THESIS

AN EVALUATION OF WILDERNESS CHARACTER AS A FRAMEWORK FOR MONITORING AND MEASURING WILDERNESS IN ROCKY MOUNTAIN NATIONAL PARK

Submitted by

Colin Robert Leslie

Department of Human Dimensions of Natural Resources

In partial fulfillment of the requirements

For the Degree of Master of Science

Colorado State University

Fort Collins, Colorado

Fall 2014

Master's Committee:

Advisor: Peter Newman

David Pettebone
Courtney Schultz

ABSTRACT

AN EVALUATION OF WILDERNESS CHARACTER AS A FRAMEWORK FOR MONITORING AND MEASURING WILDERNESS IN ROCKY MOUNTAIN NATIONAL PARK

The Wilderness Act of 1964 (Pub.L. 88–577) provided for the statutory designation of wilderness areas in the United States through the creation of the National Wilderness Preservation System (NWPS). While the Wilderness Act specifies requirements for wilderness designation, it does not specify how agencies should manage wilderness areas, other than to "[preserve] the wilderness character of the area." Over the last 50 years a number of frameworks and methods for managing and assessing wilderness have been proposed. Recently, Wilderness Character Monitoring (WCM) has emerged as a promising framework for quantify the status and trend of wilderness character within management areas. While interagency efforts have been largely successful in establishing the WCM framework across all four managing agencies, few studies have been conducted evaluating the process of WCM, particularly as it relates to the broader goals of wilderness management.

This thesis explores the potential for wilderness character concepts to inform wilderness management through the presentation of four chapters. The first chapter provides an introduction to the concept of wilderness character including a brief history of wilderness, its associated values and some management challenges. Chapters two and three present independent manuscripts that seek to better understand wilderness character from two different scales of analysis: conceptual overview and measurement of a specific wilderness value, respectively.

Chapter two (first manuscript) evaluates wilderness character by applying the WCM framework to the newly established Rocky Mountain National Park Wilderness. The introduction and methods sections provide an overview of the study area, the WCM monitoring structure, and additional evaluative criteria used for the selection of measures. Selected measures are then presented in the results section, followed by a discussion of insights and considerations gained from both the final list of measures as well as the selection process itself.

Chapter three (second manuscript) evaluates one discrete value or measure of wilderness: soundscapes. Specifically, this study examines the potential of Observer Based Source Identification Logging (OBSIL) to inform soundscapes assessments in wilderness by measuring audibility metrics. The two metrics used are a) percent time audible (PTA), which represents the extent within a given timeframe a particular source is audible; and b) the noise-free interval (NFI), which represents the length (usually average) that no non-natural sounds are audible. Findings from this study indicate both a high potential of OBSIL to inform soundscape assessments and provides several insights that support the need for better understanding of the wilderness acoustical environment.

Chapter four concludes this thesis with a discussion of insights gained regarding the potential of WCM in the larger context of wilderness stewardship.

ACKNOWLEDGEMENTS

It with sincerest gratitude that I wish to acknowledge the many individuals and groups that made this thesis possible. In particular, I wish to acknowledge and thank Rocky Mountain National Park. The expertise and passion of the numerous resource staff who contributed to this project along with the generous financial support for the research project reflect the ongoing dedication of Rocky Mountain National Park to the preservation of our natural and cultural resources. While all the individuals who contributed to this project, both small and large, are too numerous to name, know that your support and passion for education and academia reflect the highest qualities and are deeply appreciated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: WILDERNESS AT 50, NEED FOR A NEW FRAMEWORK

Introduction

The Wilderness Act of 1964 requires each agency administering any area designated as wilderness to preserve the wilderness character of that area. While the Wilderness Act provides a clear definition of what is required for an area to be designated as wilderness, it provides limited guidance on how agencies are to manage those areas once designated in order to "preserve their wilderness character". The lack of specific guidance within the Act resulted in numerous attempts among administering agencies to develop frameworks for managing wilderness. One of the more prominent frameworks, Level of Acceptable Change (LAC), reflected a recognition that the dual mission of preserving wilderness values while providing for recreational opportunities to experience those values would require concerted management efforts (Krumpe & Stokes, 1993). LAC represented a significant step forward for wilderness stewardship, but ultimately lacked a robust framework for assessing wilderness character specifically.

The ongoing need for a framework focusing specifically on wilderness character has led to the recent development of *Keeping it Wild: An Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al., 2008). This interagency strategy addresses two important challenges agencies have been facing, 1) a consistent definition of wilderness character and 2) a means for measuring it. The central component of this strategy is Wilderness Character Monitoring (WCM) which provides a framework for monitoring trends in wilderness character by identifying indicators and measures relevant to wilderness and then tracking the condition of them over time. Since the release of the initial interagency strategy, several agency-specific guidance documents have been produced for both the U.S. Forest Service and most recently the National Park Service. While these documents contain varying degrees of agency specific language and policies, the WCM framework remains largely consistent. The development of both a consistent definition for wilderness character and a framework for assessing it represent a significant step forward in the evolution of wilderness management. To appreciate both the significance of this recent evolution in wilderness character and the difficulty in getting to this point, a brief history of the wilderness concept is necessary.

Background

Wilderness: A Brief History

> A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. (“Wilderness Act,” 1964)

While many people now associate the term “wilderness” with positive ecological, recreational, spiritual and symbolic values, this was not always the case. The Wilderness Act of 1964 and the decades leading up to it represented a distinct turning point in the American mindset. In fact, only two decades before the passage of the Act most of the American public still had little interest in visiting wilderness (Hendee & Dawson, 2002). Wilderness was regarded by many with suspicion, a viewpoint that was a carryover from the pioneering past. Yet across America the vast wilderness landscape, once perceived as a limitless resource, was giving way to development, and in turn its growing scarcity was cultivating a previously unrecognized cultural value (Allin, 1997). Wilderness began to be viewed not just as a source of materials to be exploited but as a distinctive component of American culture, and it was at risk of disappearing (Scott, 2001).

Fortunately, a number of individuals began questioning the policies of development and loss of wilderness many decades earlier. In 1921, Aldo Leopold published "The Wilderness and its Place in Forest Recreation Policy", raising a number of arguments for the preservation of wilderness, purely for the sake of wilderness. Among his arguments, Leopold questioned whether the policy of development should apply in every instance, and he contended that wilderness areas would be much easier to keep than to create (Leopold, 1921). Several years after Leopold's publication, Leon F. Kneipp, assistant forester under the chief of Forest William B. Greeley, began an inventory of undeveloped areas in national forests. The end result was the creation of the Forest Service's "L-20" regulation (Scott, 2001). Among the various purposes stated in the L-20 regulation was the concept of primitive areas and conservation of values associated with those areas.

The Forest Service was not the only agency taking an early interest in the preservation of wilderness though. Only a few years earlier, the creation of the National Park Service established a system of federal park lands with the express purpose being "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (National Park Service Organic Act, 1916). In contrast to the Forest Service's mission of resource management, such as timber harvesting, the National Park Service's mission was to provide for the enjoyment and conservation of natural and cultural wonders for the public. In order to better provide for the enjoyment of the parks by the public, the National Park Service invested heavily in transportation, lodging, and other recreational infrastructure development.

This level of development, though popular among the public, did not go unnoticed and unquestioned. Leopold, for one, felt the growing public demand for both developed campsites and primitive wilderness trips was a good thing; however, they were none-the-less distinct forms of recreation, and thus required distinct settings (Leopold, 1921). The Forest Service's response to increasing development by the National Park Service was a proliferation of national forest wilderness areas. This had the effect of not only creating a vast network of "primitive" areas in contrast to development in the parks but over time helped develop a more pro-wilderness shift in national park policy as well (Allin, 1997). Yet despite the growing popularity of wilderness among agencies and the public, the lack of statutory designation and protection meant wilderness areas were still subordinate to potentially conflicting policies of managing agencies, and thus constantly at risk.

The answer to resolving this risk was the eventual passage of the Wilderness Act of 1964. While the bill was largely the work of Howard Zahniser, founder of the Wilderness Society, it was also the result of decades of work and challenges faced by early pioneers of wilderness, including John Muir, Aldo Leopold, Bob Marshall, Arthur Carhart, William Greeley and many others. Each in their own way realized that wilderness represented a wide range of both tangible and intangible attributes. Thus, if the preservation of wilderness was to be successful it would require not only the protection of the physical geography of an area, but of the values and qualities that collectively make up the character of that area as well.

The Wilderness Act addresses these requirements in several ways. First, to be considered for designation an area must meet certain requirements including: a minimum size (>5,000 acres), have minimal human impact (lack of roads or development), and contain certain recreational opportunities (opportunities for solitude or primitive and unconfined recreation). Second the Act specifies a definitive set of standards for administration of both visitor and management activities in wilderness. Specifically, wilderness "shall be devoted to the public purposes of recreational, scenic, scientific, educational, conservation, and historical use". Other uses may exist depending on additional statutory designation of the area, but they must not diminish the wilderness character of the area. Management limitations further include the prohibition of roads (permanent or temporary), use of motor vehicles or other motorized equipment, and construction of structures or installations.

Now, even 50 years after the passage of the Wilderness Act, measuring the degree to which wilderness stewardship has proved successful in preserving wilderness character remains a challenge. One potential reason is that, for the first several decades, national efforts focused more on designation of wilderness rather than management. As designation slowed, mangers and researchers began to realize that successful wilderness stewardship requires an integral understanding of wilderness values, coupled with an ability to successfully preserve them (Hendee & Dawson, 2002).

Wilderness Character: Defining the Concept

Wilderness character is a fundamental component of the Wilderness Act (1964), appearing in Sections 2(a) and 4(b) that establishes the preservation of wilderness character as the primary goal of the Act. Yet despite the inclusion of this term in the Act itself, a robust understanding and integration of wilderness character into wilderness management has been slow to manifest. A long-standing challenge faced by agencies charged with managing wilderness areas and thus preserving wilderness character was the lack of an explicit definition for wilderness character in the act. Despite this omission, Section 2(c), entitled Definition of Wilderness, provides a foundation from which a definition of wilderness character can be derived. In the definition provided below, several key words or phrases have been italicized that have been recognized as critical components to translating requirements of wilderness into a definition of wilderness character.

> "A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the *earth and its community of life are untrammeled by man*, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of *undeveloped Federal land* retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its *natural conditions* and which (1) generally appears to have been *affected primarily by the forces of nature*, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for *solitude or a primitive and unconfined type of recreation*; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain *ecological, geological, or other features of scientific, educational, scenic, or historical value*." (*Wilderness Act*, 1964)

Translating these ideas from a set of provisional requirements for an area to be designated as wilderness into a working definition of wilderness character requires an understanding of the term "character." The term "character" can be defined as *the aggregate of features and traits that form the individual nature of some person or thing* (Dictionary.com, 2014). There are two key aspects of this definition as it applies to wilderness character. The first is that character is an *aggregate* of features and traits. This means that the character of an area cannot be represented by any one particular feature or trait but instead is a function of the collection and relationship of many features. The second part of the definition is that character is the *nature* or manifestation of the aggregation of features or traits.

This interpretation of the usage of the word "character" appears consistent with that of the Interagency Wilderness Character Monitoring Team (Landres et al., 2008). Therefore, to maintain continuity with national WCM efforts the definition derived by the Interagency Wilderness Character Monitoring Team has been chosen as the working definition for this study:

> "Wilderness character may be described as the combination of biophysical, experiential, and symbolic ideals that distinguishes wilderness from other lands." (Landres et al., 2008)

While this definition expresses a succinct theoretical overview of wilderness character, applying these concepts in a wilderness setting requires the identification of tangible qualities of wilderness (Landres et al., 2008; National Park Service, 2014). Five distinct qualities have been identified from Section 2(c) of the Wilderness Act, Definition of Wilderness: untrammeled, natural, undeveloped, solitude or a primitive and unconfined type of recreation, and other features of value. Collectively these five qualities form the foundation for assessing wilderness character. Quantifying each quality, however, requires identifying specific measures and data that appropriately represent the functional components of each quality.

Problem Statement

The recent emergence of WCM as the leading a framework for measuring and monitoring wilderness character has garnered growing interested among wilderness managers. However, at this time no case studies have yet been conducted for the purpose of explicitly evaluating WCM. For the National Park Service in particular, integrating WCM into planning and management is very recent, and best practices are still emerging (National Park Service, 2014b). Given these requirements, wilderness management can be segmented into two overarching components: 1) robust inventory and evaluation (monitoring) of wilderness and 2) mechanisms that sustain or enhance its preservation. WCM has been proposed as a tool for addressing the first component of inventory and evaluation by providing guidance for the selection of measures and reporting of trends within wilderness (National Park Service, 2014b).

A primary goal of WCM is to improve decision-making among management staff through development of a comprehensive and systematic assessment of current conditions and proposed actions within wilderness (National Park Service, 2014a). Since no studies have yet been published examining the ability of WCM to achieve this primary goal, evaluations of the success or failure of the WCM are still largely based on anecdotal evidence. There are, however, two related but distinct implications of this goal. The first is that WCM will improve decision-making among management staff. The second, while slightly more indirect, is that the WCM approach does in fact provide a comprehensive and systematic assessment of wilderness character.

Evaluating the ability of WCM to improve decision-making among management staff is important and in time will warrant further evaluation as more wilderness stewardship efforts integrate WCM into the planning process. Currently most wilderness units that have undertaken WCM have only conducted one initial assessment. A longitudinal study of WCM will be important for assessing long term benefits of the program. However, at this time not enough data exists to evaluate any realized benefits to the decision-making process and thus test this first implication.

Testing the second implication, that WCM does in fact provide a comprehensive and systematic approach to assessing wilderness character, is more feasible. First, an extensive body of literature now exists on wilderness management, offering important insights regarding landscape assessment in a wilderness context. Second, Rocky Mountain National Park Wilderness, which was recently designated in 2009, was identified as an ideal location for which to conduct a case study by applying WCM in a real world setting. To help guide the evaluation WCM, a methodology was established for this research to develop specific research questions, establish assumptions, and identify any tools or platforms that could be used for additional analysis.

Methods

The first step in evaluating WCM for this thesis required developing specific research questions in order to parse the concept of comprehensive and systematic into more measurable, functional components. The primary purpose of WCM is the inventory and assessment of wilderness qualities in order to establish baseline conditions and monitor trends over time. By considering inventory and assessment within the context of comprehensive and systematic, the following research questions were identified:

1. What criteria can be used to identify the *best* existing data for capturing and evaluating qualities of wilderness character?
2. Can utilizing only *existing* data adequately capture and evaluate qualities of wilderness character based on requirements of the WCM framework?
3. What is the potential for new or emerging methods to support wilderness monitoring efforts?

To evaluate these questions, two studies were identified that could serve as separate but complimentary efforts. These studies have been compiled as individual manuscripts and are presented as chapters two and three in this thesis. Chapter four provides a discussion of research presented in this thesis as a whole including insights and recommendations for future research.

Chapter 2: Applying Wilderness Character Monitoring – A Case Study

The first study focuses on evaluating WCM by applying the WCM framework to the Rocky Mountain National Park Wilderness as a case study and addresses the first two research questions outlined above. First, a literature review of existing agency guidance documents and the academic literature was conducted in order to identify important considerations when conducting landscape assessments in a wilderness context. Next, indicators, measures and data sources were identified for Rocky Mountain National Park Wilderness utilizing recommended procedures from the original *Keeping it Wild* (Landres et. al., 2008) interagency strategy as well as *Keeping it Wild in The National Park Service* (National Park Service, 2014a). These potential indicators, measures and data sources are presented in the findings section. Finally, the discussion section provides an evaluation of both the findings from the case study as well as the process as they relate to the first two research questions regarding aspects of best and existing data.

Chapter 3: Assessing Wilderness Soundscapes Using Observer-Based Source Identification Logging

The second study of the project focuses on evaluating methods for measuring one, specific component of wilderness character: soundscapes. Soundscapes are recognized as an integral component of both wilderness and National Park Service management goals (National Park Service, 2006). Recently, soundscapes have been generating growing interest among many land management agencies. However, many methods still require the use of sophisticated equipment and require specific acoustical expertise for analysis. The purpose of this study was to evaluate the potential for a recently developed Observer Based Source Identification Logging (OBSIL) application created by the NPS Natural Sounds and Night Skies Division as a low cost and accessible method for assessing baseline soundscape conditions in wilderness.

Chapter 4: Discussion

Specific results for each of the studies discussed are presented in the individuals papers/chapters. As a component of the thesis, chapter four provides a discussion of insights and observations gained while conducting each study as related to the future administration and efficacy of this type of work. It is important to consider the limitations and opportunities for additional research in order to facilitate integration of findings from both of these studies in the larger context of wilderness stewardship.

REFERENCES

Allin, C. W. (1997). Wilderness policy. *Western Public Lands and Environmental Politics*, *2*, 209.

Hendee, J. C., & Dawson, C. P. (2002). *Wilderness Management* (3rd ed.). Fulcrum Publishing. Retrieved from http://books.google.com/books?hl=en&lr=&id=CcljwJXpi54C&oi=fnd&pg=PA2&dq=endangered+american+wilderness+act&ots=RyL7wsE816&sig=jDxyIM87sRDKnViJOyNEhFsTD44

Krumpe, E. E., & Stokes, G. L. (1993). Application of the limits of acceptable change planning process in United States Forest Service wilderness management. In *Proceedings of the 5th World Wilderness Congress Symposium on International Wilderness Allocation, Management and Research*. Retrieved from http://www.cnr.uidaho.edu/css386/Readings/Application_of_LAC_Krumpe_Stokes.pdf

Landres, P., Barns, C., Dennis, J. G., Devine, T., Geissler, P., McCasland, C. S., … Swain, R. (2008). *Keeping It Wild*. Retrieved from https://eng.ucmerced.edu/czo/files/private/research_in_wilderness_policies/rmrs_gtr212.pdf

Leopold, A. (1921). The wilderness and its place in forest recreational policy. *Journal of Forestry*, *19*(7), 718–721.

