**Mapping Threats to Wilderness Character**

**in the** [insert wilderness name]

Author names

Date

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Executive Summary

The recent update of the interagency strategy to monitor wilderness character, *Keeping It Wild 2: An Interagency Strategy for Monitoring Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015), allows on-the-ground managers and decision-makers to assess whether stewardship actions for an individual wilderness are fulfilling the legislative mandate to “preserve wilderness character.” By using credible data that are consistently collected, one can assess how wilderness character changes over time and evaluate how stewardship actions affect wilderness character. As most of these data depict spatial or geographic features in wilderness, a Geographic Information System (GIS) -based approach was developed to depict threats to wilderness character in the [insert wilderness name].

A set of measures was identified by the project team to capture the impacts to the five qualities of wilderness character (untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and other features of value). These measures were depicted using a variety of spatial datasets, which were normalized using a common relative scale such that disparate metrics could be analyzed together. Each measure was “weighted” by the team to reflect its relative impact to wilderness character. Maps generated for each of the weighted measures were then added together to produce the composite map of threats to wilderness character in the [insert wilderness name].

The map products in this report delineate the range in the condition of wilderness character—based on the measures that were identified and the datasets that were used—and serve as a baseline for evaluating threats to wilderness character in the [insert wilderness name]. Future maps of threats to wilderness character can be updated with new and improved data as they become available. The maps will also be used by [insert agency name] staff to inform and support new management plans, Wilderness Stewardship Performance planning, and management decision-making.

Acknowledgements

Acronyms and Abbreviations

DEM – Digital Elevation Model

EPA – Environmental Protection Agency

GIS – Geographic Information System

NNIS – Non-Native Invasive Species

NWPS – National Wilderness Preservation System

RAWS – Remote Automated Weather Stations

USGS – U.S. Geological Survey

Introduction

The Wilderness Act of 1964 (Public Law 88-577) established the National Wilderness Preservation System (NWPS) “for the protection of these areas, [and] the preservation of their wilderness character” (Section 2(a)). In congressional testimony clarifying the intent of wilderness designation, Howard Zahniser (1962) said, “The purpose of the Wilderness Act is to preserve the wilderness character of the areas to be included in the wilderness system, not to establish any particular use”; legal scholars (Rohlf and Honnold 1988; McCloskey 1999) subsequently confirmed that preserving wilderness character is the Act’s primary legal mandate. Furthermore, the policies of all four wilderness managing agencies state that they are to preserve wilderness character in all areas designated as wilderness.

Wilderness character is an inherent part of a wilderness, and varies across the landscape just as landscape features vary from one place to the next. Maps that depict how wilderness attributes vary across the landscape from least to most wild have been produced at a variety of scales: globally (Sanderson et al. 2002), continentally (Carver 2010), nationally (Aplet et al. 2000), and locally (Carver et al. 2008). Adding to this body of work, a recent study for the Death Valley Wilderness (Tricker et al. 2012; Carver et al. 2013) has provided a spatially explicit description of impacts to wilderness character for all lands falling within a particular National Park Service (NPS) wilderness. This approach has been strongly supported by the NPS, and further studies have been conducted for six NPS wildernesses. In 2017, the first Forest Service administered wilderness character map was developed for The Boundary Waters Canoe Area Wilderness (BWCAW). All these previous projects were managed by the Aldo Leopold Wilderness Research Institute. The [insert wilderness name] is hereby the first wilderness area to produce a wilderness character map independently.

[insert wilderness name] *Wilderness*

**Figure 1.** Wilderness map

*Purpose of this mapping project*

The purpose of this project was to develop an approach that spatially depicts threats to wilderness character in the [insert wilderness name] and how they vary across the wilderness. This mapping effort:

* Shows the current extent and magnitude of threats to wilderness character and how they vary across the [insert wilderness name].
* Provides a measurement baseline from which future monitoring can show how threats to wilderness character change spatially over time.
* Allows the SNF to analyze the potential impacts of different management actions on wilderness character.
* Identifies areas within the wilderness where resource managers should make an effort to control or mitigate impacts. These efforts may include monitoring conditions, establishing thresholds, or taking direct action.
* Identifies specific activities or impacts outside the wilderness that may pose a substantial risk of degrading wilderness character inside wilderness.
* Improves internal staff communication about wilderness and wilderness character and improves external communication between the forest and the public on related issues.
* Identifies and fills data gaps by collecting information from local staff and digitizing new spatial data.

In addition to the immediate benefits described above, this project improved and consolidated existing spatial datasets and generated new datasets. These datasets, and the maps produced by this project, lay the groundwork for future wilderness character mapping efforts in the [insert wilderness name]. When and if the [insert agency unit name] is able to conduct future iterations of the map of threats to wilderness character, the maps in this report can serve as the baseline for assessing how threats to wilderness character change spatially over time.

