the document *2020 Vision: Interagency stewardship priorities for America's National Wilderness Preservation System*[1]. *2020 Vision* charted an interagency path forward for wilderness stewardship, science, and partnerships and called for the development of an Implementation Plan that creates a shared program of work to leverage limited resources and facilitate collaboration between wilderness managers, the science community, Native American tribes, and non-profit and private-sector partners.

The 2020 Vision Implementation Plan presents these three themes with associated goals, objectives, and specific actions to guide short- and long-term stewardship:

- *Protect* wilderness resources by preserving wilderness character, preparing for ecological change, and informing wilderness stewardship decisions using the most current and credible science.
- *Connect* people to their wilderness heritage by expanding public awareness, understanding, and support of wilderness; nurturing a new generation of future stewards and scientists; and restoring trails connecting wilderness and people.
- *Foster* excellence in wilderness leadership and coordination by cultivating strong interagency leadership throughout the National Wilderness Preservation System, reinvigorating commitment to wilderness stewardship, and building workforce capacity and wilderness program resources.

As part of the Implementation Plan, the Aldo Leopold Wilderness Research Institute is leading the development of a wilderness science plan, which includes several focal areas. Each focal area summary describes the current state of the science as well as the highest priority research needs.

[1] 2020 Vision: http://www.wilderness.net/toolboxes/documents/50th/2020_Vision.pdf

Here, we present the summary for terrestrial wildlife and wilderness.

Methods

To evaluate the current state of science addressing terrestrial wildlife and wilderness, we searched for a variety of terms in publications covering the period of 1964—the year Congress passed The Wilderness Act—through the present. These searches were conducted in the Web of Science[2] database that covers peer-reviewed scientific literature, as well as Treesearch[3], a U.S. Forest Service database that includes peer-reviewed articles as well as a variety of "gray" literature reports and syntheses. Relevant research includes studies conducted both inside designated wilderness as well as in undesignated wild lands, though we did not review all studies of "wild" land or other types of protected areas.

	Number of publications	
Search terms (1964 – present)	**Web of Science**	**Treesearch**
"Wilderness" AND "United States"	408	128
"Wilderness" AND "Wildlife"	281	160
"Wilderness" AND "Animal"	190	24
"Wilderness" AND "United States" AND "Wildlife"	51	34
"National Wilderness Preservation System"	35	49
"National Wilderness Preservation System" AND "Wildlife"	4	17

After eliminating redundant citations, we reviewed these publications by reading abstracts and using within-text word searches to assess their relevance and to categorize them under the following topics:

- Science to measure the value of current wilderness areas for wildlife
- Science to determine where to designate new wilderness areas for wildlife
- Science to inform wilderness management for wildlife
- Wilderness as a laboratory for wildlife science

Current State of Knowledge

Wilderness areas historically have been designated in an ad hoc fashion through a mix of political will, avoidance of resource-use conflicts, and the public's desire for primitive recreation, solitude, and outstanding natural scenery. Despite the growing recognition of the value of wilderness for maintaining viable wildlife populations, there has been little deliberate, systematic planning or guidance by federal land-management agencies to measure the value of wilderness areas for wildlife, determine the highest-priority places to designate new wilderness for species conservation, or inform best practices for managing wilderness for wildlife.

[2] Web of Science http://webofknowledge.com (accessed September 2016)

[3] Treesearch http://www.treesearch.fs.fed.us/

Much research related to wildlife, whether in the area of restoration, informing management of wildlife, or using wilderness as a laboratory, might more appropriately be classified as ecological (rather than wildlife) research. For instance, developing restoration approaches for specific species often requires a primary focus on understanding ecosystem disturbance dynamics and the reaction of ecological elements (other than the target wildlife) to specific treatments. Similarly, research asking where to designate wilderness for wildlife conservation often involves investigation of climate change, the examination of trajectories for vegetation change over extended periods, and similar science. Finally, understanding the economic benefits of wilderness that are derived from wildlife will likely be more economics than wildlife research per se.

As noted elsewhere (Schwartz et al. 2016, Wright and Garrett 2000), there are relatively few research studies examining wildlife and wilderness. The remote character of wilderness, along with limitations on activities and tools, result in difficult logistical challenges. These factors substantially increase the cost of field studies in wilderness. A small number of papers have focused on methodological approaches to address the challenges of wildlife research conducted in wilderness that align with the mandates of The Wilderness Act (e.g., Elmeligi 2007; Schwartz et al. 2011; Schoenecker et al. 2015), while others provide support to managers trying to determine the appropriateness of scientific activities within wilderness (Landres et al. 2010). In our literature search, we found only 97 publications that were relevant to the topic of U.S. wilderness areas and wildlife (see Bibliography), and most were from the natural sciences. Here, we summarize and highlight a few papers as representative examples of the current literature.