National Park Service. (2006). *NPS Management Policies 2006.pdf*.

National Park Service. (2014a). *Keeping It Wild in the National Park Service - A User Guide to Integrating Wilderness Character into Park Planning, Management, and Monitoring* (Planning Guide No. WASO 909 121797). U.S. Department of the Interior.

National Park Service. (2014b). *Wilderness Stewardship Plan Handbook - Planning to Preserve Wilderness Character* (Planning Guide No. WASO 909 12287). U.S. Department of the Interior.

National Park Service Organic Act, 16 USC § 64th Congress (1916).

Scott, D. W. (2001). A Wilderness-Forever Future. *Pew Wilderness Center, Seattle*. Retrieved from http://wilderness.net/toolboxes/documents/awareness/Doug%20Scott-A_Wilderness-Forever_Future-history.pdf

CHAPTER 2: APPLYING WILDNERESS CHARACTER MONITORING - A CASE STUDY

Introduction

The Wilderness Act of 1964 established the preservation of wilderness character as a primary goal of the Act. Our understanding of the degree to which wilderness designation and stewardship has been successful in preserving wilderness character however has, until recently, remained tenuous at best. This deficiency has largely been the result of two challenges faced by wilderness managers: 1) the lack of an explicit definition of wilderness character and 2) a framework for assessing it.

The need for an assessment framework focusing specifically on wilderness character led to the development of *Keeping it Wild: An Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al., 2008). This interagency strategy addressed some of the challenges faced by wilderness managers by providing both a consistent definition of wilderness character along with a framework for assessing it, Wilderness Character Monitoring (WCM).

Wilderness character is “the combination of biophysical, experiential, and symbolic ideals that distinguishes wilderness from other lands” (Landres et al., 2008). In order to measure and track these ideals, WCM offers up a framework for the systematic selection, monitoring and reporting of data pertinent to wilderness character (Landres et al., 2008). Since it was first introduced in 2008, WCM has generated a growing level of interest and application among the wilderness community. However, despite the growing list of wilderness areas to which WCM has been applied, no case studies have yet been published documenting the process of applying WCM to a wilderness area.

Anecdotal evidence suggests that WCM offers a number of benefits for wilderness managers over alternative wilderness assessments; primarily the robust assessment of wilderness qualities through the utilization of existing management and research data. By utilizing existing data, the need to allocate additional financial or personnel resources should be minimized and thus facilitate more widespread integration of WCM.

While the merits of this approach are commendable, the lack of published case studies raises a number of unanswered questions. Two questions, pertaining to the use of existing data, are of particular interest and the focus of this study. First, is utilizing only existing data robust enough to adequately capture and evaluate qualities of wilderness character? Second, what criteria can be used to identify the best existing data for capturing and evaluating qualities of wilderness character? In order to understand the relationship between individual discrete data sources and wilderness character as a whole, it is necessary to understand the basic structure of the WCM framework.

The Monitoring Hierarchy

WCM is based on a hierarchical approach in which wilderness character is broken down sequentially into levels or elements of increasing specificity and detail. This structure establishes a one-to-many relationship where each level or element is generally comprised of one or more elements below it (Figure 1). A brief description of each of these levels is provided below but are explained in detail in the Forest Service *Technical Guide for Monitoring Selected Conditions Related to Wilderness Character* (Landres et al., 2009)

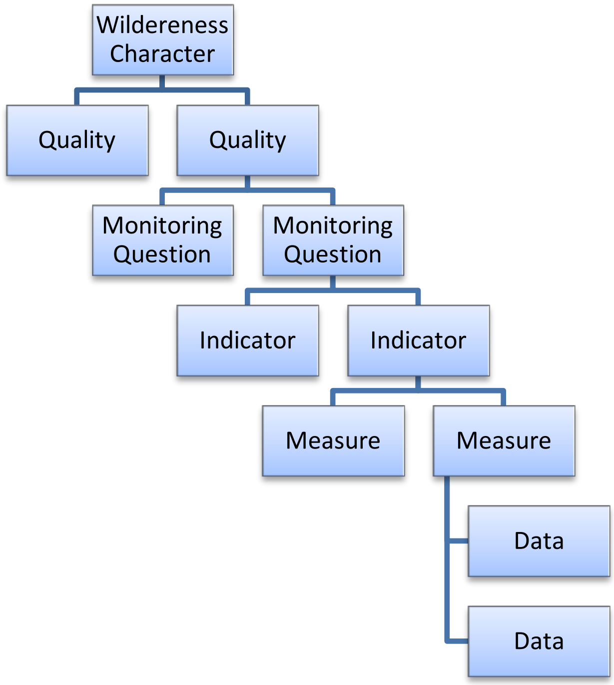


Figure 1 Monitoring elements form a hierarchy where each level represents a one-to-many relationship with the elements below it.

Qualities. These are the fundamental components of wilderness that relate directly to concepts expressed in Section 2(c) of the Wilderness Act. They include: untrammeled; natural; undeveloped; opportunities for solitude or primitive and unconfined recreation; and other features of value. The first four qualities are required and present in every wilderness while the fifth, other features of value, may or may not be present. However, when the fifth quality is present it is should be considered of equal standing with the first four. Considerations for determining if this quality is present are discussed in further detail in the findings section for evaluating this quality in the context of the Rocky Mountain National Park Wilderness case study.

Monitoring Questions. These can be thought of as topical groupings under each quality that help guide the selection of subsequent indicators and measures. Examples for the undeveloped quality might be: "What are the trends in non-recreational development inside wilderness?" and "What are the trends in mechanization inside wilderness?" These questions help refine undeveloped into topical groups focused on development and mechanization, respectively.

Indicators. These represent specific topics or elements that can inform each monitoring question. Examples for the monitoring question “What are the trends in non-recreational development inside wilderness?” for undeveloped might be: non-recreational structures, installations and developments and inholdings. While these are both types of developments, the source or initiating entity for each is likely different. Non-recreational structures, installations and developments will be largely under the prevue of the managing agency, while inholdings are a result of historic land agreements. Both *Keeping it Wild* (Landres et al., 2009) and *Keeping it Wild in the National Park Service* (National Park Service, 2014) strongly recommend the inclusion of at least 13 pre-identified indicators.

Measures. These are discrete elements that represent one aspect or specific quantity of an indicator. Following with the previous example for undeveloped, non-recreational structures, installations and developments could be represented by the following measures: number of monitoring or research installations; distance from monitoring or research installations; number of patrol cabins; and miles of non-wilderness trails. Each measure represents one specific quantity of the selected indicator. Most measures can be represented by a single numeric representation, i.e. number of installations, miles of trial, number of cabins etc.

Most indicators require multiple measures in order to fully quantify the various dimensions of the indicator. The WCM framework strongly encourages selecting at least one measure for each indicator and only selecting measures that utilize existing data (Landres et al., 2008). Measures may be directly computed from a dataset such as the “number of monitoring or research installations” or may require intermediate analysis using a specialized platform such as a Geographic Information System in order to compute “distance from monitoring or research installations”.

Data Sources. Data can come from a variety of sources including existing agency data systems, internal and external reports, national data collection efforts, and any other data related to the wilderness area. Within the WCM framework the widest degree of agency discretion is given to the selection of measures and data to inform indicators. A primary concern when identifying data is assessing the ability of the data to adequately and reliably inform trends in the measure being evaluated (Landres et al., 2009).

Baseline Conditions, Monitoring Frequency and trends.

Ultimately, the purpose of monitoring is to establish a scientifically rigorous base for assessing the trends of selected conditions over time (Fancy, Gross, & Carter, 2009). In order to assess trends over time it is necessary to establish a baseline or reference condition to which subsequent condition assessments conducted at a given frequency will be compared. Both Keeping it Wild (Landres et al., 2008) and NPS Management Policies 2006 specify that a wilderness should be evaluated against its own reference condition. Baseline conditions within the WCM framework are considered to be the first time data are collected for all measures in a wilderness character assessment (National Park Service, 2014). Once the initial assessment has been conducted, all measures should be reassessed every five years to establish trends.

Methods

In order to fully evaluate the ability of existing data to describe qualities of wilderness character, it was determined the best approach was to apply WCM as a case study to a wilderness area such that both the process and the findings could be evaluated. For this study, Rocky Mountain National Park (RMNP) Wilderness was selected as it provided both a recently designated wilderness area and was known to have a comparatively robust history of biophysical and recreational research that could support a WCM effort.

Study Site

RMNP is situated along the continental divide in the Rocky Mountains of northern Colorado. Established January 26, 1915 under the Rocky Mountain National Park Act, the park set aside 229,062 acres of mountainous landscape to protect it from destructive uses and provide for its enjoyment by the public (Rocky Mountain National Park, 1984). In particular, the park is recognized for its exceptional accessibility to wild landscapes including one of the largest expanses of alpine tundra ecosystems managed by the National Park Service within the lower 48 states (Rocky Mountain National Park, 2012). Since the time of designation, numerous boundary adjustments and land acquisitions have increased park acreage to its current total of 265,770 acres (nps.gov/romo).

As early as the 1960’s much of the park was managed as wilderness. In 1974, President Richard Nixon recommended 239,835 acres of the park to be formally designated as wilderness (Suzanne Jones & Jeff Widen, 2006). Eventually, 35 years after the first formal proposal, the Omnibus Public Land Management Act of 2009 officially designated 249,339 acres as the Rocky Mountain National Park Wilderness. The creation of this new wilderness, in addition to 2,917 acres of the Indian Peaks Wilderness already within the park boundary, set aside almost 95% of the park as designated wilderness (Figure 2).

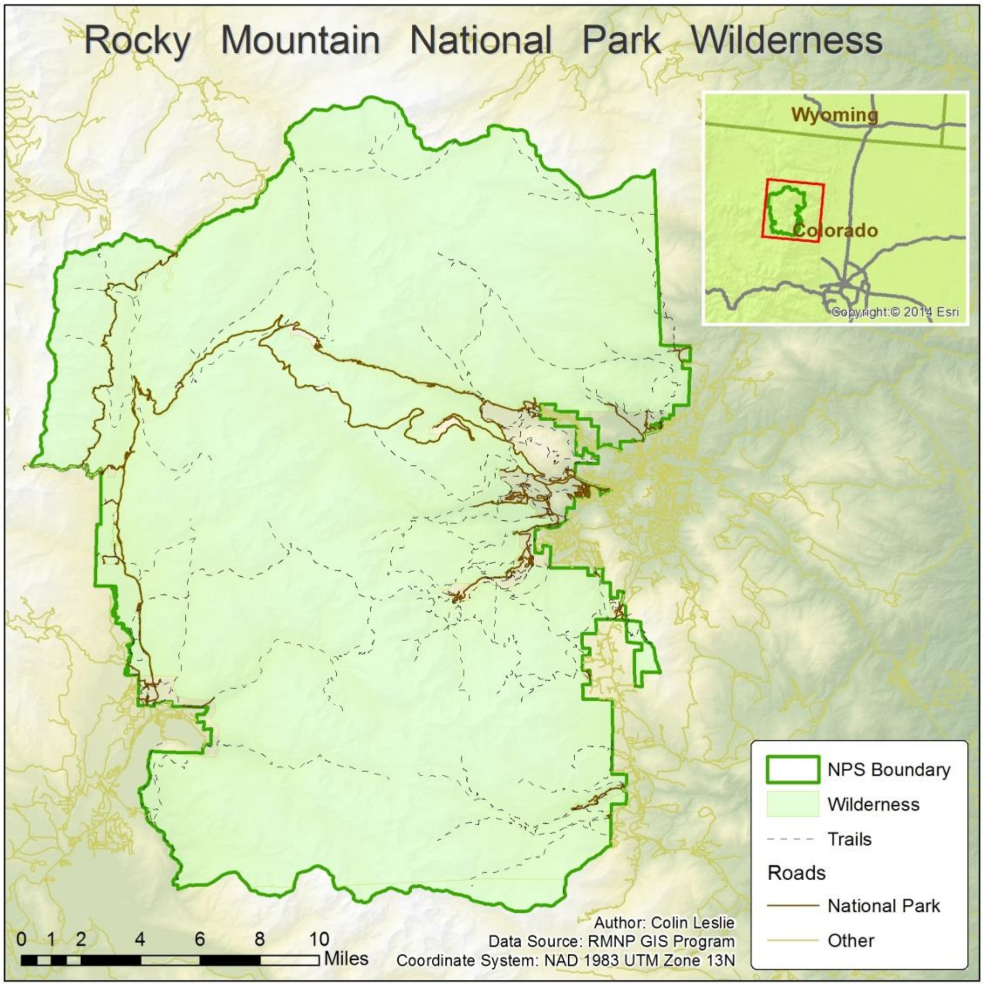


Figure 2 The Rocky Mountain National Park Wilderness is 249,339 acres in area. Combined with a small section of the Indian Peaks Wilderness, this sets aside almost 95% of Rocky Mountain National Park as wilderness.

Once the study area was selected, the process of conducting the initial assessment for a WCM effort in RMNP Wilderness (or any wilderness) can be broadly categorized into three phases: identification of potential data sources, refinement and selection of measures, and finally recording the status of selected measures as baseline conditions. Since the WCM framework by design allows for a degree of flexibility in its implementation, methods specific to this study are outlined below.

Identification of Sources

In 2012, RMNP initiated a two-year cooperative agreement with Colorado State University to conduct a wilderness character assessment for the park. In preparation of the cooperative agreement, RMNP conducted an initial internal review identifying a “laundry list” of potential measures and data sources. This document also identified primary contact information for park managers across divisions, responsible for maintaining a variety of programs and data repositories. RMNP has a long history of natural resource and recreation management and as such, many potential data sources were initially identified. After the agreement was initiated, a series of additional meetings were conducted in order to prioritize and refine measures deemed most salient by park managers. These meetings resulted in the identification of additional agency and non-agency data sources from programs, reports and studies pertaining park resources. For a full list of potential measures and data sources that were identified, see Appendix A.

Additionally, *Keeping it Wild in the National Park Service* (2014) includes 40 potential (example) measures, each with a number of known data sources. While this document was not released until half way through the two year study, it still provided a number of previously unidentified data sources that were selected for inclusion. Next, it was necessary to develop methods for the evaluation and refinement of potential measures and data.

Refinement and Selection of Sources

A large number of data sources were initially identified that related to one or more qualities of wilderness character. *Keeping it Wild in the National Park Service* (2014) provides several general recommendations to help guide managers in refinement and selection of final measures to include.

- Relevant to wilderness: The potential measure and data should pertain directly to known issues within wilderness

- Use existing data when possible: Preferable data should already exist and be recent enough to representative of current conditions
- Start with smallest number of measures possible: Use data that are most indicative of overall conditions within wilderness

While these recommendations provided valuable context, a more systematic process for refining measures was desired. Upon a review of all WCM related documents, methods for the evaluation of potential data sources were identified from both the Forest Service and the US Fish and Wildlife Service (USFWS).

The first method reviewed was developed by the Forest Service and outlined in the *Technical Guide for Monitoring Selected Conditions Related to Wilderness Character* (Landres et al., 2009). The Forest Service method utilizes a two parameter system to evaluate data adequacy and focuses on data quantity and data quality. Both parameters are subjective in the sense that they rely on a consensus of opinion among managers rather than any specific set of established criteria. Data quantity is an evaluation of the completeness of the data and is assigned a value of: 3 = Complete; 2 = Partial; or 1 = Insufficient. The second parameter is data quality and is a measure of the confidence that data were collected in a scientifically rigorous manner and is assigned a confidence value of: 3 = High; 2 = Moderate; or 1 = Low. For example, a GIS dataset of acres of invasive species removed per year by seasonal work crews who documented area through GPS collection would be considered both Complete (3) and High Quality (3).In contrast, campsite conditions based on a review of visitor comment cards would likely be both Incomplete (1) and Low Quality (1).

The second method for evaluating data was developed by the USFWS. In contrast to the Forest Service two parameter system, the USFWS utilizes a four parameter system and is intended more for prioritizing selection of potential measures than evaluating data quality or quantity. The four parameters presented below have been taken directly from the USFWS Wilderness Fellow Final Report template which was developed as a standardized template for wilderness character assessments in across the National Wildlife Refuge System.

A. Level of significance (the measure is highly relevant to the quality and indicator of wilderness character, and is highly useful for managing the wilderness): High = 3 points, Medium = 2 points, Low = 1 point

B. Level of vulnerability (measures an attribute of wilderness character that currently is at risk, or might likely be at risk over 10-15 years): High = 3 points, Medium = 2 points, Low = 1 point

C. Degree of reliability (the measure can be monitored accurately with a high degree of confidence, and would yield the same result if measured by different people at different times): High = 3 points, Medium = 2 points, Low = 1 point

D. Degree of feasibility (the measure is related to an existing effort or could be monitored without significant additional effort): High = 1 point, Low = 0 point (if 0 is given, do not use)

After evaluating each measure using the individual parameters above, scores are added together to give a composite prioritization score. For example, the number of monitoring or research installations was high significance (3), high vulnerability (3), medium reliability (2), and high feasibility (1) for a final prioritization score of 9. Stated in a more qualitative manner; the number of monitoring or scientific installations is important to wilderness character, likely to change significantly over the next 10-15 years and while current efforts are not yet as reliable as they could be, it is still a feasible measure to track without much additional effort.

For the purpose of this study, the USFWS evaluation was selected as the preferred method for a number of reasons. First, a preliminary review of potential measures indicated most data sources came from scientifically rigorous sources and therefore data quality was not deemed a top priority issue. Second, while the individual criteria in the USFWS method still rely on a subjective evaluation of measures, by limiting the degree of subjectivity for each individual criteria it provides for a slightly more robust comparison between measures. Finally, it was felt that the added level of detail for why a measure was or was not selected provided better overall transparency to the process.