*Concerns and cautions*

There are a number of potential concerns about producing maps of threats to wilderness character. Despite these concerns, managers have recognized these maps as the best available tool for spatially representing impacts to wilderness character. Major cautions about this overall effort include:

* *Creating sacrifice zones* – The map may facilitate the inappropriate creation of “sacrifice zones” or internal buffers within the wilderness, directly contravening congressional and agency mandates to preserve wilderness character across an entire wilderness. For example, if the map shows that some areas are “better” or of “higher quality” than others, the tendency may be to focus efforts on preserving wilderness character only in these specific areas while allowing wilderness character to degrade in “lower quality” areas. By showing the current extent and magnitude of threats to wilderness character and how they vary across the entire wilderness, the intent of the map is to help staff maintain high quality areas while improving lower quality areas.
* *Comparing wilderness character among wildernesses* – Since this approach has been used for other wilderness areas, the map may facilitate inappropriate comparisons of wilderness character among different wildernesses. These maps show the current extent and magnitude of threats to wilderness character in different colors (representing pixel values), and it would be easy for users to compare the quantity of a given color from one wilderness to another. Comparing these maps among different wildernesses, however, is neither valid nor appropriate because each map is built with data from the unique context of a particular wilderness.
* *Assuming that the resulting map completely describes wilderness character* – The map may be misconstrued as an accurate and precise description of wilderness character. The map is instead only an estimate of selected threats to wilderness character for which spatial data were available for this particular wilderness. As an approximate representation of threats to wilderness character, the map should not be considered an absolute and complete description. In addition, the map does not portray the threats to the symbolic, intangible, spiritual, or experiential values of wilderness character. In short, while this map is useful for the purposes outlined above, it does not describe the complexity, richness, or depth of wilderness character.
* *Updating datasets in the future such that maps are not directly comparable* – As datasets are updated over time, future iterations of the map may not be comparable with the original map. Each map is a product of both the best available spatial data and the locally defined methods for processing those data. As with all long-term monitoring efforts, changes in the type and quality of data or in the data processing techniques can make comparisons between original and subsequent data invalid. Therefore, proposals to use new or altered data, or to change data processing methods, need to be assessed carefully to ensure the comparability of map products over time.

*Report outline*

A team approach was used to develop the map of threats to wilderness character in the [insert wilderness name], tapping the experience and knowledge of [insert agency unit name] staff (see pages XXX for a full list of staff involved). Together, the project core team and other [insert agency unit name] staff have more than XXX person-years of on-the-ground experience in and with the [insert wilderness name]. The project core team, and other [insert agency unit name] staff as required, conducted multiple face-to-face meetings and had numerous phone and email conversations while developing the map products described in this report. All decisions about developing the map were made by project core team consensus.

This report provides an in-depth discussion of how the map of threats to wilderness character was developed. It is divided into three major sections:

* Overview of the process for developing the map of threats to wilderness character – describes the conceptual foundation for how the map was developed.
* Methods – describes the measures that were used to represent the degradation of wilderness character, along with the data sources, data processing methods, data and measure cautions, and the rationale for measure weighting.
* Map of threats to wilderness character – discusses some of the patterns revealed in the map, approaches to improving map development in the future, and final concerns about the overall process.

Overview of the Process for Developing the Map of Threats to Wilderness Character

This wilderness character mapping project used a Geographic Information System (GIS) to spatially describe and assess impacts to wilderness character in the [insert wilderness name]. With this approach, it is essential to understand the variety of activities and influences that “threaten” wilderness character, as well as the role of wilderness managers in mitigating or responding to such threats. In the [insert wilderness name], there has been, and continues to be, a substantial amount of human influence—ranging from a long history of human use and resource extraction, to current high visitation levels, to reasonably foreseeable future impacts from climate change. Although the [insert wilderness name] is far from being considered a “pristine” or “pure” wilderness, managers are nevertheless tasked with protecting and preserving its wilderness character from further degradation. As stated in FS policy: “Each designated wilderness is affected by a variety of human influences that vary in intensity…The goal of wilderness management is to identify these influences, define their causes, remedy them, and close the gap…between the attainable level of purity and the level that exists on each wilderness” (FSM 2320.6). Only by understanding the myriad human influences that affect—or “threaten”—wilderness character can managers meet wilderness stewardship goals.

For this report, “threats” 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).
* Impending issues that are likely to degrade wilderness character into the future (e.g. change in winter temperature, night sky obfuscation).

By identifying and depicting threats to wilderness character, the maps produced in this report provide managers with a tool to better understand the extent and magnitude of impacts to wilderness character in the [insert wilderness name] and thereby improve wilderness stewardship.

This project adheres to the interagency strategy for monitoring wilderness character, as described in *Keeping it Wild 2: An Updated Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015). This interagency strategy was formally endorsed in the fall 2015 by the Interagency Wilderness Policy Council (which is composed of the highest policy-level personnel responsible for wilderness in each of the four wilderness managing agencies). Therefore, by adhering to the interagency strategy, this project is consistent with [add agency name] and interagency policies, terminology[[1]](#footnote-1), and monitoring protocols for wilderness character.

*The five qualities of wilderness character*

*Keeping It Wild 2* provides a tangible definition of wilderness character and identifies five qualities of wilderness character that apply uniquely to every wilderness: untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and other features of value. These qualities apply to all designated wilderness areas because they are based on the legal definition of wilderness from the Wilderness Act (Section 2(c)).

Actions managers choose to take—or not take—in wilderness have the potential to degrade or improve these qualities and affect wilderness character. Challengingly, actions taken to protect or improve one quality of wilderness character may often result in the degradation of another quality (Landres et al. 2015). For example, although maintaining latrines at campsites protects water quality and benefits the natural quality, the latrines are also facilities that decrease opportunities for primitive recreation and installations that diminish the undeveloped quality. These types of tradeoffs are inherent to many aspects of wilderness stewardship, and understanding how a single action may have different effects on the qualities of wilderness character is essential for evaluating management decisions and actions in wilderness.