Measuring the value of existing wilderness areas for wildlife

A small number of studies have addressed the value of wilderness areas for particular wildlife species. Often these studies compare habitat features generally found in wilderness to those found in unprotected or highly-managed areas or examine the effects of some form of human disturbance, such as resource extraction, or management activities that do not occur in wilderness areas.

For example, Zlonis and Niemi (2004) compared breeding bird communities of hemiboreal forests in “multiple-use” managed forests and relatively unmanaged wilderness forests of Minnesota. Matching riparian and upland habitats in each system (half in managed systems, half in wilderness), they found that the total number of individuals and species detected per pointcount were higher within the unmanaged (wilderness) forest and forest adjacent to the riparian corridor. Habitat characteristics of the two forest types were examined to suggest the mechanisms for differences. The authors determined that taller overstories, higher tree species diversity, and less regenerating forest in the landscape were all linked to higher bird species richness within wilderness. As another example, Hayward et al. (1993) investigated habitat use at multiple spatial scales by boreal owls (*Aegolius funereus*) throughout the northern Rockies, combined with some demographic modeling and fine-scale studies within the Frank ChurchRiver of No Return Wilderness. The researchers concluded that the boreal owls living within the wilderness were less productive and potentially a sink population during the period of investigation that relied on immigration from the larger metapopulation for persistence. Based on

the demographic data on the owls, data from small mammal trapping, and information on forest growth, they suggested that watersheds outside wilderness were more productive and support more robust owl populations.

Often wilderness areas are convenient for directly testing the effects of a particular disturbance, as few intrusive activities are allowed. If a particular type of activity that is not allowed in wilderness has been shown to have a significant negative impact on a species, one can assume that wilderness provides some benefit for the species. Zielinski et al. (2008) evaluated the effects of motor-vehicles at two study sites in California by comparing American marten occupancy rates and probabilities of detection in areas where ORV use is legally permitted with those in wilderness areas where vehicles are prohibited. Despite predicting that females would be less common in non-use areas, the researchers found that there was "no effect of vehicle use on marten occupancy or probability of detection"—possibly because the use was relatively low (one vehicle every two hours) or because most vehicle use occurred when martens were inactive.

In the last 10 years, large-scale analyses have begun to explore a variety of wildlife landscape ecology questions. For instance, Cushman et al. (2009) used a genetically based landscape resistance model for black bears (*Ursus americanus*) to identify major movement corridors and barriers to population connectivity between Yellowstone National Park and the Canadian border. Although this study area contained abundant public lands and some of the largest wilderness areas in the contiguous United States, moving from the Canadian border to Yellowstone Park along the paths indicated by modeled gene flow required bears to cross at least six potential barriers.

We could find no studies that systematically evaluated and quantified the benefits of wilderness areas across the entire range of a vertebrate species by examining, for instance, abundance, survival, or reproductive success across multiple wilderness areas and matched non-wilderness areas. Nor could we find a study that untangled the particular mechanisms, management activities, or prohibitions that would indicate whether wilderness is more beneficial to wildlife than, say, unprotected roadless areas.

Determining where to designate new wilderness areas for wildlife

Dietz et al. (2015) recently conducted an assessment of ecological system representation in the National Wilderness Preservation System (NWPS) which identified the highest-priority areas on federal land to increase the diversity of ecosystems protected in wilderness. Similarly, Belote et al. (2016) have identified corridors within the existing protected area network using landscape "naturalness" as a proxy for the needs of many species. Previous studies have used Gap Analysis methodology to identify future protected area sites (Scott et al. 1993). These areas may serve as coarse filters for species protection; however, no national fine-scale assessment of wildlife species' needs in designated wilderness has been conducted. We could find no national study that determined where to designate new wilderness areas to protect wildlife species that are of conservation concern (endangered, threatened, rare, or sensitive species).

But on a smaller scale, one study in the state of Idaho (Merrill et al. 1995) presented four wilderness allocation options for public lands suitable for wilderness designation, ranging from status quo to the addition of all inventoried roadless areas in the state. One ecological criterion that was evaluated was the number of vertebrate species for which at least 10% of their area of distribution in the state was protected as wilderness under each of the four options. In the most conservative option (status quo), only 39% of vertebrate species were protected in 10% of their range in wilderness; in the most protective option (in which all roadless areas become wilderness), 56% of vertebrate species would be protected at the 10% threshold. No attempt was made in this study to evaluate the maximum wildlife-protection returns for the minimum acreage-protection investments.