Neither of these methods however specifically address the issue of spatial coverage. The goal of monitoring is to be systematic and comprehensive, yet work and research is often focused on addressing specific problem areas rather than gathering baseline data as a whole for wilderness (Hendee & Dawson, 2002). The result is that wilderness areas may have high quality data but only for specific areas. In addition, it was identified early on that many data were either available or relatable in a geographic information system. This is of particular interest from the standpoint of wilderness character mapping, a separate yet potentially highly informative and complementary approach to assessing wilderness character (National Park Service, 2014).

Figure 3 shows a systematic process for evaluating the spatial coverage of a data source and assigning it a level from 5 (best) to 1 (poor). This process not only provides a method for identifying the better of two similar data sources that could inform a measure, but also assists in identifying a general level of coverage for all potential measures. For example, the trails GIS layer maintained by RMNP is Level 5 data. It is already spatial, provides complete coverage, and is precise in both location and attribute data. In contrast, annual number of visitors is Level 2 data. It is not spatial, not relatable, but does provide an estimate (and thus coverage) of the annual number of visitors to RMNP and thus can serve as a proxy for the number of visitors to RMNP Wilderness. If number of visitors or at least distribution of use levels could be measures and allocated throughout the park, then annual number of visitors would likely move from Level 3 to Level 4 data. Under this scenario, annual number of visitors is now spatial and provides complete coverage, even if the exact number of visitors per trail, road or other scenic attractions (and thus precision) is still unknown.

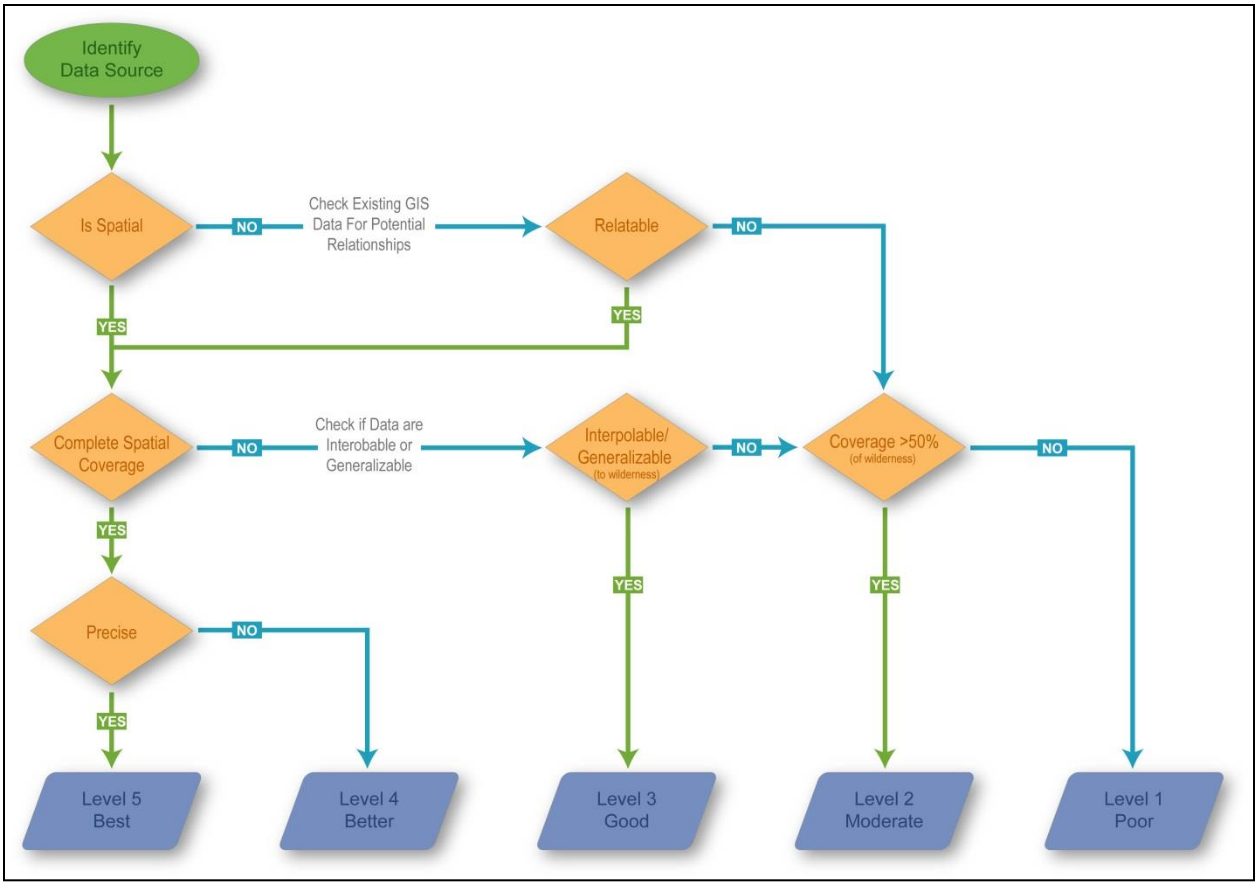


Figure 3 The flowchart above provides a systematic approach to evaluating the spatial coverage of data.

Compiling Baseline Conditions

The final component to conducting an initial assessment for WCM is the compilation of baseline conditions for final selected measures. While many of the data and measures selected for final inclusion in this study have compiled and summarized data, the high diversity of sources made the final compilation of baseline conditions beyond the scope of this study. In addition, the measures evaluated for inclusion by this study are only preliminary and still require formal vetting by RMNP staff. However, a number of maps, figures and charts have been provided throughout the findings section for select sources where summarized data were available as examples of what the final assessment may look like.

Findings

Untrammeled

Identifying measures for the untrammeled quality in RMNP focused primarily on actions related to plant or animal management and fire management. A number of plant and animal measures of interest were identified including: number of native fish removed per day, acres of plant removal projects (generally invasive species), number of re-introductions, number of animals tagged, number of elk culled per year and number of elk exclosures.

Two of these measures, native fish removed per day and number of animals tagged or banded were deemed not feasible. Most native fish are taken by recreational anglers which does not require reporting and the migratory nature of most banded animals does not allow for the estimate of the number of banded animals within wilderness at any given point in time. Acres of plant removal projects is target primarily at the removal of invasive species. While the removal of invasive species provides a beneficial outcome for natural quality, it is non-the-less dependent upon human action, thus warranting its inclusion under untrammeled. Number of reintroductions for both plant and animal species was determined to be both a reliable and feasible measure for inclusion, although its occurrence is not predicted to happen frequently.

The final two measures, number of elk culled per year and number of elk exclosures relate directly to RMNP's Elk and Vegetation Management plan. After extensive research, the park determined that high concentrations of elk were beyond the range of historic natural variability and as a result vegetation communities supporting a diversity of bird, butterfly and other plant species were being negatively impacted (Rocky Mountain National Park, 2008). Under this plan, the park established a number of additional elk exclosures to protect vegetation (many were already in place) and initiated a 20 year timeline to gradually reduce the elk population through culling to the upper limit of estimated historic population sizes. While clearly examples of agency actions that manipulate the biophysical environment, these two measures are not necessarily indicative of overall wilderness conditions. However, the plan specifically specifies intent to restore, to the extent possible, the natural range of variability in elk and vegetation communities over a 20 year period. Therefore, these measures have the potential benefit of examining the interaction between temporary degradation in one quality (untrammeled) for the long term gain in another quality (natural).

Fire is now widely recognized as a critical component of ecosystem management. As the ecological community has come to embrace a more dynamic, non-equilibrium view of ecosystems, so too have we developed an understanding that fire can occur both in varying frequency and severity (Thrower, 2006). However, the historic suppression of natural fire coupled with the need to protect private property continues to necessitate the use of both prescribed fire and the suppression or control of naturally started wildfires. As such, the measures for number of prescribed burns and number of natural fire starts that received a suppression response have been identified for inclusion. Additionally, number of visitor-ignited fires has been included for *actions not authorized by the federal land managers* as these fires are neither naturally ignited, nor started for the potential ecological benefits of prescribed burning.

Finally, number of Minimum Requirements Decision Guide (MRDG) forms have been identified for potential inclusion. The Minimum Requirements concept charges agencies with evaluating any proposed action in wilderness based on how appropriate or necessary that action is for the administration of the wilderness area (National Park Service, 2006). If the action is deemed necessary, additional considerations should be made in order to select the minimum methods and equipment necessary to carry out the action. At present, the reporting of both number of MRDGs that have been submitted as well as number that have been approved have been identified as measures. Reporting both number submitted as well as number approved can provide additional insight into how MRDGs are trending over time. A third potential measure that has not been included at this time is MRDGs that have been modified after submission to reduce impacts. Inclusion of this measure may be useful, but will require additional criteria in order to established what constitutes a significant enough modification for inclusion. The final list of identified measures along with priority and spatial scores can be found in Table 1.

Table 1. Identified measures for the untrammeled quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Authorized actions that manipulate the biophysical environment	Acres of plant removal projects	10	4
	Number of Elk culled per year	8	5
	Number of elk exclosures	8	5
	Number of reintroductions	7	4
	Number of prescribed burns	10	5
	Percent of natural fire starts that received a suppression response	10	5
	Number of submitted MRDGs involving actions that manage plants animals, pathogens, soil, water, or fire	10	2
	Number of approved MRDGs involving actions that manage plants animals, pathogens, soil, water, or fire	10	2
Unauthorized actions that manipulate the biophysical environment	Number of visitor-ignited fires	7	5

Natural

Among the five qualities of wilderness, natural quality yielded the greatest number of identified potential measures. The National Park Service and numerous other federal land management and regulatory agencies have a long history of natural resource management in general, as well as specifically related to Rocky Mountain National Park. Specifically, the NPS Inventory and Monitoring Program (I&M), US Geological Survey, LANDFIRE, and the Environmental Protection Agency all manage data collection efforts that include monitoring of conditions in RMNP. In addition to collecting a diverse array of data, all of these agencies and programs are funded separately from RMNP and thus place no additional burden on park financial or staff resources for their collection and dissemination.

The NPS I&M program monitors a range of natural resource conditions across the National Park Service and provides monitoring information through the NPS Integrated

Resource Management Applications (IRMA) data portal. I&M data were particularly informative of measures involving abundance of both native and non-native plant and animal species.

Based on recommendations from Keeping it Wild in the National Park Service (2014), a number of data sources for measures under the physical resources indicator were identified. Measures primarily focused on visibility, atmospheric deposition and water quality. Visibility is based on average deceived and is monitored through the Interagency Monitoring of Protected Visual Environments (IMPROVE). The IMPROVE data portal hosted at Colorado State University provides a number of data management and summary tools allowing for the reporting and visualization of visibility metrics (Figure 4).

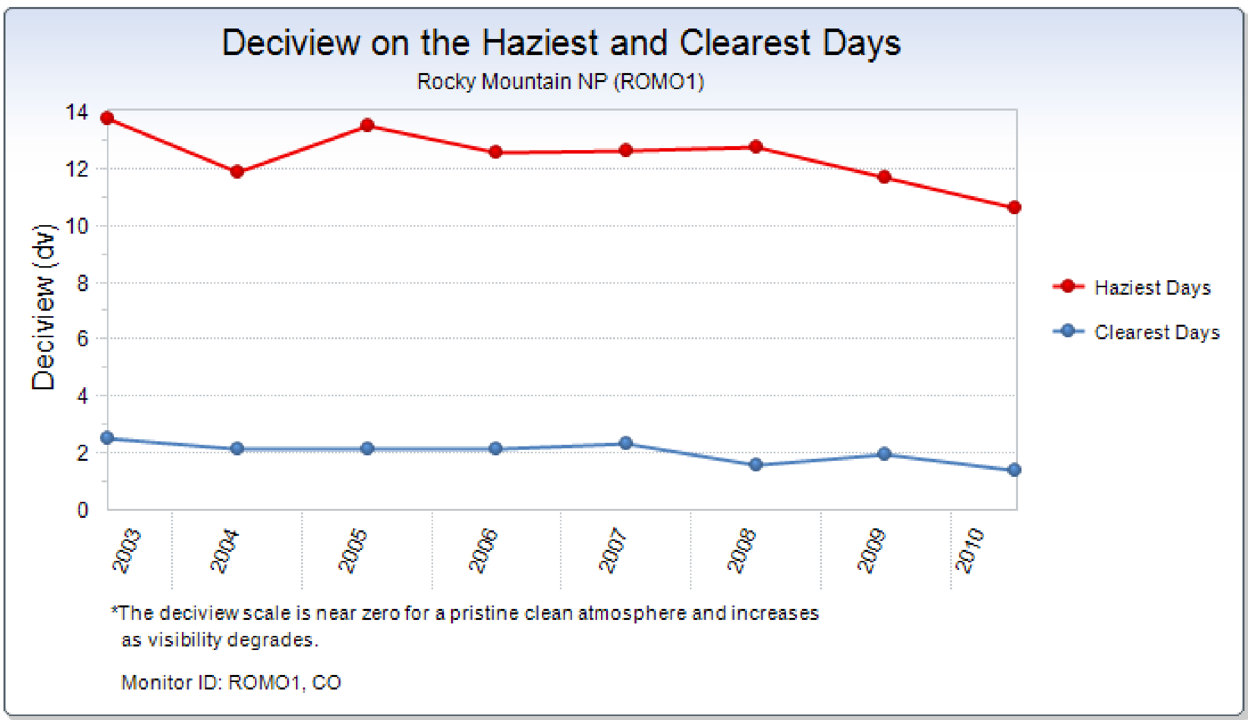


Figure 4. Deciview of the haziest and clearest day for each year between 2003 and 2010 in Rocky Mountain National Park (IMPROVE, 2014)

Atmospheric deposition data are collected by the National Atmospheric Deposition Program (NADP). The NADP monitors eight dissolved chemicals along with pH and provides annual weighted mean concentrations from 1980 to present. Chemical related to acid deposition are of primary interest including sulfate (SO4), nitrate (NO3) and ammonium (NH4). These data are available publically through the NADP data portal which provides tools for the visualization and download of raw and summarized data including automatic calculation of a trend line representing a smoothed three year average for each year (Figure 5).

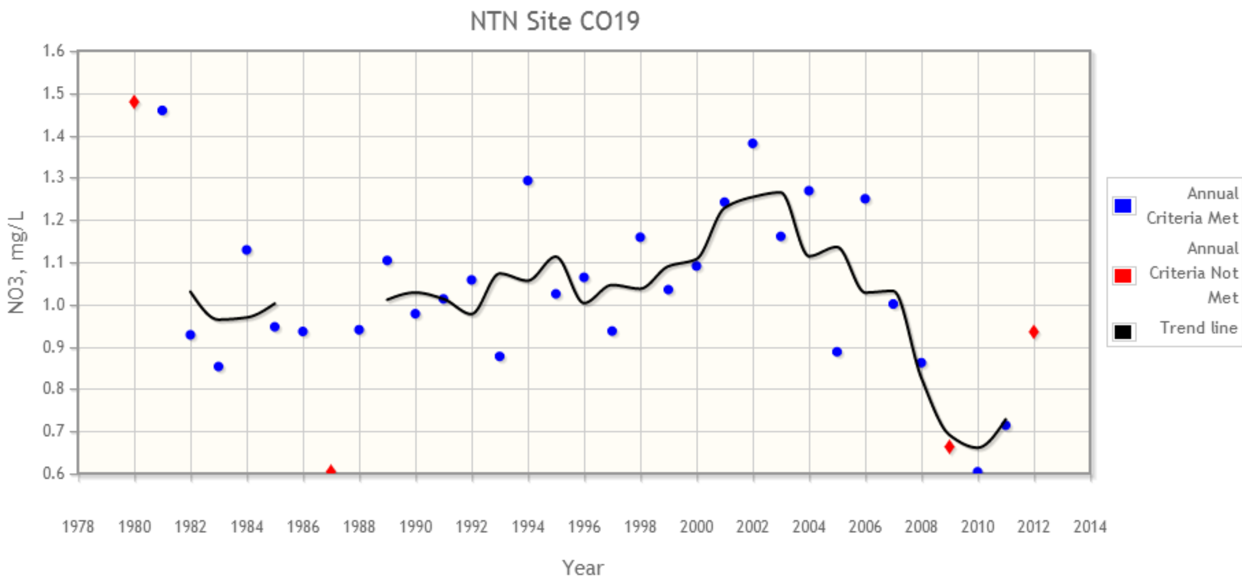


Figure 5 Nitrate (NO_3) deposition at Rocky Mountain National Park-Beaver Meadows (CO19) NTN site from 1980 to 2013 (NADP, 2014).

Water quality is monitored primarily through a distributed network of stations for which data are available for download through the EPA STOrage and RETrieval Data Wareahouse (STORET). The EPA periodically compiles these data into a Watershed Quality Assessment Report which provides a qualitative description of watershed health as well as a list of stressors that are causing impairment. For example, the St. Vrain Watershed which comprises the majority of the south eastern portion of RMNP wilderness was last rated as "Impaired Water" in 2010 with stressors causing the impairment listed in (Table 2).

Table 2 The sources or “causes” of impairment leading to the classification of the St. Vrain watershed as impaired for 2010 (EPA/STORET, 2014).

Cause of Impairment	Rivers and Streams (Miles) and Ponds (Acres)
Cadmium	3.7
pH	31.2
Zinc	131.1
Arsenic	21.1
Cause Unknown	27.3
Lead	6.0
Copper	84.2
Ammonia, Un-ionized	45.6
Manganese	6.0
Selenium	87.0
Temperature, Water	31.9
Escherichia Coli (E. Coli)	32.4

In addition to ongoing data collection and monitoring efforts from supporting agencies, a Natural Resource Condition Assessment (NRCA), completed for RMNP in 2010, was also identified. The purpose of an NRCA is specifically to help answer the question “What are current conditions for important park natural resources?” (Theobald et al., 2010). This report greatly expedited the identification of the *most* salient measures for the natural quality of RMNP Wilderness as well as providing a summary of natural resource conditions across the park.

