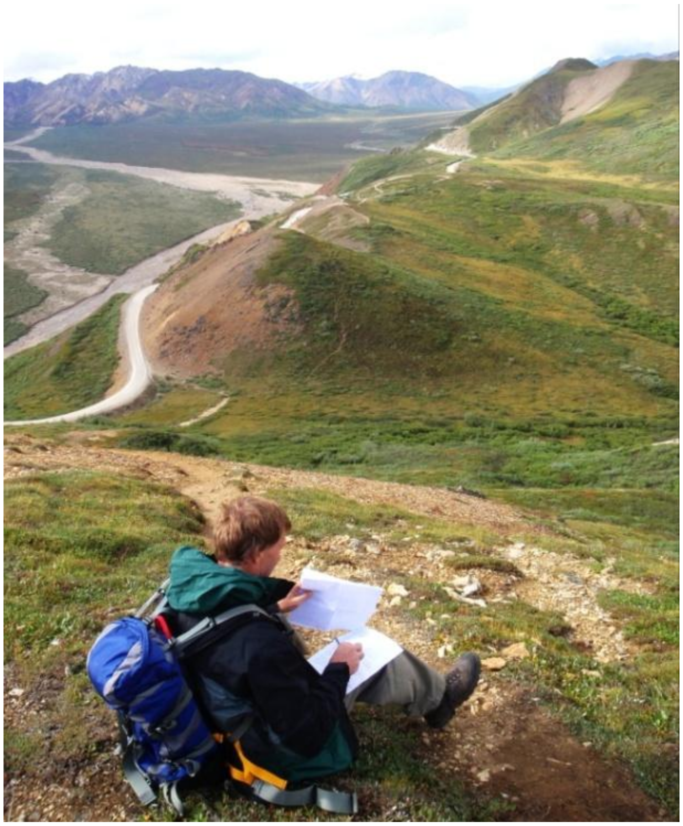
RESEARCH REPORT

U.S. Department of the Interior, U.S. Geological Survey

INFORMAL TRAIL MONITORING PROTOCOLS: DENALI NATIONAL PARK AND PRESERVE

Final Report, October 2011



Distributed by:

Virginia Tech, College of Natural Resources & Environment
Department of Forest Resources & Environmental Conservation

U.S. Geological Survey, Virginia Tech Field Unit
College of Natural Resources & Environment

INFORMAL TRAIL MONITORING PROTOCOLS: DENALI NATIONAL PARK AND PRESERVE

October 2011

Jeffrey L. Marion
Unit Leader/Adjunct Professor
Virginia Tech Field Unit
USGS Patuxent Wildlife Research Center
Virginia Tech/FREC (0324)
Blacksburg, VA 24061

Jeremy Wimpey
Postdoctoral Research Associate
Virginia Tech/Department of Forest Resources
& Environmental Conservation
Virginia Tech/FREC (0324)
Blacksburg, VA 24061

Final Report for the National Park Service, U.S. Department of the Interior

Denali National Park
P.O. Box 9
Denali Park, AK 99755

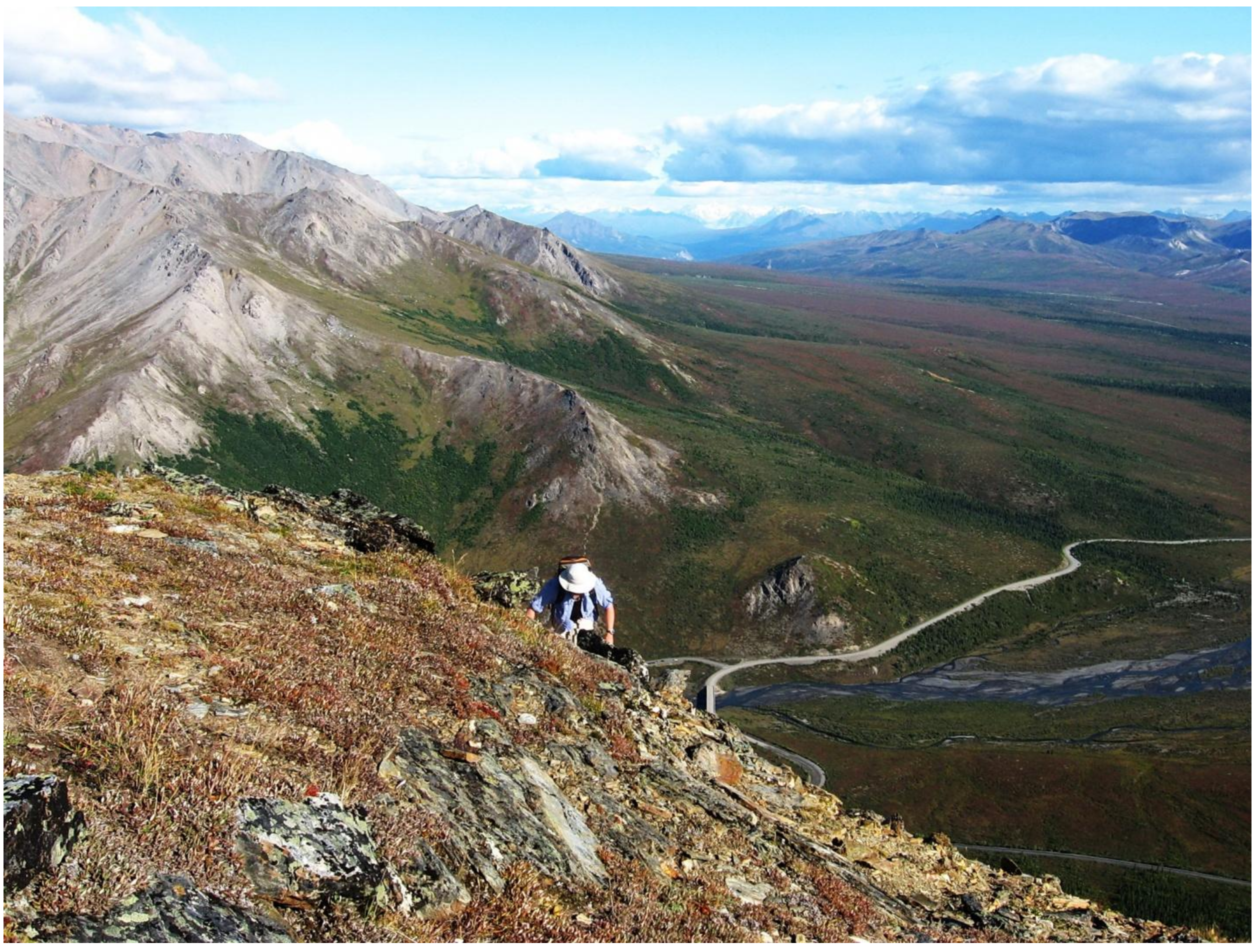
TABLE OF CONTENTS

FIGURES

TABLES

ACKNOWLEDGEMENTS

We wish to thank and acknowledge the National Park Service for sponsoring this study and the staff at Denali National Park and Preserve and Arctic National Wildlife Refuge for their assistance. We also thank the following individuals for their contributions to field work and protocol development: Logan Park, Chris Carr, Chris Monz, Dusty Vaughn, and Jennifer Reed.



INTRODUCTION

The National Park Service (NPS) accommodates nearly 300 million visitors per year, visitation that presents managers with substantial challenges at some 394 park units across some 83.6 million acres of protected lands. An increasing number of visitors inevitably contribute negative effects to fragile natural and cultural resources. Such visitation-related resource impacts can degrade natural conditions and processes and the quality of recreation experiences. According to the NPS Management Policies: "The fundamental purpose of the national park system, established by the Organic Act and reaffirmed by the General Authorities Act, as amended, begins with a mandate to conserve park resources and values…The fundamental purpose of all parks also includes providing for the enjoyment of park resources and values by the people of the United States." (NPS 2006b, Section 1.4.3). However, what might appear to be dual mandates, visitation and resource protection, are clarified to reveal the primacy of resource protection. The Management Policies acknowledge that some resource degradation is an inevitable consequence of visitation, but directs managers to "ensure that any adverse impacts are the minimum necessary, unavoidable, cannot be further mitigated, and do not constitute impairment or derogation of park resources and values" (NPS 2006b).

Managers of protected natural areas must achieve a careful balance between accommodating sustainable types and amounts of visitation and the protection of natural and cultural resources that may be harmed by visitor use. In high use areas, managers commonly apply a *containment* or concentration strategy to accommodate visitation by providing roads and developments such as parking areas, restroom facilities, and developed vista sites. These facilities focus visitor traffic on durable surfaces to contain trampling impacts and protect surrounding areas. Similarly, formal trail systems are generally regarded as an essential facility to provide access within moderate to high use portions of protected areas, accommodating recreational opportunities and protecting resources by concentrating visitor traffic on resistant tread surfaces (Marion & Leung 2001). Unfortunately, many older formal trails were not properly located, constructed, or maintained to sustain their intended uses. Preventing their degradation from recreational uses and natural processes such as rainfall and water runoff is often a substantial management challenge. Furthermore, it is generally recognized that formal trails cannot possibly access all locations within protected areas that visitors seek to visit.

In low use areas, managers commonly promote a *dispersal* strategy to accommodate visitation without formal site developments, facilities, or trails. A common objective is to preserve the area's pristine natural conditions and processes, uninfluenced by human use and impact. The limited occurrence of visitor-created trails and recreation sites may be tolerated in transitional areas or near popular attraction features but more commonly these features are actively discouraged. This is generally accomplished by asking visitors to disperse their activities and restrict traffic to the most durable natural surfaces available. These are common low impact practices advocated by the national Leave No Trace program (www.LNT.org). Unfortunately, visitor traffic along common travel corridors, on sensitive vegetation or soils, or near popular destinations can result in the creation and proliferation of visitor-created *informal* trails.

The proliferation in number and expansion in length of informal trails (ITs) are perennial management concerns. Furthermore, because ITs are not professionally designed, constructed, or maintained, they have the potential to contribute substantially greater impacts to protected area resources than formal trails. Such impacts may be related to: 1) their poor design, including routes with steep grades or that directly ascend slopes, 2) multiple routes accessing the same destinations, and 3) routes through fragile vegetation, soils, habitats and rare flora, fauna, or archaeological sites. These attributes also make ITs more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness.

Protected area managers seeking to apply dispersal strategies for avoiding or minimizing visitor resource impacts must have the means to evaluate the success of their policies and actions. Visitor resource impact monitoring programs offer an important tool for evaluating the efficacy of alternative educational, regulatory, and site management actions implemented to promote visitor dispersal. Impact monitoring programs and protocols periodically access resource conditions so that managers can determine the need for action, select effective actions, and evaluate their effectiveness over time. With respect to IT networks, monitoring protocols could be developed to evaluate their spatial distribution, aggregate lineal extent, and tread conditions.

Responding to these concerns and challenges, NPS managers at Alaska's Denali National Park and Preserve (DENA) sponsored this research to assess and monitor ITs. DENA is located in south-central Alaska and managed as a six million acre wilderness park. Developments, including structures, roads, and formal trails, are limited primarily to the park headquarters area, the Kantishna Mining District, and infrequently along the interconnecting park road. This 87-mile long park road is the primary means of visitor access within the park.

This program of research was guided by the following objectives:

1) Investigate alternative methods for monitoring the spatial distribution, aggregate lineal extent, and tread conditions of informal (visitor-created) trails within the park.

2) In consultation with park staff, develop, pilot test, and refine cost-effective and scientifically defensible trail monitoring procedures that are fully integrated with the park's Geographic Information System.

3) Prepare a technical report that compiles and presents research results and their management implications.

This report presents the protocol development and field testing process, illustrates the types of data produced by their application, and provides guidance for their application and use. The protocols described provide managers with an efficient means to document and monitor IT conditions in settings ranging from pristine to intensively visited. They were developed and field-tested at DENA, which receives a wide range of visitation, with subsequent development work through a companion study at the Arctic National Wildlife Refuge. The majority of land within both protected areas is managed as "trail-less" wilderness, where formal trails are not provided and managers seek to prevent the creation and proliferation of IT networks.

JUSTIFICATION FOR MONITORING

Sustaining any type of long-term natural resource monitoring program over time can be exceptionally challenging for agencies due to changing personnel, management priorities, and budgets. This section reviews legislative mandates, management policies and guidelines, carrying capacity, visitor perceptions of recreation resource conditions, and monitoring program capabilities. The purpose of this review is to describe legislative and management intent regarding visitor impact monitoring and its role in balancing visitor use and resource protection objectives. This section is included to assist in justifying implementation of a trail monitoring program and to describe its utility to enlist organizational support for sustaining such a program over time.

Legislative mandates challenge managers to develop and implement management policies, strategies, and actions that permit recreation without compromising ecological and aesthetic integrity. Furthermore, managers are frequently forced to engage in this balancing act under the close scrutiny of the public, competing interest groups, and the courts. Managers can no longer afford a wait-and-see attitude or rely on subjective impressions of deterioration in resource conditions. Professional land management increasingly requires the collection and use of scientifically valid research and monitoring data. Such data should describe the nature and severity of visitor impacts and the relationships between controlling visitor use and biophysical factors. These relationships are complex and not always intuitive. A reliable information base is therefore essential to managers seeking to develop, implement, and gauge the success of visitor and resource management programs.

Although numerous reasons for implementing a visitor impact monitoring program are described in the following sections, the actual value of these programs is entirely dependent upon the park staff who manage them. Programs developed with little regard to data quality assurance or operated in isolation from resource protection decision-making will be short-lived. In contrast, programs that provide managers with relevant and reliable information necessary for developing and evaluating resource protection actions can be of significant value. Only through the development and implementation of professionally managed and scientifically defensible monitoring programs can we hope to provide legitimate answers to the question, "Are we loving our parks to death?"

Legislative Mandates

Current legislation and agency documents establish mandates for monitoring (Marion 1991). Recent legislative mandates allow managers more latitude to make proactive decisions that can be defended in court if necessary. Managers who make proactive decisions should be prepared to prove the viability of their strategies, or risk public disapproval or even legal action against the agency. Survey and monitoring programs provide the means for such demonstrations.

Agency Organic Act

The National Park Service Organic Act of 1916 (16 *United States Code* (USC) 1) established the Service, directing it to:

> "promote and regulate the use…[of parks]…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."

These provisions were supplemented and clarified by the Congress through enactment of the General Authorities Act in 1970, and through a 1978 amendment expanding Redwood National Park (*16 USC 1a-1*):

> "the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established…"

Congress intended park visitation to be contingent upon the National Park Service's ability to preserve park environments in an unimpaired condition. However, unimpaired does not mean unaltered or unchanged. Any recreational activity, no matter how infrequent, will cause changes or impacts lasting for some period of time. What constitutes an impaired resource is ultimately a management decision, a judgment. The Organic Act's mandate presents the agency with a management challenge since research demonstrates that resources are inevitably changed by recreational activities, even with infrequent recreation by conscientious visitors (Cole 1982 1995a,b, Leung & Marion 2000). If interpreted overly strictly, the legal mandate of unimpaired preservation may not be achievable, yet it provides a useful goal for managers in balancing these two competing objectives.

More recently, the National Parks Omnibus Management Act of 1998 established a framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to:

> "develop a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources."

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> "A major part of protecting [park] resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."

Management Policies and Guidelines

Authority to implement congressional legislation is delegated to agencies, which identify and interpret all relevant laws and formulate administrative policies to guide their implementation. A document titled *Management Policies* (NPS 2006b) describes these policies to provide more specific direction to management decision-making. For example, relative to the need for balancing visitor use and resource impacts, the NPS *Management Policies* state that:

> “The “fundamental purpose” of the national park system, established by the Organic Act and reaffirmed by the General Authorities Act, as amended, begins with a mandate to conserve park resources and values. This mandate is independent of the separate prohibition on impairment, and so applies all the time, with respect to all park resources and values, even when there is no risk that any park resources or values may be impaired. NPS managers must always seek ways to avoid, or to minimize to the greatest degree practicable, adverse impacts on park resources and values.
>
> Congress, recognizing that the enjoyment by future generations of the national parks can be ensured only if the superb quality of park resources and values is left unimpaired, has provided that when there is a conflict between conserving resources and values and providing for enjoyment of them, conservation is to be predominant. This is how courts have consistently interpreted the Organic Act, in decisions that variously describe it as making “resource protection the primary goal” or “resource protection the overarching concern”… (*Section 1.4.3*)
>
> The impairment that is prohibited by the Organic Act and the General Authorities Act is an impact that, in the professional judgment of the responsible NPS manager, would harm the integrity of park resources or values, including the opportunities that otherwise would be present for the enjoyment of those resources or values. Whether an impact meets this definition depends on the particular resources and values that would be affected; the severity, duration, and timing of the impact; the direct and indirect effects of the impact; and the cumulative effects of the impact in question and other impacts. (*Section 1.4.5*)
>
> Impacts may affect park resources or values and still be within the limits of the discretionary authority conferred by the Organic Act. In these situations, the Service will ensure that the impacts are unavoidable and cannot be further mitigated. Even when they fall far short of impairment, unacceptable impacts can rapidly lead to impairment and must be avoided. When a use is mandated by law but causes unacceptable impacts on park resources or values, the Service will take appropriate management actions to avoid or mitigate the adverse effects.” (*Section 8.1.1*)

Thus, relative to visitor use, park managers must evaluate the types and extents of resource impacts associated with recreational activities, and determine to what extent they are unacceptable and constitute impairment. Further, managers must seek to avoid or limit any form of resource impact, including those judged to fall short of impairment. Visitor impact monitoring programs can assist managers in making objective evaluations of impact acceptability and impairment and in selecting effective impact management practices by providing quantitative documentation of the types and extent of recreation-related impacts to natural resources. Monitoring programs are also explicitly authorized in Section 4.1 of the Management Policies:

> "Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions". (*Section 4.1*)

"Further, The Service will:

- Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.
- Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.
- Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.
- Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.
- Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems" (*Section 4.2.1*).

The National Park Service has implemented a strategy designed to institutionalize natural resource inventory and monitoring on a programmatic basis throughout the agency. A service-wide Inventory & Monitoring Program has been implemented to ensure that park units with significant natural resources possess the resource information needed for effective, science-based managerial decision-making and resource protection. A key component of this effort, known as the NPS Inventory & Monitoring Program, is the organization of park units into 32 ecoregional networks to conduct long-term monitoring for key indicators of change, or "vital signs." Vital signs are measurable, early warning signals that indicate changes that could impair the long-term health of natural systems. Early detection of potential problems allows park managers to take steps to restore ecological health of park resources before serious damage can happen.

Park Planning Guidance

The Denali National Park General Management Plan (GMP) (NPS 2006a) states that formal trails near the park entrance and along the park road corridor can be developed on non-wilderness lands. Park formal trails are to be "designed and maintained to discourage social (informal, user-created) trail development." However, the GMP established a "no formal trails" policy for Denali wilderness areas, noting that "Denali offers superlative opportunities for primitive wilderness recreation. Outstanding cross country hiking, backcountry camping, and winter touring possibilities are available for those willing to approach the area in its natural condition. This huge park contains large areas with almost no trails and where evidence of human use is minimal to nonexistent."

As part of the park's Visitor Experience and Resource Protection carrying capacity program (described below), the number of unofficial (social) trails, was selected as one of three environmental indicators. The park's Backcountry Management Plan (NPS 2006a) provides guidance indicating that the majority of the park's backcountry "will be managed for dispersed, self-reliant travel, and will include opportunities for extended expeditions in very remote locations." Further, that "visitor use will remain dispersed so that no areas become overused," specifically citing and noting that this objective includes the absence of all human trails.

Carrying Capacity Decision-Making

Decisions regarding impact acceptability and the selection of actions needed to prevent resource impairment frequently fall into the domain of carrying capacity decision-making. The 1978 National Parks and Recreation Act (P.L. 95-625) requires the NPS to determine carrying capacities for each park as part of the process of developing a general management plan. Specifically, amendments to Public Law 91-383 (84 Stat. 824, 1970) require general management plans developed for national park units to include "identification of and implementation commitments for visitor carrying capacities for all areas of the unit" and determination of whether park visitation patterns are consistent with social and ecological carrying capacities. Regulations implementing the National Forest Management Act of 1976 (P.L. 94-588) dictate that, in wilderness management planning, provision be made "for limiting and distributing visitor use of specific areas in accord with periodic estimates of the maximum levels of use that allow natural processes to operate freely and that do not impair the values for which wilderness areas were created."

The NPS employs the Visitor Experience and Resource Protection (VERP) planning and decision-making framework for formal evaluations of the acceptability of visitor impacts and for establishing carrying capacity limits on visitation (NPS 1997, NPS 2006b) (Figure 1). Visitor impact monitoring programs provide an essential component of such efforts. VERP and other similar frameworks (e.g., Limits of Acceptable Change, LAC), evolved from, and have largely replaced, management approaches based on the more traditional carrying capacity model (Stankey *et al.* 1985). Under these newer frameworks, numerical standards are set for individual biophysical or social condition indicators. These limits define the critical boundary between acceptable and unacceptable change in resource or social conditions, and against which future

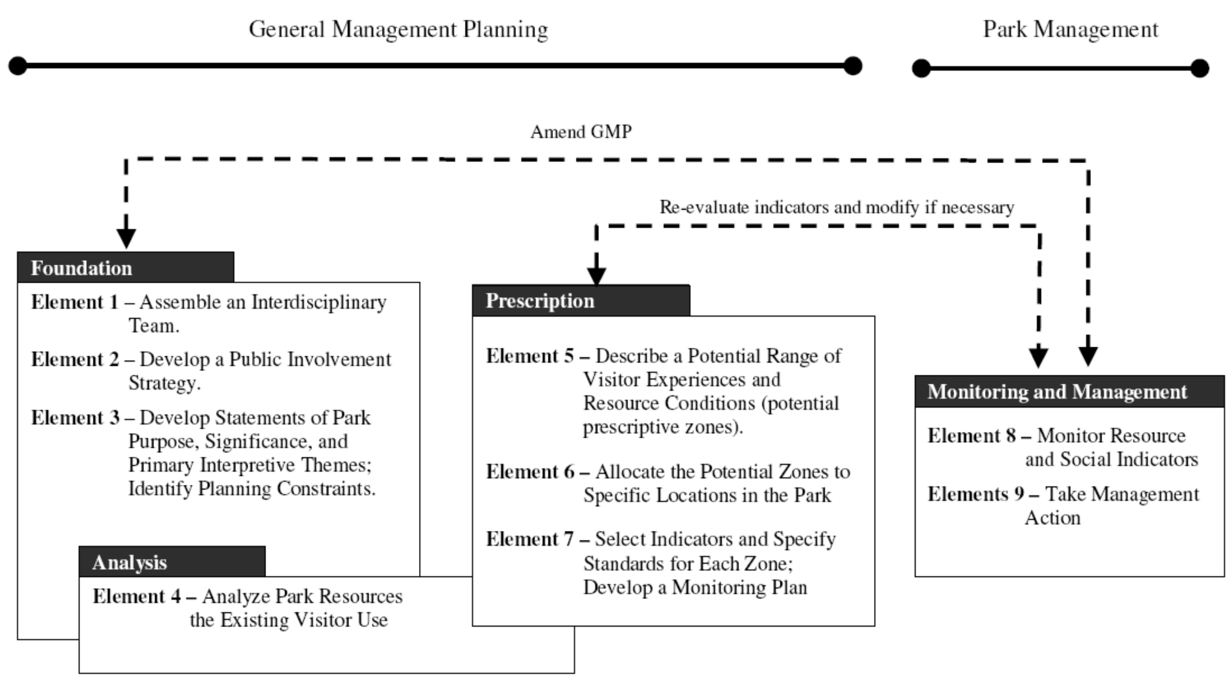


Figure 1. The NPS Visitor Experience and Resource Protection framework used to address carrying capacity decision making.

conditions can be compared through periodic monitoring. VERP is an adaptive management process wherein periodic monitoring is conducted to compare actual conditions to quantitatively defined standards of quality. If standards are exceeded, an evaluation is conducted to identify those factors that managers can effectively manipulate to improve conditions for the indicators with sub-standard (unacceptable) conditions. For example, if a standard for the individual or aggregate size of recreation sites was exceeded, managers might consider implementing one or more site management or educational actions. If the next cycle of monitoring also found sub-standard conditions, more restrictive actions like fencing or area closures would be considered.

Additional guidance on visitor carrying capacity decision-making is provided in the NPS *Management Policies* (2006):

> "Visitor carrying capacity is the type and level of visitor use that can be accommodated while sustaining the desired resource and visitor experience conditions in the park. By identifying and staying within carrying capacities, superintendents can prevent park uses that may unacceptably impact the resources and values for which the parks were established. For all zones, districts, or other logical management divisions within a park, superintendents will identify visitor carrying capacities for managing public use. Superintendents will also identify ways to monitor for, and address, unacceptable impacts to park resources and visitor experiences.
>
> When making decisions about carrying capacity, superintendents must utilize the best available natural and social science and other information, and maintain a comprehensive administrative record relating to their decisions. The decision-making process should be based on desired resource conditions and visitor experiences for the area; quality indicators and standards that define the desired resource conditions and visitor experiences; and other factors that will lead to logical conclusions and the protection of park resources and values…
>
> The general management planning process will determine the desired resource and visitor experience conditions that are the foundation for carrying capacity analysis and decision-making. If a general management plan is not current or complete, or if more detailed decision-making is required, a carrying capacity planning process, such as the Visitor Experience and Resource Protection (VERP) framework, should be applied in an implementation plan or an amendment to an existing plan.
>
> As use changes over time, superintendents must continue to decide if management actions are needed to keep use at acceptable and sustainable levels. If indicators and standards have been prescribed for an impact, the acceptable level is the prescribed standard. If indicators and standards do not exist, the superintendent must determine how much impact can be tolerated before management intervention is required." (*Section 8.2.1*)

Visitor Perceptions of Resource Conditions

Visitors to wildland environments are aware of resource conditions along trails and at recreation sites, just as are managers (Lucas 1979, Marion & Lime 1986, Vaske *et al.* 1982). Legislative mandates set high standards when they direct managers to keep protected natural areas "unimpaired" and human impacts "substantially unnoticeable." Seeing trails and recreation sites, particularly those in degraded condition, reminds visitors that others have preceded them. In remote areas even the presence of trails and recreation sites reduce perceived naturalness and can diminish opportunities for solitude. In accessible and popular areas the proliferation and deterioration of trails and recreation sites present a "soiled" or "used" appearance, in contrast to the ideal of a pristine natural environment (Leung & Marion 2000).

Visitor perceptions of an area and its naturalness are strongly influenced by encountering or seeing trail or recreation site impacts. Visitors are sensitive to overt effects of other visitors (such as the occurrence of litter, horse manure, malicious damage to vegetation) and to visually obtrusive examples of impacts such as tree root exposure, tree felling, and soil erosion. A survey of visitors to four wilderness areas, three in southeastern states and another in Montana, found that littering and human damage to recreation site trees were among the most highly rated indicators affecting the quality of recreational experiences (Roggenbuck *et al.* 1993). Amount of vegetation loss and exposed soil around a recreation site were rated as more important than many social indicators, including number of people seen while hiking and encounters with other groups at recreation sites. Hollenhorst and Gardner (1994) also found vegetation loss and bare ground on recreation sites to be important determinants of satisfaction by wilderness visitors.

Monitoring Program Capabilities

Visitor impact monitoring programs can be of significant value when providing managers with reliable information necessary for establishing and evaluating resource protection policies, strategies, and actions. When implemented with periodic reassessments, these programs produce a database with substantial benefits (Figure 2). Data from the first application of impact assessment methods can objectively document the types and extent of visitor impacts. Such work also provides information needed to select appropriate biophysical indicators and formulate realistic standards, as required in VERP or LAC planning and decision-making frameworks.

Reapplication of impact assessment protocols as part of a monitoring program provides an essential mechanism for periodically evaluating resource conditions in relation to standards. Visitor impact monitoring programs provide an objective record of impacts, even though individual managers come and go. A monitoring program can identify and evaluate trends when data are compared between present and past assessments. It may detect the appearance of impacts or deteriorating conditions before severe or irreversible changes occur, allowing time to implement corrective actions. Analysis of monitoring data can reveal insights into relationships with causal or non-causal yet influential factors. For example, the trampling and loss of vegetation or soils may be greatly reduced by shifting traffic to more resistant and resilient vegetation types or better trail alignments, instead of limiting use. Following the implementation of corrective actions, monitoring programs can evaluate their efficacy.