In addition to the actions, or inaction, of managers, wilderness character may also be affected by factors outside the jurisdiction of the [insert agency name]. For example, air pollution, night sky light pollution, and climate change are not under the direct control of wilderness managers but can still have substantial effects on the qualities of wilderness character. The inclusion of these types of external impacts in the interagency wilderness character monitoring strategy (and, consequently, in this mapping project) does not constitute an application of wilderness laws, policies, and restrictions to non-wilderness areas (i.e. the creation of a “buffer” around wilderness); instead, it is an acknowledgement that broad-scale social and ecological changes may affect wilderness character (Landres et al. 2015).

Certain activities may be legally allowed in wilderness and yet also threaten wilderness character. Although the Wilderness Act prohibits “nonconforming” uses (such as motorized use, mechanical transport, or the installation of permanent developments), specific exceptions have been permitted through special provisions in the Wilderness Act itself and in subsequent wilderness legislation. The Wilderness Act states that nonconforming uses or activities may be permitted only “as necessary to meet minimum requirements for the administration of the area for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area)” (Section 4(c)). Additional special provisions may also be legislated for a specific wilderness to allow, or require, nonconforming activities by managers or visitors. Even in situations where such uses are both legal and justifiable, however, nonconforming activities still degrade wilderness character (Landres et al. 2005; Landres et al. 2015). Over time, the cumulative effects of these legal yet nonconforming uses may cause a substantial impact to wilderness character, which emphasizes the need to carefully weigh future decisions related to such activities.

*The mapping framework*

The five qualities of wilderness character form the foundation of the interagency monitoring strategy, and are the first level of the hierarchical monitoring framework. As described in *Keeping it Wild 2*, this framework divides wilderness character into successively finer components: the qualities of wilderness character are divided into a standard set of indicators[[2]](#footnote-2), which are monitored in turn through a set of locally relevant measures[[3]](#footnote-3). For this project, measures were selected by the project core team to represent threats to wilderness character in the [insert wilderness name]. Individual measures were mapped using spatial datasets and weighted to reflect their respective influences on wilderness character. Maps of the measures were then added accumulatively using these weights to create maps of the indicators and qualities, as well as an overall map of threats to wilderness character in the [insert wilderness name] (Figure 2).

For this mapping project, measures were explicitly selected to represent features, conditions, and actions that threaten wilderness character in the [insert wilderness name]. For example, the authorized developments measure depicts where the undeveloped quality has been degraded by the presence of permanent installations. While some actions, conditions, or features in wilderness may have a positive influence on wilderness character (such as the preservation of an endangered keystone species), such “value added” features are not encompassed by the selected measures. Similarly, when actions or features have a mix of both positive and negative effects (such as management regulations that confine visitors in order to protect natural resources), the selected measures only quantify the negative impacts. The [insert wilderness name] project core team decided to adopt this “negative mapping” approach because it allows for the full magnitude of threats to be depicted. In contrast, simultaneously displaying positive and negative impacts on a single map would result in these opposing influences being mutually offset or cancelled out, thereby obscuring the true extent of their individual effects on wilderness character. Therefore, the map products presented in this report only depict threats to wilderness character and do not capture management activities that benefit or improve wilderness character.

At first glance, it could appear inappropriate or meaningless to combine measures into a single overall map since each measure captures a unique and distinct impact to wilderness character. For example, it may seem counterintuitive to combine the areal extent of invasive plants with the probability of encounters with other visitors. However, since all measures quantify threats to wilderness character, combining measures is both appropriate and important for understanding and recording the magnitude of their cumulative effects. Additional information on the rationale and methods for accumulatively combining disparate measures to produce an overall map of threats to wilderness character are described by Carver et al. (2013). While data and maps for individual measures are relevant for local management purposes, the intent of this mapping project is also to understand and report on the big picture—to represent the cumulative spatial pattern and variation of threats to wilderness character. This big picture is a powerful and effective tool for communicating wilderness issues within the agency and with external audiences (Landres et al. 2008b).



**Figure 2.** Flow chart of the framework used for mapping threats to wilderness character.

Mapping threats to wilderness character differs from wilderness character monitoring in a key way. While monitoring efforts focus on assessing change in wilderness character over time by producing a single overall trend direction (i.e. improving/upward, stable, or degrading/downward), this mapping project examined the current (baseline) extent and magnitude of threats to wilderness character and how those cumulative threats vary across the wilderness. The overall map of threats to wilderness character was therefore generated directly from the weighted measures, and did not undergo a standardization process at each level of the hierarchical framework (as is the case when deriving trends for wilderness character monitoring). This approach allowed the magnitude of threats to be depicted so that qualities with few or lightly weighted measures (i.e. fewer or milder threats) had a proportionally smaller influence on the overall map of threats to wilderness character than qualities with many or heavily weighted measures (i.e. more or greater threats).

The maps produced through this project depict the [insert wilderness name]’s 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. Each measure is depicted across the wilderness on a scale from its “optimal condition” (i.e. no threat) to its most “degraded condition” (i.e. highest current threat level). When the measures are combined accumulatively, therefore, the overall map of threats to wilderness character is similarly depicted on a scale from its optimal condition (i.e. no threats to wilderness character) to its most degraded condition (i.e. highest cumulative threat level from all measures). The optimal conditions depicted in the map products do not represent the condition of wilderness character in the [insert wilderness name] in 1964, and therefore cannot be used to determine if threats to wilderness character have increased or decreased since the time of designation.