In another study (Strittholt et al. 2001) researchers examined the ecological attributes of roadless areas in the Klamath-Siskiyou ecoregion of northwestern California and southwestern Oregon, including "natural-heritage elements"—known point-locations for plants and animal species of conservation concern, including rare and endangered species. They found that roadless areas contained nearly four times as many heritage elements than designated wilderness areas—the largest gains occurring in the plant and vertebrate categories. Of the 4,652 vertebrate records, only 212 (4.6%) were found in wilderness areas; roadless areas (which could be added to the NWPS) contained 1,749 (37.6%) vertebrates. The authors state that the "next logical step" would be "to evaluate each roadless area individually to measure its relative ecological attributes." Again, no attempt was made to compare individual roadless areas in terms of wildlife habitat or to maximize vertebrate protection with various wilderness-protection scenarios.

Some studies have sought to compare the efficacy of protecting wildlands to protecting lands that may be under greater threat (e.g., private lands) and contain greater species richness and endemism. For example, Dobson et al. (2001) contend that "although it is important to conserve large wilderness areas in mountainous areas, our analyses suggest that this is not the best way to conserve the most biodiversity." They do note, however, that "at one extreme, it will be important (and relatively easy) to set aside large areas of wilderness" and that "large-scale conservation requires a mix of strategies." They do not address the question of prioritizing areas for wilderness protection on federal lands.

Informing wilderness management for wildlife

Wilderness, albeit relatively restricted in its degree of accepted management, does allow latitude for managers to determine the most appropriate level and type of ecological restoration or recreational use.

Human recreation—even quiet and non-mechanized—may have an impact on wildlife. Knowing how the types of activities (and when and to what degree they occur) will affect wildlife species will help managers determine best practices for wildlife conservation. For example, managers of the "wilderness river" section of the Gulkana River in Alaska were interested in the impact of recreational boaters on bald eagles. Typically, restrictions on recreation rely on buffer zones to protect wildlife; but if that buffer zone is wider than the river itself, then restrictions could

effectively eliminate the entire river corridor from human use. Steidl and Anthony (1996) measured flush response rate and flush distance of breeding and non-breeding bald eagles to recreational boating along the Gulkana River over a four-year period. Flush response rate and distance was associated with perch height, distance from the river's edge, age of bird, and recreation-group size. One strategy used to establish buffer zone width is to determine the distance within which 95% of the eagles approached flush and eliminate use within that area. For this area that distance (200 m) is greater than the widest part of the river (125 m). Managers, therefore, decided to use temporal rather than spatial restrictions to eliminate the number of flushes and to determine the quota for number of boaters.

Management activities, current or historic, may negatively impact wildlife species, even in protected wilderness areas. Research can help determine what practices are helping or harming species and what mitigation or restoration activities should be undertaken. Surprisingly little research has been conducted on wilderness management and its benefit to wildlife. In one study Pilliod and Peterson (2001) examined the relationship between fish stocking and amphibian distribution and abundance in eleven high-elevation basins in the Frank Church-River of No Return Wilderness in Idaho. Trout have been introduced into historically fishless lakes in wilderness areas and remain there today. The researchers found introduced trout in 43 of the 101 sites. Accounting for the differences in habitat characteristics between fish-containing and fishless sites, they found that long-toed salamanders and Columbia spotted frogs—their study species—were significantly less abundant in lakes with introduced fish, and that areas without trout were too shallow for most amphibians to survive in over the winter. Unless trout are removed from some lakes, amphibian persistence is unlikely.

Other studies have compared wildlife habitat conditions in wilderness to conditions found in other lands with different management regimes. For example, Sauder and Rachlow (2014) explored the effect of forest composition and configuration on habitat selection by fishers (*Martes pennanti*) in three different management categories: industrial timber production, multiple use lands, and roadless/wilderness areas. Ultimately, forest composition and configuration metrics were stronger indicators for fisher habitat selection than management history. In another study, researchers studied the persistence of endangered red-cockaded woodpecker (*Picoides borealis*) populations living inside and outside wilderness, to compare the influence of active management through prescribed fire, artificial cavities, and translocation (Saenz et al. 2001). Data covering nearly two decades showed that red-cockaded woodpecker numbers were significantly higher outside of wilderness, where conditions better met their habitat needs.