- Identify and quantify site-specific resource impacts.
- Summarize impacts by environmental or use-related factors to evaluate relationships.
- Aid in setting and monitoring resource conditions standards of quality.
- Evaluate deterioration to suggest potential causes and effective management actions.
- Evaluate the effectiveness of resource protection measures.
- Identify and assign priorities to maintenance needs.

Figure 2. Capabilities of visitor impact monitoring programs.

LITERATURE REVIEW

This section begins with a review of the resource impacts associated with visitor trampling and the development and use of trails. Two primary issues associated with the development of a visitor impact monitoring program are the selection of indicators that will be monitored and their assessment procedures. Criteria for selecting indicators of change related to trails are reviewed, and prospective indicators and measurement units are presented. Common trail impact assessment procedures are also reviewed.

Visitation-Related Resource Impacts: Trails

Visitors participating in a diverse array of recreation activities, including hiking, camping, climbing, and wildlife viewing, contribute to an equally diverse array of effects on park resources, including vegetation, soils, water, and wildlife. The term *impact* is commonly used to denote any undesirable visitor-related change in these resources. This study was restricted to assessments of trampling-related impacts to vegetation and soil along ITs.

Resource impacts associated with trampling on trails include an array of direct and indirect effects (Table 1). Even light traffic can remove protective layers of vegetation cover and organic litter (Cole 2004, Leung & Marion 1996). Trampling disturbance can alter the appearance and composition of trailside vegetation by reducing vegetation height and favoring trampling resistant species. The loss of tree and shrub cover can increase sunlight exposure, which promotes further changes in composition by favoring shade-intolerant plant species (Hammitt & Cole 1998, Leung & Marion 2000).

When a trail is constructed or created from visitor use, the surface vegetation and organic litter are lost, exposing underlying mineral soil that is shaped and compacted into a durable tread to support visitor traffic. However, exposure of soil on natural surfaced trails can lead to several resource impacts, including soil compaction, muddiness, erosion, and trail widening (Hammitt & Cole 1998, Leung & Marion 1996, Tyser & Worley 1992). The compaction of soils decreases soil pore space and water infiltration, which in turn increases muddiness, water runoff and soil erosion. The erosion of soils along trails exposes rocks and plant roots, creating a rutted, uneven tread surface. Eroded soils may smother vegetation or find their way into water bodies, increasing water turbidity and sedimentation impacts to aquatic organisms (Fritz 1993). Visitors seeking to circumvent muddy or badly eroded sections contribute to tread widening and creation of parallel secondary treads, which expand vegetation loss and the aggregate area of trampling disturbance (Marion 1994, Liddle & Greig-Smith 1975).

A fairly small number of studies have examined trail impacts to arctic vegetation. Abele (1976) and Abele *et al.* (1984) conducted some early studies examining off-road vehicle impacts to Alaskan tundra, finding that moist tundra resists disturbance better than wet tundra, but it is less resilient once disturbed. Furthermore, that above-ground tundra disturbance can recover in less than 10 years, while disturbance of substrates and root systems lengthens recovery. This is particularly true in when the removal of substrates causes permafrost melting and subsidence. Also studying ORV impacts, Wooding and Sparrow (1979) note that the thick tundra normally insulates substrates from changes in temperature, when removed by recreational traffic the underlying soils absorbs greater radiation, warms, and thaws faster and deeper during the summer months, often developing a soggy quagmire that subsequent traffic seeks to avoid.

Happe *et al.* (1998) found considerable variability in ATV impacts between vegetation types in Wrangle-St. Elias National Park and Preserve, Alaska. Most highly impacted were the wet and mesic herbaceous and low shrub communities on permafrost soils, open forests with well-drained soils had greater resistance, and the fewest impacts occurred in Dryas and tall willow communities on coarse well-drained cobble, gravel and sand substrates. ORV use has steadily expanded over time and a 2002 assessment documented ORV use in 13 Alaska parks, including 65 routes and 700 miles of trails, with additional dispersed traffic in many areas (NPS 2003).

Reid and Schreiner (1985) conducted experimental human trampling research at DENA within three vegetation types to examine impact and recovery rates. A plant community's ability to tolerate recreational traffic with minimal impact is determined by its initial resistance to the effects of trampling disturbance, and its resilience, or ability to recover following disturbance. A tundra community dominated by *Dryas octopetala* was found to be the most trampling resistant and resilient community, with the boreal forest community the least resistant and resilient – the shrub tundra was intermediate. However, even in the resistant tundra plant community, a 25% reduction in plant cover was achieved with only two passes one week followed by four passes the next week, repeated over the course of the summer (40 passes/season). Total plant cover in the boreal forest was reduced by 75% under that same treatment level. The recovery rate of the graminoid alpine tundra plants (grasses and sedges) was more rapid than the woody vegetation in either the boreal forest or shrub tundra.

A more recent and comprehensive experimental trampling study of Alaskan arctic tundra was conducted by Monz (2002). This study investigated trampling within dryas and tussock tundra communities, both of which lost approximately 50% vegetative cover after 200 passes. At 500 passes the majority of cover was lost, with regeneration to approximately 80% vegetative cover after four years. Indices of resistance and resilience found the dryas tundra to be slightly more trampling resistant than the tussock tundra; both communities have substantial resilience, particularly the tussock community. Findings suggest that if the number of passes is kept below about 200 per year that regeneration of plant cover can occur in one or two growing seasons.

The creation and use of trails can also directly degrade and fragment wildlife habitats, and the presence of trail users may disrupt essential wildlife activities such as feeding, reproduction and the raising of young (Knight & Cole 1995). For example, Miller and others (1998) found decreased presence of nesting birds near trails in grassland ecosystems. Trails can alter hydrology by intercepting and channeling surface water (Sutherland *et al.* 2001), and fragment the landscape with potential barriers to flora and some small fauna (Leung *et al.* 2002, 2011, Leung & Louie 2008). Finally, visitors and livestock can also introduce and transport non-native plant species along trails, some of which may out-compete undisturbed native vegetation and migrate away from trails (Benninger-Truax *et al.* 1992, Adkison & Jackson 1996, Bhuju & Ohsawa 1998, Potito & Beatty 2005, Hill & Pickering 2006)

In summary, most trail-related resource impacts are limited to a linear corridor of disturbance, though impacts like altered surface water flow, invasive plants, and wildlife disturbance, can extend considerably further into natural landscapes (Kasworm & Monley 1990, Tyser & Worley 1992). However, even localized disturbance within trail corridors can harm rare or endangered species or damage sensitive plant communities, particularly in environments with slow recovery rates.

Table 1. Direct and indirect effects of recreational trampling on soils and vegetation.

Effects	Vegetation	Soil
Direct	Reduced height/vigor Loss of ground vegetation, shrubs and trees Introduction of non-native vegetation	Loss of organic litter Soil exposure and compaction Soil erosion
Indirect	Altered composition – shift to trampling resistant or non-native species Altered microclimate	Reduced soil pore space and moisture, increased soil temperature Increased water runoff Reduced soil fauna

Informal Trail Impacts

When formal trail networks fail to provide visitors the access and experiences they desire, visitors frequently venture "off-trail" to reach locations not accessible by formal trails. Some protected areas encourage off-trail hiking, asking visitors to disperse their activity to avoid development of trails. However, even relatively low levels of IT traffic can wear down vegetation and organic litter to create visible informal (visitor-created) trail networks (Weaver & Dale 1978, Thurston & Reader 2001). The establishment of ITs is commonplace in national parks and other protected areas, especially heavily visited areas. Often referred to as *social* trails, their proliferation in number and expansion in length over time are perennial management concerns. Furthermore, because ITs are not professionally designed, constructed or maintained they can contribute substantially greater impacts to protected area resources than formal trails. Many of these impacts are related to their poor design, including alignments parallel to slopes or along shorelines, multiple trails accessing the same destinations, routes through fragile vegetation, soils, or sensitive wildlife habitats, and disturbance to rare flora, fauna, or archaeological sites. These design attributes also make ITs far more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness.

Areas previously untrampled by human footprints can become severely degraded when repeated visitation results in the creation of ITs. A study by Thurston and Reader (2001) found an 81% mean loss of vegetation density in the center zone of new ITs, and a 71% decline in the species present. Mean soil exposure also increased by 23% in these areas. Understanding and minimizing the ecological disturbance caused by off-trail hiking is important to maintaining both the environmental and social aspects of the recreation experience. Research demonstrates that the quality of a visitor's experience is likely to decrease if degradation to a trail is present (Lynn & Brown 2003).

IT proliferation is common in high visitation settings and in some parks is responsible for extensive areas of impact. A study in Mount Rainier National Park on the impacts of IT use identified 913 degraded sites and attributed 89% of them to the presence of ITs (Rochefort & Gibbons 1992). Other studies show that certain landscapes and visitor motivations might make some areas more susceptible to IT proliferation. In areas such as open moorland in the UK, ITs and consequent degradation of the landscape are widely visible (Pearce-Higgins & Yalden 1997). Other areas appear to be more prone to off-trail hiking because most visitors who wander off the official trail are taking a shorter route to a site of interest (Keirle & Stephens 2004). Conversely, ITs are less common in areas that have more dense vegetation or topographical obstructions that impede visitor access (Lehvavirta 1999). In areas where off-trail hiking is activity discouraged, such activity is viewed as a form of depreciative behavior and causes hundreds of thousands of dollars in damage each year (Christensen & Clark 1983). In an effort to reduce IT degradation, educational and site management techniques area available for managers to deter off-trail travel (Park *et al.* 2008).

Trail Management

Several studies show that proper trail design and construction principles minimize adverse impacts to natural resources and reduce the need for trail maintenance (Leung & Marion 1996, Marion & Leung 2004, Marion & Olive 2006, Olive & Marion 2009). The source of many forms of degradation along formal trails can be related to poor design attributes such as steep grades, alignments close to the fall line (parallel to landform aspect), or to locations on perennially wet soils. Some formal trails were originally created by visitors or individuals who lacked trail design expertise or were directed by objectives in conflict with resource protection goals (Marion & Leung 2004). Well-designed trails require periodic maintenance, which can be challenging to sustain under conditions of declining agency budgets. Even well-designed and managed trails are susceptible to the several forms of degradation when subjected to high use or to high-impact behaviors or types of use (e.g., horse riding and motorized uses) (Aust *et al.* 2004).

Common knowledge and research (Wimpey & Marion 2011a, 2011b) suggest that ITs are less "sustainable" than their formal trail counterparts, because of the lack of professional design and construction associated with their creation, and subsequent lack of maintenance. Visual observation and research also suggests that visitors traveling off-trail often take the shortest path, cutting switchbacks or directly ascending slopes (Cole 1993), or the path of least resistance, avoiding dense vegetation or challenging terrain (Bayfield 1973). Finally, common knowledge assumes that off-trail hikers do not generally recognize or attempt to avoid sensitive resources (e.g., rare fauna/flora habitats), or select routes that reflect the principles of sustainable trail design (e.g., side-hill alignments) (Marion & Leung 2004).

The development, deterioration and proliferation of ITs in protected areas can be a vexing management issue for land managers. Traveling off-trail is necessary to engage in activities such as nature study, photography or exploration. Unfortunately, management experience reveals that IT systems are frequently poorly designed, including "shortest distance" routing with steep grades and fall-line alignments. Such routes are rarely sustainable under heavy traffic and subsequent resource degradation is often severe. Creation of multiple routes to common destinations is another frequent problem, resulting in "avoidable" impacts such as unnecessary vegetation/soil loss and fragmentation of flora/fauna habitats.

Once created, managers have found it difficult to deter their use and even when successful, their recovery requires long periods of time (Grabherr 1982, Cole 1990, Boucher *et al.* 1991, Roovers *et al.* 2005). Restoration work can hasten recovery but is expensive and generally requires archeological assessment and compliance work. ITs are particularly problematic because they become more visually obvious as they form, acting as a "releasor cue" that draws even more visitors off formal trails (Roggenbuck 1992, Brooks 2003). ITs are often indistinguishable from formal trails, except for the lack of formal trail blazes or markings.

Previous research has investigated the deterrence of off-trail hiking through educational messages (Johnson & Swearingen 1992) and site management (Matheny 1979, Johnson *et al.* 1987, Sutter *et al.* 1993, Park *et al.* 2008). IT proliferation and resource impact is a problem across all types of protected natural areas as shown by research and monitoring studies conducted around the globe (Grabherr 1982, Cole 1990, Ferris *et al.* 1993, Marion & Cahill 2006, Manning *et al.* 2006, Marion & Hockett 2008a, Wimpey & Marion 2011a, 2011b, Wood *et al.* 2006). However, few studies have extensively mapped or investigated the resource impacts of IT networks within protected natural areas (Cole *et al.* 1997, Leung *et al.* 2002, 2011, Marion & Hockett 2008b, Leung & Louie 2008, Wimpey & Marion 2011a), although several have collected IT counts in conjunction with campsite, recreation site, or formal trail inventories (Marion 1994, Leung & Marion 1999b, Dixon *et al.* 2004, Marion & Cahill 2006, Wimpey & Marion 2011b, Wood *et al.* 2006).

Indicators and Selection Criteria

Indicators are measurable physical, ecological, or social variables used to track trends in conditions caused by human activity so that progress toward goals and desired conditions can be assessed. An indicator is any setting element that changes in response to a process or activity of interest (Merigliano 1990). An indicator's condition provides a gauge of how recreation has changed a setting. Comparison to management objectives or indicator standards reveals the acceptability of any resource changes. Indicators provide a means for restricting information collection and analysis to the most essential elements needed to answer management questions. Examples of questions related to trails include:

Are visitors experiencing an environment where the evidence of human activity is substantially unnoticeable?

Are trail numbers and conditions acceptable given each management zone’s objectives and desired conditions?

Are visitor and trail management practices effective in minimizing the establishment of ITs or degradation in formal and ITs?

Before a monitoring program can be developed, appropriate resource indicators must be selected. A single, direct measurement of a trail’s condition is inappropriate because the overall condition is an aggregate of many components. Typically, then, monitoring evaluates various soil, vegetation, or aesthetic elements of a trail that serve as indicators of that facility’s condition. Cole (1989), Marion (1991) and Merigliano (1990) review criteria for the selection of indicators (Table 2), which are summarized here. Management information needs, reflected by the management questions such as the examples above, guide the initial selection of indicators.

Preferred indicators should reflect attributes that have ecological and/or aesthetic significance. Indicator measures should primarily reflect changes caused by the recreational activity of interest. For example, measures of soil loss related to trail construction would be inappropriate. Indicators should be measurable, preferably at an interval or ratio scale where the distances between numeric values are meaningful, i.e. a 36-inch wide trail is twice the width of an 18-inch wide trail. In comparison, a categorical ratings system based on subjective assessments rather than quantitative measures provides data at an ordinal scale. Distance between numeric values are not meaningful so computing an average or using them in statistical analyses or testing is not appropriate.

Table 2. Criteria for selecting indicators of resource condition.

Criteria	Rationale
Quantitative	Can the indicator be measured?
Relevant	Does the indicator change as a result of the process or activity of interest?
Efficient	Can the measurements be taken by available personnel within existing time and funding constraints?
Reliable	How precise are the measurements? Will different individuals obtain similar data of the same indicator?
Responsive	Will management actions affect the indicator?
Sensitive	Does the indicator act as an early warning, alerting you to deteriorating conditions before unacceptable change occurs?
Integrative	Does the indicator reflect only its condition or is its condition related to that of other, perhaps less feasibly measured, elements?
Significant	Does the indicator reveal relevant environmental or social conditions?
Accurate	Will the measurements be close to the indicator's true condition?
Understandable	Is the indicator understandable to non-professionals?
Low Impact	Can the indicator be measured with minimal impact to the resource or the visitor’s experience?

Adapted from Cole (1989), Marion (1991), Merigliano (1990), O'Connor & Dewling (1986).

Potential indicators of resource condition are numerous and there is great variation in our ability to measure them with *accuracy*, *precision*, and *efficiency*. All assessments are approximations of an indicator's true value; a measurement method is *accurate* if it closely approximates the true value. *Efficiency* refers to the time, expertise, and equipment needed to measure the indicator's condition. Unfortunately, efficient methods often yield inconsistent results when applied by different individuals. A measurement method is *precise* if it consistently approximates a common value when applied independently by many individuals (i.e., repeatability). Accurate measurements correctly describe how much change has occurred; precise measurements permit objective comparisons of change over time (Cole 1989, Marion 1991). Indicator assessment methods should also be considered when selecting indicators. When choosing a method managers must balance accuracy and precision, for each places constraints upon efficiency and cost-effectiveness. For example, recreation site condition assessments range from highly efficient but subjective evaluations (e.g. photographs or condition class ratings), to rapid assessments (ratings based on numeric categories of damaged trees), to time-consuming research-level measurements (quadrat-based vegetation loss assessments). Regardless of the method selected, comprehensive procedural manuals, staff training, and program supervision stressing quality control can improve both accuracy and precision. However, poorly managed monitoring efforts can result in measurement error that confounds data interpretation or even exceeds the magnitude of impact caused by recreational activities.

Preferred Indicators

From these indicator criteria and knowledge of how recreation affects soil, vegetation, and aesthetics, managers select preferred indicators. Table 3 includes a listing of commonly employed indicators for assessing resource conditions on trails using measurement-based approaches. Generally a small number of indicators are selected for use in LAC or VERP frameworks. However, that does not preclude monitoring of additional resource condition indicators or from also assessing various inventory indicators. Travel time to the sampling locations is often the most substantial portion of the time budget so assessing a few additional indicators can be negligible. A final consideration is the measurement units employed for reporting results and/or setting standards. Measurement-based approaches permit the most flexibility in this respect.

Trail condition indicators frequently vary by trail type. For example, trail soil loss is most prevalent for higher use formal trails but can also be a problem on some ITs that are poorly aligned or heavily used. For formal trails, preferred indicators commonly include trail widening, soil loss, and muddiness (Cole, 1991; Marion & Leung, 2001; Olive & Marion, 2009). For ITs, the total lineal extent, aggregate area of disturbance, trail width, and landscape fragmentation are possible indicators (Leung, 2008; Marion *et al*., 2006).

Table 3. Potential indicators of trail conditions and measurement units.

Trail Indicators	**Measurement Units**
Informal Trails	Length/unit area, number/unit area, % of formal trail length, #/unit length on formal trails
Tread Width	Max. value, value/unit length, running avg./unit length
Maximum Incision	Max. value, value/unit length, running avg./unit length
Cross Sectional Area	Max. value, value/unit length, running avg./unit length
Muddiness	Max. % of tread width, avg. %/unit length, running avg. %/unit length

Depending on the assessment protocols employed, managers must also consider measurement units and the unit for which standards are applied. For example soil loss can be assessed at sample points by measuring maximum incision or cross sectional area, with standards specifying maximum allowable values (Cole, 1983; Marion *et al*., 2006). Standards could also be expressed as a value per unit length or as a running average per unit length. Alternatively, if soil loss was evaluated with the problem assessment method, the standard could be set at the level of soil loss established as unacceptable and field staff would only assess soil loss occurrences at or above this level. Alternate standard measures include a length per unit area, percent of trail length, or length per unit length along a subset of trails.

In summary, managers must consider and integrate a diverse array of issues and criteria in selecting indicators for monitoring impacts on trails. Indicators will rarely score high on all criteria requiring good judgment as well as area-specific field trials and direct experience. Indicators that score high on some criteria but low on others may be retained in some instances or omitted in others. Tradeoffs are also required, such as a necessary reduction in accuracy so that precision and efficiency may be increased.

Trail Impact Assessment Surveys

This section considers assessment methods for trail surveys that could be applied to either formal or ITs. The trail information collected can be used to inform the public about trail resources, justify staffing and funding, evaluate the acceptability of existing resource conditions, analyze relationships between trail impacts and contributing factors, identify and select appropriate management actions, and evaluate changes in trail conditions and the effectiveness of implemented actions. A variety of efficient methods for evaluating trails and their resource conditions have been developed and described in the literature, as reviewed and compared by Cole (1983), Leung and Marion (2000), and Marion *et al*. (2006). Multiple trail survey protocols can also be integrated in a combined survey (Bayfield & Lloyd 1973, Olive & Marion 2009).

At the most basic level, trails can be *inventoried and mapped* with the use of Global Positioning System (GPS) devices, using either recreational grade (about 3-8m accuracy), or survey grade (<3m accuracy with post-processing) units. Such inventory/mapping surveys provide data that are input to Geographic Information System (GIS) software to provide maps of trail networks and for further analysis of trail impact attributes (Wolper *et al*. 1994, Wing & Shelby 1999). Increasing availability of high-resolution spatial data, such as LIDAR, may enable accurate trail inventory and mapping by trail feature extraction from spatial data in a GIS environment instead of field surveys (Kincey & Challis 2010). Aggregate lineal extent, area of disturbance, and landscape fragmentation indices are some examples of IT impact indicators that GPS/GIS-based trail mapping can provide. Inventory information (type of use, segment lengths, hiking difficulty), and trail maintenance information (number or location of tread drainage features), are also often assessed during basic trail surveys.

Sectional evaluations can be applied to segments of formal or ITs to characterize attributes such as hiking difficulty or resource condition. For example, condition class ratings that characterize increasing levels of resource impact can be applied to trail segments to characterize a trail network's overall condition. Alternatively, trail segments can be characterized in terms of their width, soil loss, or muddiness (Bratton *et al.* 1979). The trail segments can be defined and assessed by a fixed distance (e.g., at 100 m intervals) or by pronounced changes in the attribute being assessed.

Point sampling is a trail condition assessment method commonly applied to formal trails. Assessments are made at transects, generally spaced a fixed interval with a random start (Cole 1983, 1991), or in accordance with various strata such as level of use or vegetation type (Hall & Kuss 1989). Trail condition variables, including trail width, depth, muddiness, or substrate type, are assessed at transects and used to characterize the surveyed trail.

Problem assessment or census surveys are another common method, where continuous assessments record every occurrence of pre-defined impact problems (Cole 1983, Leung & Marion, 1999). Generally applied to formal trails, field staff record the starting and ending points for trail sections that are excessively eroded, wide, or muddy (Marion 1994). An evaluation by Marion and Leung (2001) concluded that the point sampling method provides more accurate and precise measures of trail characteristics that are continuous or frequent (e.g., tread width or exposed soil). The problem assessment method is a preferred approach for monitoring trail characteristics that are easily defined or infrequent (e.g., excessive width or secondary treads), particularly when information on the location of specific trail impact problems is needed.

Assessing Informal Trail Networks

A comprehensive review of the literature found very few reported examples of research or monitoring efforts focused on assessing IT networks (Marion *et al.* 2006). While ITs likely occur in nearly every protected area, managers have frequently ignored their presence, limiting monitoring efforts to formal trail systems. Furthermore, conventional trail condition assessment protocols are often difficult to apply to ITs due to their unique spatial characteristics (Marion & Leung 2001). IT segments are often comparatively numerous, short, and often braided in complex patterns (see Figure 3), creating sampling and assessment difficulties for point sampling or problem assessment methods (Leung & Marion 1999a).

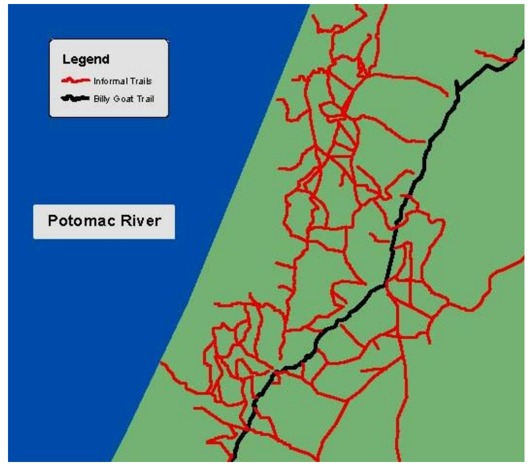


Figure 3. A “spaghetti” map showing the complex network of informal trails branching off the Potomac Gorge’s Billy Goat Trail, C&O Canal National Historical Park.

However, scientists and managers have recently been focusing greater attention to the impacts of IT networks and to developing methods for assessing and monitoring their impacts on protected area resources. Managers seeking to assess ITs must first consider two categories of attributes: spatial and resource condition. Spatial attributes include the location, arrangement, and lineal extent of ITs. Resource condition attributes include assessed degradation of vegetation, organic litter, and soils along ITs.

It is possible to assess most spatial attributes using scale-appropriate airborne remote sensing techniques if trails are not under concealing vegetation or when they are readily visible in leaf-off photography (Witztum & Stow 2004). Kaiser and others (2004) applied the best available techniques, including high spatial resolution (0.6m/pixel) digital multi-spectral imagery, digital image processing, and visual image analysis techniques, to detect and delineate new illegal immigrant trails in shrublands along the US-Mexico border. They found that an automated linear feature extraction routine (Feature Analyst in ArcView GIS), followed by manual interpretation, delineation, and editing using false color infrared imagery, yielded the most accurate results. However, this method only resulted in 56% of the GPS surveyed trail locations matching by length, in part due to shielding overhead vegetation.

Extending this work, Cao and others (2007) evaluated three trail monitoring approaches and two types of spectral transformation to aid in locating trails in imagery, procedures designed to evaluate temporal changes in US-Mexico cross-border trail networks. They found that a map-to-image differencing approach was the most sensitive and reliable in detecting new trails, though no ground-based GPS surveys were conducted for comparison. For disturbed areas where the trail networks were extensive, Principal Component Analysis (PCA) of the image was more effective at enhancing new trails. For densely vegetated areas, a Normalized Difference Vegetation Index (NDVI) image yielded more interpreted trails. The authors stress that high quality, well registered, and radiometrically matched multi-temporal image datasets are needed for efficient and reliable trail map updating procedures. Imagery from different years must also be collected at the same phenological time and time of day to minimize errors due to vegetation seasonality and sun angles.

We conclude that these techniques are impractical for most protected area managers due to the substantial expense associated with image acquisition, technician expertise and time, and substantial inaccuracies associated with the methodologies used and concealing vegetation cover. Ground-based Global Positioning System (GPS) surveys are more accurate, use existing staffing and resources, and provide more immediate results. Point-based assessment methods include access (trailhead) and transect surveys. A highly efficient method is to inventory IT junctions with protected area roads, trails, or recreation sites, documenting junction locations with a recreation or professional grade GPS, odometer, or measuring wheel (Bacon *et al.* 2006, Marion & Cahill 2006). Alternately, an approach applying transects at fixed intervals within travel zones was developed for Zion National Park to document the number and location of intersecting ITs (Marion & Hockett 2008a).

Line feature assessment methods provide more comprehensive information on the spatial distribution and lineal extent of IT networks. This method requires a GPS set to collect line features (tracks) as field staff walk all ITs within a management unit. Trail information from the GPS is then input to a Geographic Information System (GIS) for display and analysis of trail attributes (Wolper *et al.* 1994). This commonly applied protocol has been reported in several publications (Bacon *et al.* 2006, Cole *et al.* 1997, Leung *et al.* 2002, 2011, Leung & Louie 2008, Manning *et al.* 2006, Marion *et al.* 2006, Marion & Hockett 2008b). Advantages of census surveys include the ability to produce maps showing the location and spatial arrangements of IT networks, document the number of trail segments and aggregate lineal extent, perform GIS analyses to investigate proximity to rare flora or fauna or sensitive environments, evaluate landscape fragmentation, and perform other relational analyses.

Resource conditions along ITs can also be assessed to document effects on vegetation and substrates. A common method is to assign a condition class rating, generally five categories describing increasing levels of trampling impact from a faint trace to a barren and eroded tread (see examples in Manning *et al.* 2006 and Marion *et al.* 2006). ITs are broken into separate segments whenever condition classes change categories. Other tread condition indicators such as width and depth, and inventory indicators such as trail grade and vegetation type, can also be assessed using ratings and input as attributes of these segments (Rochefort & Swinney 2000). Resource condition assessments recorded for trail segments generally employ "typical" or categorical range data representative of the entire segment, resulting in some inaccuracies because these assessments are generally not measured. Measurements that are more accurate can be taken using a point sampling approach, generally employing a fixed interval between points with a random start. This method was employed by Wood and others (2006) to characterize informal tread width, depth, cross sectional area soil loss, and estimated total area of disturbance.

STUDY AREA

Denali National Park and Preserve is primarily a wilderness park, including over six million acres of land. The park's "frontcountry" consists of developments limited primarily to the park headquarters area, the Kantishna Mining District, and an interconnecting park road providing the primary means of visitor access to the park. This 92-mi park road has a 300 ft wide corridor with several wider development nodes. The initial 13 miles of the road is paved, while the remainder is graveled. A limited number of formal trails (N=19, 28 miles total) are provided within the frontcountry portions of the park. A "no formal trails" policy discourages formal and ITs in the backcountry and wilderness portions of the park "to preserve the unique wilderness character and wilderness experience" (NPS 2006b). Exceptions have been made to provide visitor opportunities at major visitor nodes or to address resource damage. Thus, most visitors leaving the frontcountry do so on foot, traveling on either ITs that have developed from repeated use, or along more dispersed non-discernable cross-country routes.