Methods

Selecting measures under each indicator of the five qualities was an iterative and collaborative decision-making process. Possible measures were first identified by the project core team, and then evaluated for both their relevance to the indicator and the availability and quality of the required data. [insert agency unit name] staff assessed data quality for each dataset using two metrics: accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness). In general, only measures that were relevant, and that had readily available data of sufficient quality, were included. For certain measures this involved developing new datasets based on institutional knowledge (i.e. drawing known locations of impacts onto paper maps). In some cases, potential measures had insufficient or non-existent data but were acknowledged by [insert agency unit name] staff for their significance to their respective indicators; these “data gap” measures are noted below under each applicable quality. As data improve or become available, the data gap measures should be reevaluated for inclusion in future iterations of the map of threats to wilderness character.

*Weighting measures*

Once all measures were selected, each was evaluated independently to determine the magnitude of its effect on wilderness character. Some measures have a greater impact to wilderness character than others; for example, the shoreline erosion measure has a relatively smaller impact (because it only occurs at one location), whereas the departure from natural fire regimes measure has a relatively greater impact (because fire suppression is widespread and causes blowdowns, tree species changes, and fuel build up). To accurately portray the variable magnitudes of the measures’ effects, each measure was assigned a “weight”—a value from 1 (low impact) to 10 (high impact)—by the project core team. The project core team then reviewed the map outputs and modified the weighting scheme to reflect their knowledge of the condition of wilderness character on the ground. While this interactive process runs the risk of allowing staff to “game the system” to produce a desired outcome, staff experience has been shown to be highly accurate in judging resource conditions (Cook et al. 2009). The project core team used caution and consensus-driven oversight to ensure accuracy in the maps produced.

Specific rationales for weights assigned to each measure can be found in tables 2, 4, 6, 8, and 10 under their respective qualities. The following questions were used to help determine weights for all measures:

* Is the measure specific to a particular area (lower weight) or spread throughout the wilderness (higher weight)?
* Does the measure represent a major management issue, e.g. suppressed fires (higher weight), or is it something relatively benign, e.g. boundary markers (lower weight).
* Does the measure depict an emerging threat that requires intensive management, e.g. the spread of non-native invasive species (higher weight), or does it depict an issue that has largely been solved and is no longer of high concern to management, e.g. sulfur deposition (lower weight)?
* Is the measure relevant to a particular time of year or season (lower weight), or is it an issue year-round (higher weight)?
* Are the data representing the measure accurate and complete (higher weight) or are they of poorer quality (lower weight)?
* Are the data qualitative (lower weight) or quantitative (higher weight)?

*Data sources and processing techniques*

Measures were mapped by applying GIS-based techniques to their respective datasets. A total of XXX datasets were used for measuring and delineating threats to wilderness character in the BWCAW. These datasets were obtained from a variety of sources and comprised local, regional, and national spatial data at varying scales, accuracy, and completeness. This variation placed limitations on how the map products were developed and necessitated the use of adaptable data processing methods, as described below. Metadata were developed for each data layer used in this mapping project, and include documentation of processing flows, quality/completeness, editing, development, and cautionary notes. All data and metadata were organized and stored on a network drive to ensure accessibility and facilitate use in future analyses. Datasets included:

* Commonly-used data layers that are stored in the [insert agency local network drive] (a centrally-located geospatial repository that is accessible to [insert agency name] staff).
* Existing data layers associated with previous or on-going [insert agency name] projects.
* Existing datasets that were edited, combined, or refined as a prerequisite for use in this project.
* Original datasets that were developed from local sources (including records, reports, and expert knowledge) and converted into a geospatial format.

A number of basic processing tasks were performed using ArcGIS[[4]](#footnote-4) for datasets before they were used as measures to create the map of threats to wilderness character. All datasets were projected in ArcGIS using the [insert relevant coordinate system] coordinate system. For vector[[5]](#footnote-5) datasets, a value was assigned to each feature by the project core team to represent its spatial impact in the [insert wilderness name]. Some of the vector datasets had features with a range of values because of the data they represent; for example, under the authorized developments measure, small markers and plaques were ranked with a value of 1, larger dams and docks with a value of 2, and functional structures with a value of 3. The vector datasets were then converted to raster grids[[6]](#footnote-6) whereby locations of the features or their associated effects were represented by the assigned values; unaffected areas of the wilderness (i.e. where no degradation occurs) were set to a value of 0.

The values for all raster grid layers were normalized[[7]](#footnote-7) by stretching them to a standardized range of values (0–255). This normalized range of values allows datasets, and therefore measures, to be evaluated together on a common relative scale (Carver et al. 2008). For example, the campsite noise inside wilderness and nitrogen deposition measures use different units (decibels vs. parts per billion) and cannot be directly compared without normalization. Lower values of normalized measures were used to represent optimal conditions (i.e. no threat) and higher values to represent degraded conditions (i.e. high threat level).

In the following sections, the measures and datasets used are described for each of the five qualities of wilderness character. Measures are organized by their weight within each quality, with higher weighted measures listed first. For each measure included in this analysis, the specific data sources, processing, and cautions are also described. All datasets and measures used the units of the original data source(s); throughout this report, metric units (e.g. kilometers) and imperial units (e.g. miles) are used interchangeably. The maps represent a grid of values (approximately 5 million pixels at a 30m resolution) and use a blue-red color ramp and the “minimum-maximum” stretch method[[8]](#footnote-8) to enhance the color contrast; areas of optimal condition (no threat) are shown in blue, while areas of degraded condition (high threat level) are shown in red.