Wilderness as a laboratory for wildlife science

In considering the role of wilderness for science, Aldo Leopold called wilderness "a base-datum of normality, a picture of how healthy land maintains itself" (Leopold 1941, p. 3). However, there has been limited use of wilderness for wildlife research (Schwartz et al. 2016, Wright and Garrett 2000). Many of these studies have focused on "wilderness-dependent" species: usually large-bodied animals with low fecundity and low population growth rates; animals that are more likely to be killed because of conflicts with people or their property; and species that exhibit

aggressive behaviors that may threaten human safety. Wolverines, mountain lions, grizzly bears, gray wolves, and Canada lynx have all been described as wilderness-dependent species (Wright and Garrett 2000). Few studies have endeavored to research wildlife in wilderness—ideal areas because they are minimally confounded by human influences.

Approximately one-third of the publications in the bibliography are studies that investigate one or a few species within a relatively small area. As Schwartz et al. (2016) note:

> Of the few studies conducted within wilderness, most focused on one species in one wilderness (e.g., Koehler and Hornocker 1977, Etchberger et al. 1989, Mace and Waller 1997, Papouchis et al. 2001, Rominger et. al. 2004, Wasser et al. 2004, Fraser et al. 2005, Stoker et al. 2011, Schoenecker et al. 2015). For example, Etchberger et al. (1989) found that human disturbance and the presence of habitat where fire had been excluded were responsible for a decrease in the range size of bighorn sheep from 79.5 to 17.0 mi^2 within Pusch Ridge Wilderness, Santa Catalina Mountains, Arizona. Other autecological studies described changes in animal behavior (Walker and Marzluff 2015) with unknown implications for fitness (e.g., Titus and VanDruff 1981). In addition to studies that use wilderness as a general term or were limited to autecological examinations of species in a single wilderness, several studies speculated on the responses of wildlife to wilderness designation based first on principles of wildlife biology and conservation biology (e.g., Mech et al. 1988).

Research Needs / Knowledge Gaps / Priorities

Wilderness areas are often located in ecological settings that have few non-wilderness analogues (with respect to ecological productivity, topography, watershed configuration). Research questions that examine broad spatial extents in wilderness often focus on observational or synthetic approaches. The existing scientific literature includes a great deal of information on the dynamics of ecosystems, the behavior, population dynamics, and ecology of wildlife, and interactions between wildlife and humans. Many of the management questions related to wildlife and wilderness may be effectively approached through careful syntheses and interpretation of this existing science. Other questions may be approached through careful matching of sites in wilderness and non-wilderness. Here, we provide a series of research questions that rely on both new analyses and syntheses of existing data, recognizing that different questions would emerge as priorities for different species, places, or stakeholders.

- Science to measure the current and future value of wilderness areas for wildlife.

- What is the ecological value for wildlife of the entire National Wilderness Preservation System?

- How does the current National Wilderness Preservation System function as a source population for surrounding lands?

    - If habitat characteristics are matched (by elevation, ecosystem type, climate, etc.), how do wilderness areas compare to other protected areas, non-designated roadless areas, and non-designated roaded areas measured by presence/absence, density, or abundance of wildlife species?

- What is the role that wilderness areas play in providing habitat for rare, sensitive, threatened, and endangered species compared to non-wilderness lands? How might this role change under a warming climate?

- What is the role of wilderness areas in mitigating the effects of climate change for wildlife? To what degree will wilderness areas be expected to function as climate refugia for different wildlife species, and how is that value influenced by their biased distribution, spatial arrangement (isolation), representation, etc.?

- What is the relative contribution of wilderness to facilitating the movement of organisms or ecosystems relative to other public and private lands? Does wilderness provide special values for movement of wildlife and, if so, what features of wilderness are important and what are the characteristics of species that benefit particularly from wilderness (as opposed to multiple-use wildlands)?

- If we assume that wilderness areas are beneficial to wildlife, are wilderness areas sufficiently large, connected, and represented to sustain viable populations of rare, sensitive, threatened, and endangered species over the long term? How will a changing climate and increasingly intensive human land uses patterns alter the ability of wilderness to help sustain these organisms? If wilderness areas do not currently (or in the future) adequately help to sustain such organisms, are there opportunities to protect additional areas to improve wildlife persistence?

- Using a gap analysis, focused on species distributions or species-habitat associations (rather than on ecological systems), what is the relative representation of wildlife in designated wilderness areas? This analysis should consider the relative contributions of other public and private protected lands, including candidate wilderness areas (e.g., roadless areas).

    - Science to measure the current and future value of wildlife for wilderness areas.

