Biological Conservation 227 (2018) 243–251

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Mapping threats to wilderness character in the National Wilderness Preservation System

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ARTICLE INFO

Keywords:
Wilderness
Wilderness character
Wilderness stewardship
Mapping

ABSTRACT

The National Wilderness Preservation System in the United States provides the greatest level of protection for the ecological and social values of lands held in trust for future generations. Although designated wilderness is the cornerstone of the US conservation portfolio, designation alone doesn't assure the protection of these areas, which are degraded by threats both inside and external to the area. This paper describes new methods for quantifying the location and cumulative magnitude of threats to wilderness, allowing agency managers and the public to evaluate whether the legal mandate from the 1964 Wilderness Act to "preserve wilderness character" is being upheld. These new methods have also been used in developing wilderness stewardship plans and analyzing the potential effects of proposed projects that would degrade wilderness character. The methods described here were developed and tested in seven wildernesses in a variety of ecological, geographic, and administrative settings, and are directly applicable to evaluating threats and improving the management of all 110 million acres of designated wilderness in the United States, as well as all areas that are increasingly recognized internationally as wilderness.

1. Introduction

The US National Wilderness Preservation System (NWPS) is the world's largest highly-protected conservation network (IUCN and UNEP, 2015). Established with the passage of the Wilderness Act in 1964, the NWPS is currently composed of 765 individual wilderness areas, totaling approximately 110 million acres (Wilderness Institute, 2016). These areas protect a wide variety of habitats, including deserts, wetlands, grasslands, mountains, tundra, and coastal areas, and range in size from the Pelican Island Wilderness in northern Florida at 5.5 acres to the Wrangell-Saint Elias Wilderness in southeast Alaska at 9 million acres.

Each wilderness is managed by one or more federal agencies: Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and U.S. Forest Service (hereafter BLM, NPS, FWS, and FS respectively). These agencies are mandated by the Wilderness Act to administer wilderness "for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character."

Although wilderness is typically considered the utmost expression of conservation in the U.S., to date there has been no means for showing when, where, and how the ecological and social values of wilderness, expressed through the phrase "wilderness character," are improving or degrading. In this paper, we demonstrate spatial methods (that have now been tested in seven wildernesses) to map threats to wilderness character. We describe the lessons learned and the limitations in developing these maps, and we demonstrate how these maps can be used to evaluate the effects of proposed projects on wilderness character. Ultimately, the purpose of this paper is to present new methods that integrate the ecological and social values of wilderness into a holistic understanding that has important applications to preserving wilderness as a cornerstone of the U.S. conservation portfolio.

1.1. Defining wilderness character

Legal scholars (e.g., McCloskey, 1999; Rohlf and Honnold, 1988) have confirmed that preserving wilderness character is the primary legal mandate of the Wilderness Act, as has the United States Congress (1983), stating, "The overriding principle guiding management of all wilderness areas, regardless of which agency administers them, is the Wilderness Act (Section 4(b)) mandate to preserve their wilderness character." Despite this clear legislative mandate, the Wilderness Act does not define wilderness character nor is there legislative history on its meaning (Scott, 2002). Legal scholars point to the statutory section that defines wilderness (Section 2(c) of the Wilderness Act) for the

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https://doi.org/10.1016/j.biocon.2018.09.010
Received 28 November 2017; Received in revised form 14 August 2018; Accepted 6 September 2018

expression of congressional intent, both ideal and practical, for the meaning of wilderness character (McCloskey, 1966, 1999; Ochs, 1999; Rohlf and Honnold, 1988). Based on this statutory definition of wilderness, the four federal agencies that administer wilderness identified the following five "qualities" of wilderness character to operationalize this definition into practical monitoring and management direction (Landres et al., 2015): 1. untrammeled, 2. natural, 3. undeveloped, 4. solitude or primitive and unconfined recreation, and 5. other features of value. These qualities link on-the-ground conditions in wilderness and the outcomes of wilderness stewardship to the statutory definition of wilderness.

The qualities of wilderness character were originally developed to monitor how they change throughout an entire wilderness. This approach ignores two important considerations. First, it ignores the spatial variation in the status and trend of these qualities. Second, it ignores how these qualities interact to show the overall or cumulative status and trend of wilderness character. Additionally, monitoring alone is not sufficient for delivering conservation outcomes (Magness et al., 2010) and spatial products are required to support wilderness planning efforts and evaluate proposed actions inside or adjacent to wilderness.