Untrammeled Quality

The untrammeled quality focuses on the degree to which wilderness is unhindered and free from modern human control or manipulation. The untrammeled quality is degraded by actions that intentionally manipulate or control ecological systems (in contrast to the natural quality, which is degraded by the *effects* of modern civilization) (Landres et al. 2015).

To spatially depict the baseline of threats to untrammeled quality in the [insert wilderness name], the project core team decided to provide a cumulative summary of all trammeling actions from 1978 (the year of the Boundary Waters Canoe Area Wilderness Act) to 2014. While some measures had data available for the entire 37-year period, other measures did not; in these cases, the most recent complete datasets were used instead.

*Indicators and measures*

*Keeping it Wild 2* delineates two indicators under the untrammeled quality. The measures selected for the [insert wilderness name] are described below for each of these indicators. No data gap measures were identified for this quality.

Indicator: Actions authorized by the federal land manager that intentionally manipulate the biophysical environment

* Measure 1 –
* Measure 2 –

Indicator: Actions not authorized by the federal land manager that intentionally manipulate the biophysical environment

* Measure 1 –
* Measure 2 –

*Data gap measures*

Additional measures under this quality were identified by [insert agency name] staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Measure 1

* *Indicator:*
* *Description:*
* *Rationale for Dismissal:*

*Data sources, processing, and cautions*

The datasets used to create the untrammeled quality map are all vector data, of fine scale, and generally of moderate to high accuracy and completeness (Table 1). The data sources, data processing information, and cautions are listed below for each measure.

**Table 1.** Untrammeled quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by [insert agency unit name] staff familiar with these data.

| **Measure** | **Source** | **Type** | **Scale** | **Accuracy** | **Completeness** |
| --- | --- | --- | --- | --- | --- |
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Measure 1

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 2

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 3

* *Sources:*
* *Processing:*
* *Cautions:*

*Weighting*

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the untrammeled quality are described below (Table 2).

**Table 2.** Measure weights and rationales for the untrammeled quality.

| **Indicator** | **Measure** | **Weight** | **Rationale** |
| --- | --- | --- | --- |
| **Actions authorized by the federal land manager that intentionally manipulate the biophysical environment** |  |  |  |
|  |  |  |
|  |  |  |
| **Actions not authorized by the federal land manager that intentionally manipulate the biophysical environment** |  |  |  |
|  |  |  |

*Maps*

The weighted measures under each indicator were added together using a raster calculator to create two maps: “actions authorized by the federal land manager that intentionally manipulate the biophysical environment” and “actions not authorized by the federal land manager that intentionally manipulate the biophysical environment” (Figure 3). All the measures were then added together using the same process to create the untrammeled quality map (Figure 4).

**Figure 3.** Indicator maps for (A) actions authorized by the federal land manager that intentionally manipulate the biophysical environment and (B) actions not authorized by the federal land manager that intentionally manipulate the biophysical environment. Blue depicts optimal condition and red depicts degraded condition.

**Figure 4.** Map of the untrammeled quality of wilderness character. Blue depicts optimal condition and red depicts degraded condition.

Natural Quality

The natural quality centers on the idea that wilderness contains ecological systems that are substantially free from the effects of modern civilization. This quality is degraded by the intended or unintended effects of modern people on ecological systems inside wilderness (Landres et al. 2015).

*Indicators and measures*

*Keeping it Wild 2* delineates four indicators under the natural quality. The measures selected for the [insert wilderness name] are described below for each of these indicators. No data gap measures were identified for this quality.

Indicator: Plants

* Measure 1 –
* Measure 2 –

Indicator: Animals

* Measure 1 –
* Measure 2 –

Indicator: Air and water

* Measure 1 –
* Measure 2 –

Indicator: Ecological processes

* Measure 1 –
* Measure 2 –

*Data gap measures*

Additional measures under this quality were identified by [insert agency name] staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Measure 1

* *Indicator:*
* *Description:*
* *Rationale for Dismissal:*

*Data sources, processing, and cautions*

A wide variety of datasets were used to create the natural quality map. These datasets included both vector and raster data, exhibited high variation in scale, had mostly high levels of accuracy, and had differing levels of completeness (Table 3). The data sources, data processing information, and cautions are listed below for each measure.

**Table 3.** Natural quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by [insert agency unit name] staff familiar with these data.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure** | **Source** | **Type** | **Scale** | **Accuracy** | **Completeness** |
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Measure 1

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 2

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 3

* *Sources:*
* *Processing:*
* *Cautions:*

*Weighting*

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the natural quality are described below (Table 4).

**Table 4.** Measure weights and rationales for the natural quality.

| **Indicator** | **Measure** | **Weight** | **Rationale** |
| --- | --- | --- | --- |
| **Plants** |  |  |  |
|  |  |  |
|  |  |  |
| **Animals** |  |  |  |
|  |  |  |
|  |  |  |
| **Air and water** |  |  |  |
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| **Ecological processes** |  |  |  |
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*Maps*

The weighted measures under each indicator were added together using a raster calculator to create three maps: “plants,” “animals,” “air and water,” and “ecological processes” (Figure 5). All the measures were then added together using the same process to create the natural quality map (Figure 6).

**Figure 5.** Indicator maps for (A) plants, (B) animals, (C) air and water, and (D) ecological processes. Blue depicts optimal condition and red depicts degraded condition.

**Figure 6.** Map of the natural quality of wilderness character. Blue depicts optimal condition and red depicts degraded condition.