Condition assessments fell into four main classes:

- Air and Climate: Condition of alpine lakes and atmospheric deposition
- Water: Extent and connectivity of wetland and riparian areas
- Biotic Integrity: Extent of exotic terrestrial plant species, extent of fish distributions, and extent of suitable beaver habitat
- Landscapes: Extent and pattern of major ecological systems and natural landscapes connectivity

The NRCA provided data for eight out of twelve identified measures for natural quality in RMNP Wilderness. While an NRCA is intended to provide a synthesis of the best existing scientific data and knowledge (Theobald et al., 2010), it includes a number of additional criteria in order to establish context for each condition assessment.

Each condition assessment is comprised of several parts including: what is being measured; why analysis of the condition is important; potential stressors that can alter the state of the resource being assessed; confidence of the data in terms of concern, evidence and agreement; current conditions; and where possible reference or historic conditions. Specific details including data sources, statistical methods, and models can be referenced directly in the RMNP NRCA report. Identified measures along with priority and spatial scores can be found in Table 3.

Table 3 Identified measures for the natural quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Plant and animal species and communities	Abundance, distribution, or number of indigenous species that are listed as threatened and endangered, sensitive, or of concern	8	2
	Abundance, distribution, or number of invasive non-indigenous species	9	4
	Change in demography or composition of communities	8	5
	Change in demography or composition of communities	8	5
Physical resources	Visibility based on average deciview and sum of anthropogenic fine nitrate and sulfate	10	4
	Ozone air polution based on concentration of N100 episodic and W126 chronic ozone exposure affecting sensitive plants	8	3
	Acid deposition based on concentration of sulfur and nitrogren in wet deposition	8	3
	Extent and magnitude of change in water quality	9	3
Biophysical processes	Area and magnitude of loss of connectivity with the surrounding landscape	9	5
	Area and magnitude of loss of connectivity with the surrounding landscape	9	5
	Area and magnitude for pathways of nonindigenous species into the wilderness	9	5
	Area and magnitude of loss of connectivity with the surrounding landscape	8	5

Undeveloped

The undeveloped quality primarily focused on the number of non-recreational installations, inholdings, and amount of mechanized activity in wilderness. Rocky Mountain National Park maintains a robust geographic information system of park infrastructure including structures, trails, roads and other permanent installations. In addition to infrastructure, RMNP Resources Management developed and maintained a database of research installations throughout the park including information on: installation date, proposed removal date, actual removal date, relative visual impact based on size, description of the installation, and geographic coordinates.

A review of park GIS data for infrastructure and research installations revealed missing as well as incorrect attribution of whether those data were located in wilderness. In order to accurately determine number of installations in wilderness, a new attribute was created for each feature class/dataset indicating if the installation was within wilderness based on the official RMNP wilderness GIS dataset. Using ESRI ArcGIS Spatial Analyst Tools, these data could be summarized for a variety of spatial extents including by the entire wilderness, watershed, management zone, or any other delineated area. Additionally, a number of alternative analysis could be performed to yield additional information regarding the distribution or density of structures in wilderness. Figure 6 below shows one potential analysis in which the distance to the closest equipment installation has been calculated on a 30x30 meter grid covering the entire wilderness. This type of analysis allows managers to view not just the number of developments, but how potential impacts from those developments vary spatially across the wilderness.

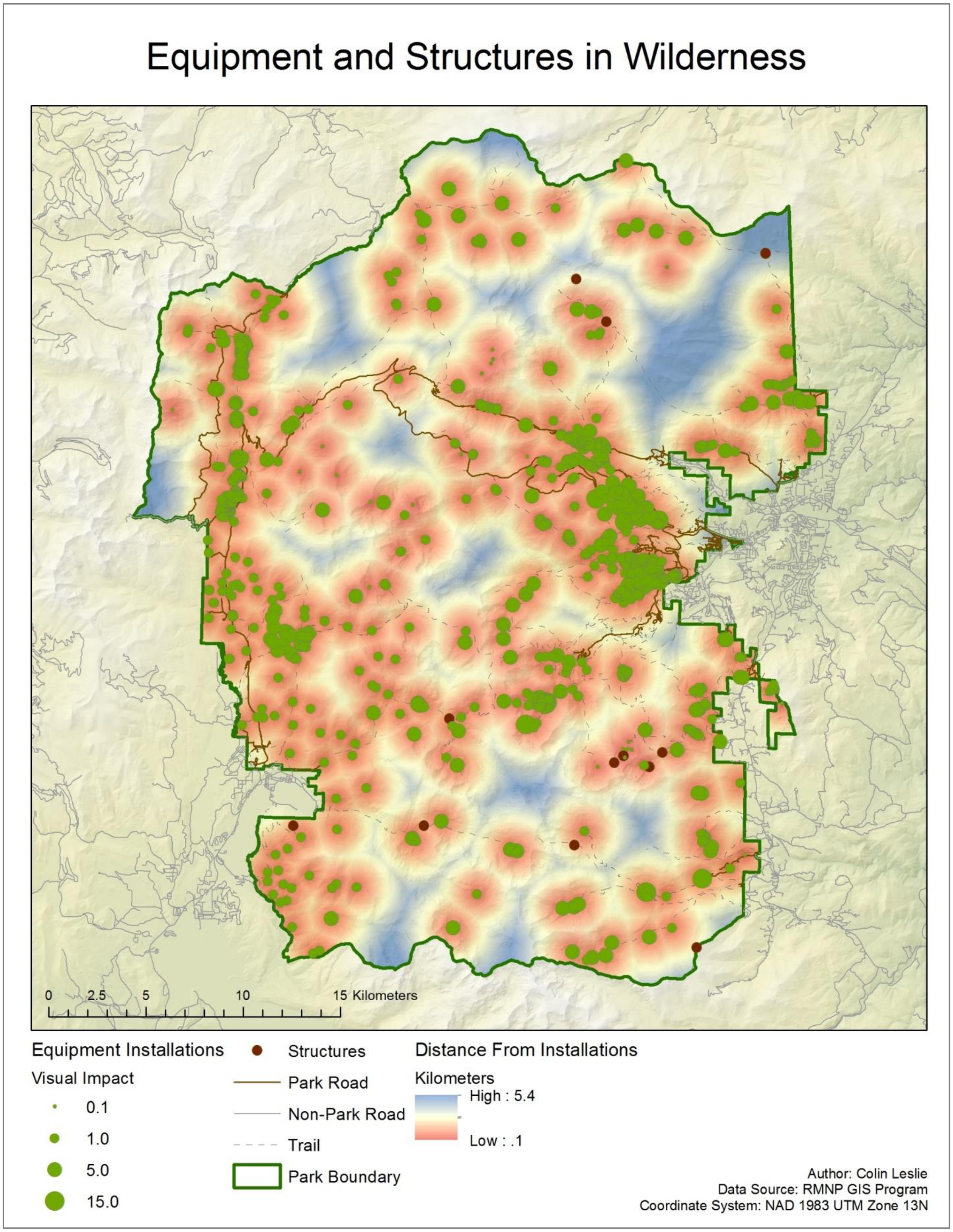


Figure 6 Along with point locations of equipment installations and structures within wilderness, this map shows the relative impact of installations as a function of Euclidean distance calculated for a 30x30 meter grid across the

landscape. The maximum calculated distance for any installation within RMNP Wilderness is roughly 5.4 kilometers.

Inholdings either completely within or adjacent to wilderness have a high potential for impact do to a generally greater degree of freedom regarding development. While there are no identified inholdings currently within RMNP Wilderness, a number of areas designated as potential wilderness are adjacent to or surround private inholdings. If these areas are considered further in the future this measure can provide a course estimation of how this indicator has changed.

The level of mechanized equipment use in the wilderness was also identified as a relevant measure. Two measures that were specifically identified were hours of helicopter use and hours of motorized equipment or mechanized transport. Data to quantify and track these measures is most likely available from park dispatch, Law Enforcement, fire management, and MRDG forms from the wilderness management office. At this time, only one measure has been identified for hours of helicopter use as the distribution of the type of use is unknown. However, splitting this measure into two measures, emergency and non-emergency use, could be considered. The final list of identified measures along with priority and spatial scores can be found in Table 4.

Table 4 Identified measures for the undeveloped quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Non-recreational structures, installations, or developments	Number of monitoring or research structures	9	3
	Number of patrol cabins	8	5
	Miles of non-wilderness class trail	8	5
Inholdings	Number of properties in or adjacent to wilderness	6	5
Biophysical processes	Hours of helicopter use	9	1
	Hours of motorized equipment or mechanical transport	9	1

Solitude

Opportunity for solitude or a primitive and unconfined recreation establishes a definite intent for the type of recreation that wilderness should provide. Solitude is a complex multi-dimensional phenomena. However, the concept of remoteness reflected both in the literature as well as the WCM framework allowed for the identification of a number of potential measures for RMNP Wilderness.

Three measures were identified for the *remoteness from sights and sounds of people inside the wilderness* indicator including: number of visitors, number of encounters on wilderness trails and length-of-stay for overnight trips. These measures were all determined to be significant to wilderness vulnerable to change over the next ten years, or both. RMNP is roughly 95% wilderness with an annual visitation of roughly three million people. As such, it is likely that the majority of visitors step foot within wilderness at some point during their visit. The NPS Visitor Use Statistics office provides annual as well as monthly reports on the number of park visitors through the NPS IRMA data portal. This measure is recognized as a very course measure of visitation with minimal information on spatial distribution, however no alternative measures were identified.

Number of encounters on wilderness trails provides a more directly applicable measure to opportunity for solitude in wilderness. At present, data for this measure are only available on a select number of trails within the park. Despite limited data, this measure has been selected for a number of reasons including: a high degree of significance to wilderness, high degree of vulnerability to change over the next ten years, well established collection protocols, and high feasibility for expansion under existing wilderness management.

Finally length-of-stay is has been shown to be an important attribute in obtaining solitude in wilderness under certain conditions (Cole & Hall, 2012). RMNP requires overnight users to obtain a permit and to camp at designated backcountry campsites. As a result, RMNP maintains a database of all wilderness permits issued, the number of nights the permit was issued for, and selected campsites for each night. This database can be queried to obtain descriptive statistics for length-of-stay directly or can be related to the park campsite GIS dataset in order to determine length-of-stay by area such as management zone, trail system or other area of interest.

While the indicator described above addresses sights and sounds of people in wilderness, two related measure were identified that did fit directly into this indicator or others. Therefore, the indicator *remoteness from no-natural sights and sounds* was created for the measures visibility of non-recreational infrastructure and audibility of non-natural sounds within wilderness. Visibility of non-recreational infrastructure focuses on measuring the visibility of non-recreation structures or installations in wilderness such as those identified under the *non-recreational structures, installations, or developments* indicator for undeveloped quality. Basic models for visibility can be generated using viewshed analysis techniques in a GIS or more advanced models such as visual magnitude (Chamberlain & Meitner, 2013)or improved line of site algorithms can provide a more refined measure of the visual impact of an object on the surrounding landscape (Liu, Zhang, Chen, & Chen, 2008).

The management of soundscapes in order to preserve natural sound environments is of particular interest for park managers. While humans can directly produce sounds in wilderness (talking, walking, other activities) this measure focuses more on the presence of non-natural sounds from sources such as aircraft and road vehicles. Monitoring aircraft and roadway noise can be accomplished using a number of different metrics and measurement techniques.

Currently, the most extensive monitoring in RMNP has been conducted by the NPS Natural Sounds and Night Skies office using acoustical recording equipment in the field and then post processing of data in order to compute a range of metrics.

A number of discrete studies have also examined the issue of anthropogenic noise in RMNP. A study on hiker's exposure to transportation noise examined relationships between transportation noise and visitor's experience around the Bear Lake Road corridor within the park (Park, Lawson, Kaliski, Newman, & Gibson, 2010). While techniques in acoustical modeling of outdoor environments such as the one conducted by Park, Lawson, Kaliski, Newman, & Gibson (2010) continue to improve, it is also recognized that direct measurement of the acoustical environment remains an important aspect of quantifying soundscapes (Miller, 2008). Through consultation with the NPS Natural Sounds and Night Skies office, a method for Observer Based Source Identification Logging (OBSIL) was identified an piloted during the summer of 2013. This pilot study examined the potential for OBSIL as a simple, low cost method for measuring two metrics related to soundscapes, percent time audible (PTA) and noise free interval (NFI). Full results from this study have been presented in an accompanying paper to this document, but in general reveal OBSIL to be a complimentary measurement technique to longer term deployment of acoustical monitoring equipment for evaluating how soundscapes vary across the wilderness.

The potential impact of surrounding outside development on a wilderness area is also an important consideration. The indicator *remoteness from occupied and modified areas outside the wilderness* is intended to address these impact. Two measures were selected for this indicator, night sky visibility averaged over the wilderness and distance from roads outside of wilderness. The NPS Natural Sounds and Night Skies office officially defines night skies under the term natural lightscapes. Natural lightscapes can be impacted by a number of factors including the amount of light being generated by nearby sources such as cities, as well as atmospheric scattering which can be directly impacted by air quality (NPS.gov, 2014).

Distance from roads outside wilderness was selected as a measure as roads have the potential to impact both the visual and auditory environment. The precise visual and auditory impact of roads requires complex modeling and is dependent upon a number of factors including terrain, distance, vegetation, and atmospheric conditions to name a few. However, distance from roads provides an easy to model measure that utilizes readily available GIS data. Measuring distance or remoteness from roads can be conducted either equally for all road types or roads could be weighted based on attributes such as road type, level of use, highway class etc.

The final two indicators, *facilities that decrease self-reliance* and *management restrictions on visitor behavior* are intended to address the concept of primitive and unconfined recreation. RMNP's Backcountry and Wilderness Management Plan established four management classes, each intended to satisfy varying combinations of desired social, resource and management conditions. One measure was identified for each of these indicators. Management class 3 includes around 27,474 acres and allows camping only in designated campsites. Management classes 2 and 4 also include some designated camping but also provide for dispersed camping, whereas management class 1 is designated as day use only. From these management classes, two potential measures were identified, number of designated backcountry campsites and acres subject to restricted activities. The first measure, number of designated backcountry campsites, informs the indicator *facilities that decrease self-reliance*. The second measure, acres subject to restricted activities, informs the indicator *management restrictions on visitor behavior*.

It is important to note that while both of the measures potentially degrade the opportunity for solitude or a primitive and unconfined type of recreation quality, they also potentially enhance measures under the natural quality. This study does not seek to establish the degree to which this purpose has been realized but simply to draw attention to potential interactions among qualities such as this. The final list of identified measures along with priority and spatial scores can be found in Table 5.

Table 5 Identified measures for the solitude quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Remoteness from sights and sounds of people inside the wilderness	Number of visitors	8	2
	Number of encounters on wilderness trails	10	2
	Length-of-stay for overnight trips	8	4
Remoteness from non-natural sights and sounds	Visibility of non-recreational infrastructure	8	4
	Audibility of non-natural sounds within wilderness	8	2
Remoteness from occupied and modified areas outside the wilderness	Night sky visibility averaged over the wilderness	7	1
	Distance from roads outside of wilderness	8	4
Facilities that decrease self-reliant recreation	Number of designate backcountry campsites	7	4
Management restrictions on visitor behavior	Acres subject to restricted activities	8	4

Other Features of Value

Only one potential measure has been identified at this time for the other features of value quality. The indicator *loss of cultural resources* and the associated measure, number of disturbances to cultural resource, was identified in *Keeping it Wild in the National Park Service* (National Park Service, 2014) and found to be present in RMNP. However, it should be noted that no specific features pertaining to wilderness were identified in the 2009 Omnibus Public Lands Act which designated RMNP wilderness. While this does not necessarily preclude features such a research natural areas (which are present in RMNP wilderness) from inclusion in this quality, these features must be evaluated carefully to determine if and how their existence as a specific feature maintains the wilderness resource. The selected measure for this quality are listed in Table 6.

Table 6 Identified measure for the other features of value quality in RMNP including prioritization and spatial scores.

Indicator	RMNP Measure	Prioritization Score	Spatial Score
Loss of cultural resources	Number of disturbances to cultural resources	8	3

Discussion

The purpose of this study was ultimately to determine if WCM can in fact be adequately performed using the guidelines established by in *Keeping it Wild* (Landers et al, 2008) and subsequent guidance documents. While there are numerous factors that can influence the success or failure of WCM, the primary issue examined by this study is that of using existing data to construct a wilderness character assessment. Evaluating the use of existing data however required developing two separate but related questions. First, is utilizing only existing data robust enough to adequately capture and evaluate qualities of wilderness character? Second, what criteria can be used to identify the best existing data for capturing and evaluating qualities of wilderness character? After reviewing the final list of potential measures as well as the process used in their identification and refinement for this study, a number of answers to these questions became apparent.

Utilizing Existing Data

A key recommendation for WCM is to try and utilize existing data to the greatest extent possible in order to identify and select measures to represent qualities of wilderness character.

While no formal hypothesis was developed on the success or failure of this recommendation, the general consensus at the onset of this study was that utilizing only existing data would be inadequate for representing all thirteen indicators established in *Keeping it Wild* (Landres et al., 2008) and later in *Keeping it Wild in the National Park Service* (National Park Service, 2014). However, after extended consultation with park staff, multiple reviews of independent research, and identification of numerous data sources recommended in *Keeping it Wild in the National Park Service* (National Park Service, 2014), at least one measure was identified for each indicator. To the extent that data were identified for each indicator, the recommendation of using existing data was a success. The question of how adequately those data capture and evaluate the overall status of wilderness character though, is less clear.

Assuming the five qualities of wilderness character do in fact capture the multi-dimension aspect of wilderness character, then the adequacy of an assessment is primarily determined by the degree to which measures and data can comprehensively describe the quality to which they are attributed. Although this effort did not focus on an explicit evaluation of minimum inputs (measures and data) necessary to comprehensively describe each quality, many questions related to this topic were raised during the selection process.