Park visitation doubled to 88,165 following opening of the George Parks Highway in 1972, and has increased to 378,855 in 2010, with backcountry overnight stays of 38,625 (http://www2.nature.nps.gov/stats). DENA, like many national parks, will continue to face increasing pressures to maintain and expand opportunities for visitors to experience the park and its unique biological, physical, and scenic resources. Therefore, the NPS has supported monitoring and research to provide accurate data on the associated effects of visitor use on park resources.

The primary visitor activity in Denali is a shuttle or tour bus ride along the park road. Busses stop at developed rest areas and the shuttle busses also stop at Eielson Visitor Center, road corridor campgrounds, and at other locations requested by day and overnight hikers. Visitor trampling impacts to vegetation and soils occur at places along the park road wherever visitor use is concentrated, primarily at these developed rest areas, campgrounds and visitor center. However, visitors also venture away from these developments to hike and experience Denali's scenic resources, flora, and fauna. ITs have developed along the more popular hiking routes and the effects of visitor trampling have worn away vegetation cover, and in some places, eroded soils. Some day-use and all overnight visitors venture quite far from the park road.

Current Management

Along the park road visitor facilities attract and contain visitor use on hardened surfaces in most places. Formal and ITs have become established around rest areas, campgrounds, and the visitor center. Vegetation loss and soil erosion are evident on these trails and the proliferation of ITs is extensive in some areas. Some efforts to limit traffic to a few selected trails use signs and rope borders to limit the areal extent of impacts. However, these practices are not employed in other areas where well-developed ITs are present. Elsewhere along the road corridor, formal park trails have not been developed. Dispersed day hiking is possible at nearly any location along the park road as visitors are permitted to exit shuttle buses at places of their choosing, though area closures are created where needed to protect sensitive wildlife areas like wolf den sites. A number of locations along the park road are popular drop-off points for day hikers and ITs have developed at these locations.

METHODS

The project called for working collaboratively with park staff to clarify trail-related impact monitoring objectives and develop supporting trail monitoring protocols suitable for long-term application by park staff. The principal collaborator, who also provided extensive logistical and personal assistance, was Joe Van Horn, the park's Wilderness Program Coordinator. Project staff visited different park environments to become familiar with the distribution, extent, and condition of IT networks. Monitoring challenges and opportunities were discussed extensively with park staff. For example, challenges include the widely dispersed and sometimes discontinuous spatial patterns of DENA ITs and the time-consuming nature of ground-based surveys. Opportunities to employ the increased accuracy of GPS devices and resolution of satellite and aerial photography, multi-spectral data, LIDAR imaging, and analytical techniques were examined. For example, Witztum and Stow (2004) used high resolution aerial imagery to map the location of recreation trails in the open area of southern California with 74% accuracy. They were also able to map the fraction of bare ground associated with the trails. This technology is in its infancy but is rapidly improving, driven by border security concerns.

Project staff obtained relevant GIS datasets and satellite/aerial images from park staff and explored a number of prospective aerial and ground-based methods for obtaining the information required by park staff. Potential products were developed to illustrate resulting data related to trail monitoring and the advantages/disadvantages of alternative methods. One issue that guided the selection of monitoring indicators and assessment methods was measurement scale (Table 4). Where possible, strong preference was given to developing indicator protocols at ratio measurement scales as these permit the greatest accuracy in characterizing indicator conditions and flexibility in statistical techniques for describing conditions or analyzing the influence of influential factors.

Table 4. Measurement scales relevant to the selection of indicator assessment protocols.

Measurement Scale	Description (example)
Nominal	Indicator attributes are categories, which cannot be ordered (e.g., a trail is either a formal or informal trail)
Ordinal	Indicator attributes can be rank-ordered but distances between categories are not equivalent or meaningful (e.g., a condition class rating for trails)
Ratio	Indicator values have uniform, equivalent intervals and an absolute zero value (e.g., a measurement of trail width or depth).

Through this exploratory work and collaboration with park staff, project team members selected and refined procedures for a preferred IT monitoring program that meets the needs of park staff and is sustainable given anticipated agency staffing/funding constraints. Off-road vehicle monitoring efforts within the region and park were also examined through collaboration with

Kevin Meyer, Environmental Specialist/Soil Scientist, with the Regional Office's Rivers, Trails and Conservation Assistance Program.

Procedures were experimentally developed, extensively field tested in different park environments, revised, and reapplied. Park staff fully participated in this process, including both Resources Management staff involved in some formal trials and Rangers involved in the experimental application of procedures in selected park areas.

Use of trade, product, or firm names does not imply endorsement by the U.S. Government.

RESULTS

This section begins by reviewing the development of park monitoring objectives related to ITs. This is followed by a review of previous IT monitoring efforts at DENA, and by the sequence of monitoring protocols considered and refined over the course of the study. This documentation includes discussion of the relative merits and limitations of alternative monitoring methods, which can aid DENA and other protected area managers in future monitoring decision-making. The final set of monitoring protocols are included in Appendix 1, with discussion in this section and presentation of selected monitoring results to illustrate their application within the park and the resulting types of data they provide.

Monitoring Objectives

Protected area managers who need to make decisions regarding the selection, implementation, and evaluation of actions to address IT impacts can benefit from monitoring data that characterize the location, lineal extent, and tread conditions of IT networks. The protocols described in this document provide managers with the means to document and monitor IT conditions in settings ranging from pristine to intensively visited. These data can be used to evaluate the acceptability of existing resource conditions, analyze relationships between trail impacts and influential factors, identify and select appropriate management actions, and evaluate the effectiveness of implemented actions.

Through collaboration with park managers the following monitoring program objectives were developed, with refinements made throughout the study period.

1. Documents the number, distribution, aggregate lineal extent, and general condition of ITs within the following areas of interest: a) the Denali Road corridor, b) formal trail corridors, and c) within permanently defined travel zones away from road and formal trail corridors.
2. Provide accurate quantitative assessments for a variety of trail condition indicators on selected ITs whose alignments are relatively static and formal trails.
3. Document the hiker's Route Finding Experience as they move through backcountry travel corridors.

Park staff desired a monitoring program with the following attributes: comprehensive, flexible, efficient, accurate (approximation of "true" values), and precise (assessment consistency or repeatability between field staff). Most monitoring programs focus on the provision of a single protocol that includes multiple inventory and condition assessment indicators. DENA staff required greater flexibility to address information needs that varied between frontcountry and backcountry zones and from general to very specific. Our work therefore focused on developing an interrelated set of protocols that managers could select from to address their changing information needs. The protocols also needed to be comprehensive, providing data on an array of different indicators for discontinuous and continuous ITs, formal trails, and even visitor route finding experiences. Efficiency was required so that managers could sustain implementation of the monitoring program, applying the most efficient protocols as a census assessment, others within sampled areas, and by optionally adding some indicators when information needs required their use. Finally, accuracy and precision were addressed by preference for indicator assessments with ratio measurement scales, careful development of detailed and illustrated assessment protocols, extensive revisions based on field testing in a variety of park environments, and several precision trials involving protocol application by different individuals to the same sample areas.

Previous Visitor Impact Monitoring Investigations

DENA park staff have conducted several previous visitor impact monitoring efforts, which we reviewed and considered. The earliest began in the mid-1970s and employed periodic photographic images of formal and ITs taken at permanent photopoints. Park records include many sets of photos taken through 1997. Photographs were reorganized and renamed in 1996/97 and new photopoint data collection procedures were developed though it appears that this work was never completed (Baxter 1997) Photographic monitoring of ITs can be quite useful in providing a visual record of changing conditions at the photopoints selected, however, there are numerous limitations if this is the only method applied. For example, photo-based methods provide no data on the distribution, proliferation, or aggregate lineal extent of IT development over time. They also provide limited quantitative data on IT conditions, though it is possible to make direct comparisons of attributes like tread width or soil exposure between photographs if they are taken from the same photopoints using the same camera focal lengths.

A more comprehensive park-wide effort initiated in 1995 by Resource Manager Elaine Furbish. Known as the Trail and Nodes Monitoring Program, Furbish (1996) applied trail condition measurements in a three-tiered monitoring system designed to:

1. Detect the creation of new impacted areas, including trails and various other sites impacted by foot traffic within the road corridor,
2. Evaluate the condition of all impacted areas through application of standardized monitoring procedures, and
3. Monitor changes in conditions at selected locations, particularly those with substantial impact or having historical significance.

Assessment procedures were developed and applied to all trails within the park road corridor. Trail procedures were designed to identify and obtain basic inventory and trail condition information on all park trails during each monitoring cycle. Trails were broken into segments 200 meters long, or shorter when traversing different vegetation types. Predominant vegetation type and ten condition assessments were made for each segment. Condition indicators include: loss of vegetation cover, increase in soil exposure, trail width, trail depth, continuity, organic litter disturbance, soil erosion, number of collateral (parallel) trails, portion of trail with collateral trails, and litter (trash). Assessments were estimated (no measurements) for the entire segment by selecting from among five quantitatively described indicator ratings. Following each segment field staff determine if more intensive monitoring is needed based on the degree of deterioration. Intensive monitoring may consist of a photopoint, tread depth measurements for computing soil loss (cross sectional area method), and groundcover estimates in adjacent and off-trail plots. The tread depth and groundcover plots provide more quantitative measurements of changes in trail condition taken at permanently referenced points.

This trail monitoring program may be classified as a multiple parameter rating-based rapid survey with added measurements at locations that exhibit more severe problems or an apparent threat of future problems. Results from each monitoring cycle can provide data to evaluate problems with trail proliferation and condition. In addition, because all trails are evaluated (a census), this approach permits computation of aggregate measures of degradation.

While this trail monitoring program is relatively efficient it does have several limitations. The precision (rater consistency) and accuracy associated with estimating measures and assigning indicator ratings for 200 meter trail segments is not likely to be high unless trail conditions are homogeneous. Differences in starting points and variability in measuring wheel readings (that increase with distance covered) will prevent future workers from referencing the same 200 meter trail segments without permanently established reference points. Comparability of measurements is thus suspect for individual segment comparisons and measurement scale problems could hinder trail-wide analyses.

Indicator ratings, though quantitatively defined, are assessed using an ordinal scale (Table 4) with rating classes that lack consistently uniform intervals (e.g. trail depth: 0-3, 3-8, 8-15, 15-30, >30 cm). It is statistically inappropriate to average such ratings (Marion 1991, p. 15) as have been done in computing the impact indices used to report monitoring results. Another concern is the need to calibrate the impact rating categories to the distribution of values for the area in which they are applied (Marion 1991, p. 21). Failure to calibrate may lead to a disproportionate clustering of values in only one or two broadly defined categories. This reduces the sensitivity of monitoring to detect changes, potentially allowing substantial change without causing a shift from one rating category to another. A final problem relates to ordinal ratings where the highest category is open-ended (e.g. >30 cm in the example above), so that continued change above this value is not reflected in indicator measures and managers are unable to monitor excessive change.

An improved alternative approach using a ratio scale was also employed where closed rating categories are numerically defined but midpoint values are used in analysis and reporting. For example, 0-5 (2.5)%, 6-25 (15.5)%, 26-50 (38)%, 51-75 (63)%, 76-100 (88)% is used to assess vegetation cover on- and off-trail, with the mid-point values in parentheses used in subsequent analyses as a ratio scale indicator. While this approach is statistically acceptable, it infers greater precision than is justified when applied to 200 meter trail segments. It would be more appropriate if assessed at a large number of representative sample points.

Development of Monitoring Protocols

Initial discussions with park staff and a review of the literature revealed a trail condition assessment program developed by Kevin Myers of the NPS Alaska Regional Office for All Terrain Vehicle (ATV) tracks (Meyer 2002). Meyer (2011) also describes manual and GPS field mapping methods for assessing OHV trails. These protocols include basic trail inventory and condition assessment indicators similar to the DENA program developed by Furbish. Trail condition indicators are assessed for trail segments mapped by GPS devices. Indicators are based on ordinal categorical ratings with the same limitations previously described. These assessments are primarily oriented toward providing an inventory of physical trail characteristics and development of management options, such as trail hardening prescriptions or visitor use restrictions. Their use for long-term monitoring appears to be a secondary objective. However, condition assessments can be combined with ranking weights to produce useful condition indices (Meyer 2011). This system has been applied to some DENA trails, including those in the Cantwell, Windy Creek area.

As we began investigating monitoring options we initially considered what types of IT information could be gathered from aerial and satellite photography, or from LIDAR imaging. However, our examination and consideration of available datasets indicated the following problems:

1) faint ITs do not always show up in aerial imagery, particularly in areas of moderate to high shrub or tree cover,
2) where trails do appear it is impossible to distinguish trails created or used primarily by park visitors from those used by wildlife.
3) quantitative measures of trail condition, including tread width, depth, and vegetation cover are not possible.
4) LIDAR imagery is unavailable for the park.

Considerations regarding the use of highly accurate GPS devices were more promising, as park staff have and routinely use these devices, which could obtain sub-meter accuracy in nearly all park settings. A decision was made to fully incorporate their use in mapping ITs and recording all indicator data assessed for trail segments and at sampling points. Advantages include the efficient collection, storage, and transfer of field data to office computers, collection of highly accurate spatial data on the distribution and lineal extent of IT networks, and the ability to conduct spatial analyses using the full complement of GIS capabilities. Accurate GPS mapping also allows a return during future assessments to previously mapped trails, transects, or sample points to repeat assessments, and the ability to differentiate new ITs from pre-existing trails. These attributes substantially strengthen the capability of IT monitoring protocols, enhancing assessment efficiency and measurement accuracy and precision.

Initial work focused on the development of efficient condition class assessments for IT surveys using GPS mapping to find and document all ITs within specified search areas. A data dictionary was developed for Trimble GPS units that incorporated condition class (CC) ratings assessed for homogeneous portions of mapped ITs. This was to be paired with point sampling data to assess trail condition indicators such as tread width, depth, muddiness, secondary treads, and tread vegetation cover. The efficiency and management value of including a general CC assessment of the visibility and condition of ITs during GPS mapping caused us to expend considerable effort at developing an optimal set of CC descriptors.

Subsequent field testing in a variety of park environments led to a cycle of edits, testing, and refinement of the CC descriptions to improve their applicability to a wide range of environmental settings and their ability to differentiate different trail condition levels. For example, travel through the DENA backcountry frequently occurs in a variety of landscape types including: open tundra, patches of low or high shrubs, and riparian or montane settings with substantial rock or gravel substrates with limited vegetation groundcover. The CC descriptors must be able to effectively and consistently differentiate IT visibility and condition classes in each landscape type. This turned out to be an exceptionally challenging process, as illustrated by our inclusion of four of about six versions of CC descriptors (Table 5) that we developed and field tested.

Table 5. Evolution in the development of Trail Condition Classes, from the 1st version, this page, to its eventual replacement with separate quantitative indicators for vegetation and exposed soil cover (see following pages).

Faint: Regular choices have to be made when it joins a side trail or animal trail as to which one should be followed. Often not sure you are on something that is really going to last. Frequently questioning whether you are on a trail at all. This category is on the edge of where you would actually stop mapping a trail segment and say that you are not on a trail. The visibility of the trail changes frequently in response to very minor changes in vegetation, substrate, or topography. Sometimes the only clue you have that you are on a trail that is used by people are footprints or the location. The trail tread still looks like the natural ground surface or vegetation for the most part with only minor evidence of wear or alteration. You may not be able to see the trail even 10 -15 feet ahead of you, especially in non-vegetated areas.

Vegetated areas: The trail is visible primarily because of seasonal wear, minor compositional changes, or only very minor cover loss (0-5%). If there is a trail depression it is slight and formed by compression only rather than elimination of the vegetation mat. Depth of depression is generally less than in 1”-2” range even in compressible vegetation types.

Unvegetated areas: There is a slight compression of soils or gravels that defines the travel path. There is no real sorting of particle size. On talus, the trail is still outsloped and requires attention to balance. There is no real development of a distinct outside edge. Trail width and footing is narrow, one right in front of the other like an animal trail rather than a distinct, secure bench.

Continuous: This class of trail can generally be followed without loss. It now feels more like you are walking at continuous trail then something that will end around the next willow bush. You are no longer decision making or just jumping from one piece to another. Impact is fairly consistent along it, not constantly fading in and out. Choices at intersections about how to proceed are clear. In unvegetated areas the only place that it is typically lost is for short stretches in cobbles or coarse gravels. While the wear that is present is obvious and permanent from season to season, human use has still not completely altered the natural ground surface characteristics or vegetation in the area of the trail tread.

Vegetated areas. The overall impression is a trail where some damage and cover loss of vegetation due to use has definitely taken place occurred relative to the surrounding area, but that some vegetation is still surviving in the trail despite use. For example, in areas with 100% vegetative cover, the live vegetative cover on the trail still is between 5% to 95%. A definite trail depression is usually present, but it may be more rounded in form rather than sheared or sharp sided, and formed more by compression of the vegetation rather than completely cutting through the vegetative mat.

Unvegetated areas: In unvegetated substrates some sorting of gravels, stones has started to place, but the primary reason for the visibility of the trail is the compression of the material, not sorting. On scree slopes the trail is still strongly outsloped, but footing is good. There is a trail platform. The trail can generally be followed across silts, sands, and small gravel substrates, but may be harder to spot in coarse gravels where the compression/depression is minor.

Well-Developed: No question about following this type of trail, decision points are rare. You feel like you are almost on a typical hiking trail. You don’t have to pay attention to stay on it, even in unvegetated areas such as a creek bottom, gravel bars or talus hillsides. You can see this trail well ahead of you. Wear is obvious and permanent from season to season.

Vegetated areas: The overall impression one has of the trail is that there is now much more bare ground and detritus than live vegetation and/or that substantial cover loss relative to the surrounding vegetation has taken place. For example, in areas with 100% vegetative cover, there would be less than 5% live vegetative cover on the trail. There is usually a distinct trail depression cut down into the vegetative mat and some incision into the soil layer present.

Unvegetated areas: In unvegetated substrates the sorting of gravels, stones has taken place to a degree that there is a noticeable compositional difference in particle size from the trail tread to the surrounding area. Larger particles have been moved to the outside edge of trail by use and/or compressed down into the substrate. A trail depression is definitely present. On scree slopes a distinct trail bench created by regular and repeated use has moved material to outside edge and is wide enough for comfortable walking, possibly even side to side foot placement. The trail is easy to follow across all but cobble sized substrates.

Trail Condition Classes (2nd version)

Class 1: Trail barely distinguishable; no or minimal disturbance of vegetation and/or organic litter.

Vegetation is irregularly trampled down creating a route that is generally visible, though following this class of trail requires careful attention to remain on it. Gaps longer than 15 feet should not be mapped.

Class 2: Trail distinguishable; some loss of vegetation cover and/or minimal disturbance of organic litter.

Vegetation is consistently trampled down and compressed; the route is rarely discontinuous. Small changes in vegetation composition may be evident, e.g., fragile broad-leafed plants may be reduced in cover compared to adjacent untrampled vegetation.

For barren substrates: Trail is faint but distinguishable and may have some discontinuous areas. Trail is visible due to limited depression of surface stones into substrates, sorting of gravel, or overturned stones. On talus, trail width and footing is narrow, like an animal trail.

Class 3: Trail obvious; vegetation cover lost and/or organic litter pulverized in some areas.

Vegetation cover is thoroughly trampled down and up to half the off-trail vegetation cover is lost. Organic litter is partially pulverized and soil exposure is slightly more than in off-trail areas. Trail is continuous and easy to follow.

For barren substrates: Trail is obvious and easily followed. Trail is visible due to a distinctive flattening of substrates or from overturned stones. On talus, the tread is often widened and cupped.

Class 4: Vegetation cover lost and/or organic litter pulverized within the center of the tread, some bare soil exposed.

More than half of the off-trail vegetation cover is lost and soil exposure is common. Only resistant vegetation (e.g., grasses, sedges, or low mosses) survive within the tread (ignore overhanging vegetation rooted outside the tread). Pulverized organic litter may be present and some compaction of the soil is evident.

Class 5: Nearly complete or total loss of vegetation cover and organic litter within the tread, bare soil is widespread.

Nearly all of the vegetation cover and organic litter have been lost, leaving more than 90% of the substrate as bare soil, rock, or gravel.

Trail Condition Classes (3rd version)

Apply the first four categories to trails that cross areas with at least 75% vegetation or organic litter cover; apply the last two categories to trails that cross more barren areas. Apply a minimum mapping distance of 30 ft to avoid rapid changes in condition class, i.e., mentally average tread conditions as you hike to avoid assessing changes in condition of less than 30 feet.

Class 0: Trail barely distinguishable; no or minimal disturbance of vegetation and/or organic litter.

Vegetation is irregularly trampled down creating a route that is generally visible, though there may be some discontinuous gaps (gaps longer than 15 feet should not be mapped).

Class 1: Trail distinguishable; some loss of vegetation cover and/or minimal disturbance of organic litter.

Vegetation is consistently trampled down and compressed and up to one-quarter of the off-trail vegetation cover is lost. Organic litter is partially pulverized but soil exposure is the same or only slightly more than in off-trail areas. The trail is continuous and some changes in vegetation composition are evident, e.g., fragile broad-leafed plants may be reduced in cover compared to off-trail vegetation.

Class 2: Vegetation cover lost and/or organic litter pulverized within the center of the tread, some bare soil exposed.

Approximately 25-75% of the off-trail vegetation cover is lost with only resistant vegetation (e.g., grasses, sedges, or low mosses) surviving within the tread (ignore overhanging vegetation).

Class 3: Nearly complete or total loss of vegetation cover and organic litter within the tread, bare soil is widespread.

More than 75% of the off-trail vegetation cover has been lost, leaving the underlying substrates substantially exposed. Some patchy pulverized organic litter may be present.

Barren Substrate Classes

Class B1: Trail is faint but distinguishable. Trail is visible due to limited depression of surface stones into substrates, sorting of stones, or overturned stones. On talus, trail width and footing is narrow, like an animal trail; side-hill trails are outsloped.

Class B2: Trail is obvious and easily followed. Trail is visible due to a pronounced flattening of substrates, sorting of stones, or overturned stones. On talus, the tread is often widened and cupped.

Trail Condition Classes (4th version)

Apply the first four categories to trails in areas that have at least 75% ground vegetation or organic litter cover; apply the last two categories to trails that cross more barren areas. Apply a minimum mapping distance of 30 ft to avoid rapid changes in condition class, i.e., mentally average tread conditions as you hike to avoid assessing changes in condition of less than 30 feet.

Vegetated Substrates Classes

Class 0 — Trail barely distinguishable or discontinuous; no or minimal disturbance of ground vegetation and/or organic litter.

Ground vegetation rooted within the tread is irregularly trampled down, though there may be some small discontinuous gaps (gaps longer than 15 ft should not be mapped).

Class 1 — Trail distinguishable and continuous; some loss of tread vegetation cover and/or minimal disturbance of organic litter. Lightly impacted compared to adjacent areas.

Vegetation rooted within the tread is consistently trampled down and compressed and up to one-quarter of the off-trail ground vegetation cover is lost. Organic litter is partially pulverized but soil exposure is the same or only slightly more than in off-trail areas. Some changes in vegetation composition are evident, e.g., fragile broad-leafed plants rooted in the tread are somewhat reduced in cover compared to off-trail vegetation.

Class 2 — Vegetation cover lost and/or organic litter pulverized within the center of the tread, some bare soil exposed. Moderately impacted compared to adjacent areas.

Approximately 25-75% of the off-trail vegetation cover is lost with only resistant vegetation (e.g., grasses, sedges, or low mosses) surviving within the tread (ignore overhanging vegetation).

Class 3 — Nearly complete or total loss of vegetation cover and organic litter within the tread, bare soil is the predominant tread surface. Heavily impacted compared to adjacent areas.

More than 75% of the off-trail ground vegetation cover has been lost, leaving the underlying substrates substantially exposed. Some patchy pulverized organic litter may be present.

Barren Substrates Classes

Class B1 — Trail is faint but distinguishable. Trail is visible due to limited depression of surface stones into substrates, sorting of stones, or overturned stones. On talus, trail width and footing is narrow, like an animal trail; side-hill trails are outsloped.

Class B2 — Trail is obvious and easily followed. Trail is visible due to a pronounced flattening of substrates, sorting of stones, or overturned stones. On talus, the tread is often widened and cupped.

Trail Condition Assessment (CC option abandoned, final version)

Applied at sample point locations.

Vegetation Cover On-Trail (VO): Imagine a 1 ft wide belt transect centered on the pole extending *between* the trail boundaries perpendicular to the trail. Within this band estimate the percentage of *live* vegetative ground cover < 1 ft tall (including herbs, grasses, low shrubs, live mosses, lichens (all colors), and any largely intact cryptogrammic crusts) rooted within the band using the coded categories listed below. For this and the following indicator, it is helpful to narrow your decision to two categories and concentrate on the boundary value that separates them. For example, if the vegetation cover is either category 6-25% or 26-50%, you can simplify your decision by focusing on whether vegetative cover is greater than 25%. Alternately, consider that analyses will use the midpoint values for these categories so it may be helpful to base your decision on which midpoint value is most representative of the trail tread cover. Cover categories:

0-5% (1=2.5), 6-25% (2=15.5), 26-50% (3=38), 51-75% (4=63), 76-95% (5=85.5), 96-100% (6=98)

Vegetation Ground Cover Off-Trail (VF): Assess vegetation cover in an adjacent, untrampled off-trail location several feet beyond trail boundaries. The intent is to locate a "control" area that depicts what the vegetation cover on the trail tread would resemble had it never been trampled. Select a control that has the same proportion and size of rocks as the tread quadrat. In instances where you cannot decide between two categories, select the category with less vegetative cover. The rationale for this is simply that the first visitors would tend to select a trail route with the least amount of vegetation. Note that if some of the trail substrates would likely be barren due to exposed rock, then the control substrates or control vegetation estimates must reflect that.

Bare Soil On-Trail (BO): As in vegetation cover assessments above, but estimate bare/exposed soil cover, defined as rocks, gravel, roots, and exposed soil of all types, including organic soils with finely pulverized organic litter. Total cover for each band transect should approximately equal the sum of your mid-point estimates for VO, BO), and organic litter cover.

Bare Soil Off-Trail (BF): As above, with the cover estimate of bare soil made in the same off-trail location used for the vegetation assessment.

As evidenced in the modifications shown, field staff sought to make the descriptors more quantitative to improve assessment consistency but efforts to perfect them retained what were considered to be unacceptable limitations, particularly precision problems when CC classes were assessed by different staff on the same set of ITs and compared. Inter-rater reliability (precision) trials were conducted to explore these problems further. During these we applied a variety of IT assessment protocols to the same IT network located in a sloping meadow at Savage Box, near the DENA road entrance station. Field staff included Jeff Marion, Joe Van Horn, three doctoral students, and two seasonal park staff. From census mapping data, Figure 4 and Table 6 illustrates a comparison performed by two experienced staff, and Figure 5 and Table 8 report data for all seven field staff. We also assessed the ability of field staff to evaluate two quantitatively defined trail depth (incision) categories while performing trail mapping work (Figure 6, Table 8). A careful review of all these results reveals what we considered to be unacceptable levels of variation across field staff. Even data from assessing just two quantitatively defined trail depth categories, while better, retains unacceptably low levels of precision.

Our interpretation of these data are that CC class assessments made by *moving staff* are inherently problematic. While the data yielded are similar from different field staff, the poor level of precision is likely to confound management efforts to detect real changes in resource conditions over time.

There are several possible explanations for these findings. Searching for and carefully mapping a dense IT network with Trimble GPS units can be a sufficiently challenging task; adding tasks that require staff to constantly monitor attributes like CC class and tread depth add to the complexity. Furthermore, CC classes and tread depths change along a trail so attempts to categorize constantly changing trail conditions presents staff with a difficult and frustrating decision process. Finally, trail conditions sometimes change for short trail segments, requiring staff to stop, enter data, and start again. We sought to address this problem by establishing a minimum segment length (30 ft) over which a tread condition change must manifest itself before requiring staff to stop and register the change. This distance is generally entirely visible to the field staff, yet sufficiently long to improve the efficiency of data collection. Such a decision rule is clearly necessary but it also adds complexity to the field assessment process.