Undeveloped Quality

The undeveloped quality centers on the idea that wilderness is without permanent improvements or modern human occupation. This quality is degraded by the presence of structures and installations, as well as the use of motor vehicles, motorized equipment, and mechanical transport, because these increase people’s ability to occupy or modify the environment (Landres et al. 2015).

*Indicators and measures*

*Keeping it Wild 2* delineates three indicators under the undeveloped quality. The measures selected for the [insert wilderness name] are described below for each of these indicators. No data gap measures were identified for this quality.

Indicator: Presences of non-recreational structures, installations, and developments

* Measure 1 –
* Measure 2 –

Indicator: Presence of inholdings

* Measure 1 –
* Measure 2 –

Indicator: Use of motor vehicles, motorized equipment, or mechanical transport

* Measure 1 –
* Measure 2 –

*Data gap measures*

Additional measures under this quality were identified by [insert agency name] staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Measure 1

* *Indicator:*
* *Description:*
* *Rationale for Dismissal:*

*Data sources, processing, and cautions*

The datasets used to create the undeveloped quality map are all vector data, of fine scale, and generally of moderate to high accuracy and completeness (Table 5). The data sources, data processing information, and cautions are listed below for each measure.

**Table 5.** Undeveloped quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by [insert agency unit name] staff familiar with these data.

| **Measure** | **Source** | **Type** | **Scale** | **Accuracy** | **Completeness** |
| --- | --- | --- | --- | --- | --- |
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Measure 1

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 2

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 3

* *Sources:*
* *Processing:*
* *Cautions:*

*Weighting*

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the undeveloped quality are described below (Table 6).

**Table 6.** Measure weights and rationales for the undeveloped quality.

| **Indicator** | **Measure** | **Weight** | **Rationale** |
| --- | --- | --- | --- |
| **Presence of non-recreational structures, installations, and developments** |  |  |  |
|  |  |  |
|  |  |  |
| **Presence of inholdings** |  |  |  |
|  |  |  |
|  |  |  |
| **Use of motor vehicles, motorized equipment, or mechanical transport** |  |  |  |
|  |  |  |
|  |  |  |

*Maps*

The weighted measures under each indicator were added together using a raster calculator to create three maps: “presence of non-recreational structures, installations, and developments,” “presence of inholdings,” and “use of motor vehicles, motorized equipment, or mechanical transport” (Figure 7). All the measures were then added together using the same process to create the undeveloped quality map (Figure 8).

**Figure 7.** Indicator maps for (A) presence of non-recreational structures, installations, and developments, (B) presence of inholdings, and (C) use of motor vehicles, motorized equipment, or mechanical transport. Blue depicts optimal condition and red depicts degraded condition.

**Figure 8.** Map of the undeveloped quality of wilderness character. Blue depicts optimal condition and red depicts degraded condition.

Solitude or Primitive and Unconfined Recreation Quality

The solitude or primitive and unconfined recreation quality focuses on the outstanding opportunities that exist in wilderness to experience solitude, remoteness, and primitive recreation free from the constraints of modern society. This quality is degraded by tangible attributes of the setting that reduce these opportunities, such as visitor encounters, signs of modern civilization, recreation facilities, and management restriction on visitor behavior (Landres et al. 2015).

*Indicators and measures*

*Keeping it Wild* *2* delineates four indicators under the solitude or primitive and unconfined recreation quality. The measures selected for the [insert wilderness name] are described below for each of these indicators. No data gap measures were identified for this quality.

Indicator: Remoteness from sights and sounds of human activity inside wilderness

* Measure 1 –
* Measure 2 –

Indicator: Remoteness from sights and sounds of human activity outside the wilderness

* Measure 1 –
* Measure 2 –

Indicator: Facilities that decrease self-reliant recreation

* Measure 1 –
* Measure 2 –

Indicator: Management restrictions on visitor behavior

* Measure 1 –
* Measure 2 –

*Data gap measures*

Additional measures under this quality were identified by [insert agency name] staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Measure 1

* *Indicator:*
* *Description:*
* *Rationale for Dismissal:*

*Data sources, processing, and cautions*

A wide variety of data sources were used to create the solitude or primitive and unconfined recreation quality map. These datasets included both vector and raster data in a range of different scales and with high variability in accuracy and completeness (Table 7). The data sources, data processing information, and cautions are listed below for each measure.

**Table 7.** Solitude or primitive and unconfined recreation quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by [insert agency unit name] staff familiar with these data.

| **Measure** | **Source** | **Type** | **Scale** | **Accuracy** | **Completeness** |
| --- | --- | --- | --- | --- | --- |
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|  |  |  |  |  |  |

Measure 1

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 2

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 3

* *Sources:*
* *Processing:*
* *Cautions:*

*Weighting*

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the solitude or primitive and unconfined recreation quality are described below (Table 8).