For example, RMNP has an extensive history of scientific research, particularly in the area of natural resource management. The result is that for the natural quality, the number of identified data sources and measures far exceeded the recommended number. Early discussions with park managers focused primarily on what data (and at what scale) would be most representative of wildlife species status throughout the wilderness. Potential data included known ranges for an individual species such as elk, a species index representing the statistical relationship between numbers of native and non-native species, or the status of potential habitat for a known indicator species such as beaver. While discussions with staff proved extremely helpful in identifying the range of potential natural resource data, selecting the most salient data to represent measures for the natural quality would have proved extremely difficult if not for the inclusion of the RMNP NRCA.

The primary purpose of an NRCA is to identify the most relevant natural resource condition assessments for an area and represents extensive effort by numerous subject matter experts. For this wilderness character assessment, selecting the most salient measures required little more than correlating findings in the NRCA with recommended indicators for the natural quality. By successfully matching up most natural resource conditions examined in the NRCA with indicators for the natural quality, confidence was fairly high that the natural quality was being comprehensively represented.

The same confidence held true for the undeveloped quality, where most infrastructure is accounted for through existing inventories. Conversely, opportunities for solitude or primitive and unconfined type of recreation offered lower confidence, as several important values identified in the literature, such as length of stay or number of wilderness encounters (Cole and Hall, 2012), were either unrepresented or underrepresented in identified data and measures. Other features of value is also fairly tenuous as criteria for identifying the importance of a specific feature to the overall resource of wilderness are at this time largely undeveloped.

Finally the comprehensiveness of data and measures selected for the untrammeled quality represents the lowest confidence of all the qualities. While measures selected for the undeveloped quality are capable of tracking actions, they do not currently evaluate the extent to which those actions influence the biophysical environment, or other qualities of wilderness character. Although the untrammeled quality is evaluated on equal footing with other qualities in WCM, the use of the term in the Wilderness Act of 1964 itself is intended to represent the ideal state of wilderness rather than a specific quality (Scott, 2002). While the existence of a truly untrammeled system may no longer be possible due to human modification of the global environment, minimizing human manipulation of the wilderness environment is still a worthy goal. To this end the inclusion of a quality tracking human action in wilderness is important, but at present the measures selected for the untrammeled quality offer limited operational insight as both the individual and cumulative impact of actions is unknown. Understanding the degree to which management actions are manipulating the wilderness environment will require not just an inventory of actions, but an integrated understanding of the relationship between those actions and positive or negative effects on the other qualities of wilderness character.

Selecting Best Data

In addition to evaluating the potential of existing data to inform wilderness character, developing a process to determine the *best* or most relevant measures among a set of potential data was also of interest. Developing a systematic process for prioritizing and evaluating potential data provided a number benefits throughout the selection and reporting process. First, by utilizing an evaluative framework such as the one developed by the USFWS while doing an initial inventory of data sources, high priority measures could be identified and then recorded for follow-up consideration. This proved especially useful considering the multidisciplinary nature of wilderness, as often the evaluation of data required follow-up consultation with subject matter experts. In addition to the organizational benefits, an unforeseen but potentially more important benefit is that of transparency. Since WCM is intended to track trends over time, it is likely that relevant data and measures will change. For example, a measure that was deemed not feasible (ability to consistently monitor it) during this assessment may be feasible in the future due to technological advancements. Conversely, a measure that was deemed as highly vulnerable to change now, may stabilize in the future, thus decreasing its overall priority. Evaluating and recording changes in specific attributes can provide managers with additional insights over the long term.

A second benefit to developing a systematic data evaluation method was increased understanding of data coverage. Discrepancies among data quality, coverage, and availability can result in data gaps regarding key components of qualities of wilderness character. Data gaps are likely to be common when attempting to only utilize existing data as historically most agencies have focused on addressing individual resource management issues and not necessarily measuring baseline condition in wilderness (Hendee & Dawson, 2002). This was observed in several circumstances were data was ranked as a high priority under the USFWS framework, but received a low spatial score due to insufficient coverage, such as "number of encounters on wilderness trails," for the opportunities for solitude or a primitive and unconfined type of recreation quality (Table 5). In this instance, the measure received a prioritization score of 10, indicating both a high significance and vulnerability, but a spatial score of 2 indicating that data were available for less than 50% of applicable areas in the wilderness.

Both the prioritization and spatial coverage evaluations provided key insights into each of the selected measures. A couple of additional questions were raised though while evaluating measures, including what metrics to track and what scale to summarize data at. For example, the undeveloped quality assesses the level of non-recreational development and generally relies on tracking the *number* of structures or installations in wilderness. Under this measure, trends are tracked by changes in the number of structures at the scale of the wilderness as a whole. As shown in Figure 6, other possible methods for quantification could involve either distance or density functions calculated using a GIS. These methods can provide managers greater insight into how a measure varies across the wilderness. Literature pertaining directly to assessing low levels of development such as that found in wilderness is sparse.

Finally, it should be recognized that data also varied greatly in their level of synthesis and, thus, representation of wilderness resources as a whole. By far, the Natural Resource Condition Assessment for RMNP provided one of the most highly synthesized data sets for this study including a scientifically robust assessment of the confidence in the data, current and reference or baseline conditions, and, finally, any important stressors for the conditions such as visitor use, climate change, land use change, or pollution, to name a few. While these data provide a robust assessment of wilderness conditions, they also represent a significant investment of time and research by a range of professional scientists across multiple agencies. For some data synthesized in the Natural Resource Condition Assessment, such as atmospheric deposition in alpine lakes, the National Atmospheric Deposition Program (NADP) track most of the same pollutants, but at a much coarser scale. While obviously related efforts, the tradeoffs between these two collection efforts should be more thoroughly evaluated before choosing one over the other. These represent just a few of tradeoffs that must be considered when selecting data for a monitoring effort.

REFERENCES

Aplet, G., Thomson, J., & Wilbert, M. (2000). Indicators of wildness: Using attributes of the land to assess the context of wilderness. In *Proceedings: Wilderness Science in a Time of Change. Ogden (UT): USDA Forest Service, Rocky Mountain Research Station. Proc. RMRS-P-15*. Retrieved from http://www.fs.fed.us/rm/pubs/rmrs_p015_2/rmrs_p015_2_089_098.pdf

Chamberlain, B. C., & Meitner, M. J. (2013). A route-based visibility analysis for landscape management. *Landscape and Urban Planning*, *111*, 13–24. doi:10.1016/j.landurbplan.2012.12.004

Christensen Jr, N. L. (2000). The evolving role of science in wilderness to our understanding of ecosystems and landscapes. Retrieved from https://www.leopold.wilderness.net/library/documents/science1999/Volume3/Christensen_3-3.pdf

Cole, D. N. (1983). Assessing and monitoring back-country trail conditions. *Res. Pap. INT-303. Ogden, UT: USDA For. Serv., Lntermountain Forest and Range Exper. Stn*, *10*, 2.

Cole, D. N., & Hall, T. E. (2012). The effect of use density and length of stay on visitor experience in wilderness. Retrieved from http://www.leopold.wilderness.net/pubs/769.pdf

Dictionary.com. (2014). character. Retrieved from http://dictionary.reference.com/browse/character

Hall, T. E. (2001). Hikers' perspectives on solitude and wilderness. *International Journal of Wilderness*, *7*(2), 20–24.

Hendee, J. C., & Dawson, C. P. (2002). *Wilderness Management* (3rd ed.). Fulcrum Publishing. Retrieved from http://books.google.com/books?hl=en&lr=&id=CcljwJXpi54C&oi=fnd&pg=PA2&dq=endangered+american+wilderness+act&ots=RyL7wsE816&sig=jDxyIM87sRDKnViJOyNEhFsTD44

Johnson, B. J., Hall, T. E., & Cole, D. N. (2005). Naturalness, primitiveness, remoteness and wilderness: Wilderness visitors' understanding and experience of wilderness qualities. *University of Idaho & Aldo Leopold Wilderness Research Institute, Moscow, Idaho*. Retrieved from http://www.cnr.uidaho.edu/wrc/Publications/Johnson_Hall_Cole_Wilderness_qualities_report.pdf

Landres, P., Barns, C., Dennis, J. G., Devine, T., Geissler, P., McCasland, C. S., … Swain, R. (2008). *Keeping It Wild*. Retrieved from https://eng.ucmerced.edu/czo/files/private/research_in_wilderness_policies/rmrs_gtr212.pdf

Landres, P., Boutcher, S., Liese, D., Hall, T., Tamara Blett, Terry Carlson, … Deb Bumpus. (2009). *Technical guide for monitoring selected conditions related to wilderness character* (General Technical No. WO-80). US Department of Agriculture, Forest Service.

Liu, L., Zhang, L., Chen, C., & Chen, H. (2008). An Improved LOS Method for Implementing Visibility Analysis of 3D Complex Landscapes (pp. 874–877). IEEE. doi:10.1109/CSSE.2008.1157

Merriam-Webster. (2014a). trammel. Retrieved from http://www.merriam-webster.com/dictionary/trammel

Merriam-Webster. (2014b). trample. Retrieved from http://www.merriam-webster.com/dictionary/trample

Miller, N. P. (2008). US National Parks and management of park soundscapes: A review. *Applied Acoustics*, *69*(2), 77–92. doi:10.1016/j.apacoust.2007.04.008

National Park Service. (2006). *NPS Management Policies 2006.pdf*.

National Park Service. (2014). *Keeping It Wild in the National Park Service - A User Guide to Integrating Wilderness Character into Park Planning, Management, and Monitoring* (Planning Guide No. WASO 909 121797). U.S. Department of the Interior.

Park, L., Lawson, S., Kaliski, K., Newman, P., & Gibson, A. (2010). Modeling and mapping hikers' exposure to transportation noise in Rocky Mountain National Park. *Park Science*, *26*(3), 59–64.

Rocky Mountain National Park. (1984). ROMO Land Protection Plan.

Rocky Mountain National Park. (2008). Final Environmental Impact Statement - Elk and Vegetation Management Plan.

Rocky Mountain National Park. (2012). ROMO Park Foundation Statement.

Scott, D. W. (2002). " Untrammeled,"" Wilderness Character," and the Challenges of Wilderness Preservation. *Wild Earth*, *11*(3/4), 72-79.

Suzanne Jones, & Jeff Widen. (2006). Rocky Mountain National Park Wilderness Act - Fact Sheet.pdf.

Theobald, D. M., Baron, J. S., Newman, P., Noon, B., Norman, J. B., Leinwand, I., … Hartman, M. (2010). *ROMO_Natural Resources Condition Assessment Theobald 2009* (Natural

Resource Report No. NPS/NRPC/WRD/NRR—2010/228) (pp. 1–206). Fort Collins, CO: U.S. Department of the Interior, National Park Service, Natural Resource Program Center.

Thrower, J. (2006). Adaptive Management and NEPA - How a Nonequilibrium View of Ecosystem Mandates Flexible Regulation. *Ecology LQ*, *33*, 871.

Wilderness Act, 16 U.S.C. § 1131-1136 (1964).

CHAPTER 3: ASSESSING WILDERNESS SOUNDSCAPES USING OBSERVER BASED SOURCE IDENTIFICATION LOGGING

Introduction

The National Park Service (NPS) is charged with preserving a diversity of natural and cultural resources, including natural soundscapes (National Park Service, 2006). Natural sounds and conversely the minimization of anthropogenic sounds is now recognized as important for maintaining the health of ecological systems (Barber et al., 2011) as well as providing quality visitor experience (Mace, Corser, Zitting, & Denison, 2013). Wilderness designation provides yet another basis for monitoring soundscapes, as non-natural sounds can negatively impact opportunities for solitude (Dawson, 2004), one of the primary qualities of wilderness (Landres et al., 2008).

Monitoring soundscapes requires a diversity of approaches, both in recording methods and metrics. One common method involves measuring the sound pressure level (SPL) at a particular site through long term deployment of acoustical recording devices. Data from these recordings can either be used to report SPL directly for different times of day or sources. When attempting to assess the potential impact of SPL at a site on humans, sound levels are commonly adjusted using A-Weighting. This adjustment accounts for the fact that the relative loudness of SPL as perceived by the human ear varies depending on frequency. These types of measurements are particularly helpful for establishing ambient SPL as well as the percent of time that SPL exceeds thresholds known to cause various responses in humans such as a rise in blood pressure or heart rate, disruption of sleep and speech interference at set distances (National Park Service, Natural Sounds and Night Skies Division, 2011).

Measurement techniques such as those described above rely on deploying acoustic measurement devices over generally long periods of time. While recorded data can often be analyzed to determine metrics related to SPL, even the best analysis software still has difficulty performing some forms of auditory analysis. Human hearing is generally highly sensitive to minute changes in the acoustic environment including patterns, level and frequency (Schulte-Fortkamp, Brooks, & Bray, 2008). This is one reason the NPS Natural Sounds and Night Skies Division (NSNSD) continues to utilize human observation (listening) of all recorded data in order to identify the start time and stop time of individual sources within the audio stream.

This type of observation allows for the calculation of audibility metrics in addition to SPL metrics for an acoustic environment. The most common audibility metrics are percent time audible (PTA) and noise free interval (NFI) (Miller, 2008). PTA refers to the percentage of time a source or category is audible relative to the length of total observation. In contrast, NFI refers to the length of time that a particular source or category is *not* audible during an observation window. Depending on the number of samples, standard descriptive statistics can be calculated for both of these metrics and often include the minimum, maximum, and mean or median values for each.

Often times, audibility metrics are derived from pre-recorded sound samples. In order to assist in the identification and classification of sources in pre-recorded samples, the NSNSD has been working on development of a source identification logging application for the iOS mobile operating system. While this application has been primarily used for post-processing of sound samples, it can also be used for the collection of measurements directly in the field. When this form of measurement is conducted in the field it is generally referred to as Observer Based Source Identification Logging (OBSIL).

The use of OBSIL is of interest for its potential as a practical tool for conducting baseline soundscape assessments in wilderness. The presence of non-natural sounds in wilderness is generally understood to negatively impact wilderness character (Iglesias Merchan, Diaz-Balteiro, & Soliño, 2014; Rossman, 2000). In particular, the presence of anthropogenic noise from transportation including vehicles and aircraft is of concern for visitor experience (Pilcher, Newman, & Manning, 2009; Schuster, Johnson, & Taylor, 2004). As a component of an ongoing wilderness character assessment in Rocky Mountain National Park (RMNP), this pilot study was conducted in order to evaluate the potential for OBSIL as a rapid assessment method for measuring audibility of sound sources within wilderness. The NSNSD has conducted acoustical monitoring in RMNP for a number of years; however, monitoring has been primarily focused on establishing ambient (background) levels as well as monitoring noise from commercial aircraft. To conduct these measurements, sites were generally located in remote areas to minimize interference of most sources other than aircraft. While these are useful measurements for understanding certain aspects of the acoustical environment, wilderness visitors are subject to a diversity of sources including vehicles, other visitors, wind, and running water, to name a few. Therefore, the primary objective of this study was to design a sample method focusing on locations and sources most likely to influence wilderness visitors.

Methods

Sampling using the OBSIL method required specifying a number of parameters up front including: specific sources and categories to record; how long to conduct each observation; when to sample; where to sample; and finally any additional environmental information such as weather conditions or GPS location. The NSNSD has developed 28 source categories of interest for outdoor acoustical environments (Table 7). Each of the categories is further broken down into individual sources, such as individual aircraft type (Table 8). The categories below do not represent a comprehensive list of all possible sources and additional sources can be added if necessary (note that some gaps exist in codes for future additional of sources). Using a consistent set of sources allowed for more efficient source logging in the field by permitting easy recoring (or toggle in the case of the iOS application) of sources without the need to define categories on the fly. Using established and consistent sources also aids in comparison of data across multiple studies and ongoing collection efforts. Once source categories were identified, they were programmed into the NSNSD iOS source logging application (Figure 7).

Table 7 Source categories of interest for monitoring outdoor acoustic environments as compiled by NSNSD.

Code Primary	Natural	Description	Code Primary	Natural	Description
0	O	No Sound Audible	21	Y	Wind
1	N	Aircraft	22	Y	Water
2	N	Vehicle	23	Y	Thunder
3	N	Watercraft	24	Y	Mammal
4	N	Oversnow	25	Y	Bird
5	N	Train	26	Y	Reptile
6	N	Motor	27	Y	Amphibian
7	N	Grounds Care	28	Y	Insect
8	N	People	29	Y	Animal (Unknown non-human, any species)
9	N	Domestic animal	30	Y	Geothermal / Mass Movement
10	N	Building Sounds	39	Y	Natural Other
11	N	Construction	40	Y	Natural Unknown
19	N	Non-natural Other	41	O	Artifact
20	N	Non-natural Unknown	99	O	Unknown (cannot tell if natural or non-natural)

Table 8 Individual sources for the general aircraft source category.

Code - Primary	Code - Secondary	Natural	Description
1	1	N	Aircraft
1	1.1	N	Jet
1	1.11	N	Jet, Air Tour
1	1.12	N	Jet, Commercial
1	1.13	N	Jet, G/A
1	1.14	N	Jet, Military
1	1.2	N	Prop
1	1.21	N	Prop, Air Tour
1	1.22	N	Prop, Commercial
1	1.23	N	Prop, G/A
1	1.24	N	Prop, Military
1	1.25	N	Prop, Ultralight
1	1.3	N	Helicopter
1	1.31	N	Helicopter, Air Tour
1	1.32	N	Helicopter, Commercial
1	1.33	N	Helicopter, G/A
1	1.34	N	Helicopter, Military

Figure 7 The sound source logging application developed by NSNSD allows a user to input site location information such as names, latitude and longitude (left) and then record the length of detection by toggling on and off pre-defined sources (right).

The next critical component was determining an observation length for each sample location. Observation length can vary anywhere from a few minutes to several hours, but was ultimately determined by the needs and constraints of the study. Longer observation times would allow increased statistical inference for both PTA and NFI at a specific sample location by increasing the ratio of total observation time to the duration of any individual source detection period within the sample. However, real world sampling limitations of time and personnel required balancing tradeoffs between sample length and number of samples. Longer observations would increase the statistical inference of any individual sample, but reduce statistical inference of how PTA of NFI may vary spatially across the landscape.