1.2. Overview of mapping threats to wilderness character

We developed methods to map threats to the qualities of wilderness character and combine them to show the spatially-explicit cumulative impacts to wilderness character. The resultant maps depict the current degree of departure or degradation from an "optimal condition" of wilderness character. This optimal condition reflects an ideal manifestation of wilderness character as expressed in the Wilderness Act—in other words, a state in which there are no threats to wilderness character. These maps show tangible, on-the-ground degradation from this optimal condition, and can be used in the following ways:

- Set a baseline of current conditions from which future change in wilderness character can be monitored.
- Evaluate the potential impacts to wilderness character from projects and activities that are being proposed within or adjacent to a wilderness area.
- Help evaluate the cumulative potential impacts to wilderness character from alternative plans during development of a wilderness management plan.

To date, the scientific community has focused on inventorying attributes of landscapes such as remoteness and naturalness that make them more or less suitable for potential wilderness designation (McCloskey and Spalding, 1989; Aplet et al., 2000; Sanderson et al., 2002; Fisher et al., 2010; Carver et al., 2012; Watson et al., 2016). By combining these spatial attributes in a Geographical Information System (GIS), Lesslie and Taylor (1985), Carver and Fritz (1999) and Lesslie (2016) developed what they call a "wilderness quality continuum" for a landscape. This approach is useful for policy and planning decisions, such as identifying potential lands to protect as wilderness (Lesslie and Taylor, 1985; Muller et al., 2015). However, once a wilderness area is protected, how do managers assess current and potential threats that are both internal and external to the area?

To address this question, Tulloch et al. (2015) used spatial data to understand the distribution of threats in and adjacent to protected areas and the costs of managing them. Threats and impacts to wilderness character are defined as a combination of historical activities that continue to degrade wilderness character (e.g., historical logging activity, departure from natural fire regimes), current actions or influences that degrade wilderness character (e.g., non-native invasive species, administrative motorized/mechanized use), and impending issues that are likely to degrade wilderness character into the future (e.g., change in winter temperature, night sky obfuscation) (Tricker et al., 2017). Approaches to mapping threats range from depicting the spatial distribution of a single threat (e.g., Schmidt et al., 2002) to additive scoring approaches for multiple threats (Halpern et al., 2008). The approach outlined in this paper draws on this body of work by using spatial data and GIS techniques to map individual threats to the qualities of wilderness character.

The hierarchical framework for monitoring trends in wilderness character (Landres et al., 2015) is used to develop spatially-explicit maps of threats to wilderness character. This framework divides wilderness character into the following successively finer components:

Qualities – the primary elements of wilderness character that link directly to the statutory language of the Wilderness Act.

Indicators – distinct and essential components under each of the qualities.

Measures – specific elements for which data are collected to assess trend in an indicator.

The qualities and indicators are nationally consistent across all four wilderness managing agencies and across all wildernesses regardless of geographic location, ecosystem, and size. The measures are specific to each wilderness based on local threats, management concerns, and data availability. The mapping approach presented in this paper utilizes this framework to create a GIS-based model that iteratively builds a series of maps for each of these hierarchical levels (Fig. 1). Individual measures are mapped using spatial datasets and weighted to reflect their respective influence on wilderness character. These map layers are then added accumulatively using these weights to create maps for the indicators and qualities, and an overall map of threats to wilderness character.

2. Study areas

Seven wilderness areas were selected to test the robustness and compatibility of the mapping approach (Fig. 2, Table 1). These wilderness areas vary in size from 70,905 to 7,167,192 acres, range in distance from urban populations (urban-proximate versus remote), offer unique types of access (e.g., watercraft in the Boundary Waters Canoe Area Wilderness [BWCAW], shuttle buses in the Denali Wilderness, bush planes in the Gates of the Arctic Wilderness), have different levels of visitation (from 10,000 to over a million visitors per year), and fall within a variety of ecoregions (Table 1). The rationale for selecting these diverse types of study areas is not to present results from different wildernesses and compare them but instead to demonstrate that this mapping approach can be applied to any wilderness area within the NWPS.

3. Approach

Developing a map of threats to wilderness character involves several steps, encompassing a combination of administrative and technical tasks. The first step is assembling a multi-disciplinary team, including a project coordinator and a GIS specialist who have in-depth knowledge of the wilderness. This team is responsible for the following tasks that dictate the overall approach to each project: answer a set of strategic questions that will define the project parameters; select the measures to include in the wilderness character map; identify spatial data to depict the degradation to each measure; and choose weights that reflect the impact each measure has on the wilderness area.

There are several strategic decisions that underpin the entire process of developing these maps. These decisions must be discussed and agreed on by the project team at the beginning of the mapping process, which then provides the foundation for all subsequent tasks and allows the project to move forward in a deliberate and efficient manner. These decisions cover a wide scope of issues, such as determining project goals, how to interpret the wilderness character framework, how far back in time to track actions in wilderness and at what spatial resolution to perform the GIS analysis. These decisions are influenced by existing staff knowledge of wilderness character, data availability for