**Table 8.** Measure weights and rationales for the solitude or primitive and unconfined recreation quality.

| **Indicator** | **Measure** | **Weight** | **Rationale** |
| --- | --- | --- | --- |
| **Remoteness from sights and sounds of human activity inside wilderness** |  |  |  |
|  |  |  |
|  |  |  |
| **Remoteness from sights and sounds of human activity outside the wilderness** |  |  |  |
|  |  |  |
|  |  |  |
| **Facilities that decrease self-reliant recreation** |  |  |  |
|  |  |  |
|  |  |  |
| **Management restrictions on visitor behavior** |  |  |  |
|  |  |  |
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*Maps*

The weighted measures under each indicator were added together using a raster calculator to create four maps: “remoteness from sights and sounds of human activity inside wilderness,” “remoteness from sights and sounds of human activity outside the wilderness,” “facilities that decrease self-reliant recreation,” and “management restrictions on visitor behavior” (Figure 9). Two supplementary maps of opportunities for solitude (created by adding together the measures under the first two indicators) and opportunities for primitive and unconfined recreation (created by adding together the measures under the last two indicators) were also produced for management purposes (Figure 10). All the measures were then added together using the same process to create the solitude or primitive and unconfined recreation quality map (Figure 11).

**Figure 9.** Indicator maps for (A) remoteness from sights and sounds of human activity inside wilderness, (B) remoteness from sights and sounds of human activity outside the wilderness, (C) facilities that decrease self-reliant recreation, and (D) management restrictions on visitor behavior. Blue depicts optimal condition and red depicts degraded condition.

**Figure 10.** Combined indicator maps for (A) opportunities for solitude inside wilderness, and (B) opportunities for primitive and unconfined recreation inside wilderness. Blue depicts optimal condition and red depicts degraded condition.

**Figure 11.** Map of thesolitude or primitive and unconfined recreation quality of wilderness character. Blue depicts optimal condition and red depicts degraded condition.

Other Features of Value Quality

The other features of value quality centers on unique and tangible features of a wilderness that are integral to the wilderness character of that place. These features may include cultural resource sites, paleontological sites, or any other features not included under the other four qualities that have ecological, geological, scientific, educational, scenic, or historical value (Landres et al. 2015). This quality is degraded by loss or damage to other features integral to wilderness character.

*Indicators and Measures*

*Keeping it Wild 2* delineates two indicators under the other features of value quality. The measures selected for the [insert wilderness name] are described below for each of these indicators. No data gap measures were identified for this quality.

Indicator: Deterioration or loss of integral cultural features

* Measure 1 –
* Measure 2 –

Indicator: Deterioration or loss of other integral site-specific features of value

* Measure 1 –
* Measure 2 –

*Data gap measures*

Additional measures under this quality were identified by [insert agency name] staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Measure 1

* *Indicator:*
* *Description:*
* *Rationale for Dismissal:*

*Data sources, processing, and cautions*

The other features of value quality datasets are all vector data, of fine scale, with high levels of accuracy and completeness (Table 9). The data sources, data processing information, and cautions are listed below for each measure.

**Table 9.** Other features of value quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by [insert agency unit name] staff familiar with these data.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure** | **Source** | **Type** | **Scale** | **Accuracy** | **Completeness** |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

Measure 1

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 2

* *Sources:*
* *Processing:*
* *Cautions:*

Measure 3

* *Sources:*
* *Processing:*
* *Cautions:*

*Weighting*

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the other features of value quality are described below (Table 10).

**Table 10.** Measure weights and rationales for the other features of quality.

| **Indicator** | **Measure** | **Weight** | **Rationale** |
| --- | --- | --- | --- |
| **Deterioration or loss of integral cultural features** |  |  |  |
| **Deterioration or loss of other integral site-specific features of value** |  |  |  |

*Maps*

The weighted measures under each indicator were added together using a raster calculator to create two maps: “deterioration or loss of integral cultural features” and “deterioration or loss of other integral site-specific features of value.” All the measures were then added together using the same process to create the other features of value quality map. Although the measures selected for this quality contributed to the overall map of threats to wilderness character, the indicator and quality maps are excluded from this report due to the sensitive nature of the cultural resource data.

Map of Threats to Wilderness Character

Interpreting the map products generated by this project requires a clear understanding of the methods that were used and their associated limitations. For example, the maps for the natural and solitude or primitive and unconfined recreation qualities used both vector and continuous raster data sources and are distinctly different in appearance from the maps for the qualities that only used vector data sources. Furthermore, some datasets were depicted as being spread uniformly across an area when in reality the impact was concentrated to specific locations within that area (e.g. visitor use was depicted evenly across each travel zone even though certain campsites receive more use than others). In addition, it is important to bear in mind that the maps were generated through the analysis of a multitude of datasets: to understand why certain areas are degraded one must “drill down” into the individual qualities, indicators, and measures.

The methodology described in the previous sections produced maps for each of the XX weighted measures; these were then added together accumulatively to produce a single map of threats to wilderness character in the [insert wilderness name] (Figure 12). The map of threats to wilderness character represents a grid of values (approximately XXX pixels at a XXm resolution), and uses a blue-red color ramp and the “minimum-maximum” stretching technique to best represent those values for display and discussion. An equal interval reclassification[[9]](#footnote-9) of the overall map was performed to transform the range of values for all pixels onto a scale of 0 (most degraded condition, highest cumulative threat level from all measures) to 100 (optimal condition, no threats to wilderness character). These values were then split into ten equal categories (i.e. 0-10, 11-20, 21-30, etc.) to clearly emphasize the variation in the magnitude of threats to wilderness character across the [insert wilderness name] (Figure 13).

The histogram of the distribution of pixel values (Figure 14) shows that most pixels fall within the XX category, indicating that the majority of the wilderness has high quality wilderness character that has not been substantially impacted by threats.

**Figure 12.** Map of threats to wilderness character in the [insert wilderness name]. Blue depicts optimal condition and red depicts degraded condition.