Data from previous acoustical monitoring efforts in RMNP revealed the average daytime (7am to 7pm) audible length of detection for commercial aircraft (a primary source of interest) is between 2 and 4 minutes with an average NFI of around 3 minutes. Using this as a starting point, an observation length of 30 minutes was selected. This length was determined to be provide a reasonable observation widow to calculate PTA and NFI for sources of interest, while allowing for five to eight samples to be collected per day depending on distance and terrain between sample points. While sources such as jet aircraft can occur at any time of day, a daytime sample window between 7am and 7pm was selected as it offered the greatest potential for capturing the diversity of anthropogenic noise sources wilderness visitors might encounter.

After parameters for sources of interest, observation length and sample window were established, sample locations/points were selected using a spatially balance sample design. A spatially balanced sample design helps improve sampling efficiency by maximizing spatial independence of sample points (Theobald et al., 2007). This method generates sample points using inclusion probabilities based on a probability surface (raster). A probability surface can relate to a single variable or a combination of variables. The focus of this study was to evaluate audibility of sources for wilderness visitors and while visitors are free to travel to any area within wilderness, most utilize the trail system for primary transportation.

The trail system in the Wild Basin region of RMNP was selected for this study. This area of the park is popular for day use and overnight visitors but has a low amount of development and is generally considered a high quality wilderness area by RMNP staff. Using the Kernel Density function in ESRIs ArcGIS Spatial Analyst Toolbox, a density surface was calculated for all trails in the Wild Basin region using a grid size of 10 meters and a search radius of 100 meters. All trails were considered and no weighting was applied. The trail density surface was rescaled into 100 equal interval classes, which was then divided by 100 to create a probability surface with values between .01 and 1 (Figure 8). Using the Create Spatially Balance Points in ESRI's ArcGIS Geostatistical Analyst toolbox, a sample of 100 points was generated. Unfortunately, unforeseen weather events cut the field survey short and only 28 of the original 100 points were surveyed before the area became inaccessible. Figure 8 below shows those sample points for which data were collected. While these points cover only a few of the trails in Wild Basin, they do provide a distribution from the primary trailhead to one of the furthest points accessible by trail in the region. Considerations for how this sample design could be modified for future efforts are explored further in the discussion section.

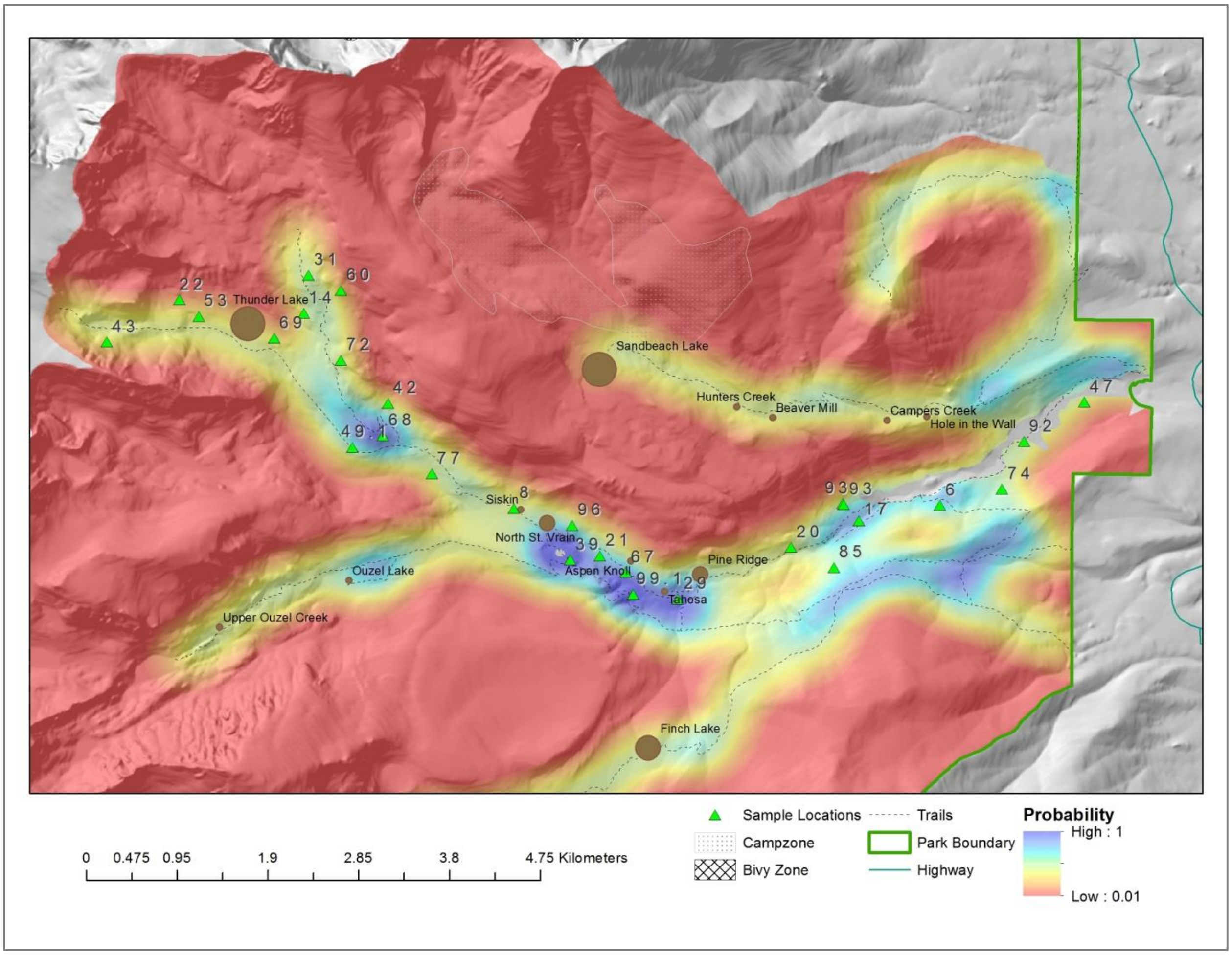


Figure 8 Sample locations and probability surface based on trail density in the Wild Basin area of RMNP.

Results

In total, 29 observation sessions were conducted for a total of 14.5 hours. Due to the lower than anticipated sample size, not enough data were collected to stratify sampling based on day of week. Therefore, all samples were combined for analysis, and descriptive statistics were run for all primary sources.

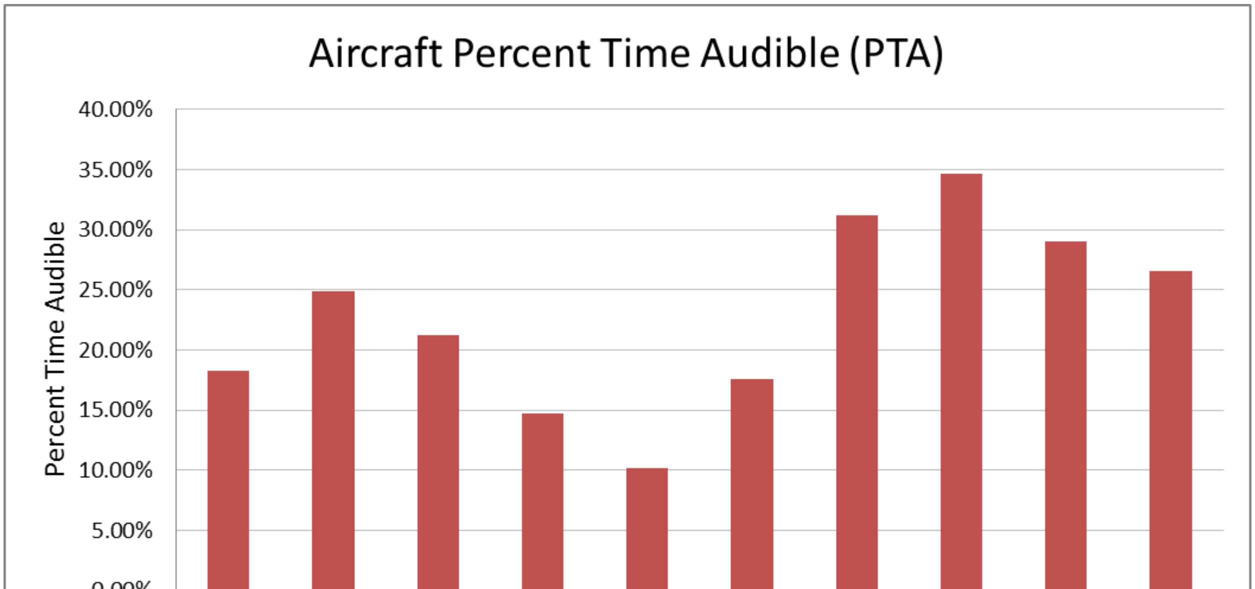
Table 9 shows descriptive results for the length of events across all samples, as well as PTA. For the length of individual events, the average, minimum, maximum and standard deviation have been reported. Lengths are in seconds, which is both the native output from the logging application and also simplifies calculations. For anthropogenic noise sources, the average length of an aircraft event was 134 seconds (2 minutes 14 seconds). The minimum length for an aircraft event was 7 seconds and the maximum length was 508 seconds (8 minutes 28 seconds). The extremely short minimum duration likely represents an event that either ended shortly after the logging session began, or was detected shortly before the logging session ended. The 508 second maximum duration is likely the result of concurrent events in which one or more new aircraft were detected before the previous detection event ended. Neither of these durations invalidate the sample, but they are important artifacts of the sample method.

Table 9 Length and percent time audible (PTA) for all primary source categories detected. Length is reported in seconds and represents all positive detections of that source.

Source	**Number of Observations (n = 29)**	**Length of Individual Events (seconds)**				**Percent Time Audible (PTA)**	
		Mean	Min	Max	Std. Dev.	Samples - Present	Samples - All
Aircraft	24	134	7	508	92	24%	20%
Amphibian	1	2	1	2	1	0%	0%
Bird	25	305	2	1800	509	57%	49%
Insect	20	212	2	1800	427	42%	29%
Mammal	15	252	3	1796	484	23%	12%
People	12	59	2	256	58	10%	4%
Thunder	3	14	2	60	14	12%	1%
Vehicle	2	29	1	105	30	32%	2%
Water	23	1207	6	1800	678	96%	76%
Wind	20	569	1	1800	622	63%	44%
Animal (Unknown)	1	26	6	46	28	3%	0%

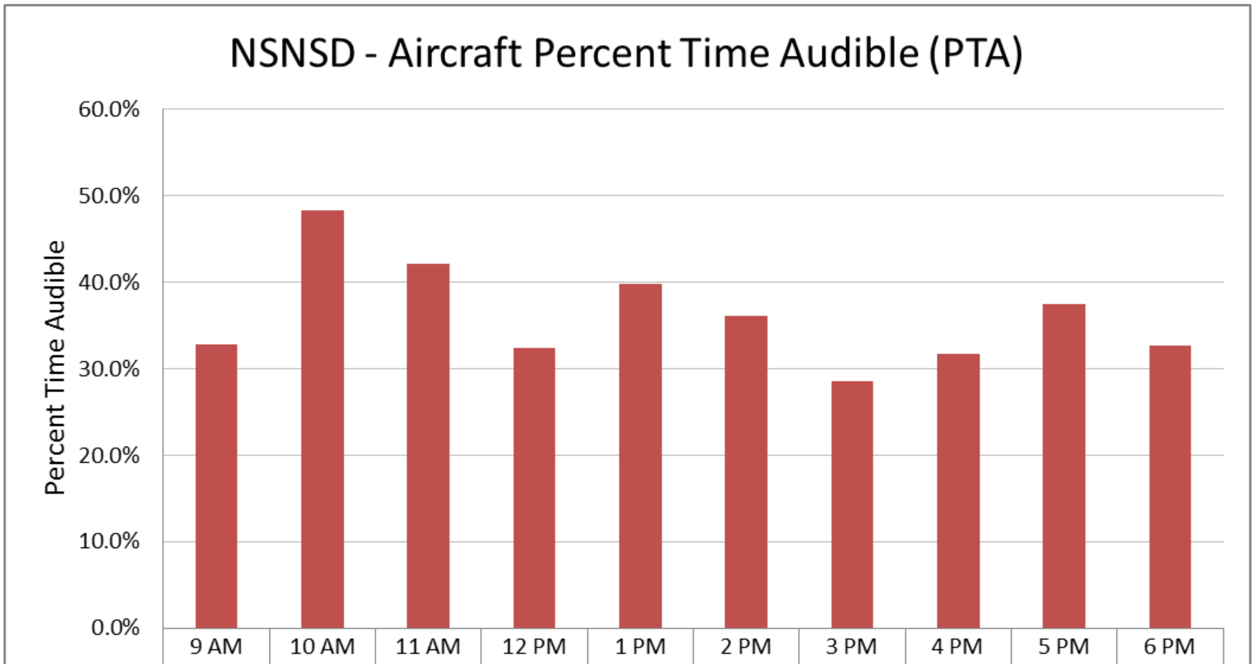
Percent time audible was also calculated for each source category. PTA has been calculated based on two sets of criteria. The first calculation, “samples – present,” was calculated for only those logging sessions where a detection of that source occurred. Written out, this metric can be interpreted as “When a source was detected during a 30 minute observation, how much of the observation on average was it audible.” The second calculation, “samples – all,” was calculated using all samples, including those samples where no detection occurred. A comparison of the two calculations reveals that the inclusion of all samples lowered the PTA for all sources.

Two additional analysis of interest were PTA by hour of the day and NFI by hour of the day. For PTA by hour, aircraft was used for the source of interest and is shown in Figure 9. It is important to note the low sample size for 9am and 6pm and therefore this graph should be interpreted as only a rough estimation of PTA for those hours. For visual comparison, data collected by NSNSD has been provided showing the distribution of PTA for aircraft throughout the day (Figure 10). Overall, PTA from this study is lower than that of the NSNSD data.



	9 AM 1	10 AM 4	11 AM 4	12 PM 5	1 PM 4	2 PM 4	3 PM 2	4 PM 2	5 PM 2	6 PM 1
Aircraft	18.22%	24.86%	21.21%	14.75%	10.17%	17.56%	31.14%	34.61%	29.06%	26.56%

Figure 9 Percent time audible for aircraft between 9am and 6pm. The number between the hour and PTA denotes the sample size for that hour.



	9 AM	10 AM	11 AM	12 PM	1 PM	2 PM	3 PM	4 PM	5 PM	6 PM
Aircraft	32.8%	48.3%	42.1%	32.4%	39.8%	36.1%	28.6%	31.7%	37.5%	32.7%

Figure 10 Percent time audible based on data from NSNSD site ROMO101. PTA has been calculated from a sample size of 3 days (3 hours total for each hour of the day).

In addition to PTA, NFI was calculated for each hour for which observations were collected. Figure 11 shows the average calculated NFI between the hours of 9am and 6pm. The maximum NFI for an observation is directly related to the total length of the observation period. Since the observation length for this study was 30 minutes, the maximum possible NFI is also 30 minutes. The interpretation of results presented in Figure 11 would read “The longest NFI observed during a 30 minutes sample for a given hour of the day is X minutes and X seconds”. The long NFI during the 5pm hour is the result of the masking effect of flowing water during one of the two samples. During this observation, which occurred directly next to a stream, flowing water was audible during 100% of the observation and was the only source detected during the entire observation.

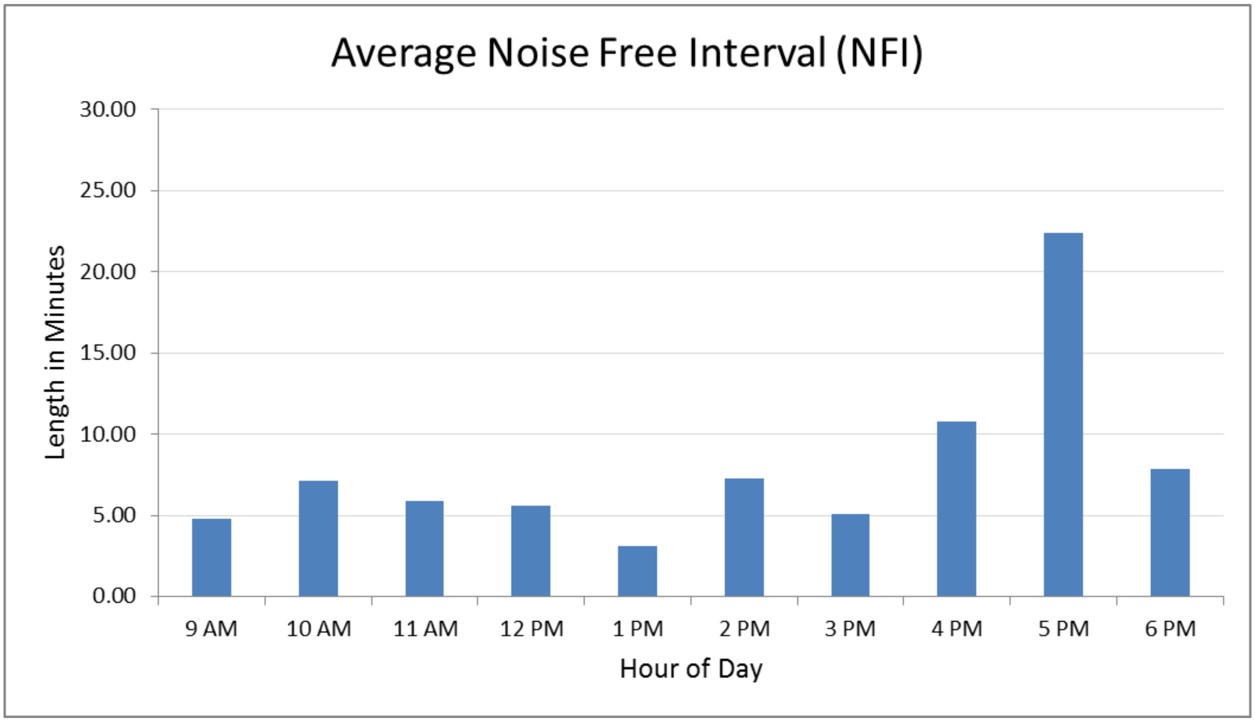


Figure 11 The average noise free interval (NFI) between 9am and 6pm.