Given the large standard deviation values and wide range (Table 7) we decided to evaluate CC and trail condition assessments at specific points, such as along a line transect and with point sampling. However, results from line transects, illustrated from two experienced staff in Figure 7, reveal similar problems with low precision. Several factors could explain the variations here. Variation in the number of trails located by different field staff were related to differences in how far out they walked the transects; at the upper end of the study area some staff failed to walk the entire transect lines. Some staff omitted trails they felt were too faint or were created by wildlife, while others included them as mixed wildlife/human use trails (specific guidance for differentiating wildlife trails had not been developed at this time). Differences in condition class ratings, both between surveyors and between their own assessments when mapping the ITs and when assessing the transects (done on different days), are also apparent. Given the accuracy of the GPS units and variation in cross-country hiking along the transect lines (which were downloaded into and appeared on their GPS screens), the field staff could have been assessing slightly different locations along the trails that were bisected by the transects. Given the accuracy of the GPS devices and hiking variation we would expect the trail locations could have been up to about 12 ft from each other.

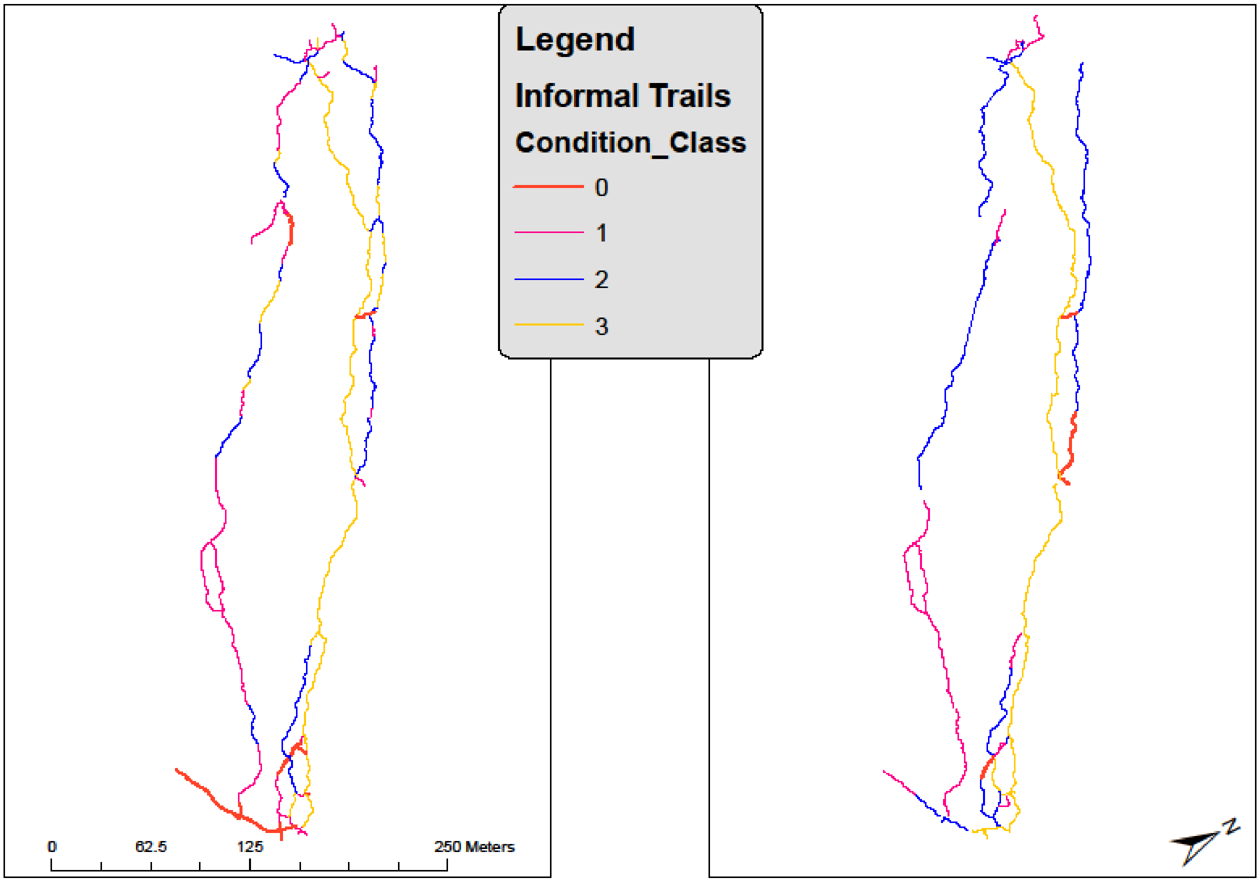


Figure 4. Comparison of data for two experienced staff with a 4-class CC system. Note lack of agreement in CC classes and segmenting.

Table 6. Summary table comparing CC data from two experienced staff, including segment counts and aggregate length by CC class.

Condition Class	Segment Count	Aggregate Length (m)	Staff
0	8	193	JW
1	28	573	JW
2	25	510	JW
3	30	722	JW
0	3	133	LP
1	14	446	LP
2	14	779	LP
3	11	623	LP

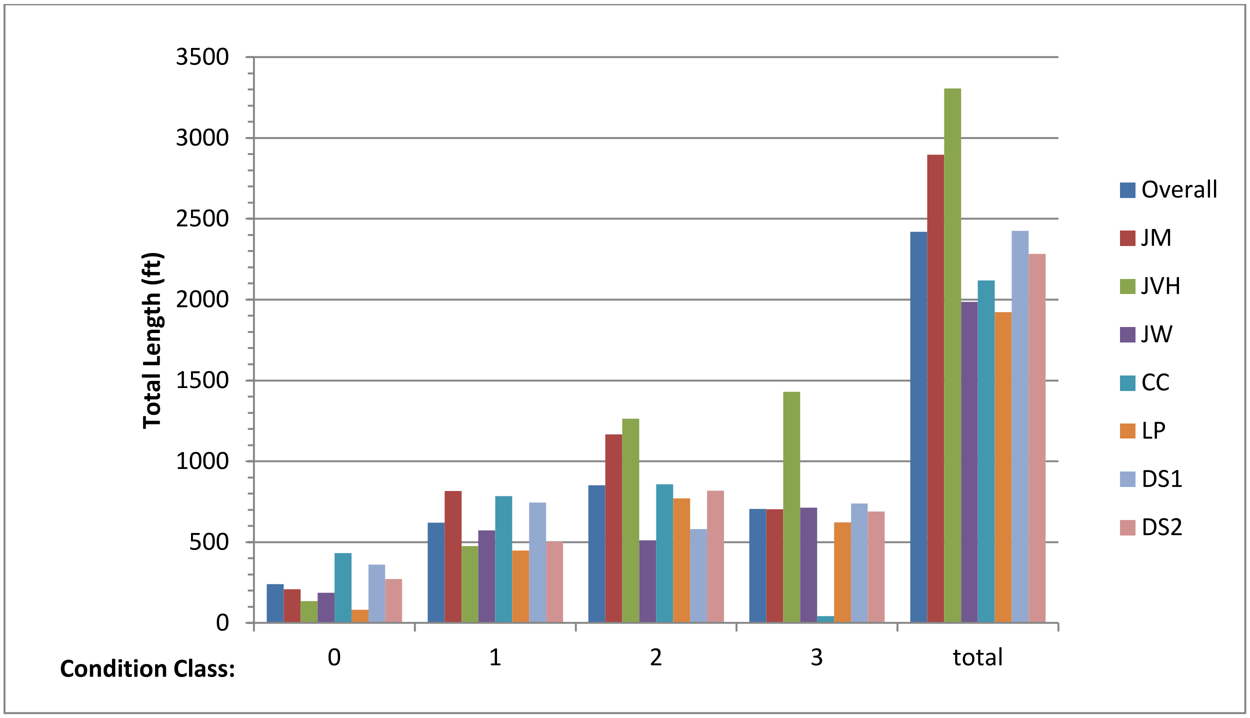


Figure 5. Variation among seven field staff in total lengths of IT's by condition class in the Savage Box study area; data for each field staff are indicated by different colored bars.

Table 7. Summary data for CC assessments of IT segments in the Savage Box study area (presented in Figure 5) independently made by seven field staff. Mean values are in lineal feet, with Standard Deviation and Min/Max values to illustrate differences among field staff.

Condition Class	Overall		Range	
	Mean	Std Dev	Min	Max
0	240	124	82	433
1	621	156	448	816
2	853	279	511	1263
3	706	403	43	1431
Totals	2419	510	1922	3306

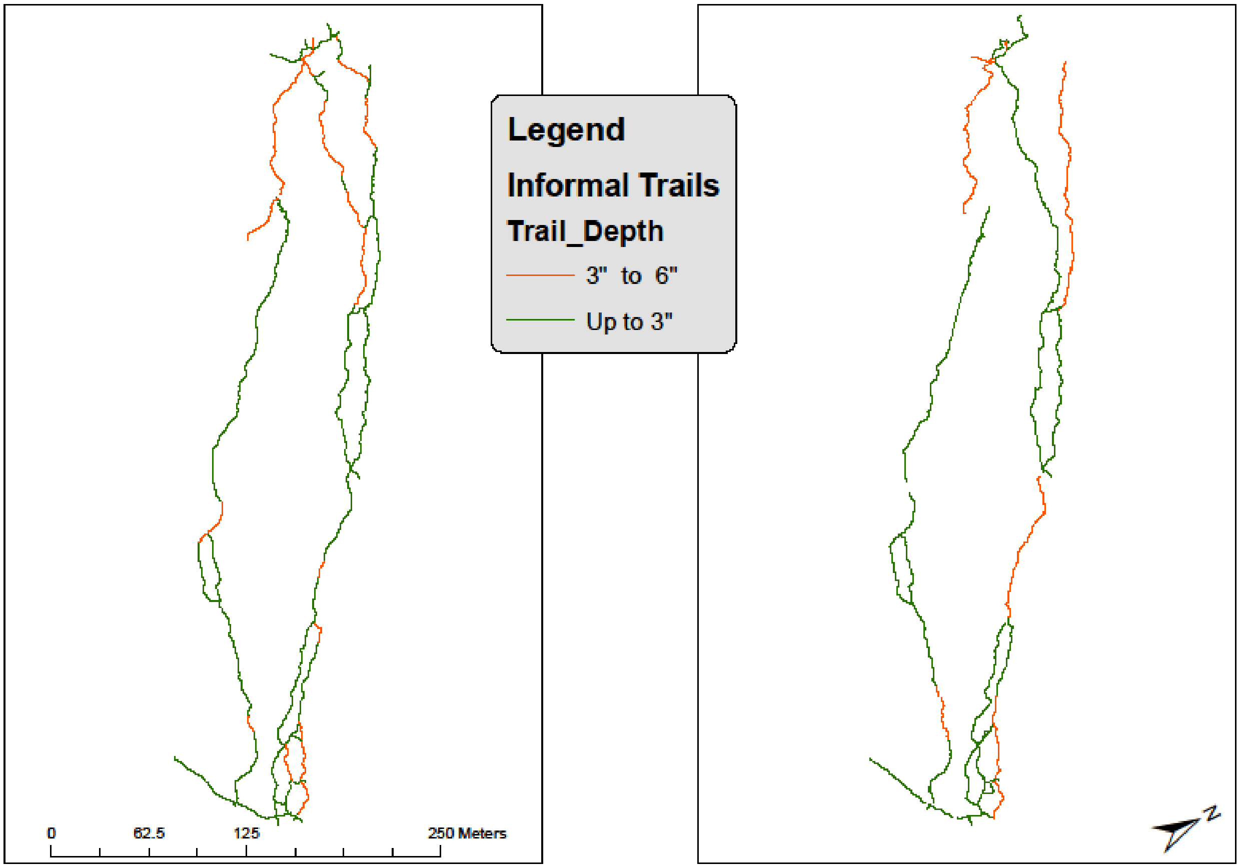


Figure 6. Comparison of data for two experienced staff with a 2-class trail depth estimation. Note lack of agreement in depth classes and segmenting.

Table 8. Summary table comparing trail depth from two experienced staff, including segment counts and aggregate length by trail depth class.

Trail Depth (in)	Segment Count	Aggregate Length (m)	Staff
3 – 6	23	552	JW
< 3	68	1446	JW
3 – 6	7	564	LP
< 3	27	1255	LP
Unassigned	8	16	LP

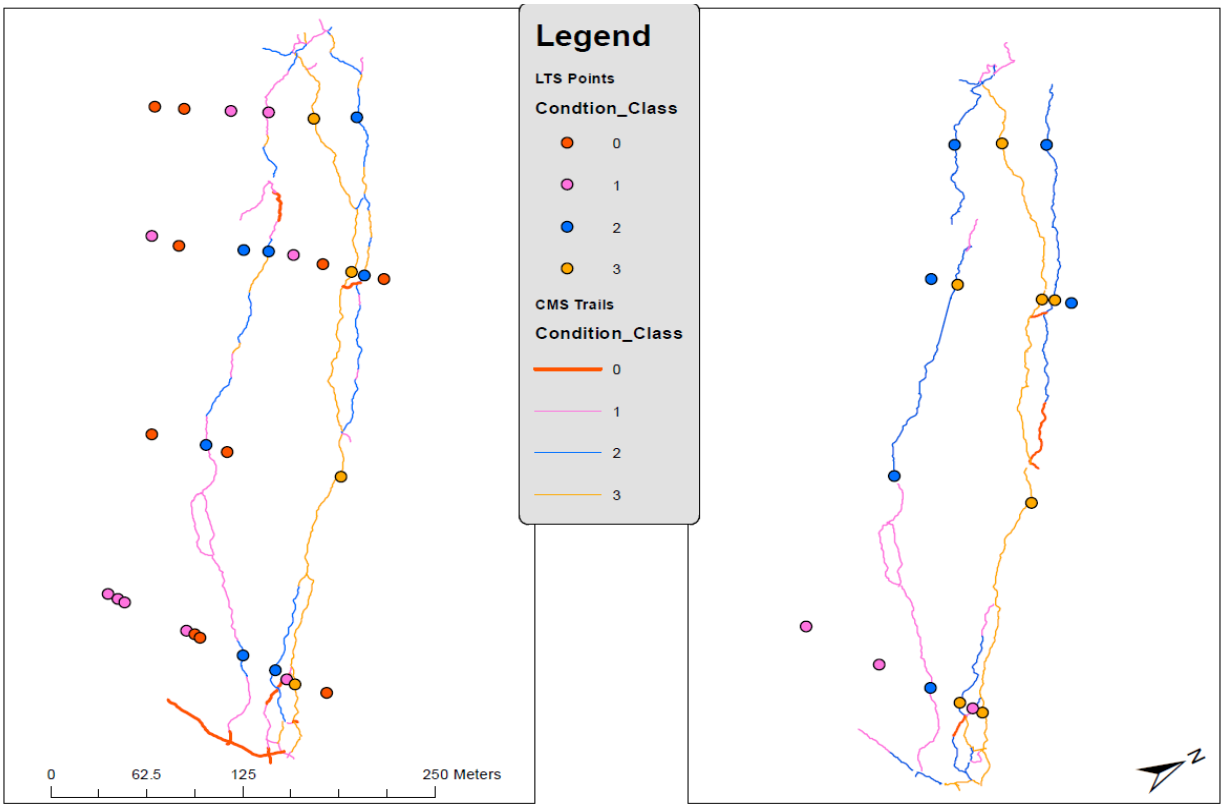


Figure 7. Comparison of data from GPS trail mapping and four identical line transects placed perpendicular to the prevailing direction of visitor traffic for the Savage Box area. Note comparisons between staff can be made by comparing line or point data from left and right figures. Comparison of an individual's assessment of CC during the line transect (point data) can be made to that individuals CC assessment during trail mapping (line data). Assessments were conducted independently over a time span of two days.

As a final precision trial we set out 35 flags along an IT segment in Savage Box and had four field staff assess CC, trail depth, and vegetation cover along transects at each location. Mean data from this trial are presented in Table 9. These results indicate that field staff are far more consistent in assessing CC at fixed points along trails. Given the broader range in possible values, staff assessments of trail depth and vegetation cover for the transects were similarly very consistent, and considered acceptable.

Table 9. Summary table comparing mean values from independent assessments by four field staff of Condition Class, trail depth, and trail vegetation cover at the same 35 marked transects along an informal trail in Savage Box.

Trail Indicator	**Field Staff**				Range
	LP	JVH	JM	CC	
Condition Class	2.1	2.2	2.2	2.2	1-3
Trail Depth (in)	1.1	0.9	0.9	-	0-5
Vegetation Cover (%)	41	44	48	49	3-98

After evaluating results from our field work and precision trials, a decision was made to abandon the CC option entirely and substitute separate quantitatively defined indicators for vegetation cover and exposed soil, made on- and off-trail at specific sample points, with mid-point values for percent cover categories used in subsequent calculations to obtain ratio scale absolute difference measures (i.e., subtracting mid-point tread cover values from off-trail “control” mid-point cover values). These are presented on the final page of Table 5 and used in our recommended protocols (Appendix 1).

Several additional complications added to the challenge of developing IT monitoring protocols. First, IT’s are frequently discontinuous due to their low use and the effects of topography or woody vegetation on route selection. For example, in open flat terrain ITs frequently disappear due to traffic dispersion, reappearing when topography refocuses traffic on a common route such as through a low swale or along flat narrow river bench. Similarly, traffic is also refocused by the presence of woody shrubs or trees, with trails forming only when traffic passes through woody vegetation. Discontinuous ITs present two notable survey difficulties. First, field staff must be adept at searching out discontinuous segments when mapping. Careful attention to the local topography and vegetation types will generally guide staff to the locations where they can expect ITs to develop. However, field staff must be very conscientious in keeping track of IT segments that have and have not been mapped. For example, a comparison of mapping data from two experienced staff of the same trail network in Figure 7 reveals omissions for several trail segments.

Secondly, any protocol that requires point sampling at a specified interval cannot easily be applied to sample discontinuous trail segments. In several high use DENA areas, field staff were confronted by a network of discontinuous trails which defied traditional trail survey methodologies. In response, final protocols emphasize census mapping and transect surveys. Census mapping may still fail to locate and include all ITs, or staff may accidentally omit some segments (as depicted in Figure 7). A far more reliable method, which we incorporated into the protocols, is to establish a series of permanent transects that cross the prevailing direction of visitor traffic. Staff use GPS units to walk each transect, stopping to assess the presence and condition of all ITs crossing the transect. This protocol is illustrated in Figure 7, where four transects were established across the Savage Box study area to intersect with the network of trails trending up and down the sloping meadow. A principle advantage of this method, or any method that involves trail assessments at sample points along a trail, is that more careful assessments or measurements can be made at sample point and transects, in comparison to assessments assigned for trail segments.

A final significant challenge in developing IT assessment protocols for DENA is a substantial population of large fauna, including caribou and moose which create trails, some of which visitors may use. This latter challenge created substantial concern and discussion, with two options considered: 1) assess all trails (wildlife and visitor-created), and 2) omit trails created and predominantly used by wildlife when certainty is high. Following considerable discussion, field investigation, and protocol refinements, we recommend the second option and have developed criteria for increasing the precision of such determinations.

Trails developed and or used primarily by wildlife are indeed different to those who are trained to observe these subtle differences. First and foremost, wildlife trails generally don’t start at visitor developments or roads and lead into the backcountry, often splitting and eventually disappearing. Visitor trails also access certain attraction features like vistas, popular destinations like waterfalls, or follow known routes of visitor use. Such spatial attributes are generally a good indicator of visitor-created trails. Exceptions that demand caution include wildlife trails that cross roads or trails, so field staff are cautioned to search the opposite side of the road or trail for a "mirror" trail of the same general width and condition. Knowledge about the ecology and natural history of the wildlife can also assist decision-making. For example, sheep trails frequently descend steeply to cross the road at narrow mountain gaps, while caribou trails frequently appear as numerous roughly parallel routes through flat to gently sloped terrain. Moose trails favor areas with willow thickets and evidence of their browsing along the trail is common. Animal trails often meander while human trails are generally more directionally consistent over longer distances. Human trails actively seek out and remain within the easiest topography and vegetation for travel, wildlife trails are generally more haphazard. In areas of woody vegetation, narrow trails created by smaller mammals can be discounted because they go directly under branches that would obstruct human passage.

Close inspection of the trail tread can also offer distinguishing criteria. Animal feces/pellets and hoof or boot prints in or near the trail tread are common and fairly reliable indicators. Hoofs generally shear off the trail edges, which are often nearly vertical, where the sides of human trails are more rounded. The width of trails can be an important indicator, wildlife trails are narrower than human trails (often less than 8 inches). In damp or wet soils wildlife generally make no effort to detour around wet areas or to step on clumps of higher ground or vegetation, humans do, leaving trampled and flattened clumps of grasses as evidence of their passing.

Clearly some trails used by wildlife are used by visitors and vice-versa. Their common use on some portions of ITs could lessen assessment precision and accuracy. However, the concern that changes in wildlife populations or patterns of movement will confound trail monitoring results are substantially less when field staff are instructed to omit ITs for which there is relatively high certainty that wildlife is the predominant use. Assessing all trails could substantially increase assessment time. Greater accuracy in comparisons over time are permitted by including a Use Type indicator with categories for: a) human, and b) mostly human/some wildlife. The accuracy of GPS surveys also allows field staff to return to the same trail and determine, in the field, the use type assessment from a previously mapped trail segment.

Description of Monitoring Protocols

In this section we introduce and describe each of the following formal and informal trail survey methodologies included in Appendix 1: 1) Access, 2) Line Transect, 3) Census Mapping, 4) Point Sampling, and 5) Route Finding Experience. These were experimentally applied at the end of the survey development process and we include representative data for some to illustrate possible products from these survey methods. Full datasets from this work are contained in Excel spreadsheets and ArcGIS databases and will be transferred to DENA staff as baseline data. At the end of this section guidance on the establishment of monitoring zones and a decision process for selecting levels of monitoring effort using a decision tree and roundtable process are also included.

Access Survey

Objectives: This survey documents the number and distribution of all ITs that intersect a road or formal trail corridor. This is an efficient survey method that can be conducted quickly but doesn't provide information on trail alignments or destinations. Optional procedures are included for assessing trail conditions at sample points near the trailhead.

Guidance: This survey could be conducted early in the monitoring process to inform the roundtable zoning process. Staff training should focus on developing consistent judgment on when to assess or not assess trace trails, those that are faint or discontinuous – a set of reference photographs are included to assist in the consistency of these judgments.

The Access Survey is conducted by staff who are familiar with the distribution of hiking/backpacking use along the Denali Park Road. Likely candidates include Rangers who routinely patrol the road and/or staff from the Backcountry desk involved with backcountry permits. Consultations with bus operators to discover popular day-hiking locations are also helpful. The Denali Road can be assessed by driving to and searching on foot all locations where human use trails might be expected to occur. Note that trails may depart from locations not visible from a vehicle, such as 100 ft out along a stream corridor. Ground searches on foot are focused along the interface boundary between disturbed road corridor vegetation/substrates and more pristine natural vegetation/substrates.

Detailed procedures are included in Appendix 1 and summarized here. Trails judged to be predominantly created and used by wildlife are included but omitted from resource assessments (see special guidance, pg 75, in the protocols). Note that some wildlife trails may occur in areas that receive regular human use (e.g., near bus stopping or common drop-off locations) – these should be assessed and labeled as "mixed human/wildlife use"). A Trimble GPS with sub-meter accuracy is used for this survey to obtain accurate spatial data on IT trailheads and to efficiently enter and transfer optional IT condition assessment data. Data dictionaries for each survey method were developed and are provided as a product of this research. A "search log" lineal feature is recorded to document the spatial extent of all ground searches from each monitoring cycle and point features and oblique digital photographs are collected to document each IT trailhead. Figure 8 illustrates spatial data from an Access Survey of the initial section of Denali Rd provided by this procedure. Note the documentation of the searched areas with the search log feature within the enlarged inset.

A variety of optional condition assessment indicators are included and described. These indicators include trail width, vegetation and soil maximum incision, vegetation cover on- and off-trail, bare soil on- and off-trail, and the presence of tread problems like muddiness or active soil erosion. Soil incision is a traditional measure of soil loss, to which was added a total incision indicator for assessing the degree to which trampling has also flattened tundra vegetation. Ground vegetation cover and bare soil cover are assessed on- and off-trail in six numerically defined categories. Data should be recorded as coverage class midpoint values for analyses, with subsequent computation of absolute difference values by subtracting trail from trail-side measures.

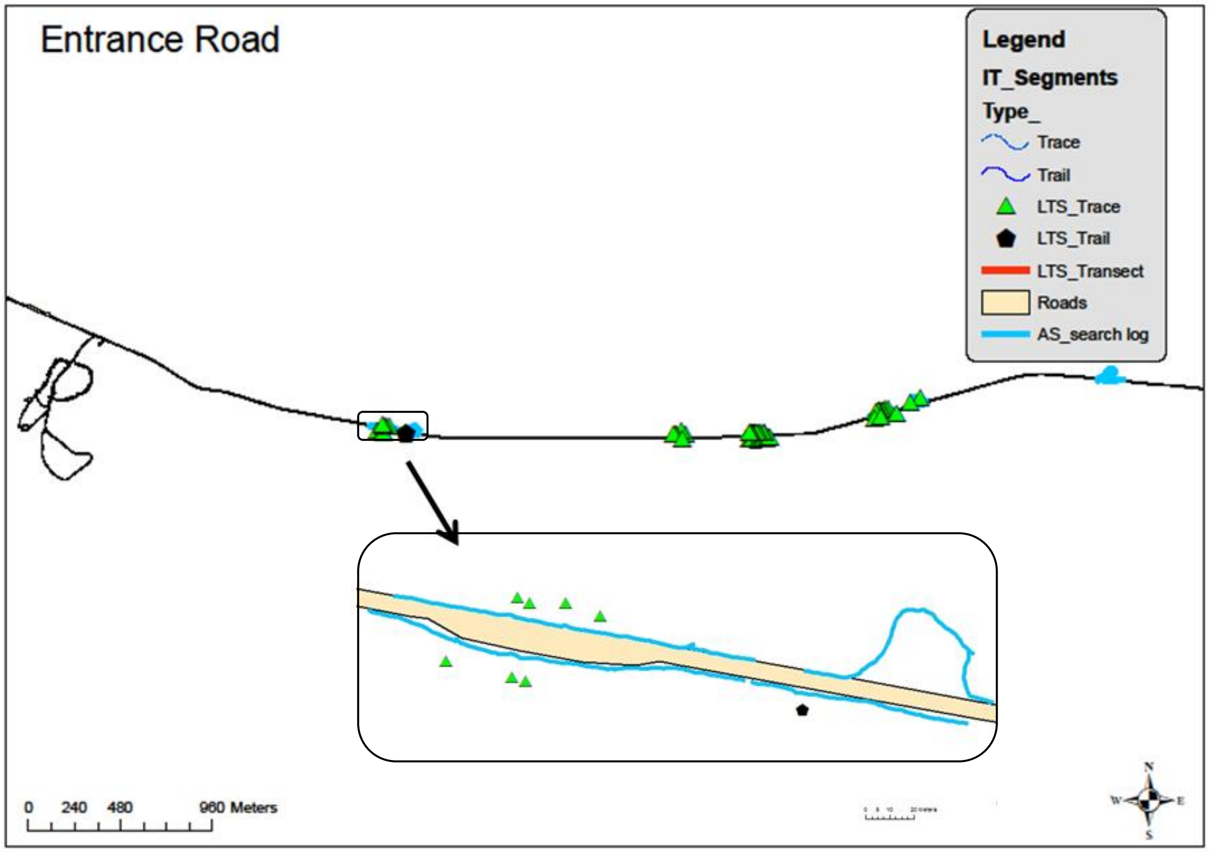


Figure 8. Access survey data from application along the Denali Road, showing an overview for a road segment with an enlarged inset view for one trailhead location.

Line Transect Survey

Objectives: This survey finds and documents the number, location, and condition of ITs in areas near roads and formal trails.

Guidance: Line transect survey (LTS) areas are identified by the roundtable procedure. One or more line transects are established within these areas roughly perpendicular to the anticipated direction of travel. All well-defined ITs that intersect with each transect are inventoried as point features, with assessments of use type, trail width, maximum incision, vegetation cover, and bare soil (described in the Access Survey section) recorded for each trail. LTS is less labor intensive than census trail mapping, yet provides accurate and meaningful sample data on trail locations and conditions for decision-making. A possible exception is when the area to be surveyed has a higher density of tall brush – consider the Census grid method, described next, for these areas. Generally, LTS transects are placed close to roads to pick up the start of ITs, at locations where topography or vegetation constricts traffic, or at more distant points to see if ITs are continuing into the backcountry. When possible, place an adequate number of transects to generate a sufficiently large "N" of sample points to characterize IT conditions.