    - What role does wildlife play in the social, cultural, and economic values realized by people from designated wilderness?

    - To what extent does the socio-economic value of wildlife in wilderness extend to areas outside wilderness?

    - Which wildlife species, if any, are critical to maintaining the ecological characteristics and ecological values of particular wilderness areas and therefore frame the character of the wilderness?

    - Which wildlife serve as keystone species for wilderness areas, with disproportionate effects on community structure and ecosystem functions?

- Unit-/area-specific questions. By answering these questions managers empower themselves to ask how management of the particular wilderness either supports, or harms, the maintenance of these critical ecological processes or ecological players (wildlife). These inquiries could uncover knowledge gaps and identify wildlife research priorities.

    - Which wildlife species and which ecological functions performed by wildlife are key to each wilderness area?

    - Are there key species whose dynamics are critical to the character of each wilderness area?

    - Similarly, are there ecological disturbances, dynamics, or interactions that are critical to the character of each wilderness area?

    - Which wildlife species does the public value most from this wilderness area and what are the economic, cultural, and social of these species?

    - How might managers communicate more effectively with local constituents to nurture the relationship between people and key wildlife in this wilderness area? Does the ecological trajectory of the wilderness, when considered in light of threats (e.g., climate change, invasive species) suggest that wildlife species valued by the public in this wilderness will persist?

- Science to determine where to designate new wilderness areas for wildlife.

- Where are the best opportunities to designate new areas (that meet wilderness characteristics) to increase the complementarity of the wilderness system (e.g., add representation of new species or habitats)?

- How could the principles of systematic conservation planning be applied to improve the designation of new wilderness areas that explicitly considers wildlife? Could the GAP analysis initiated in the 1990s (Scott et al. 1993) be updated with a synthesis of new research regarding the relative value of different land designations for wildlife conservation (including connectivity), and to inform evaluation of wilderness land designations and management planning?

- What is the relative role of wilderness and non-wilderness lands (private and public) in wildlife connectivity, both for maintaining the continuity of populations of wide-ranging species and facilitating movement of species distributions as ecosystems respond to climate change?

        - How can the results of a comprehensive connectivity analysis be used to inform conservation and management planning (e.g., optimizing the designation of new wilderness areas to maximize opportunities for primitive recreation and other human activities while also minimizing negative effects on wildlife)?

    - Science to inform wilderness management for wildlife.

    - Research priorities in this broad topic area will largely be specific to individual wilderness areas or groups of wilderness within similar social, geographic, or ecological contexts. One of the primary challenges will be identifying management-wildlife interactions that warrant investigation and setting priorities.

        - What are the effects of land-use legacies (i.e. historic land uses) in wilderness areas on wildlife?

        - How do management activities within wilderness affect wildlife (e.g., fish stocking, water catchments, vegetation, and fire management)?

        - To what degree do management activities and other human disturbances on adjacent lands affect wildlife in wilderness areas? What are the edge effect distances for wilderness areas in different landscape contexts? What reserve characteristics (e.g., size and shape) or network configurations of wilderness benefit wildlife?

- In the era of climate change, to what extent does management of wilderness need to become less "hands-off" to promote adaptation to climate change for native animals and plants? What are the tradeoffs between the potential for enhanced ecological condition and the inherent loss of untrammeled condition?

    - What are the effects of human recreation on wildlife, considering factors such as different recreational activities and intensities, seasonality, and taxonomic differences (Larson et al. 2016)? How can negative effects from human recreation be avoided or mitigated using spatial restrictions, seasonal closures, visitation quotas or other management strategies?

    - How do anthropogenic light and noise disturbances affect wildlife?

    - How does hunting influence the ecological condition of the wilderness? What is the relationship between hunting and social and cultural connections to the wilderness?

    - Do dogs that accompany visitors in wilderness areas significantly influence wilderness character, ecological systems, or wildlife in wilderness? Under what conditions are effects significant? Is management or regulation necessary to mitigate potential negative effects?

- Do horses and other pack animals that accompany visitors in wilderness areas significantly influence wilderness character, ecological systems, or wildlife in wilderness? Under what conditions are effects significant? Is management or regulation necessary to mitigate negative effects?

- What is the impact of 'primitive' trail facilities on fish and wildlife (e.g., both avoidance and attraction to trails)? Are there negative consequences for wetlands, talus slopes, or other relatively rare fish/wildlife habitats that result from management for minimum trail design in wilderness? (e.g., removing bridges in favor of stream crossings may increase bank erosion and stream siltation from livestock, thereby affecting reproductive success of fish and amphibian species.)

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