Discussion

Results from this pilot study indicate OBSIL has potential as a viable method for assessing baseline soundscape conditions in wilderness or similar outdoor acoustic environments. This type of acoustical monitoring allows for the relatively rapid assessment of a broad geographic area using a minimum number of tools and no installation of equipment. Although the sample for this study was cut short, a number of important observations and insights were gained.

First, some sources, both natural and anthropogenic, were more consistently detected at least once during an observation. Of the 29 sites sampled, common sources included: aircraft n=24; birds, n=25; insects, n=20; water, n=23; and wind n=20. When these sources were present, the natural sources were on average audible 42% to 96% of the time Table 9. The most prevalent non-natural sound was aircraft, which was audible on average 24% of the time during observations were a detection occurred and 20% overall. While the percentage of time that aircraft was audible was substantially lower than other common natural sources, it was still detected during the majority of observations.

Another key insight is that when certain sources such as flowing water are present, they may be acting as a masking source. Since the OBSIL method only measures audibility based on detection, it is difficult to determine the full potential of flowing water as a masking source in this type of environment as no measurements of SPL were made. However, the common occurrence of flowing water (n=23) and generally constant presence (mean length = 1207 seconds or 12:07 minutes) suggests that when present, water constitutes a significant portion of the auditory environment. If this is the case, anthropogenic sounds such as aircraft may be being mitigated at least in part by masking effects from sources such as water. Table 10 shows a sample observation where masking was a possibility. In this sample, no aircraft were detected, while running water (a stream in this case) was detected for the entirety of the observation.

Table 10 Example of a thirty minute observation where no aircraft were detected.

SampleLocation ID: 20				**Date: 8/16/2013**					
Event Start	**Event End**	**Length (sec)**	**Length (min)**	**Natural**	**Primary**		**Secondary**		**PTA**
					Code	Description	Code	Description	
13:37:35	14:07:35	1800	30:00	Y	22	Water	22.2	Flowing Water	100.0%
13:38:30	13:38:33	3	00:03	Y	28	Insect	28	Insect	0.2%
13:38:43	13:48:51	608	10:08	Y	28	Insect	28	Insect	33.8%
13:41:46	13:41:51	5	00:05	N	8	People	8.1	Voices	0.3%
13:47:03	13:47:40	37	00:37	N	8	People	8.1	Voices	2.1%
13:47:44	13:48:34	50	00:50	N	8	People	8.1	Voices	2.8%
13:47:57	13:48:12	15	00:15	Y	25	Bird	25	Bird	0.8%
13:49:00	13:49:23	23	00:23	N	8	People	8.1	Voices	1.3%
13:51:59	13:52:28	29	00:29	N	8	People	8.1	Voices	1.6%
13:55:20	13:55:25	5	00:05	Y	28	Insect	28	Insect	0.3%
13:57:02	13:58:11	69	01:09	Y	25	Bird	25	Bird	3.8%
13:57:35	13:57:45	10	00:10	Y	28	Insect	28	Insect	0.6%
13:58:12	13:58:26	14	00:14	Y	28	Insect	28	Insect	0.8%
13:59:25	14:01:38	133	02:13	Y	28	Insect	28	Insect	7.4%
14:00:18	14:02:41	143	02:23	Y	25	Bird	25	Bird	7.9%
14:02:42	14:02:47	5	00:05	Y	28	Insect	28	Insect	0.3%
14:02:58	14:04:46	108	01:48	Y	21	Wind	21	Wind	6.0%
14:03:03	14:07:06	243	04:03	Y	28	Insect	28	Insect	13.5%
14:03:23	14:06:07	164	02:44	Y	25	Bird	25	Bird	9.1%
14:06:25	14:07:02	37	00:37	N	8	People	8.1	Voices	2.1%
14:07:06	14:07:10	4	00:04	Y	25	Bird	25	Bird	0.2%
14:07:14	14:07:25	11	00:11	N	8	People	8.1	Voices	0.6%

While PTA is one metric for quantifying the acoustic environment, it does not provide any information on the frequency of a source, which is better described by the source's NFI. Some sources, such as aircraft, have a large area of influence compared to other non-natural sources. Results from this study indicated that for almost all hours of the day, the NFI for aircraft was under 10 minutes. The one exception for this sample was 5 PM, which had a NFI of around 22 minutes. A review of the source data indicated however that this is the result of an outlier where water was the only source detected during one of the two samples collected during the 5 PM hour. The most likely implication is that achieving a long NFI most likely requires the presence of significant masking source, such as running water.

While the potential of a natural masking source to increase NFI is apparent, a number of additional questions need to be addressed in order to further quantify the potential effect. First, measurements will need to be conducted on a site specific basis to establish SPL levels for both the masking source and the source being masked if a relative area of potential influence is to be modeled. Second, if considering masking as a tool for managing visitor experience (such as trail location), visitor attitudes and preference between the natural and non-natural sources should be researched further. Simply put, not all visitors may consider walking next to a loud stream an optimal trade-off to periodically hearing aircraft.

Collectively though, results from this study suggests that soundscapes at least in some areas of wilderness may provide better-than-expected visitor experiences when compared to current acoustical monitoring measures. Currently, the majority of soundscapes research has focused primarily on addressing areas known to be highly impacted by anthropogenic noise (Taff et al., 2013). Understanding the status of soundscapes in relatively low impact areas, however, is important both for quantifying the overall status of wilderness and establishing baselines conditions for monitoring into the future.

The OBSIL method evaluated in this study offers a number of benefits for wilderness soundscape assessment. The primary benefits are: the ability to successfully measure two key audibility metrics relating to the wilderness visitor experience; coverage of a broad geographic area; and minimal equipment, observer training and post processing requirements. In addition, the ability to customize both the sample (observation) length and sample locations offers wilderness managers a wide range of flexibility in designing a monitoring effort. Selecting a particular sample length or spatial distribution of sample locations will depend on the specific management questions. If commercial aircraft are a primary source of interest, longer observations sampled at a lower density throughout the wilderness may be most appropriate. If the influence of vehicle and visitor noise within a certain destination region are of interest, shorter duration observations sampled at a higher density may provide the most insight into the acoustic environment.

Ultimately, any soundscape assessment or monitoring effort should be clear on both the temporal (daily, seasonal etc.) and spatial limitations of the sample design. The sample design for this study used trail density as the primary variable in developing a probability surface. The intent of this study was to assess the acoustic environment most likely to be experienced by wilderness visitors and visitors tend to hike primarily on established trails. The sample was also conducted during August/September, a popular but significantly lower use season than mid-summer. While this provides a reasonable assessment of a typical wilderness visitor experience in the Wild Basin region of RMNP wilderness, it cannot be extrapolated to the wilderness as a whole. The Wilderness Act simply requires that a wilderness provide opportunities for solitude and a primitive and unconfined recreation. It does not limit this opportunity solely to established transportation networks, such as trails. Therefore, a generalizable wilderness soundscape assessment should be likely based on a random spatial sample, rather than a probabilistic one.

The intent of this study is not to suggest that OBSIL be considered a replacement for existing acoustical monitoring programs. Rather, OBSIL provides a complimentary method for expanding soundscape assessments across a greater percentage of management areas that would otherwise be too costly in time, money and other resources to measure. Given the flexible sample design and growing interest in protecting natural soundscapes, OBSIL methods warrant further research in order to better understand the potential for soundscape management in wilderness.

REFERENCES

Barber, J. R., Burdett, C. L., Reed, S. E., Warner, K. A., Formichella, C., Crooks, K. R., … Fristrup, K. M. (2011). Anthropogenic noise exposure in protected natural areas: estimating the scale of ecological consequences. *Landscape Ecology*, *26*(9), 1281–1295. doi:10.1007/s10980-011-9646-7

Dawson, C. P. (2004). Monitoring outstanding opportunities for solitude. *International Journal of Wilderness*, *10*(3), 12–14.

Iglesias Merchan, C., Diaz-Balteiro, L., & Soliño, M. (2014). Noise pollution in national parks: Soundscape and economic valuation. *Landscape and Urban Planning*, *123*, 1–9. doi:10.1016/j.landurbplan.2013.11.006

Landres, P., Barns, C., Dennis, J. G., Devine, T., Geissler, P., McCasland, C. S., … Swain, R. (2008). *Keeping It Wild*. Retrieved from https://eng.ucmerced.edu/czo/files/private/research_in_wilderness_policies/rmrs_gtr212.pdf

Mace, B. L., Corser, G. C., Zitting, L., & Denison, J. (2013). Effects of overflights on the national park experience. *Journal of Environmental Psychology*, *35*, 30–39. doi:10.1016/j.jenvp.2013.04.001

Miller, N. P. (2008). US National Parks and management of park soundscapes: A review. *Applied Acoustics*, *69*(2), 77–92. doi:10.1016/j.apacoust.2007.04.008

National Park Service. (2006). *NPS Management Policies 2006.pdf*.

National Park Service, Natural Sounds and Night Skies Division. (2011). *Rocky Mountain National Park Acoustic Monitoring Snapshot*. Fort Collins, CO: U.S. Department of the Interior, National Park Service.

Pilcher, E. J., Newman, P., & Manning, R. E. (2009). Understanding and managing experiential aspects of soundscapes at Muir Woods National Monument. *Environmental Management*, *43*(3), 425–435.

Rossman, B. (2000). Impairment of park soundscapes. *Director*, 44.

Schulte-Fortkamp, B., Brooks, B. M., & Bray, W. R. (2008). Soundscape: An Approach to Rely on Human Perception and Expertise in the Post-Modern Community Noise Era. *Acoustics Today*, *3*(1), 7–15.

Schuster, E., Johnson, S. S., & Taylor, J. G. (2004). Wilderness experience in Rocky Mountain National Park 2002: Report to RMNP. *Open-File Report. U. S. Geological Survey*, (445).

Taff, D., Newman, P., Lawson, S. R., Bright, A., Marin, L., Gibson, A., & Archie, T. (2013). The role of messaging on acceptability of military aircraft sounds in Sequoia National Park. *Applied Acoustics*. doi:10.1016/j.apacoust.2013.09.012

Theobald, D. M., Stevens Jr, D. L., White, D., Urquhart, N. S., Olsen, A. R., & Norman, J. B. (2007). Using GIS to generate spatially balanced random survey designs for natural resource applications. *Environmental Management*, *40*(1), 134–146.

CHAPTER 4: DISCUSSION

The purpose of this thesis was to evaluate wilderness character monitoring (WCM) in order to better understand its potential as a comprehensive and systematic framework for assessing wilderness character. By applying WCM to Rocky Mountain National Park (RMNP) Wilderness as a case study, insights were gained regarding the adequacy of existing data to support a wilderness character assessment as well as what methods may be used to systematically select the best data from existing sources. This case study was compiled as an individual manuscript (chapter 2) and serves as an evaluation of both the final measures selected for RMNP Wilderness as well as the process by which those measures were selected. In addition, a second study was conducted focusing on evaluating the potential of Observer Based Source Identification Logging (OBSIL) as a method for assessing wilderness soundscapes. This study, which has also been compiled as an individual manuscript (chapter 3), compliments the case study in RMNP Wilderness by focusing on a method to further develop one specific aspect of wilderness character.

Every wilderness is comprised of a unique combination of biophysical, experiential and symbolic values that define its wilderness character. As such, the particular measures and data that represent those values will vary, making each WCM effort distinctive for that particular wilderness. Even so, two studies conducted for this thesis offer valuable insight into the potential of WCM as a comprehensive and systematic framework for assessing wilderness character

The need to begin assessing and monitoring wilderness character is important, even if the dynamics of wilderness is not fully understood. A challenge to this approach though, is that the ultimate goal of any monitoring program is to provide an estimate of the status of a system.

Providing such an estimate requires a high degree of confidence that the proper data are being collected to adequately describe the variability of the system. Unfortunately, given the limited availability of resources for many agencies, often a surveillance type approach is taken, focusing on what is available for monitoring rather than building upon relevant theory and hypothesis (Nichols & Williams, 2006). The result is that the comprehensiveness of WCM will likely vary extensively depending upon the particular scientific and managerial history of the wilderness area.

Indeed, even for RMNP Wilderness, confidence varied greatly even among individual qualities of wilderness character. Confidence in the natural and undeveloped qualities was relatively high due to an extensive history of research and management that could provide data for measures representing these qualities. In contrast, confidence in the untrammeled and opportunities for solitude or a primitive and unconfined type of recreation qualities was lower, as historically less effort has been focused on data that would inform these.

While the high variability in confidence among qualities is a challenge that deserves extensive future research, it should not be interpreted as an invalidation of WCM. Rather, it should serve as a caveat to the interpretation of any findings resulting from a WCM effort. WCM is simply a tool to help managers better understand the status wilderness character. To this end, while a single metric indicating the status of wilderness character as good or bad may be desired, it is neither appropriate at this time, nor is it necessarily the most useful product of a WCM effort. Deriving a single metric for wilderness character would require the weighting of measures, indicators or qualities to account for the relative importance of each. While weighting can be done subjectively though a consultation with managers or subject matter experts, there is currently no objective, scientifically based method, for weighting one indicator or measure higher than another. Additionally, the Wilderness Act of 1964 does not provide any statutory basis for interpreting the importance of one quality of wilderness as more significant than another.

The larger benefit of WCM is the commitment to ongoing collection and evaluation of data that can help inform managers of important wilderness issues. Wilderness stewardship, in contrast to many traditional disciplines within public land management, requires constant interdisciplinary discussion and decision making to ensure its success. Therefore, it may be important to consider WCM not simple as a standalone effort, but as part of a larger wilderness stewardship effort incorporating principles of adaptive management. The National Park Service *Wilderness Stewardship Plan Handbook* (National Park Service, 2014b) addresses this issue at least in part by referring to wilderness character monitoring as a building block to an overall wilderness stewardship planning process. The *Wilderness Stewardship Plan Handbook* (National Park Service, 2014b) prescribes no specific order in which these building blocks to a stewardship plan need to occur but rather leaves them flexible to accommodate needs of the park unit.

Given the complexity of wilderness, which involves a combination of ecological, recreational and experiential dimensions, a stewardship plan will likely involve a dynamic decision making process, such as adaptive management. If this is the case, then WCM is best suited to perform the monitoring function of an adaptive management plan. Exactly how monitoring is integrated into an adaptive management plan can vary, from a specific component of a structured decision making process to variable role in a more dynamic form of decision analysis (Lyons, Runge, Laskowski, & Kendall, 2008). Even so, choosing *what* to monitor must be guided primarily by the larger management context within which the program sits, in order to make sure that evaluation of the measures being tracked can inform realistic management capabilities (Williams, 2011).

Both *Keeping it Wild* (Landres et al., 2008) and *Keeping it Wild in the National Park Service* (National Park Service, 2014a) emphasize that selected measures can change over time as the needs and abilities of the administering agency change. The soundscapes study conducted in the Wild Basin region of RMNP is a prime example. The OBSIL method explored in this study is the result of a relatively recent technological advancement and that able to fill an important data gap (need) in understanding soundscapes as they can potentially influence wilderness experience. Ensuring that institutional mechanisms are in place to adapt monitoring programs based on new research and technological advances is critical to the long term success of wilderness character monitoring.

Ultimately, there is no single number or empirical formula for the preservation of wilderness. Rather, successful preservation of wilderness is predicated on an integral understanding of both the philosophical and operational realities of wilderness stewardship (Christensen, 2000). While this thesis certainly does not resolve any of the philosophical arguments surrounding wilderness, it does demonstrate the need to continue developing a better understanding of the relationship between the stewardship goals we are trying to accomplish and how we determine if we are meeting them.

REFERENCES

Christensen Jr, N. L. (2000). The evolving role of science in wilderness to our understanding of ecosystems and landscapes. Retrieved from https://www.leopold.wilderness.net/library/documents/science1999/Volume3/Christensen_3-3.pdf

Landres, P., Barns, C., Dennis, J. G., Devine, T., Geissler, P., McCasland, C. S., … Swain, R. (2008). *Keeping It Wild*. Retrieved from https://eng.ucmerced.edu/czo/files/private/research_in_wilderness_policies/rmrs_gtr212.pdf

Lyons, J. E., Runge, M. C., Laskowski, H. P., & Kendall, W. L. (2008). Monitoring in the Context of Structured Decision-Making and Adaptive Management. *The Journal of Wildlife Management*, *72*(8), 1683–1692.

National Park Service. (2014a). *Keeping It Wild in the National Park Service - A User Guide to Integrating Wilderness Character into Park Planning, Management, and Monitoring* (Planning Guide No. WASO 909 121797). U.S. Department of the Interior.

National Park Service. (2014b). *Wilderness Stewardship Plan Handbook - Planning to Preserve Wilderness Character* (Planning Guide No. WASO 909 12287). U.S. Department of the Interior.

Nichols, J. D., & Williams, B. K. (2006). Monitoring for conservation. *Trends in Ecology & Evolution*, *21*(12), 668–673.

Williams, B. K. (2011). Adaptive management of natural resources—framework and issues. *Journal of Environmental Management*, *92*(5), 1346–1353. doi:10.1016/j.jenvman.2010.10.041

APPENDIX A – EVALUATION OF POTENTIAL MEASURES CONSIDERED

USFWS Prioritization Framework

Directions: In each row, write the potential measure in the left column under the appropriate indicator. Add or delete rows as needed. Use the criteria and ranking guide below to create an overall score for each measure. If the combined score for criteria A and B is ≤ 2, STOP and do not score criteria C and D. Those measures with the highest overall scores should be the highest priority for assessing trends in wilderness character.