LTS areas are defined by polygon layers and transects that are downloaded to the Trimble GPS units so that field staff can navigate to the start of each line transect and walk along each one as they look for bisecting ITs. As ITs are found, field staff record location and condition assessment data for the eight quantitative indicators included as "optional" indicators under the Access Survey. Figure 9 illustrates the application of the Line Transect protocol to the Igloo Canyon Lakes area. Data yielded by this procedure includes the number of IT's that intersect each transect and how they change over time. For example, assessments for Igloo Canyon depicted in Figure 9 found a total of 19 IT's along 10 transects. Data for the IT condition assessment indicators would reveal improving or deteriorating IT conditions when periodically reapplied.

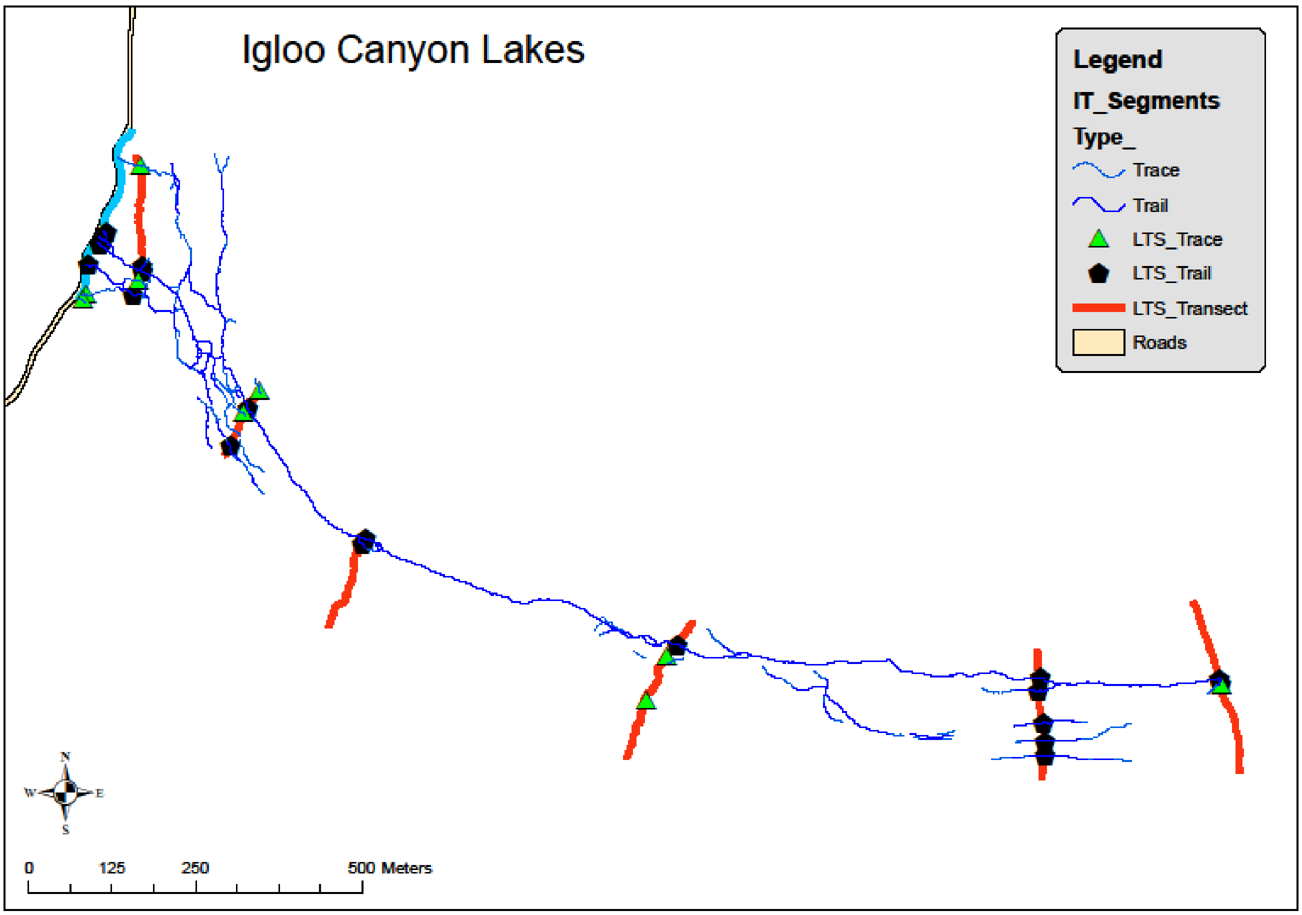


Figure 9. Line transects applied to the Igloo Canyon Lakes travel corridor with census mapping of IT's also shown to illustrate the full distribution of trails. Note presence of a well-used formal trail and numerous discontinuous "trace" trails of human use or wildlife origin.

Census Mapping Survey

Objectives: This survey documents the location, spatial distribution, and lineal extent of all visually obvious ITs judged to be predominantly human use within selected search polygons defined by the roundtable review process. Optional procedures are included for assessing trail conditions if needed. When reapplied over time, census mapping survey procedures allow managers to accurately track and characterize changes in the number, spatial distribution, and length of ITs, and optionally, changes in their condition. Data can also be used to help decide which ITs should be closed and to evaluate the success of management efforts to close selected trails or prevent the creation of new trails.

Guidance: Census mapping areas (CMA) are identified by the roundtable procedure. All ITs within each CMA, except those that are extremely faint/discontinuous and those that are "mostly wildlife in origin and use, are inventoried as line features, with point features recorded at all trail/road intersections to aid GIS editing. Discontinuous trails are mapped, provided their sections qualify under the criteria for assessing IT's, as described in the Access Survey section (with "mostly wildlife" trails omitted). Optional assessments of use type, trail width, maximum incision, vegetation cover, and bare soil (described in the Access Survey section) can be made at locations where ITs intersect a GIS grid (e.g., 25 or 50-meter grid) superimposed over the CMA and downloaded for viewing during survey work on a GPS unit.

As previously discussed, our extensive experimentation and refinements of the condition class rating descriptors did not yield a sufficiently precise assessment option whereby condition classes could be assigned to IT segments. The alternative recommended in these protocols is to either apply the line transects to obtain quantitatively assessed tread condition data at each intersection with an IT, or to apply a grid as an optional procedure in this survey method. Field staff would glance at their GPS screen during the census mapping and stop whenever the IT they are following intersected a grid line. Point assessments using the eight quantitative indicators included as "optional" indicators under the Access Survey would be assessed at each point. Figure 10 illustrates the Census Mapping protocol as applied in the Tattler Creek drainage (Line Transects and a 50-meter grid are also shown).

Table 10 reports summary data from the census mapping conducted in Tattler Creek. The statistics reported can be reassessed over time to evaluate changes in IT networks and the extent to which trails become continuous across the travel zone.

Table 10. Summary of census mapping data from Tattler Creek.

Informal Trails (#): 184
Aggregate Length: 19,361 ft
Zone Length: 10,535 ft
Longest Continuous Trail: 1,759 ft (17% of zone length)
Breaks to Cross Zone (#): 19
Continuous Trails Crossing the Zone (#): 0

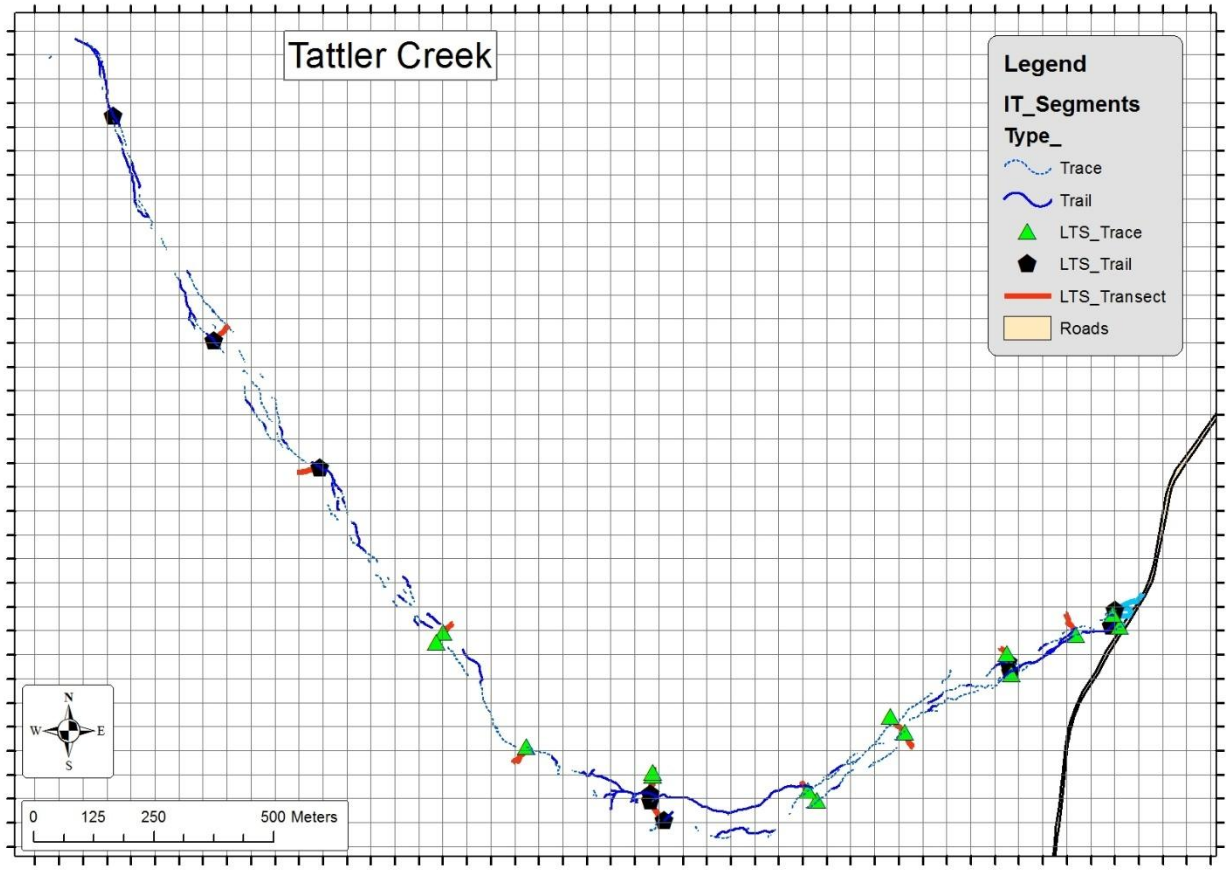


Figure 10. Census mapping of the predominantly discontinuous IT's paralleling the Tattler Creek drainage with the optional 50-meter grid superimposed for point sampling data collection. These trails are receiving greater use since the discovery of dinosaur fossils.

Point Sampling Survey

Objectives: This survey provides more accurate quantitative assessments for a variety of trail condition indicators on selected formal or informal trails whose alignments are relatively static.

Guidance: Managers in the round-table process can identify selected informal or formal trails for which more accurate data are required, perhaps to evaluate their condition in relation to standards of quality or evaluate the efficacy of management actions. Prior to fieldwork, managers must define the beginning and endpoints of each trail segment to be assessed and the point sampling interval (e.g., 200 or 300 ft). Sample points can be generated with a VB script (Points on Poly) with a GIS, incorporating a random start. The selected sample points are then downloaded to a GPS device with sub-meter accuracy and field staff can navigate to these same sample points during each monitoring assessment to assess tread conditions.

Figure 11 shows a well-used and eroded fall-aligned trail ascending Primrose Ridge, with data yielded by the Point Sampling survey presented in Table 11.

Primrose Ridge

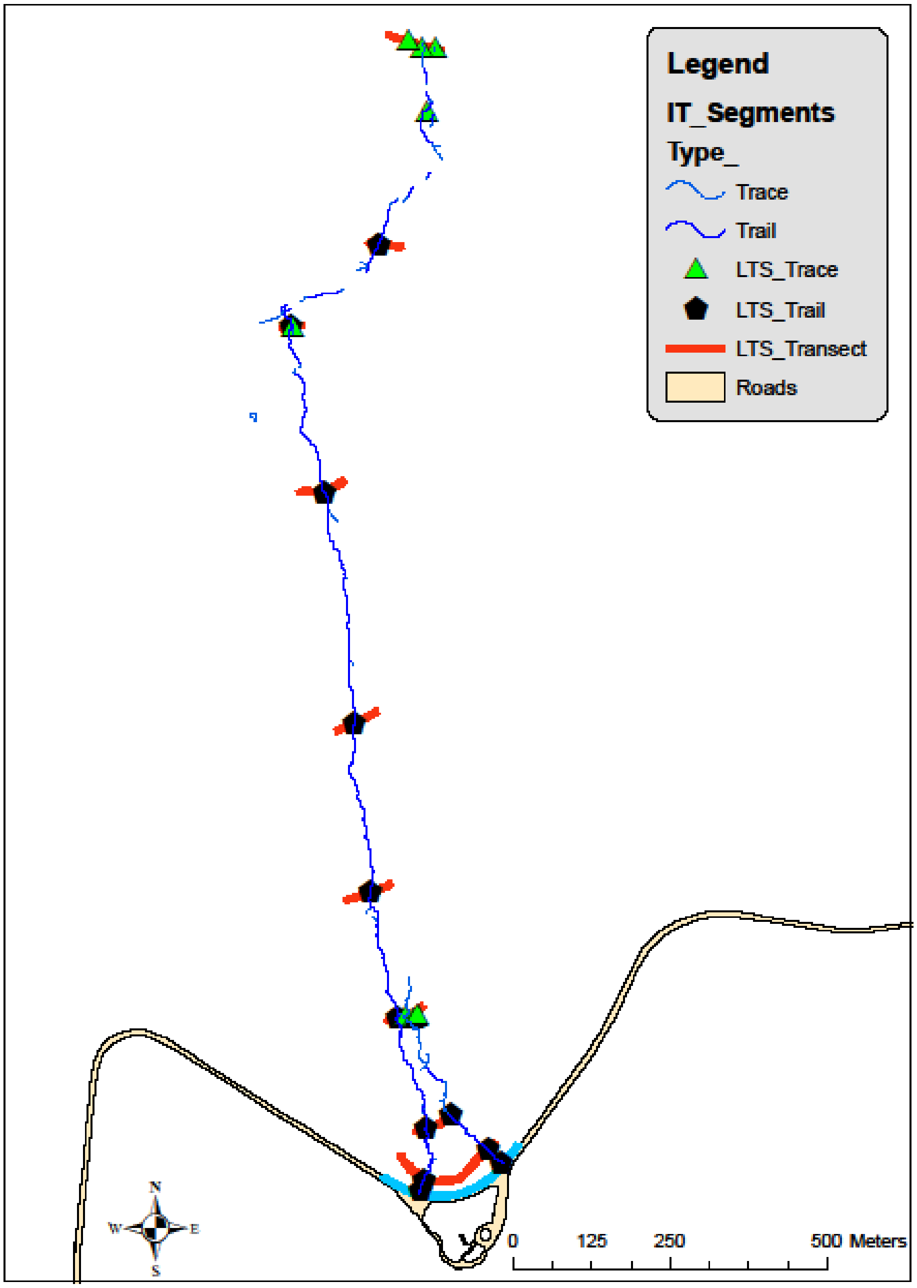


Figure 11. An informal trail with a mostly continuous tread has formed in the Primrose Ridge area. The Access, Line Transect, Census Mapping, and Point Sampling surveys were applied.

Table 11. Point Sampling survey data provide descriptive quantitative data for a number of trail condition indicators.[1]

Measures	**Trail Width** (in)	**Total Incision** (in)	**Soil Incision** (in)	**Vegetation Loss** (%)	**Soil Exposure Gain** (%)
Mean	15.6	4.8	2.7	67.3	75.2
Max	21	11	6.7	83	95.5
Min	11	0.7	0	13	12.5

1 - These data are based on 25 sample points. Absolute difference (AD) values are present for vegetation loss and soil exposure gain, computed by subtracting trail transect mid-point cover class values from off-trail "control" mid-point cover values. AD values provide an estimate of change from pre-trail conditions.

Route Finding Experience Survey

Objectives: This survey is used to inventory the hiker's Route Finding Experience (RFE) as they move through backcountry travel corridors identified by the roundtable. Data is used to inform and direct future monitoring decisions (e.g., data showing that it is easy to travel through an area on trails might suggest the need for LTS or CMA mapping). These data inform managers about the degree to which visitors engage in active route finding decision-making while hiking, as opposed to traveling along a visually obvious trail for long distances.

Guidance: Survey is to be performed by backcountry staff and/or visitors who are given Garmin GPS units. A timer will signal data collection every 15 minutes. The data collector may also collect a data point whenever they feel their RFE has changed from one "level" to another.

<u>RTE Class Descriptions</u>

Class R1 - I am spending more time off trails than on trails. It is difficult to piece together trails or routes that take me in the direction I want to travel and bushwhacking is often required.

Class R2 **-** I am walking on a trail most of the time, but I have to remain alert and make frequent choices about which trails to follow. Occasional short trail gaps may exist and periodic backtracking and/or bushwhacking are required.

Class R3 **-** I am generally always on a trail, and can easily navigate along trails in the direction I want to travel.

Figure 12 illustrates the application of the Route Finding Experience survey to a backcountry hike from Savage Box to Mount Margaret and back to the Denali Road at Primrose Ridge.

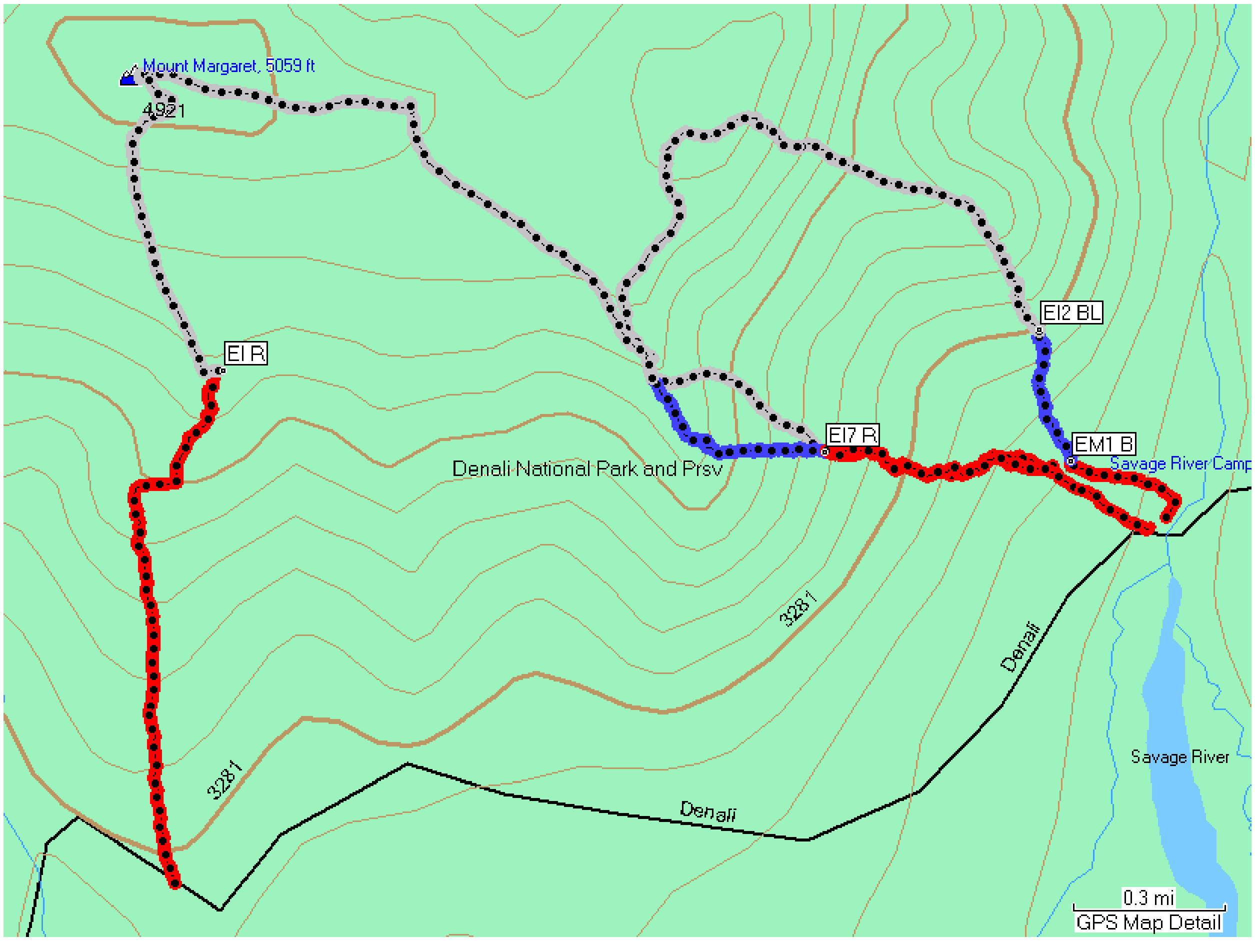


Figure 12. Route Finding Experience survey applied to a backcountry hike from Savage Box to Mount Margaret and back to the Denali Road at Primrose Ridge.

Legend: Red – R3, trailed experience, trail(s) clearly visible, no difficulty following route
Blue – R2, mixed experience, trail becoming discontinuous
Gray – R1, trail-less experience, route finding skills needed

ESTABLISHING MONITORING ZONES

The spatial distribution of visitation can vary substantially within protected natural areas, ranging from very high near popular attraction features to very low in remote inaccessible areas. The establishment of monitoring zones can help designate the priorities and intensities of trail monitoring efforts. The most remote areas require no monitoring effort if there is good reason to believe that no visitor-created trails exist. In contrast, areas near roads, campgrounds, or other facilities may have or could develop dense networks of human trails that require more intensive monitoring. Therefore, an initial step in the trail monitoring effort is to establish zones to prescribe trail monitoring effort, from none to intensive. The following section describes a process for accomplishing this objective, though it is expected that over time, and as data is collected, that such monitoring guidance will be updated and revised.

Levels of Monitoring Effort

The type of trail monitoring employed will depend on the existing and expected number, extent, and condition of trails. Higher levels of monitoring effort will generally be applied to areas and trails that receive more intensive use and impact. Several types of trail monitoring protocols are recommended, which are listed here and fully described in later sections.

- No trail monitoring within remote/inaccessible areas.
- Access survey – This method provides an efficient census of all ITs leaving a road or formal trail corridor, documented by point data. The condition of IT segments can also be optionally assessed.
- Line transect survey – This method provides IT condition data assessed along one or more transects arranged perpendicular to the prevailing direction of travel within travel corridors. IT locations are depicted by point data for each transect/trail intersection.
- Census mapping survey – This method provides comprehensive mapping data for all ITs within a defined monitoring area, or an intelligent search through a travel corridor. The condition of IT segments can also be optionally assessed.
- Point sampling survey – This intensive survey method provides more comprehensive quantitative condition data taken at regularly spaced points along well-established formal or ITs.
- Route finding experience survey – This method is an opportunistic assessment of the trail-less experience applied by visitors or backcountry staff during backcountry hikes.

Regardless of the protocol used, they should be replicated periodically (e.g., every 3-10 yrs) to document change over time. Furthermore, surveys should only be conducted in the last half of the summer use season when evidence of human use on trails is most pronounced.

Monitoring Zones

The geography and probable use patterns of the protected area are used to define trail zones. These can be organized by distance from roads and expected impacts.

1. Infrastructure areas (roads, parking areas, visitor centers, remote airstrips, buildings, etc.)
2. Frontcountry nodes (dense networks of trails leading from infrastructure areas to attraction features)
3. Road corridor areas with trails expected
4. Road corridor areas with no trails expected
5. Closed areas (e.g., wildlife closures)
6. Well-used formal or informal trails with static alignments
7. Backcountry travel corridors with likely trail formation to attraction features
8. Backcountry travel corridors with no trail formation expected
9. Remote/inaccessible areas

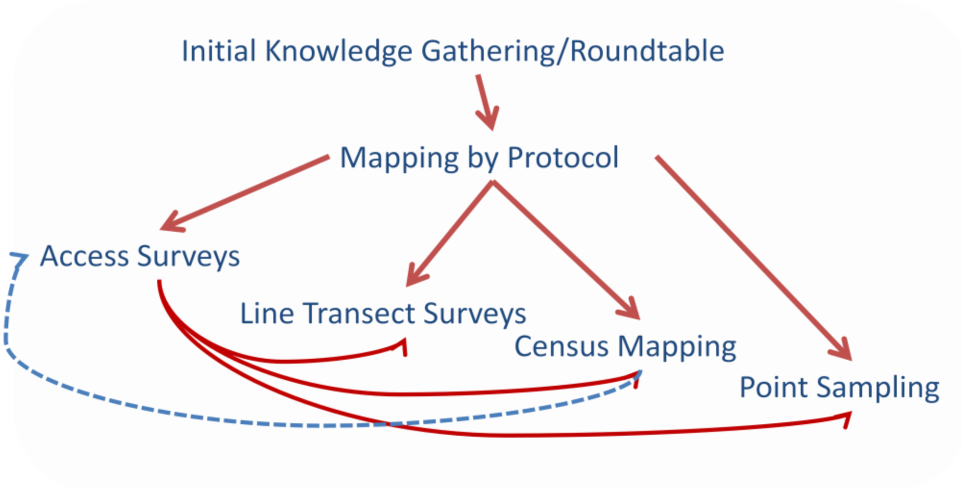


Figure 13. Suggested informal trail monitoring decision tree. Initial monitoring strategies are to be selected by roundtable discussion and zoning of the park by managers and staff.

Zone Establishment with a Roundtable Process

The key to establishing the zones is to collect data on known and suspected areas of trail establishment. Gathering a group of the most relevant and experienced staff to have a roundtable discussion and draw lines on maps is a useful method. Other data sources are hiker contact locations from backcountry patrols; interviews of visitors, local guides, hike leaders; a survey of access points along roads; previous trail monitoring data, a plot of the hikes listed in guidebooks; trip reports on the web; and special destination or attraction feature points.

Data from the roundtable effort could be assembled into GIS layers to show discrete areas of probable human trail development defined by mapped polygons. Each polygon is assigned an initial level of trail monitoring (type, intensity, and priority). Additional layers include known and suspected trails and access points, formal trails, developed sites (roads, parking areas, administration areas, campgrounds, ranger stations, etc.) and closures.

In monitoring zones 1, 4, 5, 8, and 9, trail monitoring will generally not be conducted, except as captured through the roadside access survey. For the remaining zones, roundtable staff will need to decide between four types of monitoring (Figure 13). Generally, the route finding assessments are applied only to zone 7, backcountry travel corridors with likely trail formation. Similarly, point sampling is applied only to zone 6, well-used formal or informal trails with static alignments. For the remaining zones, 2, 3, and 7, line transect surveys are generally recommended as the most appropriate and efficient first step for areas that require some level of monitoring beyond the roadside trail survey. This survey requires about 25-35% of the time required to conduct the more comprehensive trail census mapping, which is generally more appropriate for high-use areas with dense networks of ITs. However, where time permits, managers may also find that trail mapping provides useful information for documenting longer ITs that do not occur in areas of dense trail networks.

In considering whether to monitor an area or the type of monitoring to apply, consider both existing conditions and expected changes in use or management actions. For example, areas with few trails that are in acceptable condition may be less important to monitor, though documenting baseline conditions even for such trails remains an important management objective. However, areas with few trails in poor condition or areas expected to see increased use or where management actions are likely will generally be areas of higher priority monitoring. The monitoring process should be a key component of adaptive management decision making.

As trail monitoring data is collected, the boundaries between the zones can be adjusted. For example, increased use in an area may lengthen trails that then allow day hikers to move further away from roads over time. This would extend the outer boundary of monitoring zones—with an accompanying change in monitoring prescription.

CONDUCTING MONITORING

The full set of monitoring protocols are included in Appendix 1 for easy extraction and use. Paper copies of the field protocols should be photocopied onto waterproof paper and carried by field staff to consult. A listing of field equipment needed for each protocol is included for reference and should be checked by field staff prior to departure. Appendix 2 contains an overview of the monitoring workflow process, including a section on pre-fieldwork setup tasks. For example, most protocols require that the GPS units contain data dictionaries or background datasets such as search areas or line transects.

Following the completion of fieldwork, Appendix 2 also includes recommended data post-processing tasks and protocols for file naming and long-term storage. Monitoring data analysis tasks are also listed.