**Figure 13.** Map of threats to wilderness character in the [insert wilderness name] reclassed into ten equal categories. Blue depicts optimal condition and red depicts degraded condition.

**Figure 14.** Histogram of the values of the map of threats to wilderness character. Blue depicts optimal condition and red depicts degraded condition.

*Improvements*

The map products presented in this report could be improved in a number ways. The maps are highly dependent on the wide range of spatial datasets that depict threats to wilderness character. Improving the data quality of the existing datasets (by improving data accuracy or completeness) or adding datasets for the data gap measures would benefit future iterations of the maps. For example, a wider availability of improved land cover maps and a higher resolution DSM would increase the accuracy and effectiveness of the viewshed model, and thereby improve future maps of the solitude or primitive and unconfined recreation quality.

The issue of data quality also highlights the need for effective and holistic management of the [insert agency unit name] spatial data. Clear communication among staff, as well as with external agencies, researchers, and others working in wilderness, would allow for improvements in the quality and availability of wilderness datasets; this in turn would result in more effective and efficient wilderness stewardship. By raising awareness of data needs among field staff and encouraging the use of GPS units to record spatial data, new datasets could be created and existing datasets could be ground-truthed for accuracy or otherwise improved; it would be particularly useful, for example, to test the output of the viewshed models against observations in the field. Furthermore, regular meetings between GIS specialists and wilderness staff would ensure the preservation of institutional knowledge in the form of spatial datasets. While generally successful in these areas, increased collaboration and involvement would allow [insert agency unit name] staff and partner organizations to better realize how they can contribute to—and benefit from—spatial data and GIS applications.

This mapping approach also highlighted the difficulties in accounting for “value added” features of the landscape. While some features or actions may have a positive influence on wilderness character (thereby adding value), all the measures used for this mapping project quantify loss or degradation from an ideal condition. For example, if the presence of a threatened species such as Canada lynx had been used as a measure (such that areas, or pixels, where the species had been sighted were assigned a higher value), all areas without lynx sightings—even if they were not suitable habitat—would have been devalued. This issue is further complicated by features and actions that have both positive and negative impacts to wilderness character. For example, although the purpose of many BWCAW regulations is to protect natural resources (such as rules governing the use of designated campsites, the disposal of fish or food remains, the prohibition on burning trash, etc.), they also confine visitor freedom. In this case, the BWCAW rules and regulations measure quantifies these management restrictions for their negative impact to the solitude or primitive and unconfined recreation quality, without accounting for the value added to wilderness character by the preservation of the natural quality. A future improvement to this mapping approach would be to find a way to quantify features and actions that add value to wilderness character, rather than only including those that degrade wilderness character.

*Final concerns about mapping threats to wilderness character*

A major concern of this work is that end-users will ascribe false levels of accuracy to the map products. The tendency to attribute higher levels of reliability and precision to maps because they look accurate is common to almost all GIS analyses. The maps produced through this project are only an estimate of selected measures of wilderness character and their spatial variability and pattern; they are not a final determination of wilderness character in the [insert wilderness name]. Underscoring this point, the maps do not portray the symbolic, intangible, spiritual, and experiential values of wilderness character that are unique to individual persons, locations, and moments. Wilderness researchers and managers have debated the merits of even attempting to quantify or map threats to wilderness character; while some emphasize the need to develop indicators that can be used to aid wilderness monitoring, management, and long-term planning (e.g. Landres 2004), others point out that quantitative analyses do not reflect important qualitative attributes of wilderness character, such as how wilderness affects each of us in different ways (e.g. Watson 2004). Although the maps do not depict all nuances of wilderness character, they still provide useful information on tangible threats. Ultimately, the maps should be viewed as a tool that wilderness stewards can use to further refine the effectiveness of their efforts to “preserv[e] the wilderness character of the area” and perpetuate the “enduring resource of wilderness” (Wilderness Act of 1964).

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1. Terminology used in this report to describe threats to wilderness character—including “degraded,” “negative impact,” “significant,” etc.—reflects common vocabulary used in laws, policies, and interagency wilderness character monitoring documents. These terms do not imply an analysis of impacts or determination of significant effects, such as required by the National Environmental Policy Act or other agency decision-making processes. [↑](#footnote-ref-1)
2. Indicators are distinct and important elements within each quality of wilderness character. They have measurable attributes that can be the focus of wilderness character monitoring efforts. [↑](#footnote-ref-2)
3. Measures are specific and tangible aspects of an indicator that can be measured to gain insight into the status of the indicator and to assess trends over time. [↑](#footnote-ref-3)
4. GIS software developed by Environmental Systems Research Institute. [↑](#footnote-ref-4)
5. Vector data type uses points, lines, and polygons to represent features. [↑](#footnote-ref-5)
6. Raster data type consists of rows and columns of cells, with each cell storing a single value. [↑](#footnote-ref-6)
7. Normalization of measures was achieved using a linear rescaling of the input values (slicing) onto a 0–255 scale on an equal interval basis. [↑](#footnote-ref-7)
8. The stretch method defines the type of histogram stretching that was applied to raster datasets to enhance their appearance. The minimum-maximum stretch applies a linear stretch on the output minimum and output maximum pixel values, which were used as endpoints for the histogram (ESRI 2015). [↑](#footnote-ref-8)
9. This reclassification scheme divides the range of attribute values into equal-sized sub-ranges, allowing the user to specify the number of intervals while ArcMap determines where the breaks should occur (ESRI 2015). [↑](#footnote-ref-9)