A. Level of significance (the measure is highly relevant to the quality and indicator of wilderness character, and is highly useful for managing the wilderness): High = 3 points, Medium = 2 points, Low = 1 point

B. Level of vulnerability (measures an attribute of wilderness character that currently is at risk, or might likely be at risk over 10-15 years): High = 3 points, Medium = 2 points, Low = 1 point

C. Degree of reliability (the measure can be monitored accurately with a high degree of confidence, and would yield the same result if measured by different people at different times): High = 3 points, Medium = 2 points, Low = 1 point

D. Degree of feasibility (the measure is related to an existing effort or could be monitored without significant additional effort):
High = 1 point, Low = 0 point (if 0 is given, do not use)

Table 11 The USFWS criteria can be used to create a composite score for every potential measure to assist with selection of the most relevant measures.

POTENTIAL MEASURE	Criteria for Prioritizing Potential Measures				OVERALL SCORE	Comments
	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility		
UNTRAMMELED QUALITY						
Indicator: Authorized actions that manipulate the biophysical environment **Measure:**						
Indicator: Unauthorized actions that manipulate the biophysical environment **Measure:**						
NATURAL QUALITY						
Indicator: Plant and animal species and communities **Measure:**						
Indicator: Physical resources **Measure:**						
Indicator: Biophysical processes **Measure:**						
UNDEVELOPED QUALITY						
Indicator: Non-recreational structures, installations, or developments **Measure:**						
Indicator: Inholdings **Measure:**						
Indicator: Use of motor vehicles, motorized equipment, or mechanical transport **Measure:**						
SOLITUDE OR PRIMITIVE AND UNCONFINED RECREATION QUALITY						
Indicator: Remoteness from sights and sounds of people inside the wilderness **Measure:**						
Indicator: Remoteness from occupied and modified areas outside the wilderness **Measure:**						
Indicator: Facilities that decrease self-reliant recreation **Measure:**						
Indicator: Management restrictions on visitor behavior **Measure:**						
Other Features Quality (if applicable)						
Indicator: Loss of cultural resources **Measure:**						

Spatial Score Analysis

Directions: For each measure and corresponding data source, begin in the top left "Identify Data Source". Use the criteria provided below to determine an overall Spatial Score for the data source using the flowchart.

- **Is Spatial**: Are the data in a spatial/GIS format?
- **Complete Spatial Coverage**: Do the data cover or apply to the entire wilderness area?
- **Precise**: Does the resolution of the data provide a relatively precise measure relative to expect variability in the wilderness area?
- **Relatable**: If the data are not natively spatial, can they be related to an existing spatial dataset based on a common attribute?
- **Interpolable/Generalizable**: If the data do not completely cover the wilderness area, can they be interpolated using statistical techniques to give an estimate of conditions across wilderness?
- **Coverage >50%**: If the data cannot be interpolated, does existing data cover 50% or more of the wilderness?

Once a score has been obtained, record it in the table below along with the data source and summary method.

- **Spatial Score**: Indicates the level of spatial coverage for the data relative to the wilderness area.
- **Data Source**: The program, report, or archive from which the data were or can be obtained
- **Summary Method**: How are the data reported. Represented as metric/area unit. For example, total acres per wilderness area would be represented by "Acres/Wilderness"

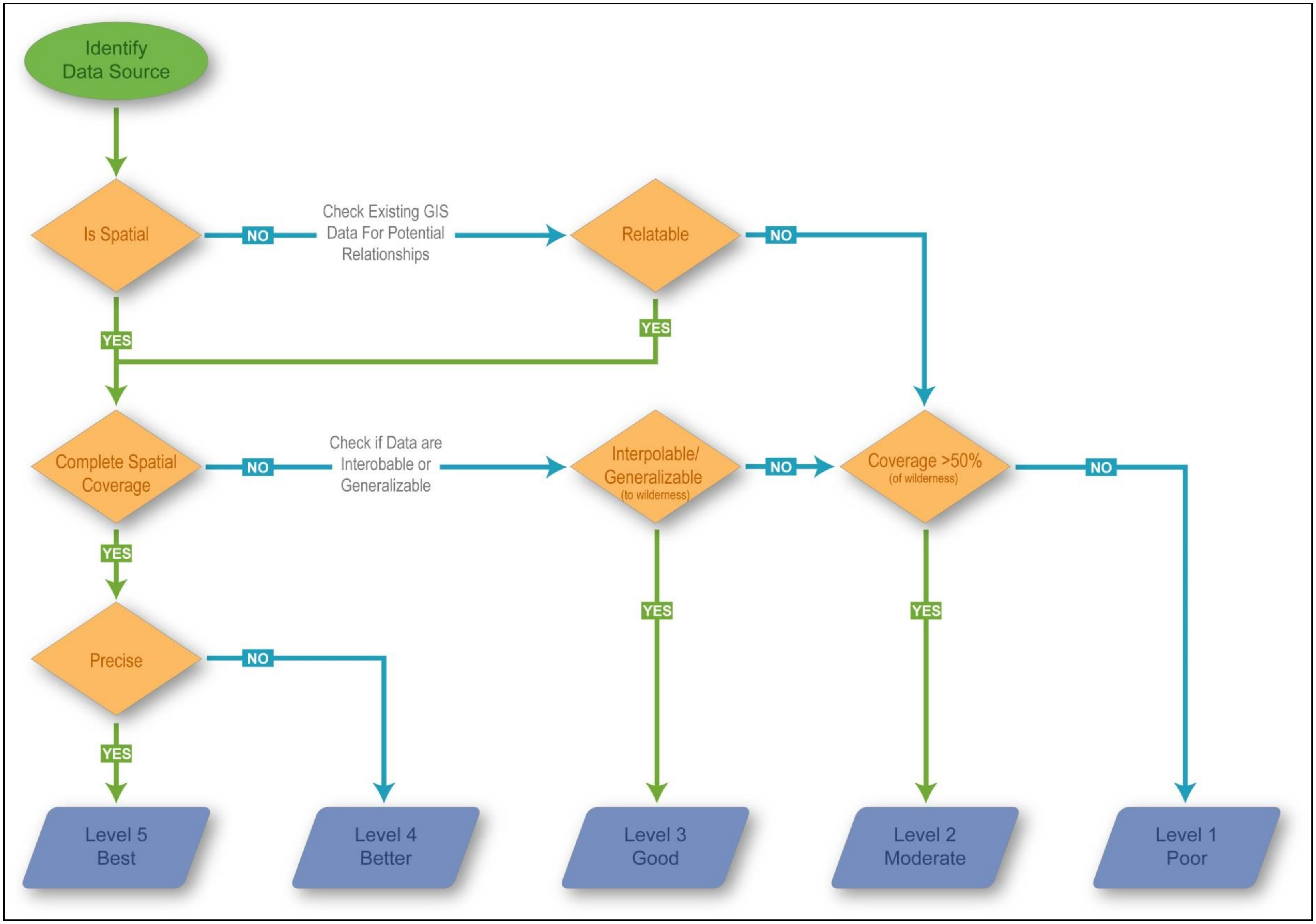


Figure 12 Framework for assigning a spatial score for identified data sources.

Measures and Scores

Table 12 Identified potential sources for measures and data along with USFWS prioritization score and spatial score

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria					Metric	Summary Area	Spatial Score
							A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
Untrammeled	Authorized actions that manipulate the biophysical environment	Number of actions to manage plants animals, pathogens, soil, water, or fire	Acres of plant removal projects	RMNP Resource Management - Botanist		Y	3	3	3	1	**10**	Acres	Wilderness/ Watershed/ Other Unit	**4**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of Elk culled per year	RMNP EVMP	2012	Y	2	2	3	1	**8**	Count	Wilderness	**5**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of elk exclosures	RMNP EVMP, GIS or Scientific Installations DB		Y	2	2	3	1	**8**	Count	Wilderness/ Watershed/ Other Unit	**5**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Native fish removed per day	RMNP Resource Management – Wildlife Biologist		N	1	2	1	0	**4**	Count	Wilderness	**2**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of reintroductions	RMNP Resource Management – Wildlife Biologist		Y	2	1	3	1	**7**	Count	Wilderness	**4**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent		USFWS Criteria					Metric	Summary Area	Spatial Score
						Recommended Measure	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of prescribed burns	FMO	2013	Y	3	3	3	1	**10**	Count	Wilderness	**5**
		Percent of natural fire starts that received a suppression response	Percent of natural fire starts that received a suppression response	FMO	2013	Y	3	3	3	1	**10**	Percent	Wilderness	**5**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of animals tagged or banded	RMNP Resource Management – Wildlife Biologist		N	2	1	1	0	**4**	Count	Wilderness	**1**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of submitted MRDGs involving actions that manageplants animals, pathogens, soil, water, or fire	RMNP Wilderness Office	2013	Y	3	3	3	1	**10**	Count	Wilderness/ Watershed/ Other Unit	**2**
		Number of actions to manage plants animals, pathogens, soil, water, or fire	Number of approved MRDGs involving actions that manageplants animals, pathogens, soil, water, or fire	RMNP Wilderness Office	2013	Y	3	3	3	1	**10**	Count	Wilderness/ Watershed/ Other Unit	**2**
	Unauthorized actions that manipulate the biophysical environment	Number of unauthorized actions by agencies, citizen groups, or	Number of visitor-ignited fires	FMO	2013	Y	3	1	2	1	**7**	Count	Wilderness/ Watershed/ Other Unit	**5**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria: A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
		individuals that manipulate plants, animals, pathogens, soil, water, or fire												
Natural	Plant and animal species and communities	Abundance, distribution, or number of indigenous species that are listed as threatened and endangered, sensitive, or of concern	Number of indigenous species that are listed as threatened and endangered, sensitive, or of concern	RMNP ESA Listing/ NPS IRMA	2013	Y	2	2	3	1	**8**	Count	Wilderness	**2**
		Number of extirpated indigenous species	Number of extirpated indigenous species	RMNP Resource Management/ NPS IRMA	2013	N	2	1	2	1	**6**	Count	Wilderness	**2**
		Number of non-indigenous species	Number of non-indigenous speices	RMNP Resource Management/ NPS IRMA	2013	N	2	1	2	1	**6**	Count	Wilderness	**2**
		Number of non-indigenous species	Species Index (ratio of native to non-native species)	RMNP Resource Management/ NPS IRMA		N	2	1	1	1	**5**	Count	Wilderness	**2**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
		Abundance, distribution, or number of invasive non-indigenous species	Proportion and abundance of non-native exotic plant species	NRCA Report	2010	Y	3	3	2	1	**9**	Percent	Watershed	**4**
		Change in demography or composition of communities	Extent and connectivity of fish distributions	NRCA Report	2010	Y	3	2	2	1	**8**	Extent	Wilderness/ Watershed/ Other Unit	**5**
		Change in demography or composition of communities	Extent of suitable beaver habitat	NRCA Report	2010	Y	3	2	2	1	**8**	Extent	Wilderness/ Watershed/ Other Unit	**5**
		Change in demography or composition of communities	Number of elk, beaver or pika	RMNP Resource Management/ NPS IRMA		N	2	2	3	1	**8**	Count	Wilderness	**2**
		Change in demography or composition of communities	Acres of habitat restored	RMNP Resource Management	2013	N	1	2	3	1	**7**	Acres	Wilderness/ Watershed/ Other Unit	**4**
	Physical resources	Visibility based on average deciview and sum of anthropogenic fine nitrate and sulfate	Visibility based on average deciview	IMPROVE Data	2010	Y	3	3	3	1	**10**	Visibility	Wilderness	**4**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent		USFWS Criteria					Metric	Summary Area	Spatial Score
						Recommended Measure	A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score			
		Ozone air polution based on concentration of N100 episodic and W126 chronic ozone exposure affecting sensitive plants		EPA AIRS Data	2013	Y	2	2	3	1	**8**	Concentration	Wilderness	**3**
		Acid deposition based on concentration of sulfur and nitrogren in wet deposition	Acid deposition based on concentration of sulfur and nitrogren in wet deposition	National NADP/NTN data (sites CO19, CO89, CO98)	2013	Y	2	2	3	1	**8**	Concentration	Wilderness	**3**
		Extent and magnitude of change in water quality	Extent and magnitude of change in water quality	I&M Monitoring Data	2001	N	2	1	3	1	**7**	Concentration	Wilderness	**3**
		Extent and magnitude of change in water quality	Atmospheric deposition of nutrients and pollutants in high elevation lakes	NRCA Report	2010	Y	3	3	2	1	**9**	Levels	Lake	**3**
		Extent and magnitude of human-caused stream bank erosion	Extent and magnitude of human-caused stream bank erosion	USGS/EPA Water Quality Portal		N	2	2	3	1	**8**	Extent	Wilderness	**2**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
		Extent and magnitude of disturbance or loss of soil or soil crusts	Extent and magnitude of disturbance or loss of soil or soil crusts	I&M Monitoring Data	2013	N	2	1	3	1	**7**	Extent	Wilderness/ Watershed/ Other Unit	**5**
	Biophysical processes	Area and magnitude of loss of connectivity with the surrounding landscape	Connectivity of natural landscapes	NRCA Report	2010	Y	3	3	2	1	**9**	Connectivity	Wilderness	**5**
		Area and magnitude of loss of connectivity with the surrounding landscape	Extent and proportion of major ecological systems	NRCA Report	2010	Y	3	3	2	1	**9**	Extent	Watershed	**5**
		Area and magnitude for pathways of nonindigenous species into the wilderness	Pathways for exotic species	NRCA Report	2010	Y	3	3	2	1	**9**	Extent	Wilderness/ Watershed/ Other Unit	**5**
		Area and magnitude of loss of connectivity with the surrounding landscape	Connectivity of riparian and wetlands	NRCA Report	2010	Y	3	2	2	1	**8**	Connectivity	Wilderness	**5**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
Undeveloped	Non-recreational structures, installations, or developments	Index of authorized physical development	Number of monitoring or research structures	RMNP Scientific Installations Database	2013	Y	3	3	2	1	**9**	Count	Wilderness/ Watershed/ Other Unit	**3**
			Number of animals tagged or banded	RMNP Resource Management – Wildlife Biologist		N	2	2	1	0	**5**	Count	Wilderness	**1**
		Index of authorized physical development	Number of patrol cabins	RMNP GIS		Y	3	1	3	1	**8**	Count	Wilderness/ Watershed/ Other Unit	**5**
		Index of authorized physical development	Miles of non-wilderness class trail	RMNP GIS		Y	3	1	3	1	**8**	Miles	Wilderness/ Watershed/ Other Unit	**5**
	Inholdings	Area of existing or potential impact of inholdings	Number of properties in or adjacent to wilderness	RMNP GIS		Y	3	1	1	1	**6**	Count	Wilderness	**5**
	Use of motor vehicles, motorized equipment, or mechanical transport	Type and amount of administrative and nonemergency use of motor vehicles, motorized equipment or mechanical	Hours of helicopter use	RMNP Fire/Dispatch/Law Enforcement		Y	3	3	2	1	**9**	Hours	Wilderness	**1**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
		transport												
		Type and amount of administrative and nonemergency use of motor vehicles, motorized equipment or mechanical transport	Hours of motorized equipment or mechanical transport	RMNP Wilderness Office – MRDG		Y	3	3	2	1	**9**	Hours	Wilderness	**1**
Solitude or Primitive and Unconfined Recreation	Remoteness from sights and sounds of people inside the wilderness	Amount of visitor use	Number of visitors	NPS Stats Office	2013	Y	2	3	2	1	**8**	Visitors	Wilderness	**2**
		Number of trail contacts	Number of encounters on wilderness trails	RMNP Wilderness Office	2013	Y	3	3	3	1	**10**	Encounters	Trail	**2**
			Number of camping nights per year (1 camping night = 1 visitor camping for 1 night)	RMNP Backcountry Permit Database	2012	N	1	2	2	1	**6**	Nights	Wilderness	**4**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
			Length-of-stay for overnight trips	RMNP Backcountry Permit Database	2012	Y	3	1	3	1	**8**	Nights	Wilderness	**4**
	Remoteness from non-natural sights and sounds		Visibility of non-recreational infrastructure	RMNP GIS		Y	2	2	3	1	**8**	Area	Wilderness	**4**
		Extent and magnitude of intrusions on the natural soundscape	Audibility of non-natural sounds within wilderness	NPS Natural Sounds and Night Sky office		Y	3	3	1	1	**8**	Audibility	Wilderness	**2**
	Remoteness from occupied and modified areas outside the wilderness	Night sky visibility averaged over the wilderness	Night sky visibility averaged over the wilderness	NPS Natural Sounds and Night Sky office		Y	3	2	1	1	**7**	Visibility	Wilderness	**1**
			Area from which outside development is visible	RMNP GIS		N	2	1	2	1	**6**	Area	Wilderness	**4**
			Distance from roads outside of wilderness	RMNP GIS		Y	3	1	3	1	**8**	Area	Wilderness	**4**

Quality	Indicator	Keeping it Wild (NPS) Measure	Potential RMNP Measure	Data Source	Year Most Recent	Recommended Measure	USFWS Criteria: A. Significance	B. Vulnerability	C. Reliability	D. Feasibility	Prioritization Score	Metric	Summary Area	Spatial Score
	Facilities that decrease self-reliant recreation	Type and number of agency-provided recreation facilities	Number of designate backcountry campsites	RMNP GIS		Y	2	1	3	1	**7**	Count	Wilderness	**4**
	Management restrictions on visitor behavior	Type and extent of management restrictions	Acres subject to restricted activities	RMNP GIS		Y	3	1	3	1	**8**	Area	Wilderness	**4**
Other Features (if applicable)	Loss of cultural resources		Number of disturbances to cultural resources	RMNP ASMIS Database		Y	2	2	3	1	**8**	Count	Wilderness	**3**