DISCUSSION

Research Challenges and Solutions

Denali National Park and Preserve has a "unique status as a park that offers an undeveloped Alaskan wilderness park experience distinct from the wilderness and park experience in the other states" (NPS 2006a). The DENA Backcountry Management Plan (BMP) (NPS 2006a) highlights the park's ability to provide:

> "…superlative opportunities for primitive wilderness recreation. Outstanding cross-country hiking, backcountry camping, and winter touring possibilities are available for those willing to approach the area in its natural condition. This huge park contains large areas with almost no trails and where evidence of human use is minimal to nonexistent. These conditions are in contrast to most wilderness areas in the contiguous 48 states where maintained trails, designated campsites, footbridges, and signs are standard. These conditions also contrast with much of Alaska, where similar opportunities abound, but are very difficult to reach. A large portion of Denali's backcountry is readily accessible to visitors who can reach the park by either highway or railroad from either Anchorage or Fairbanks—Alaska's two cities and major connection points for out-of-state visitors."

This report presents Denali National Park staff with a flexible array of trail survey protocols for assessing and monitoring resource and experiential conditions on informal and formal trails. Given that the park is predominantly managed as "trail-less" wilderness, the management vision for backcountry and wilderness visitation promotes self-reliant route-finding, as opposed to travel along a continuous trail from a departure point to destination. According to the Backcountry Management Plan: "backcountry access and travel in Denali will continue without designated routes or constructed trails to allow for freedom to explore and to minimize signs of human presence." However, heavier visitation in some areas, particularly by day users, continues to create IT networks that appear to be expanding over time. Managers require the ability to document the extent to which visitor-created trails are appearing and expanding and of changes in their tread conditions. Periodic application of monitoring protocols can inform management decision-making by providing quantitative data for a variety of indicators. Managers could evaluate these changes, compare them to management objectives or numerical standards, and implement visitor or resource management actions to avoid or minimize them.

This research faced a number challenges: 1) protocols had to be flexible and highly efficient due to limited staffing and budgets, 2) traditional trail survey methods have been developed for single, well-used/discerned, continuous trails, rather than lightly used, discontinuous, braided trail networks, and 3) some wildlife create trails that can be confused with visitor-created trails.

To address these challenges we developed a "toolbox" of IT monitoring protocols, allowing managers to select from these only those trail survey options and indicators that address their information needs, which may additionally vary by management zone. A roundtable decision tree process (Figure 13) was developed to assist managers in selecting the most appropriate protocol(s). The most efficient of these, the Access Survey (Figure 8), documents the number and distribution of IT's that intersect the Denali Road, or a formal trail. All protocols incorporate

GPS technologies to increase their efficiencies and accuracy and facilitate quick computer input of spatial data for storage, analysis, and mapping.

For assessing IT conditions our work sought originally to incorporate highly efficient condition class ratings, based on qualitative descriptive ratings of progressively greater levels of trampling-related groundcover impact. We developed, applied, evaluated, and revised several iterations of IT condition class descriptors, incorporating more quantitative criteria in an effort to perfect a rating system applicable to a variety of DENA environments. Our results primarily pointed out the inherent difficulties associated with any effort to apply such ratings when staff are moving and/or to assess segments of trails. Experimental trials documented unacceptable levels of precision (consistency) between field staff. Precision was also poor when assessing only two levels of a quantitatively defined trail incision indicator, reinforcing our conclusion that condition assessments should be made only at specific points or transects, rather than while conducting walking surveys and assessing segments of trails.

We achieved higher, acceptable, levels of precision when field staff were directed to make condition class and quantitatively defined indicator assessments at specific points along trails. However, we conclude that quantitatively defined indicators of trail tread and undisturbed trailside conditions provide more informative, accurate, and precise information with a very limited increase in assessment times. Experience has shown that the most substantial amount of field time is devoted to traveling rather than assessment time, so we judge the additional time as acceptable. As an example, we replaced condition class ratings with quantitatively defined conditions for vegetation and exposed soil cover on- and off-trails and computation of absolute difference values. This approach has the advantage of providing more flexible ratio scale data that is less limiting when conducting relational analyses, statistical testing, or quantitative comparisons to formal indicator standards, if developed.

The challenge of monitoring IT networks with discontinuous trails is best overcome through reliance on survey options that focus on their trailheads, where use is generally highest and most concentrated, and on permanent line transects perpendicular to the prevailing direction of travel. Census mapping of IT's can also be helpful, particularly if staff are well-trained and thorough. Traditional point sampling trail survey protocols are more problematic, particularly given the time required to search out if or where a surveyed trail might reappear, or deciding which braid to continue surveying if multiple trails are present.

This research also had to adequately address the challenge of monitoring IT networks in areas with large fauna, which also create and use ITs. When assessing visitor-associated trampling impacts an objective is to minimize assessment protocols that would be affected by changes in wildlife populations or their geographic patterns of use. As previously noted we considered two options: 1) assess all trails (wildlife and visitor-created), and 2) omit trails created and predominantly used by wildlife when certainty is high. Following considerable discussion, field investigation, and protocol refinements, we opted for the second option and developed criteria for increasing the precision of such determinations. A Use Type indicator was incorporated within the protocols, with categories for: a) human, and b) mostly human/some wildlife. The accuracy of GPS surveys also allows field staff to return to the same trail and determine, in the field, the use type assessment from a previously mapped trail segment.

This decision was a difficult one and early in the fieldwork, staff clearly had difficulty distinguishing the predominant use of trails receiving mixed human and wildlife use. As a general practice we opted to instruct field staff to include and assess trails for which they could not determine a "predominant" use. As fieldwork progressed we continually refined our guidance and discovered an array of reasonably reliable criteria for differentiating wildlife trails from those used predominantly by humans. Any procedure that permits such judgments will inevitably introduce some measurement error into the monitoring assessments and temporal comparisons. However, some areas do have large numbers of wildlife trails and their assessments would substantially slow field staff in the collection of unnecessary data that could also confound subsequent analyses.

Monitoring Protocols

A flexible array of monitoring protocols were developed, field tested, and refined. As recommended in the current DENA BMP (NPS 2006a), a "social trails working group" should be created to develop coordinated actions that address IT creation and proliferation. This group can also evaluate IT monitoring needs, identify management zones and monitoring protocols to be implemented within each zone, and guide the application of the monitoring program and subsequent reporting and use of data.

While the five types of monitoring protocols can be flexibly applied on an "as needed" basis, there is some benefit to obtaining sufficient funding to more comprehensively apply an array of protocols when initiating the program to establish baseline conditions for future comparisons. For example, there would be substantial benefit to a comprehensive application of the *Access* survey along the entire 92 miles of the Denali Road, with subsequent data summaries and GIS mapping to examine the current number and distribution of ITs throughout the park. This might also be combined with *Line Transect* surveys at selected distances (e.g., 100, 1000, and 2500 ft from the Denali Road) for perhaps 15-25 of the major travel corridors leading away from the road.

Following this initial survey, *Census Mapping* might be applied to a selection of travel corridors containing the most developed IT networks. Based on Line Transect data, *Point Sampling* could be applied to a selection of formal trails or ITs found to be particularly wide, eroded, or muddy. The outermost band of Line Transect data might also be evaluated to identify which travel corridors retain one or more ITs leading into the Wilderness. These corridors might then be targeted for the *Route Finding Experience* surveys. Other topics for consideration are the need for quantitative indicators and data required by future decision-making, or planning related to VERP carrying capacity processes.

Informal Trail Management Strategies

A range of management strategies and actions to avoid or minimize visitation-related resource impacts are available to protected area managers, including the development of formal trail systems allowing visitor access within road-less natural areas. In moderate to high use zones managers generally provide formal trails as part of a "*containment*" strategy that minimizes the aggregate areal extent of visitor impacts by concentrating traffic on durable tread surfaces (Hammitt & Cole 1998, Leung & Marion 1999c). Formal trails are generally designed, constructed, and maintained to accommodate intensive recreation traffic while minimizing trampling-related impacts. This strategy is based on a well-documented asymptotic use-impact relationship, whereby a majority of trampling impact occurs with moderate levels of traffic, and diminishing additional impact as traffic levels increase further (Cole 1992, Leung & Marion 2000, Newsome *et al*. 2002). Thus, confining trampling impacts to a limited network of formal trails avoids more widespread degradation caused by less structured patterns of visitor activity and traffic.

In higher use areas managers are frequently challenged by the development of informal (visitor-created) trails, and whether their use should be discouraged, prohibited, or tolerated. ITs that develop as shortcuts or duplicative and alternate routings, or traverse areas of sensitive habitat, rare species, or archaeological sites, are generally considered to be unacceptable (Table 12). However, ITs created to access attraction features or points of interest, like climbing and fishing spots not accessed by formal trails, or through areas of constricting topography, like a narrow mountain pass, are often acceptable. In keeping with a containment strategy, use of these ITs prevents the occurrence of more widespread impacts. However, sometimes ITs can proliferate into dense networks of duplicative routes with substantial amounts of trampling damage and "avoidable" impact. For example, an IT study at Potomac Gorge near Washington D.C. mapped 9.9 mi of ITs (46,663 ft^2 of trampling disturbance) on the highly visited Bear Island (Figure 3), which also has 2.0 mi of formal trails (Wimpey & Marion 2011b).

In low use zones, managers frequently implement "*dispersal*" strategies designed to prevent the occurrence of visitor impacts (Hammitt & Cole 1998, Leung & Marion 1999c). Land managers seek to avoid the occurrence of ITs by promoting low impact outdoor practices such as those developed by the national Leave No Trace (LNT) program (www.LNT.org). Visitors are asked to disperse all activities on the most durable natural surfaces available to avoid or minimize trampling-related impacts. A common management objective in these zones is to keep them trail-less, preserving a natural landscape with no visible human impact.

Table 12. Impact management strategy by use level and zone, with characterizations of the acceptability to management of different informal trail (IT) types.

Impact Management Strategy	**Containment** *Mod-High Use Zones*	**Mixed** *Transition Zone*	**Dispersal** *Low Use Zone*
Formal Trails	Acceptable	Often Acceptable	Unacceptable
Shortcut/duplicative IT's	Unacceptable	Unacceptable	Unacceptable
IT's in sensitive/rare spp. habitat	Unacceptable	Unacceptable	Unacceptable
IT's to points of interest	Acceptable	Often Acceptable	Sometimes Acceptable
IT's in constrictive topography	Acceptable	Often Acceptable	Sometimes Acceptable

Unfortunately, management experience with the dispersal strategy has revealed a number of challenges that limit its effectiveness, including: 1) visitation levels that are too high to support effective dispersal, 2) limited availability of highly durable surfaces, 3) topography or vegetation that constricts traffic to common routes, and 4) inadequate educational programs that fail to communicate when and how activities should be dispersed, what durable surfaces are, and a compelling rationale for practicing dispersal. Educational programs rarely reach all visitors and communicating when they should use formal trails, informal trails, or disperse their traffic can be difficult. Encouraging visitors to forgo an IT for more challenging dispersed travel can be equally difficult, particularly when topography or woody vegetation conspires to constrain route selection to a river-side bench or mountain pass. Even the presence of a faint or discontinuous IT leading toward a destination or point of interest will attract visitors and act to reduce dispersal compliance.

Recreation ecology research has demonstrated that trails can develop at relatively low levels of traffic on less resistant and resilient vegetation and soil types (Cole 1987, 1995a,b, Marion & Cole 1996). ITs that develop in low use zones managed under a dispersal strategy are generally unacceptable (Table 12). Exceptions *could* include IT development to or near attraction features or in areas where topography or vegetation constricts traffic. In these areas, trails are created when visitor traffic is unavoidably concentrated to a level that exceeds the tolerance of native substrates to sustain it. Potential management responses include: 1) discourage or limit use of the area, 2) enhance education efforts to promote greater dispersal, 3) implement site management to close and restore ITs, 4) tolerate and/or encourage IT use to avoid development of additional trails, or 5) design and construct resistant formal trails (generally inappropriate). A principal management challenge with options 4 and 5 is providing visitors with a consistent educational message regarding when to disperse activity or use a formal or informal trail. Historically, DENA staff have relied principally on use limitations, and to a lesser extent on education, to limit IT development. These topics are addressed further in a following section.

Transition zones between accessible high use areas and remote low use areas frequently present the greatest challenges to protected area managers, as neither a containment or dispersal strategy is entirely appropriate or effective in managing visitor impacts. Formal trails could be developed to sustain traffic to points of interest or through areas of constricted topography, but these may be viewed as inappropriate developments in some backcountry or wilderness settings. Managers are often willing to accept the creation and use of some ITs, provided they don't proliferate into duplicative routings, impact sensitive areas, or include particularly impact-susceptible alignments (Table 12). Recent research reveals that visitors often choose less sustainable trail alignments and can create unnecessarily duplicative networks of trails that entail a substantial amount of avoidable impact (Leung *et al.* 2011, Wimpey & Marion 2011a). Furthermore, visitors may have difficulties distinguishing formal trails from ITs, and in deciding when to use trails or to disperse their traffic. A preferred strategy for transition areas might be to tell visitors to use well-established trails (formal or informal) when available (avoid faint trails to promote their recovery), and to disperse traffic when off-trail. Managers could then perform site management actions to close and restore inappropriate or duplicative ITs and faint trails.

Visitor Management Options

Denali National Park managers can influence backcountry visitation-related resource impacts by regulating or educating visitors. Backcountry overnight visitation at DENA experienced substantial expansion in the 1970's, from 5,491 in 1971 to 30,334 in 1980 (NPS, 2011). Since then visitation has stabilized, ranging from 32,579 in 2000 to 38,625 in 2010. Approximately half of this visitation occurs on Mount McKinley and half is comprised of backcountry/wilderness backpackers. Data on visitors who day-hike in the park is not collected, though a park study provided an estimate of 48,000 day-hikers in 1978 (Womble 1979).

To regulate backcountry visitation, the 1976 Backcountry Management Plan (BMP) established a system of backcountry units and assigned use limits ranging from 2 to 12 overnight visitors/night to each one. The extremely low use limits were developed based on considerations related to preserving outstanding opportunities for solitude and the prevention of IT and campsite development. We suspect that this regulation has been the single most effective management tool acting to limit the formation and proliferation of ITs. However, day-hiking visitation, which may be rising over time, is likely responsible for some IT formation in frontcountry areas near the Denali Road and possibly in transition areas leading to the backcountry. Other relevant regulations include a group size limit of 12 (6 in two areas) and a mandatory but free permit system for backpackers, primarily for the educational opportunities it affords. The plan also states that "Commercial and non-commercial groups will be required to have a group leader who is trained in Leave No Trace principles for tundra environments generally and Denali National Park and Preserve in particular."

DENA managers have adopted Leave No Trace (LNT) educational messages to educate backcountry visitors, using the following media: websites, visitor centers, printed media, personal contacts, and a Backcountry Information Center (BIC) where permits are provided. All backcountry visitors are required to watch an informative 30-minute video program presented at the BIC, where staff also provide additional LNT information and provide printed guidance. However, a review of educational messaging available at the website, in the BIC, and in the Backcountry Orientation Video (required viewing by backcountry overnight visitors), reveals that very little information specifically addresses low impact practices related to avoiding the creation of ITs. The main thrust of the current educational program is visitor safety, primarily related to bears, weather and navigational preparedness, and stream crossings.

The 2006 BMP (NPS 2006a) directs park staff to "Develop Leave No Trace guidelines that are specific for Denali National Park and Preserve…" a task which we support and provide additional suggestions for in this section. We also note that the national LNT program has developed an Alaskan Tundra Skills & Ethics booklet (not referenced in the BMP), and during this study and collaborations with ANWR staff we have concluded that there is a need for revising the current booklet with improved guidance based on the results of this study and recent management experience. A suggested "first draft" of LNT practices for avoiding the creation of ITs based on a dispersal strategy is included in Figure 14.

In addition to improving the guidance and specificity of LNT educational practices related to avoiding IT creation and use, another salient management challenge is the effective communication of LNT messages to day-hikers, who do not require use permits and rarely visit the BIC. A suggested option is preparation of a "Day-hikers Brochure" which could be available at visitor centers and distributed by bus drivers to passengers who plan to hike away from the Denali Road and formal trails. We suspect that an effective educational program could be established directing backcountry campers and serious day hikers to use formal and ITs when in high traffic Denali Road corridor areas and to disperse their use in most situations outside such areas. Less serious day hikers, primarily sightseeing bus riders, should likely simply be asked to use available trails. We doubt that it would be effective to direct these hikers to disperse their hiking activities.

Figure 14. A suggested "first draft" of revised Leave No Trace practices for avoiding the creation of ITs based on a dispersal strategy.

LEAVING NO TRACE OF YOUR VISIT IN DENALI NATIONAL PARK

Denali National Park is managed as a six million acre trail-less wilderness, where formal trails are not provided and managers actively seek to prevent the creation and proliferation of informal (visitor-created) trails. The management objective is to preserve opportunities for visitors to experience a remote and pristine Alaskan landscape influenced only by natural processes. When traveling through the Denali wilderness you will need to develop and apply navigational and route-finding skills and much of your cross-country hiking will be "off-trail." While wildlife trails may occasionally be found and used, an important management goal is to not "link them up" as a continuous trail network. That would compromise the unique Denali wilderness experience that few U.S. parks are capable of providing. Be aware that cross-country navigation will substantially slow your hiking speed and is physically challenging, so allow ample time to reach your destination. The information and guidance below is provided to help you "Leave No Trace" of your Denali National Park visit. Accept the personal responsibility to help us achieve our stewardship objectives so your grandchildren can experience a pristine Denali wilderness when they visit.

DISPERSE YOUR ACTIVITY IN PRISTINE AREAS

Will your recreational visit require off-trail travel? If not, then stick to formal marked trails and recreation sites in developed park areas. Recognize that the resource impacts of your visit on formal trails and sites are quite low; when you venture away from these resistant trails and sites your potential for harming natural resources is substantially higher. Accept the personal responsibility to "*Leave No Trace*" of your visit if you must venture away from formal trails and recreation sites.

You may encounter informal (visitor-created) trails and sites, often only distinguishable from their formal counterparts by their lack of blazes, markings, or signs. Understand that off-trail traffic frequently leads to the proliferation of these informal networks of trails and sites. Furthermore, studies show that visitor-created trails and sites are more susceptible to resource impacts because they lack professional design, construction, and maintenance.

If your visit includes travel into low-use pristine areas, or far from formal trails and recreation sites in popular areas, disperse your footsteps and activities to avoid repeat traffic and visible impact. If each person takes a slightly different route, a distinct trail won't form because no single plant receives multiple footfalls. Your objective in these areas is to avoid concentrated hiking or recreational activity that leaves visible impact to plants and soils. Do not use informal trails or recreation sites, including those that are lightly impacted, to promote their recovery. Research shows that even a few passes by hikers or more than one night of camping can substantially delay their recovery to natural conditions.

The degree of dispersal needed depends on the substrates your group encounters. Rock surfaces that lack plant or lichen cover can tolerate concentrated traffic, as can barren gravel shorelines or dry washes, and snow or ice. Walking single file is acceptable only where there is little chance of trampling plants. If you must travel or camp on vegetation, look for dry grassy meadows and tundra – grasses have flexible stems and leaves that resist damage and recover quickly. In contrast, low woody shrubs and broad-leafed herbs are highly susceptible to trampling damage – avoid these. When in doubt, periodically examine the effects of your group's passage and minimize visible impact by increasing dispersal or use of durable surfaces.

Even low or inconsistent traffic along the same routes can lead to the development of trails. Cross-country hikers will discover that topography and vegetation often acts to concentrate their traffic to common routes with fewer obstacles. Resist this tendency if you see any evidence of trail formation and keep your group broadly dispersed, with single file traffic only on durable rock, gravel, or snow surfaces. Recognize that dispersed off-trail travel requires constant route-finding vigilance and is considerably slower and more difficult than hiking on trails. Plan your schedule to allow plenty of time for off-trail hiking! Failure to disperse your group's traffic will accelerate the formation of continuous trails that will attract further use and impact.

Dispersed Camping. In pristine areas, minimize camping impacts by selecting the most resistant site available and staying only one night. Avoid *any* pre-existing camping spots to promote natural recovery. When possible, also avoid areas highly visible to others, vegetated shorelines, and areas with bird nesting activity or recent signs of wildlife. Locate your cooking area on the most durable site available, like a large rock slab, gravel, or barren area. Unless durable surfaces are available, prevent trail creation by limiting the number of trips and varying your routes to water, sleeping, and cooking areas. Monitor the effects of your activities, concentrating use on the most durable surfaces or dispersing your activities—whatever's necessary to avoid creating lasting impact.

Before departing, naturalize and disguise the site—your objective is for no one to see or use the site again. Fluff up flattened vegetation and organic material and replace any rocks or sticks you may have moved. Add leaf litter or pine needles to any scuffed up areas. If available, place a small log or large branch across your tenting and cooking areas to deter future use. Almost any forested setting can accommodate a single night of use each year without showing permanent effects; grassy areas can handle several nights. If you need to stay in one area longer, for example to conduct a wildlife study, plan on moving your campsite when lasting vegetation or soil impacts begin to show.

Also included in the 2006 BMP is guidance directing park staff to form a "social trails working group…to address specific problem areas through coordinated action" (NPS 2006a). An Access Management tools table was included to provide more specific guidance for addressing anticipated situations (Table 13). The development of improved LNT practices related to discouraging IT creation and the targeting of day-hikers should substantially aid management efforts selected for implementation by the working group.

Site Management Options

Research suggests that the efficacy of IT management efforts is enhanced by integrating visitor education and site management actions For example, a well-used informal trail provides a strong visual "releaser-cue" to visitors, inviting its use even though educational efforts may have effectively communicated to visitors that they should disperse their traffic (Hockett *et al.* 2010). Research has found that visitors are more likely to engage in inappropriate behavior if they see others engage in similar behavior (Gramann & Vander Stoep 1987, Reiter & Samuel 1980), or in this case see evidence that others have used in IT. It follows that management efforts designed to make ITs less visible to visitors would be expected to further reduce their use and enhance natural recovery.

Table 13. Access management tools included in the 2006 DENA BMP.

Situation	Strategy	Application of Access Management Tools
No social trail formation; terrain allows dispersal or travel on durable surfaces (e.g., gravel river beds).	Keep use dispersal	Provide Leave-No-Trace education for backcountry users to encourage continued dispersal and travel on durable surfaces.
No social trail formation at existing use levels, but terrain does not allow for dispersal or travel on durable surfaces.	Maintain use at level such that social trail formation does not begin.	Provide Leave-No-Trace education for backcountry users; manage guided groups to limit use; monitor level of use to detect increases; and limit number of visitors if necessary.
Social trails are present and are either stable or deteriorating, but additional dispersal is possible.	Encourage additional dispersal to lower levels of use on the social trail.	Provide Leave-No-trace education for backcountry users and encourage voluntary dispersal coordination through a social trails working group (see #2 below).
Social trails are present but stable at existing levels of use; little opportunity for dispersal.	Concentrate use on social trail and limit use sufficiently to prevent deterioration.	Educate visitors or restrict them to social trail, and limit numbers of visitors if necessary.
Social trails are present and are deteriorating; additional dispersal is not possible because of terrain.	Lower use levels until condition stabilizes.	Limit number of visitors or use temporary closures to restrict use.
In addition, the National Park Service may temporarily close some areas around social trails to allow rehabilitation even if conditions are stable.		

Research at Potomac Gorge near Washington, D.C., investigated and documented the efficacy of educational and site management options (Hockett *et al.* 2010). In an experimentally designed study, one treatment posted educational signs asking visitors to remain on a formal trail, along with small symbolic prompter signs attached to logs placed across all ITs branching off of the formal trail. A second treatment brushed up the initial visible portions of ITs in an effort to disguise them, or at least make them appear as low use trails. The educational sign treatment reduced observed off-trail traffic from 30% to 6.5% and adding the brushing treatment further reduced the off-trail rate to 2.0%. The brushing work in this study consisted of adding organic leaf litter to the trail treads, along with a few sticks and rocks. The intent was to naturalize the ITs appearance, rather than physically obstruct traffic. This was done because the objective was to protect native vegetation and rare plants – previous studies that used substantial brushing to obstruct IT use found that many visitors simply went around the obstructions, creating new trails. This was particularly true when the intent of the brushing treatments was not explained through educational signs (Johnson *et al.* 1987). Some visitors actively removed the brush.

The implications of these studies for DENA staff are that they could enhance the effectiveness of educational actions by adding or expanding efforts to conduct physical trail closure work. However, in many DENA environmental settings there is little organic litter or brush available to place on ITs and in some settings this action could make ITs intended for closure more visually obvious. This is likely acceptable as long as the work clearly communicates that the actions are intended to close the trails to use. For example, at Acadia NP managers have had success concentrating traffic on preferred sustainable ITs by clipping woody shrubs to keep them open and placing the clipped materials on adjacent duplicative ITs to discourage their use (Figure 15).

This could be an effective practice in higher traffic areas where duplicative trails have developed. Further development and experimentation with alternate site management treatments is needed at DENA to identify effective practices. In non-wilderness areas we suggest such experimentation might include educational signs and/or symbolic prompter signs (Figure 15).

Finally, as noted in previous discussions and recognized by DENA staff in Table 13 guidance, managers will need to make determinations of when traffic should be focused on ITs, with closure of near-by duplicative ITs, and when visitors should be directed to disperse all traffic. Making these decisions and communicating appropriate site specific guidance to visitors will be a significant ongoing challenge. We suspect that in the Denali Road corridor, site management actions and signs may both be necessary for the effective closure of ITs.

Figure 15. Example of a recommended 3x4 inch prompter sign to deter IT use, and illustration of effective brushing work from Little Moose Island, Acadia NP.

LITERATURE CITED

Abele, G. 1976. Effects of Hovercraft, wheeled and tracked vehicle traffic on tundra. *In*: Nat Res Counc Can Assoc Comm Geotch Res., Tech Memo 116: 186-215.

Abele, G., Brown, J. & Brewer, M.C. 1984. Long-term effects of off-road vehicle traffic on tundra terrain. *J. Terrain Mechanics* 21(3): 13-27.

Adkison, G.P. & Jackson, M.T. 1996. Changes in ground-layer vegetation near trails in Midwestern U.S. forests. *Natural Areas Journal* 16: 14-23.

Aust, M.W., Marion, J.L. & Kyle, K. 2004. Research for the development of Best Management Practices for minimizing horse trail impacts on the Hoosier National Forest. Virginia Tech, Dept. of Forestry, Final Research Report. Blacksburg, VA. 77 p.

Bacon, J., Roche, J., Elliot, C. & Nicholas, N. 2006. VERP: Putting principles into practice in Yosemite National Park. *The George Wright Forum 23*(2): 73-83.

Baxter, V.A. 1997. Trails Monitoring and Assessment Manual. USDI Denali National Park, Research and Resource Management Division, Denali Park, AK.

Bayfield, N.G. & Lloyd, R.J. 1973. An approach to assessing the impact of use on a long distance footpath - the Pennine Way. *Recreation News Supplement* 8: 11–17.

Benninger-Truax, M., Vankat, J.L. & Schaefer, R.L. 1992. Trail corridors as habitat and conduits for movement of plant species in Rocky Mountain National Park, Colorado, USA. *Landscape Ecology* 6(4): 269-278.

Bhuju, D.R. & Ohsawa, M. 1998. Effects of nature trails on ground vegetation and understory colonization of a patchy remnant forest in an urban domain. *Biological Conservation* 85: 123-135.

Boucher, D., Aviles, J., Chepote, R., Domínguez Gil, O. & Vilchez, B. 1991. Recovery of trailside vegetation from trampling in a tropical rain forest. *Environmental Management* 15: 257-262.

Bratton, S.P., Hickler, M.G. & Graves, J.H. 1979. Trail erosion patterns in Great Smoky Mountains National Park. *Environmental Management* 3: 431–445.

Cao, L., Stow, D., Kaiser, J. & Coulter, L. 2007. Monitoring cross-border trails using airborne digital multispectral imagery and interactive image analysis techniques. *Geocarto International* 22(2): 107-125.

Christensen, H.H. & Clark, R.N. 1983. Increasing public involvement to reduce depreciative behavior in recreation settings. *Leisure Sciences* 5(4): 359-379.

Cole, D.N. 1982. Wilderness recreation site impacts: effect of amount of use. USDA Forest Service Research Paper INT-284. Ogden, UT. 34 p.

Cole, D.N. 1983. Assessing and monitoring backcountry trail conditions. Research Paper INT-303, USDA Forest Service, Intermountain Research Station. Ogden, UT. 10 p.

Cole, D.N. 1987. Research on soil and vegetation in wilderness: A state-of-knowledge review. *In*: Lucas, R.C. comp. Proceedings – National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions; Fort Collins, CO. General Technical Report INT-220. USDA Forest Service, Intermountain Research Station, Ogden, UT, pp. 135-177.

Cole, D.N. 1989. Wilderness campsite monitoring methods: A sourcebook. General Technical Report INT-259. USDA Forest Service, Intermountain Research Station, Ogden, UT. 57p.

Cole, D.N. 1990. Trampling disturbance and recovery of cryptogamic soil crusts in Grand Canyon National Park. *Great Basin Naturalist* 50: 321-325

Cole, D.N. 1991. Changes on trails in the Selway-Bitterroot Wilderness, Montana, 1978-89. Res. Pap. INT-450. USDA Forest Service, Intermountain Research Station, Ogden, UT. 5 p.

Cole, D.N. 1992. Modeling wilderness campsites: Factors that influence amount of use. *Environmental Management* 16: 255–264.

Cole, D.N. 1993. Minimizing Conflict between Recreation and Nature Conservation, In Ecology of Greenways Design and function of linear conservation areas. eds D.S. Smith, P.C. Hellmund, p. 222. University of Minnesota Press, Minneapolis, MN.

Cole, D.N. 1995a. Disturbance of natural vegetation by camping: Experimental applications of low-level stress. *Environmental Management* 193: 405-416.

Cole, D.N. 1995b. Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. *Journal of Applied Ecology* 32: 203-214.

Cole, D.N. 2004. Impacts of hiking and camping on soils and vegetation: A review. *In*: Environmental Impacts of Ecotourism. R. Buckley (editor). CABI Publishing, Cambridge, MA.

Cole, D.N., Watson, A.E., Hall, T.E. & Spildie, D.R. 1997. High-use destinations in wilderness: Social and biophysical impacts, visitor responses, and management options. Research Paper INT-RP-496. Rocky Mountain Research Station, Ogden, UT.

Dixon, G., Hawes, M. & McPherson, G. 2004. Monitoring and modeling walking track impacts in the Tasmanian Wilderness World Heritage Area, Australia. *Journal of Environmental Management* 71(4): 305-320.

Ferris, T.M.C., Lowther, K.A. & Smith, B.J. 1993. Changes in footpath degradation 1983–1992: A study of the Brandy Pad, Mourne Mountains. *Irish Geography* 26: 133-140.

Fritz, J.D. 1993. Effects of trail-induced sediment loads on Great Smoky Mountains National Park high gradient trout streams. M.S. Thesis. Tennessee Technological University, Cookville, TN.

Furbish, C.E. 1996. Trails and Nodes Monitoring Program: Annual Progress Report. USDI National Park Service, Denali National Park, Research and Resource Management Division.

Grabherr, G. 1982. The impact of trampling by tourists on a high altitudinal grassland in the Tyrolean Alps, Austria. *Plant Ecology* 48: 209-217.

Gramann, J.H. & Vander Stoep, G.A. 1987. Prosocial behavior theory and natural resource protection: a conceptual synthesis. *Journal of Environmental Management* 24: 247-257.

Hall, C.N. & Kuss, F.R. 1989. Vegetation alteration along trails in Shenandoah National Park, Virginia. *Biological Conservation* 48: 211–227.

Hammitt, W.E. & Cole, D.N. 1998. Wildland Recreation: Ecology and Management (2nd Ed.). John Wiley and Sons, New York, NY.

Happe, P.J., Shea, K.E. & Loya, W.M. 1998. Assessment of All-Terrain Vehicle (ATV) Impacts within Wrangell-St. Elias National Park and Preserve, Alaska. 1997. WRST Research and Resource Management Report, No. 98-1. Wrangell-St. Elias National Park and Preserve, Copper Center, AK.

Hill, W. & Pickering, C.M. 2006. Vegetation associated with different walking track types in the Kosciuszko alpine area, Australia. *Journal of Environmental Management* 78: 24-34.

Hockett, K., Clark, A., Leung, Y.F., Marion, J.L. & Park, L. 2010. Deterring Off-trail Hiking in Protected Natural Areas: Evaluating Options with Surveys and Unobtrusive Observation. Final Research Report. Virginia Tech College of Natural Resources & Environment, Blacksburg, VA.

Hollenhorst, S. & Gardner, L. 1994. The indicator performance estimate approach to determining acceptable wilderness conditions. *Environmental Management*. 18(6): 901-906.

Johnson, B.R., Bratton, S.P., & Firth, I. 1987. The Feasibility of Using Brushing to Deter Visitor Use of Unofficial Trails at Craggy Gardens, Blue Ridge Parkway, North Carolina (CPSU Report No. 43). National Park Service Cooperative Studies Unit, Institute of Ecology, University of Georgia, Athens, GA.

Kaiser, J.V., Stow, D.A. & Cao, L. 2004. Evaluation of remote sensing techniques for mapping transborder trails. *Photogrammetric Engineering & Remote Sensing* 70(12): 1441–1447.

Kasworm, W.F. & Monley, T.L. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. *In*: L.M. Darling & W.R. Archibald (Eds.), Bears: Their Biology and Management: Proceedings of the 8th International Conference (pp. 79-84). International Association for Bear Research and Management, Victoria, BC.

Keirle, I. & Stephens, M. 2004. Do walkers stay on footpaths? An observational study of Cwm Idwal in the Snowdonia National Park. *Countryside Recreation* 12(2): 7-9.

Kincey, M. & Challis, K. 2010. Monitoring fragile upland landscapes: The application of airborne lidar. *Journal of Nature Conservation* 18(2): 126-134.

Knight, R.L. & Cole, D.N. 1995. Wildlife responses to recreationists. *In:* Knight, R.L. & K.J. Gutzwiller., eds. Wildlife and Recreationists: Coexistence through Management and Research. Island Press, Washington, DC. pg. 51-70.

Lehvavirta, S. 1999. Structural elements as barriers against wear in urban woodlands. *Urban Ecosystems* 4(1): 45-56.

Leung, Y.F. & Louie. 2008. Visitor Experience and Resource Protection, Data Analysis Protocol: Social Trails. Final Technical Report submitted to USDI National Park Service, Yosemite National Park. North Carolina State University, Dept of Parks, Recreation, and Tourism Management, Raleigh, NC. 17 p.

Leung, Y.F. & Marion, J.L. 1996. Trail degradation as influenced by environmental factors: A state-of-knowledge review. *Journal of Soil and Water Conservation* 51: 130-136.

Leung, Y.F. & Marion, J.L. 1999a. Assessing trail conditions in protected areas: An application of a problem-assessment method in Great Smoky Mountains National Park, USA. *Environmental Conservation* 264: 270-279.

Leung, Y.F. & Marion, J.L. 1999b. Characterizing backcountry camping impacts in Great Smoky Mountains National Park, USA. Journal of Environmental Management 57, 193-203.

Leung, Y.F. & Marion, J.L. 1999c. Spatial strategies for managing visitor impacts in National Parks. *Journal of Park and Recreation Administration* 17(4): 20-38.

Leung, Y.F. & Marion J.L. 2000. Recreation impacts and management in wilderness: A state-of-knowledge review. *In:* Cole, D.N., McCool, S.F., Borrie, W.T., O'Loughlin, J. (comps) Wilderness science in a time of change conference, Vol 5. Wilderness ecosystems, threats and management. Proceedings RMRS-P-15-Vol-5. USDA Forest Rocky Mountain Research Station, pp 23–48.

Leung, Y.F., Newburger, T., Jones, M., Kuhn, B. & Woiderski, B. 2011. Developing a monitoring protocol for visitor-created informal trails in Yosemite National Park, USA. *Environmental Management* 47: 93-106.

Leung, Y.F., Shaw, N. Johnson, K. & Duhaime, R. 2002. More than a database: Integrating GIS data with the Boston Harbor Islands visitor carrying capacity study. *George Wright Forum* 19(1): 69–78.

Liddle, M.J. & Greig-Smith, P. 1975. A survey of tracks and paths in a sand dune ecosystem, I. Soils. *Journal of Applied Ecology* 12: 893-908.

Lucas, R.C. 1979. Perceptions of non-motorized recreational impacts: A review of research findings. *In:* Ittner, R.; Potter, D.R.; Agee, J.K.; Anschell, S., eds. Recreational Impact on Wildlands: Conference Proceedings; Seattle, WA. R-6-001-1979.: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station and USDI National Park Service: 24-31.

Lynn, N.A. & Brown, R.D. 2003. Effects of recreational use impacts on hiking experiences in natural areas. *Landscape and Urban Planning* 64(1/2): 77-87.

Manning, R., Jacobi, C. & Marion, J.L. 2006. Recreation monitoring at Acadia National Park. *The George Wright Forum* 23(2):59-72.

Marion, J.L. 1991. Developing a natural resource inventory and monitoring program for visitor impacts on recreation sites: A procedural manual. Natural Resources Report NPS/NRVT/NRR-91/06. Denver, CO: USDI National Park Service, Natural Resources Publication Office. 59p.

Marion, J.L. 1994. An assessment of trail conditions in Great Smoky Mountains National Park. Research and Resources Management Report. USDI National Park Service, Southeast Region, Atlanta, GA. 155p.

Marion, J.L. & Olive, N. 2006. Assessing and understanding trail degradation: results from Big South Fork National River and Recreational Area. USDI, U.S. Geological Survey, Final Research Rpt., Virginia Tech Field Station, Blacksburg, VA. 82p.

Marion, J.L. & Cahill, K. 2006. Monitoring the resource Impacts of visitor use: A protocol for the long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore. USDI, U.S. Geological Survey, Final Research Rpt., Virginia Tech Field Station, Blacksburg, VA.

Marion, J.L. & Cole, D.N. 1996. Spatial and temporal variation in soil and vegetation impacts on recreation sites. *Ecological Applications* 62: 520-530.

Marion, J.L. & Hockett, K. 2008a. Trail and campsite monitoring protocols: Zion National Park. USDI, U.S. Geological Survey, Final Research Rpt., Virginia Tech Field Station, Blacksburg, VA. 65p.

Marion, J.L. & Hockett, K. 2008b. Frontcountry recreation site and trail conditions: Haleakalä National Park. USDI, U.S. Geological Survey, Final Research Rpt., Virginia Tech Field Station, Blacksburg, VA. 88p.

Marion, J.L. & Leung, Y.-F. 2001. Trail resource impacts and an examination of alternative assessment techniques. *Journal of Park & Recreation Administration* 191: 17–37.

Marion, J.L. & Leung, Y.F. 2004. Environmentally sustainable trail management. *In*: Buckley, R. (ed.), Environmental Impact of Tourism, Cambridge, MA: CABI Publishing. pp. 229-244.

Marion, J.L., Leung, Y.F. & Nepal, S. 2006. Monitoring trail conditions: New methodological considerations. *George Wright Forum* 232: 36–49.

Marion, J.L. & Lime, D.W. 1986. Recreational resource impacts: Visitor perceptions and management responses. *In*: Kulhavy, D.L.; Conner, R.N., eds. Wilderness and Natural Areas in the Eastern United States: A Management Challenge Nacogdoches, TX: Stephen F. Austin State University, School of Forestry: 229-235.

Matheny, S.J. 1979. A successful campaign to reduce trail switchback shortcutting. *In*: Recreational impacts on wildlands. USDA Forest Service, Portland, OR. pp. 217-221.

Merigliano, L.L. 1990. Indicators to monitor wilderness conditions. *In*: D.W. Lime Ed., Managing America's Enduring Wilderness Resource. University of Minnesota, Agricultural Experiment Station and Extension Service, St. Paul, MN. pp. 205–209.

Meyer, K. 2002. Proposed Best Management Practices (BMPs) for OHV/ATV Trail Management in Alaska, Draft. USDI, National Park Service, Alaska Regional Office, Trails and Conservation Assistance Program.

Meyer, K. 2011. A Comprehensive Framework for Off-Highway Vehicle Trail Management. USDA Forest Service, Missoula Technology & Development Program, 1123-2804-MTDC.

Miller, S.G., Knight, R.L. & Miller, C.K. 1998. Influence of recreational trails on breeding bird communities. *Ecological Applications* 8: 162-169.

Monz, C.A. 2002. The response of two arctic tundra plant communities to human trampling disturbance. *J. of Environmental Mgmt*. 64: 207-217.

NPS. 1997. The Visitor Experience and Resource Protection (VERP) framework: A handbook for planners and managers (Publication No. NPS D-1215). USDI National Park Service, Denver Service Center, Denver, CO.

NPS. 2003. Off-Road Vehicle (ORV) Use in Alaska National Park System Units. USDI National Park Service, Alaska Region, Alaska Support Office, Anchorage, AK.

NPS. 2006a. Denali National Park and Preserve Final Backcountry Management Plan, General Management Plan Amendment and Environmental Impact Statement. USDI National Park Service, Denali National Park and Preserve, Denali Park, AK.

NPS. 2006b. Management Policies. USDI National Park Service, Washington, D.C.

NPS. 2011. National Park Service Visitor Use Statistics. USDI, NPS Public Use Statistics Office. http://www.nature.nps.gov/stats/viewReport.cfm

Newsome, D., Moore, A.A. & Dowling, R.K. 2002. Natural Area Tourism: Ecology, Impacts and Management. Channel View Publications, Cleveden, UK.

O'Connor, J.S. & Dewling, R.T. 1986. Indices of marine degradation, their utility. *Environmental Management* 10: 335-343.

Olive, N.D. & Marion, J.L. 2009. The influence of use-related, environmental, and managerial factors on soil loss from recreational trails. *Journal of Environmental Management* 90: 1483–1493.

Park, L.O., Marion, J.L., Manning, R.E., Lawson, S.R. & Jacobi, C. 2008. Managing visitor impacts in parks: A multi-method study of the effectiveness of alternative management practices. *Journal of Parks and Recreation Administration* 26(1): 97-121.

Pearce-Higgins, J.W. & Yalden, D.W. 1997. The effect of resurfacing the Pennine Way on recreational use of blanket bog in the Peak District National Park, England. *Biological Conservation* 82(3): 337-343.

Potito, A.P. & Beatty, S.W. 2005. Impacts of recreation trails on exotic and ruderal Species distribution in grassland areas Along the Colorado Front Range. *Environmental Management* 36, 36(2): 230-236.

Reid, R.S. & Schreiner, E.S. 1985. Long-term experimental trampling on plant communities in Denali National Park, Alaska, USA. Resource Management Office, Denali National Park, Alaska. Unpublished report. 94 pp.

Reiter, S.M. & Samuel, W. 1980. Littering as a Function of Prior Litter and the Presence or Absence of Prohibitive Signs. *Journal of Applied Social Psychology* 10: 45-55.

Rochefort, R.M. & S.T. Gibbons. 1992. Mending the meadow: High-altitude meadow restoration in Mount Rainier National Park. *Restoration and Management Notes* 10: 120-126.

Roggenbuck, J.W., Williams, D.R. & Watson, A.E. 1993. Defining acceptable conditions in wilderness. *Environmental Management*. 17(2): 187-197.

Roovers, P., Bossuyt, B., Gulnick, H. & Hermy, M. 2005. Vegetation recovery on closed paths in temperate deciduous forests. *Journal of Environmental Management* 74(3): 273-281.

Stankey, G.H., Cole, D.N., Lucas, R.C., Peterson, M.E., Frissell, S.S. & Washburne, R.F. 1985. The Limits of Acceptable Change (LAC) System for wilderness planning. USDA Forest Service General Technical Report INT-176.

Sutherland, R.A., Bussen, J.O., Plondke, D.L., Evans, B.M. & Ziegler, A.D. 2001. Hydrophysical degradation associated with hiking-trail use: a case study of Hawai'iloa Ridge Trail, O'ahu, Hawai'i. *Land Degradation & Development* 12: 71-86.

Sutter, R.D., Benjamin, S.E., Murdock, N. & Teague, B. 1993. Monitoring the effectiveness of a boardwalk at protecting a low heath bald in the southern Appalachians. *Natural Areas Journal* 13(44): 250-255.

Thurston, E. & Reader, R.J. 2001. Impacts of experimentally applied mountain biking and hiking on vegetation and soil of a deciduous forest. *Environmental Management* 27: 397-409.

Tyser, R.W. & Worley, C.A. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). *Conservation Biology* 6(2): 253-262.

Vaske, J.J., Graefe, A.R. & Dempster, A. 1982. Social and environmental influences on perceived crowding. *In*: Boteler, F.E., ed. Proceedings: Third Annual Conference of the Wilderness Psychology Group; Morgantown, WV. Morgantown, WV: West Virginia University, Division of Forestry: 211-227.

Weaver, T. & Dale, D. 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. *The Journal of Applied Ecology* 15: 451-457.

Wimpey, J. & Marion, J.L. 2011a. A spatial exploration of informal trail networks within Great Falls Park, VA. *Journal of Environmental Management* 92: 1012-1022.

Wimpey, J. & Marion, J.L. 2011b. Formal and informal trail monitoring protocols and baseline conditions: Great Falls Park and Potomac Gorge. Final Research Report. U.S. Geological Survey, Distributed by the Virginia Tech College of Natural Resources & Environment, Blacksburg, VA.

Wing, M. & Shelby, B. 1999. Using GIS to integrate information on forest recreation. *Journal of Forestry* 97: 12–16.

Witztum, E.R. & Stow, D.A. 2004. Analyzing direct impacts of recreation activity on coastal sage scrub habitat with very high resolution multi-spectral imagery. *International Journal of Remote Sensing* 25(17): 3477-3496.

Wolper, J., Mohamed, S., Burt, S. & Young, R. 1994. Multisensor GPS-based recreational trail mapping. *In*: Proceedings of ION GPS 1994. Vol 7/6, pp. 237–244. Alexandria, VA: Institute of Navigation.

Womble, P. 1979. Survey of backcountry users in Mount McKinley National Park, Alaska: A report for management. Cooperative Park Studies Unit, University of Washington, Seattle, WA.

Wood, K.T., Lawson, S.R. & Marion, J.L. 2006. Assessing recreation impacts to cliffs in Shenandoah National Park: Integrating visitor observation with trail and recreation site measurements. *Journal of Park & Recreation Administration* 24(4): 86-110.

Wooding, F.J. & Sparrow, S.D. 1979. An assessment of damage caused by off-road vehicle traffic on subarctic tundra in the Denali Highway area of Alaska. *In:* Ittner, R.; Potter, D.R.; Agee, J.K.; Anschell, S., eds. Recreational Impact on Wildlands: Conference Proceedings; Seattle, WA. R-6-001-1979. USDA Forest Service, Pacific Northwest Forest and Range Experiment Station and USDI National Park Service. pp. 89-93.

APPENDIX 1: MONITORING PROTOCOLS FOR ASSESSING FORMAL AND INFORMAL TRAILS

Denali National Park

ESTABLISHING MONITORING ZONES

The spatial distribution of visitation can vary substantially within protected natural areas, ranging from very high near popular attraction features to very low in remote inaccessible areas. The establishment of monitoring zones can help designate the priorities and intensities of trail monitoring efforts. The most remote areas require no monitoring effort if there is good reason to believe that no visitor-created trails exist. In contrast, areas near roads, campgrounds, or other facilities may have or could develop dense networks of human trails that require more intensive monitoring. Therefore, an initial step in the trail monitoring effort is to establish zones to prescribe trail monitoring effort, from none to intensive. The following section describes a process for accomplishing this objective, though it is expected that over time, and as data is collected, that such monitoring guidance will be updated and revised.

Levels of Monitoring Effort

The type of trail monitoring employed will depend on the existing and expected number, extent, and condition of trails. Higher levels of monitoring effort will generally be applied to areas and trails that receive more intensive use and impact. Several types of trail monitoring protocols are recommended, which are listed here and fully described in later sections.

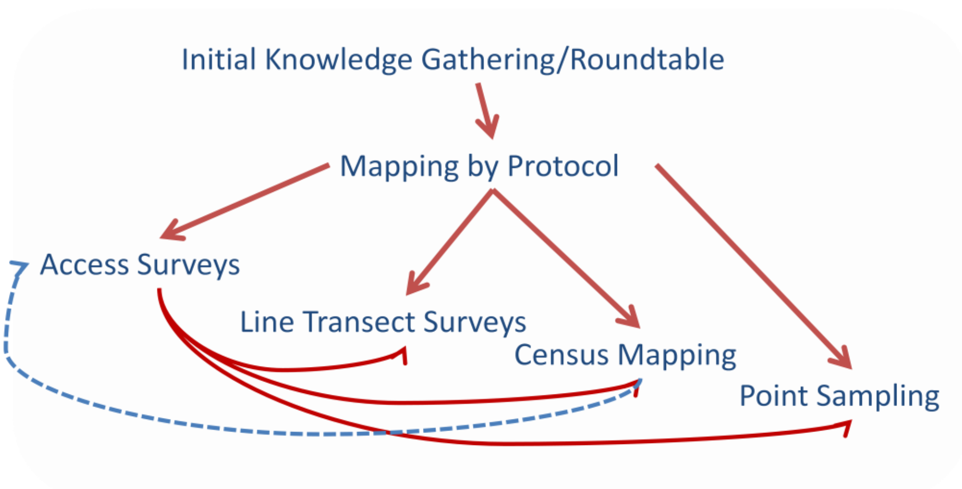
- No trail monitoring within remote/inaccessible areas.
- Access survey – This method provides an efficient census of all informal trails leaving a road or formal trail corridor, documented by point data. The condition of informal trail segments can also be optionally assessed.
- Line transect survey – This method provides informal trail condition data assessed along one or more transects arranged perpendicular to the prevailing direction of travel within travel corridors. Informal trail locations are depicted by point data for each transect/trail intersection.
- Census mapping survey – This method provides comprehensive mapping data for all informal trails within a defined monitoring area, or an intelligent search through a travel corridor. The condition of informal trail segments can also be optionally assessed.
- Point sampling survey – This intensive survey method provides more comprehensive quantitative condition data taken at regularly spaced points along well-established formal or informal trails.
- Route finding experience survey – This method is an opportunistic assessment of the trail-less experience applied by visitors or backcountry staff during backcountry hikes.

Regardless of the protocol used, they should be replicated periodically (e.g., every 3-10 yrs) to document change over time. Furthermore, surveys should only be conducted in the last half of the summer use season when evidence of human use on trails is most pronounced.

Monitoring Zones

The geography and probable use patterns of the protected area are used to define trail zones. These can be organized by distance from roads and expected impacts.

1. Infrastructure areas (roads, parking areas, visitor centers, remote airstrips, buildings, etc.)
2. Frontcountry nodes (dense networks of trails leading from infrastructure areas to attraction features)
3. Road corridor areas with trails expected
4. Road corridor areas with no trails expected
5. Closed areas (e.g., wildlife closures)
6. Well-used formal or informal trails with static alignments
7. Backcountry travel corridors with likely trail formation to attraction features
8. Backcountry travel corridors with no trail formation expected
9. Remote/inaccessible areas



Suggested informal trail monitoring decision tree. Initial monitoring strategies are to be selected by roundtable discussion and zoning of the park by managers and staff.

Zone Establishment with a Roundtable Process

The key to establishing the zones is to collect data on known and suspected areas of trail establishment. Gathering a group of the most relevant and experienced protected area staff to have a roundtable discussion, while drawing lines on maps, is a useful method. Other data sources are hiker contact locations from backcountry patrols; interviews of visitors, local guides, hike leaders, and bus drivers; a survey of access points along roads; previous trail monitoring data, a plot of the hikes listed in guidebooks; trip reports on the web; and special destination or attraction feature points.

Data from the roundtable effort could be assembled into GIS layers to show discrete areas of probable human trail development defined by mapped polygons. Each polygon is assigned an initial level of trail monitoring (type, intensity, and priority). Additional layers include known and suspected trails and access points, formal trails, developed sites (roads, parking areas, administration areas, campgrounds, ranger stations, etc.) and closures.

In monitoring zones 1, 4, 5, 8, and 9 trail monitoring will generally not be conducted, except as captured through the roadside access survey. For the remaining zones roundtable staff will need to decide between four types of monitoring. Generally, the route finding assessments are applied only to zone 7, backcountry travel corridors with likely trail formation. Similarly, point sampling is applied only to zone 6, well-used formal or informal trails with static alignments. For the remaining zones, 2, 3, and 7, line transect surveys are generally recommended as the most appropriate and efficient first step for areas that require some level of monitoring beyond the roadside trail survey. This survey requires about 25-35% of the time required to conduct the more comprehensive trail census mapping, which is generally more appropriate for high-use areas with dense networks of informal trails. However, where time permits, managers may also find that trail mapping provides useful information for documenting longer informal trails that do not occur in areas of dense trail networks.

In considering whether to monitor an area or the type of monitoring to apply, consider both existing conditions and expected changes in use or management actions. For example, areas with few trails that are in acceptable condition may be less important to monitor, though documenting baseline conditions even for such trails remains an important management objective. However, areas with few trails in poor condition or areas expected to see increased use or where management actions are likely will generally be areas of higher priority monitoring. The monitoring process should be a key component of adaptive management decision making.

As trail monitoring data is collected, the boundaries between the zones can be adjusted. For example, increased use in an area may lengthen trails that then allow day hikers to move further away from roads over time. This would extend the outer boundary of monitoring zones—with an accompanying change in monitoring prescription.

One issue of concern is training field staff to distinguish between trails that are primarily created and used by wildlife from those that are created and primarily used by visitors. The following text box contains information to guide that decision-making, but field experience and training are also needed to improve the precision (consistency) of these judgments. This guidance can be revised as other indicators are noticed and refined to improve these determinations.

Distinguishing Visitor & Wildlife Trails

Field staff will need to distinguish between informal trails that are primarily created and used by park visitors from those that are primarily created and used by "wildlife." Trails that are "mostly wildlife" are omitted from the Census Survey and are recorded but not assessed for resource condition in the Access and Line Transect Surveys. These criteria are included to help distinguish between these "type of use" determinations.

Spatial Criteria: Visitor trails frequently start at the Denali Road near a high-use location and lead into the backcountry, often splitting into parallel routes but eventually becoming discontinuous and disappearing. These trails also lead to attraction features like vistas or follow traditional routes of visitor use. These spatial attributes can be a good indicator of visitor-created trails. Wildlife trails that intersect the road generally have a "mirror" image trail directly across the road – look for these.

Visitor trails are generally "directionally consistent" over longer distances – consistently heading towards some destination. Visitor trails actively seek out and remain within the easiest topography and vegetation for human travel. Wildlife trails are generally more haphazard, they meander and often don't purposefully avoid wet areas.

Wildlife Sign Criteria: Knowledge about the ecology and natural history of the wildlife can assist decision-making. For example, sheep trails frequently descend steeply to cross the road at narrow mountain gaps, while caribou trails frequently appear as numerous roughly parallel routes through flat to gently sloped terrain. Moose trails favor areas with willow thickets and evidence of their browsing along the trail is common. In areas of woody vegetation, trails created by smaller mammals can be discounted because they are very narrow (<8 in) and go directly under branches that would obstruct human passage. These types of trails are the easiest to discount/omit.

Close inspection of the trail tread also offer distinguishing criteria. Animal feces/pellets and hoof or boot prints in or near the trail tread are common and fairly reliable indicators. Hoofs generally shear off the trail edges, which are often nearly vertical, where the sides of human trails are more rounded. The width of trails can be an important indicator; wildlife trails are narrower than human trails (often less than 8 inches). Wildlife generally make no effort to detour around wet areas or to step on clumps of higher ground or vegetation, humans do, leaving visually obvious trampled and flattened clumps of

ACCESS SURVEY

Objectives

This survey documents the number and distribution of ITs that intersect a road or formal trail corridor. This is an efficient survey method that can be conducted quickly but doesn't provide information on trail alignments or destinations. Optional procedures are included for assessing trail conditions at sample points near the trailhead.

Guidance

This survey could be conducted early in the monitoring process to inform the roundtable zoning process. Staff training should focus on developing consistent judgment on when to assess or not assess faint or discontinuous informal trails – a set of reference photographs are included to assist in the consistency of these judgments. Trails judged to be predominantly created and used by wildlife are recorded with a GPS point but are excluded from further resource condition assessments (see guidance: *Distinguishing Visitor and Wildlife Trails*, page 75). Note that some wildlife trails may occur in areas that receive frequent human use (e.g., near bus stopping or common drop-off locations) – these should be assessed and generally labeled as "mixed human/wildlife use"). A Trimble GPS is used for this survey to obtain accurate spatial data on IT trailheads and to efficiently enter and transfer optional IT condition assessment data.

The Access Survey is conducted by staff who are familiar with the distribution of hiking/backpacking use along the Denali Park Road. Likely candidates include Rangers who routinely patrol the road and/or staff from the Backcountry desk involved with backcountry permits. Consultations with bus operators to discover popular day-hiking locations are also helpful. The Denali Road can be assessed by driving to and searching on foot all locations where human use trails might be expected to occur. Note that trails may depart from locations not visible from a vehicle, such as 100 ft out along a stream corridor. Ground searches on foot are focused along the interface boundary between disturbed road corridor vegetation/substrates and more pristine natural vegetation/substrates.

Methods

<u>Materials</u>

- ✓ Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- ✓ Trimble GPS w/submeter accuracy, charged battery(s), antenna, stylus, appropriate data dictionary.
- ✓ Tape measure, 6 ft.
- ✓ Geotag-enabled digital camera that links with Trimble GPS position data (preferred). Option: use a standard digital camera, set it's time date/time to match the Trimble unit, and use a software program that matches date/time stamps to record location data to the photo file (geotagging).
- ✓ Telescopic antenna or presentation pointer (extending to 4 ft).
- ✓ Logbook

<u>Field Procedures</u>: Survey staff should be familiar with the amount and distribution of hiking/backpacking use along the road or trail corridor to be assessed, particularly the locations where visitors are most likely to depart the road or formal trail corridor. Consultations with experienced public or private staff may yield important guidance and advice on locations where visitors commonly begin or end their off-road/off-trail hikes.

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the Access Survey data dictionary from the pick list. Select the Map screen and open the Layers dialog. Select the Setup screen, and open the Logging Settings dialog.
- Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.
- Drive or bike the road or hike the formal trail and use prior information and personal knowledge to stop and carefully check locations where ITs are expected. When driving roads, always get out and walk roadsides to locate trails in areas near pullouts, parking lots, and areas where visitor-created trails are expected. Record a "Search Log" lineal feature that documents the extent of your search. Away from pullouts, roadsides may be able to be surveyed by a non-driving vehicle passenger.
- Focus your assessment on ITs at the outer boundary of human-caused disturbance associated with road/trail construction or maintenance work, e.g., look at the leading edge of undisturbed native vegetation, even if it is located some distance from the road or trail.
- *Include all ITs that have the following attributes*: 1) visitor- or wildlife-created trails that show clear signs of trampling disturbance created by this year's traffic, 2) segments that extend at least 20 feet in length, and 3) trails that remain clearly visible if you cover one eye (this eliminates faint trails that are indistinct without depth perception). Note that ordered gravel in gravelly substrates can qualify as a trail if visually obvious. Figure 1 provides reference photos of relatively faint ITs to illustrate different types of resource changes that provide visual clues for discerning these trails. Do not include formal trails or extremely faint, discontinuous IT's. Assign *Use Type* determination as: a) human, b) mostly human/some wildlife, or c) mostly wildlife. See guidance: *Distinguishing Visitor and Wildlife Trails*, page 75.

At the outer boundary of road or trail-related disturbance where you locate an IT, collect an "Access Trail Photo Point." Walk back toward the road or formal trail about 10-15 ft from the trailhead location and take a vertical photograph showing the trail in relation to the leading edge of vegetation and including the horizon near the top of the photo. Be sure to orient the camera in a downward angle to clearly document the trail's tread conditions – refer to Figure 1 for examples. Record a GPS point at this location. Tread condition assessments may be assessed using these photos.

At the outer boundary of road or trail-related disturbance where you locate an IT, walk out the IT 20 feet and collect a GPS point using the "Access" point type in the data dictionary. Take a photo of this location from a height of 4.5 feet with a 50mm lens and clearly showing the tread condition and barely including the horizon with a distinctive feature. Record the azimuth from the camera to the waypoint location. At this point, assess the trail's use type and any of the optional condition assessment indicators described below. If the trail splits before this point, collect the GPS point and assess these indicators for the last section of trail immediately prior to the split.

Optional Condition Assessment Protocols – Not assessed for mostly wildlife use IT's.

1) *Trail Width (TW):* Measure the trail width between the outer trail boundaries. These boundaries are defined as visually obvious trampling-related changes in ground vegetation height (trampled vs. untrampled), cover, composition (e.g., grass, forb, lichen), or, when vegetation cover is reduced or absent, changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 2). The objective is to define the trail tread that receives about 95% of the traffic, selecting the most visually obvious outer boundary that can be consistently identified by you and future trail surveyors. Measure and record the tread width to the nearest inch.

2) *Total Incision (TI):* Extend a telescoping antenna or shock-corded tent pole section across the trail and beyond trail boundaries so that it rests on what you consider to be the pre-trail surface of the lowermost ground vegetation layer (i.e., on top of the moss/lichen mat and/or at the base of grass clumps and forbs). Use a tape measure to obtain a maximum value (nearest ¼ inch: 0, .25, .5, .75) from the bottom of the pole to the lowermost point on the trail tread beneath the pole (support it in the middle if it bends downward on wider trails). Subtract soil incision (next indicator) from this measure to yield a measure reflecting trampling-related compaction or loss of the vegetation mat.

3) *Soil Incision (SI):* Same procedures as above, but now align the extension pointer at the trail boundary with the interface between the upper soil surface and lower vegetation mat. Note that this interface may be below the tread, in which case record a value of 0 for this indicator. If soil loss has occurred, use a tape measure to obtain a maximum value (nearest ¼ inch) from the bottom of the pointer to the lowermost point on the trail tread. This measure primarily reflects the trampling-related compaction or loss of the soil. Arctic Refuge: substitute a Yes/No response for this measure based on whether soil loss has occurred.

4) *Vegetation Cover On-Trail (VO):* Imagine a 1 ft wide belt transect centered on the pole extending *between* the trail boundaries perpendicular to the trail. Within this band estimate the percentage of *live* vegetative ground cover < 1 ft tall (including herbs, grasses, low shrubs, live mosses, lichens (all colors), and any largely intact cryptogrammic crusts) rooted within the band using the coded categories listed below (see Figure 2). For this and the following indicator, it is helpful to narrow your decision to two categories and concentrate on the boundary value that separates them. For example, if the vegetation cover is either category 6-25% or 26-50%, you can simplify your decision by focusing on whether vegetative cover is greater than 25%. Alternately, consider that analyses will use the midpoint values for these categories so it may be helpful to base your decision on which midpoint value is most representative of the trail tread cover. Cover categories:

   0-5% (1=2.5), 6-25% (2=15.5), 26-50% (3=38), 51-75% (4=63), 76-95% (5=85.5), 96-100% (6=98)

5) *Vegetative Ground Cover Off-Trail (VF):* Assess vegetation cover in an adjacent, untrampled off-trail location several feet beyond trail boundaries. The intent is to locate a "control" area that depicts what the vegetation cover on the trail tread would resemble had it never been trampled. Select a control that has the same proportion and size of rocks as the tread quadrat. In instances where you cannot decide between two categories, select the category with less vegetative cover. The rationale for this is simply that the first visitors would tend to select a trail route with the least amount of vegetation. Note that if some of the trail substrates would

likely be barren due to exposed rock, then the control substrates or control vegetation estimates must reflect that.

6) *Bare Soil On-Trail (BO):* As in #5 above, but estimate bare/exposed soil cover, defined as rocks, gravel, roots, and exposed soil of all types, including organic soils with pulverized organic litter (see Figure 2). Total cover for each band transect should approximately equal the sum of your mid-point estimates for #5, #7, and organic litter cover.

7) *Bare Soil Off-Trail (BF):* As above, with the cover estimate of bare soil (not organic litter) made in the same off-trail location used for the vegetation assessment.

8) *Tread Problems (TP):* Record as 1) None, 2) Mud <1”, 3) Mud 1-3”, 4) Mud >4”, 5) Active Erosion Occurring.

Figure 1. Reference photos illustrating faint and/or discontinuous ITs defined by the effects of trampling disturbance, including: 1) reduction in woody vegetation, 2) flattening, abrasion, or reduction in herb and grass cover, 3) compressed or reduced moss and lichen cover, and/or 4) sorting or disturbance of rocks.

Cover Categories: 1 (0-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%), 5 (76-95%), 6 (96-100%)
Vegetation (V): Includes all plants <6" tall, including thin mosses and lichens.
Bare Soil (B): Includes bare soil, gravel, roots, rock, and water (excludes organic litter)

Figure 2. Representative photos illustrating the placement of telescopic antenna or shock-corded tent pole extending beyond trail borders and from which is measured veg/soil maximum incision to deepest spot along the tread. Trail width is assessed along the antenna between the blue lines. Vegetation and bare soil (see definitions and cover categories above) are assessed for the trail in a band 1 ft wide centered on the pointer. See reference assessments included in yellow on the photos. Off-site vegetation and bare soil values are assessed in representative undisturbed areas several feet beyond the ends of the pointer.

LINE TRANSECT SURVEY

Objectives

This survey finds and documents the number, location, and condition of ITs in areas near roads and formal trails.

Guidance

Line transect survey (LTS) areas are identified by the roundtable procedure. One or more line transects are established within these areas roughly perpendicular to the anticipated direction of travel. All qualifying ITs (see Access Survey section guidance) that intersect with each transect are inventoried as point features, with assessments of use type, trail width, maximum incision, vegetation cover, and bare soil recorded for each trail. LTS is less labor intensive than census trail mapping, yet provides accurate and meaningful sample data on trail locations and conditions for decision-making. Generally, LTS transects are placed close to roads to pick up the start of ITs, at locations where topography or vegetation constricts traffic, or at more distant points to see if ITs are continuing into the backcountry. When possible, place an adequate number of transects to generate a sufficiently large “N” of sample points to characterize IT conditions.

LTS areas are defined by polygon layers and transects that are downloaded to the Trimble GPS units so that field staff can navigate to the start of each line transect and walk along each one as they look for bisecting ITs. As ITs are found, field staff record location and condition assessment data for the eight quantitative indicators included as “optional” indicators under the Access Survey. Figure 9 illustrates the application of the Line Transect protocol to the Igloo Canyon Lakes area. Data yielded by this procedure includes the number of IT’s that intersect each transect and how they change over time. For example, assessments for Igloo Canyon depicted in Figure 9 found a total of 19 IT’s along 10 transects. Data for the IT condition assessment indicators would reveal improving or deteriorating IT conditions when periodically reapplied.

Methods

<u>Materials</u>

- Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary, and LTS polygons.
- Tape measure, 6 ft.
- Compass
- Telescopic antenna or presentation pointer (extending to 4 ft).
- Logbook

<u>Field Procedures</u>: Load into Trimble GPS’s TerraSync mapping software the boundary polygons circumscribing areas to be surveyed and configure the data dictionary for data entry.

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the LTS data dictionary from the pick list.
- Select the Map screen and open the Layers dialog. Select “Background Files...,” locate the appropriate mapping area polygon layer and designate it as the background layer. Conduct all mapping efforts in the field within this polygon, making note for later revision if the boundary polygon needs to be modified based on the field visit.

- Select the Setup screen, and open the Logging Settings dialog. Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.
- Begin by exploring the previously defined LTS area to get a sense of its size and location, likely direction of travel for visitors, and presence of ITs. Reassess the boundaries of the search polygon developed by the roundtable process and record point and/or polygon features and descriptive notes if needed to document alterations based on local topography, existing trails, or possible additional areas where trails could develop.
- Identify the most appropriate locations for one or more transects that cross the entire area roughly perpendicular to the direction of visitor travel. These can be placed to assess trail numbers both close to and further away from the road or formal trail to document decreasing trail numbers with distance. They may also be placed strategically at locations where trails are most likely to form. Examples include patches of woody vegetation, areas where topography concentrates visitor traffic, and areas that might attract visitor use or traffic. However, make an effort to include alignments that allow field staff to remain mostly on the transect alignments. A minimum of three transects should be defined, fewer if no trails are present, more if the area extends a long distance with trails throughout. The spacing between transects and their alignment will vary according to the size and shape of the LTS area (Figure 3).
- Select and navigate to an endpoint for the first transect. Identify a transect alignment that is most likely to cross ITs that may be discontinuous and identify a physical feature located beyond the end of the transect to guide your line of travel.
- Start recording a “LTS Transect” feature to document the transect you walk, then take, record, and follow a transect compass bearing as you walk the transect, looking for and assessing (collect/nest an “LTS Point”) each IT you encounter (as defined in the Access Survey section, including “mostly wildlife” trails). Excluding the “mostly wildlife trails,” assess each IT for the eight condition assessment indicators included in the optional Access Survey protocols (see also guidance in Figure 2). If you must deviate off the transect to avoid dense brush select the direction that allows the least deviation and return to the line transect as soon as practical. Beware of dangerous wildlife when walking through dense brush, using loud voices to alert animals of your presence.
- Move to the next transect and repeat these steps. When all transects have been collected, record some summary notes about the LTS area and then move to a new LTS area.

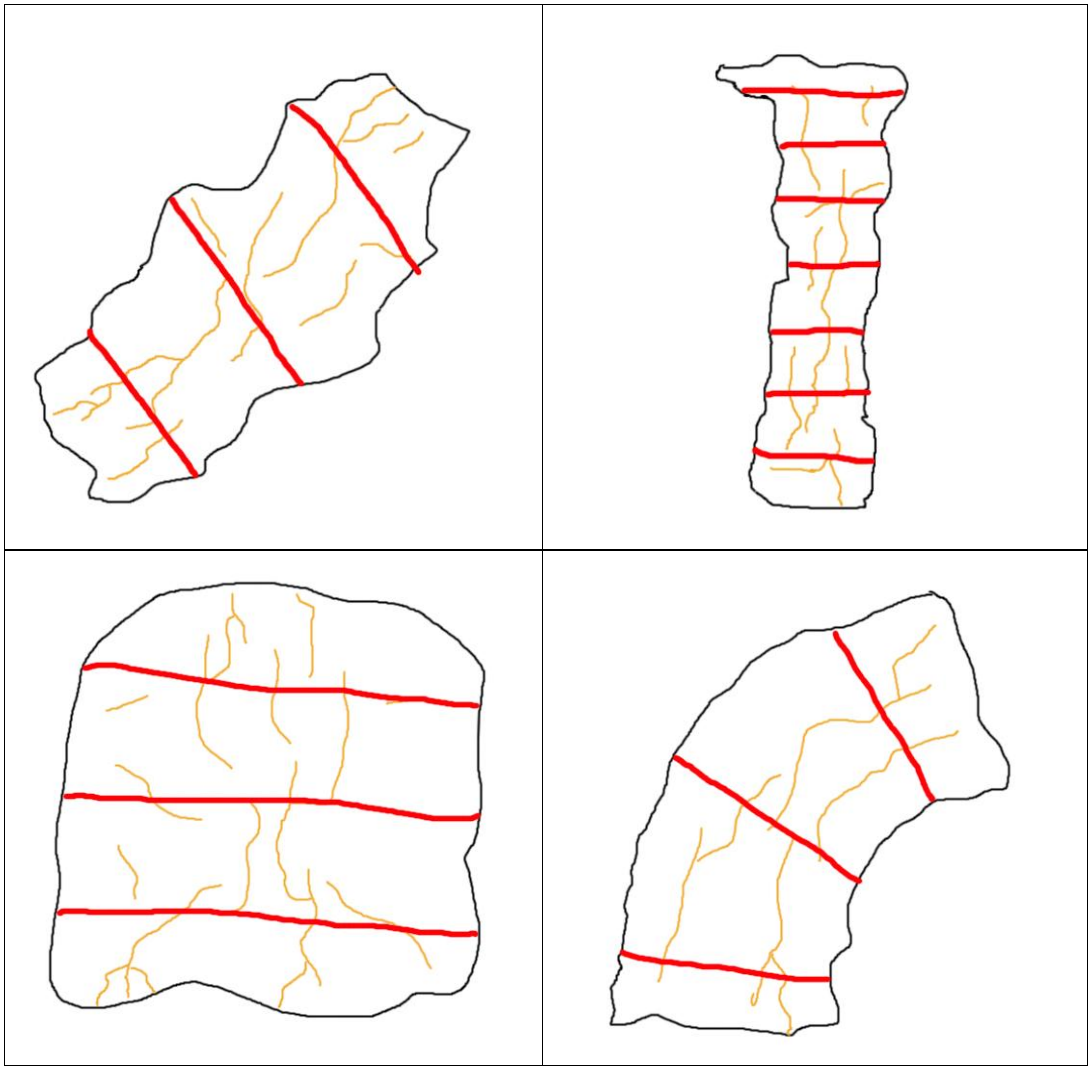


Figure 3. Diagrams illustrating possible transect placements based on shape and size of LTS survey area and direction of travel. Note that polygon boundaries do not need to be recorded.

CENSUS MAPPING SURVEY

Objectives

This survey documents the location, spatial distribution, and lineal extent of all ITs within selected search polygons defined by the roundtable review process (see Access Survey section for specific guidance on which IT's to assess, *but note that "mostly wildlife use" IT's are omitted from Census surveys*). Optional procedures are included for assessing trail conditions if needed. When reapplied over time, census mapping survey procedures allow managers to accurately track and characterize changes in the number, spatial distribution, and length of ITs, and optionally, changes in their condition. Data can also be used to help decide which ITs should be closed and to evaluate the success of management efforts to close selected trails or prevent the creation of new trails.

Guidance

Census mapping areas (CMAs) are identified by the roundtable procedure. All ITs within each CMA are inventoried as line features, with point features recorded at all trail/road intersections to aid GIS editing. Optional assessments of use type, trail width, maximum incision, vegetation cover, and bare soil (described in the Access Survey section) can be made at locations where ITs intersect a GIS grid (e.g., 25 or 50-meter grid) superimposed over the CMA and downloaded for viewing during survey work on a GPS unit.

Methods

Materials

- Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary, and CMA polygons.
- Compass
- Optional: GIS grid vector file downloaded to GPS unit.
- Telescopic antenna or presentation pointer (extending to 4 ft).
- Tape measure, 6 ft.
- Geotag-enabled digital camera that links with Trimble GPS position data (preferred). Option: use a standard digital camera, set it's time date/time to match the Trimble unit, and use a software program that matches date/time stamps to record location data to the photo file (geotagging).
- Logbook

Field Procedures: Begin by exploring the previously defined CMA area to get a sense of its size and location, and presence of ITs. Reassess the boundaries of the search polygon developed by the roundtable process and record point and/or polygon features and descriptive notes if needed to document alterations based on local topography, existing trails, or possible additional areas where trails could develop.

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the CMA data dictionary from the pick list.
- Select the Map screen and open the Layers dialog. Select "Background Files...," locate the appropriate CMA mapping area polygon layer and designate it as the background layer.

Conduct all mapping efforts in the field within this polygon, making note for later revision if the boundary polygon needs to be modified based on the field visit.

- Select the Setup screen, and open the Logging Settings dialog. Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.
- Beginning in one corner of the CMA polygon, record each IT segment as an ”IT_Segment”. Include all ITs as defined in the Access Survey, *omitting “mostly wildlife use” trails*. Note that trail segments must be at least 20 ft in length, and that mapping should cease for gaps of more than 20 ft. If the CMA has a dense network of interconnected trails if may be helpful to carry some flagging or wire pine flags to place at intersections to denote which trails have been mapped.
- Ensure that the GPS records points as you move along each trail segment, every time the unit beeps and updates the point count, it has placed a node along the line you are collecting with the GPS. You are collecting a trail and need to make sure you collect points along it that adequately capture the location and shape of the trail. Watch the background file showing the CMA boundaries and stop assessing all trails at the study area boundary. To promote efficiency in post-hoc data cleanup, pause data collection in the Data or Map screens when standing still. This prevents the unit from collecting a cloud of points when it is not moving.
- At intersections with other ITs, nest an ”IT_Junction” to improve mapping accuracy in GIS data editing. Use the Options menu in the Data screen and select “Nest,” then select the “IT_Junction” point feature. While the point is averaging positions, record the number of trail segments meeting at this junction. For example, a “T-intersection” has three connecting segments. Once the minimum number of positions have been collected for the “IT_Junction”, close the feature, and continue mapping by unpausing/resuming data collection on the GPS.
- Resource Condition Photos: Periodically take digital photos of representative trails that are being mapped. Record ”CMA Photo Point” at each point, attribute with camera photo numbers, and azimuth of image. These photos can be examined to document the general conditions and attributes of the mapped trails. Photos could also be replicated during subsequent surveys for comparing changes in resource conditions (e.g., width, depth, substrates, muddiness).
- Continue mapping until all ITs within the CMA boundaries have been walked and recorded.
- Resource Condition Comments: At the conclusion of mapping work for each separate area, prepare a written summary that qualitatively describes the area and resource conditions along the trails. Focus your comments on the relative proportion of trails that are obvious and distinct vs. faint and inconsistent and on proportions that are primarily derived from human use vs. wildlife use. Also note the number of occurrences of “problem” sections due to excessive muddiness or rutting that may contribute to trail proliferation and tread widening.

Optional Grid-Based Trail Condition Assessment Protocols

The primary focus of census mapping is to efficiently document the number, lineal extent and spatial distribution of ITs. Resource condition impacts such as severe muddiness and rutting generally cause the proliferation of additional parallel trails that census mapping can document. However, sometimes it may be beneficial to also have qualitative or quantitative data on the condition of the mapped ITs. Trials at DENA revealed that field staff moving along the trails frequently differed in their subjective walking assessments of attributes such as condition class and trail width. Adding condition assessment indicators that are continuously assessed and altered for different segments of the mapped trails also increases the complexity of the mapping process and slows it down.

Two efficient options for characterizing the resource condition of ITs include taking representative resource condition photos of ITs during the census mapping fieldwork and writing a resource condition summary for each area mapped. Both these options are included in the standard procedures.

More comprehensive and accurate quantitative data on the resource conditions of IT networks can be collected with the Line Transect Procedures described previously, or by adding optional grid-based trail condition assessment described here. Better data can be collected when assessments are performed at specific sample points rather than for trail segments. Point data can be averaged to obtain a more accurate and robust estimate of IT conditions for various areas.

A recommended method for efficiently sampling IT networks during or after census mapping is to create a grid superimposed on the CMA and viewable on the GPS. The size of the grid spacing (e.g., 25m) determines the number of sample points that are collected and could vary by CMA based on trail density. Survey staff stop at each IT/grid intersection and assess trail conditions for any subset of the indicators described in the Access Survey. For efficiency, assess trails only the first time they cross a grid line segment i.e., don’t assess a second crossing within the same grid cell.

POINT SAMPLING SURVEY

Objectives

This survey provides more accurate quantitative assessments for a variety of trail condition indicators on selected formal or informal trails whose alignments are relatively static.

Guidance

Managers in the round-table process can identify selected informal or formal trails for which more accurate data are required, perhaps to evaluate their condition in relation to standards of quality or evaluate the efficacy of management actions. Prior to fieldwork, managers must define the beginning and endpoints of each trail segment to be assessed and the point sampling interval (e.g., 200 or 300 ft). Sample points can be generated with a VB script (Points on Poly) with a GIS, incorporating a random start. The selected sample points are then downloaded to a GPS device and field staff can navigate to these same sample points during each monitoring assessment to assess tread conditions.

Methods

Materials

- Field manual, data/photos from prior surveys, paper data forms and pencil for backup.
- Trimble GPS, charged battery(s), antenna, stylus, appropriate data dictionary.
- Tape measure, 6 ft.
- Clinometer
- Compass
- Telescopic antenna or presentation pointer (extending to 4 ft).
- Geotag-enabled digital camera that links with Trimble GPS position data (preferred). Option: use a standard digital camera, set it's time date/time to match the Trimble unit, and use a software program that matches date/time stamps to record location data to the photo file (geotagging).

Field Procedures:

- Open TerraSync on the GPS and select the Data screen to create a new rover file. Select the point sampling data dictionary from the pick list.
- Select the Map screen and open the Layers dialog. Select the Setup screen, and open the Logging Settings dialog. Ensure logging intervals for all features in the data dictionary are set to 1 second and are based on time, not distance. Logging velocity is unnecessary, set H-Star logging to Auto, and set Allow Position Update to Confirm.
- Start a line feature to map the trail you are assessing. Navigate to the first trail sample point, if it is located off-trail then move to the closest point on the trail perpendicular to the point location . *Rejection of a sample point:* During the first survey, there may be rare occasions when you need to reject a sample point due to the presence of uncharacteristic settings, like trail intersections, stream-crossings, and other odd uncommon situations. The data collected at sample points should be roughly "representative" of the adjacent sections of trail on either side of the sample point. Use your judgment but be conservative when deciding to relocate a sample point. The point should be relocated by moving forward along the trail an additional 30 ft to remove the bias of subjectively selecting a point.

- At each sample point, collect a "PS_Point" with the GPS and enter the indicator assessment data and photo numbers associated with that point. Assess the eight indicators included in the optional Access Survey protocols (see also guidance in Figure 2) and the additional indicators included below.

8) *Secondary Treads (ST):* Count the number of trails (excluding the sampled trail), regardless of their length, that closely parallel the sampled trails at the sample point. These are trails that split from and return to the sampled trail, remaining within 10 feet.

9) *Trail Grade (TG):* Two field staff should position themselves on the trail 5 ft either side of the transect. A clinometer is used to determine the grade (% slope) by sighting and aligning the horizontal line inside the clinometer with a spot on the opposite person at the same height as the first person's eyes. Note the percent grade (right-side scale in clinometer viewfinder) and record (indicate units used). Note: if conducted by one person then place clinometer on a clipboard with the window facing you. Orient the clipboard to be parallel to the trail grade and record <u>degrees</u> off the visible scale in the window. Be sure to note the units (degrees) and convert the data to percent slope = [tan (degrees)] x 100 after field work.

10) *Trail Slope Alignment Angle (TSA):* Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Position yourself about 5 ft downhill along the trail from the transect and sight a compass along the trail to a point about 5ft past the transect; record the compass azimuth (0-360, not corrected for declination) on the left side of the column. Next face directly upslope (i.e., the fall line where water would flow downhill from a point 15-20 ft away to your feet), take and record another compass azimuth - this is the aspect of the local landform. The trail's slope alignment angle ($<90^0$) is computed by subtracting the smaller from the larger azimuth (done after data entry). Note, if water would flow down to the transect from both sides and there is nothing lower than the trail (i.e., water would drain down the tread), then record the same azimuth measure. If water would flow down to a lower area next to the trail then the trail at that point is still assessed as a side-hill trail.

11) *Digital Photographs:* Take a photo of the transect from directly above, looking down and including the transect endpoints. This photo will help confirm, explain, or illustrate the transect substrate classes or to verify field estimates and allow assessments if there is missing data. Also take an oblique photo standing 5-10 feet away from the transect that captures the entire transect and preferably some distinctive background features. This photo will help in relocating the transect in the future once the GPS units gets field staff within a few meters. Check both photos for quality and retake if they have poor exposures or focus. Record these photo numbers in the GPS unit so they can be georeferenced.

- Collect all equipment and move on to the next sample point.

ROUTE FINDING EXPERIENCE SURVEY

Objectives

This survey is used to inventory the hiker's Route Finding Experience (RFE) as they move through backcountry travel corridors identified by the roundtable. Data is used to inform and direct future monitoring decisions (e.g., data showing that it is easy to travel through an area on trails might suggest the need for LTS or CMA mapping). These data inform managers about the degree to which visitors engage in active route finding decision-making while hiking, as opposed to traveling along a visually obvious trail for long distances.

Guidance

Survey is to be performed by backcountry staff and/or visitors who are given Garmin GPS units. A timer will signal data collection every 15 minutes. The data collector may also collect a data point whenever they feel their RFE has changed from one "level" to another.

Methods

<u>Materials Needed</u>

- o RFE instructions sheet
- o Garmin GPS with spare batteries
- o Timer (watch/snooze alarm or repeating countdown timer)

<u>Field Procedures</u>: Data collector embarks on a backcountry trip, starting the repeating timer to alarm every 15 minutes.

- The Garmin GPS is turned on and a track log is initiated.
- When the alarm sounds it is reset and begins counting down again. When each alarm sounds, the data collector creates a waypoint and appends their RFE code (Class R1 - R4, see descriptions below) for the last 50 ft of their hike. (WP # - R#). Optional: Enter the WP # into a notebook to add descriptive comments, include survey date.
- In addition to the time interval waypoints, the collector should stop and record a RFE Waypoint whenever they feel their RFE has changed. The collector can switch to a longer time interval (1/2 hour to 1 hour suggested) when they feel they have moved into a consistent RFE area. They should still collect waypoints when they feel RFE has changed in addition to the longer time interval waypoints.
- Upon completion, field staff should prepare a written account of additional trip information, additional reflections on the trip, the spatial distribution of use impacts, and suggestions for future RTE surveys.

<u>RTE Class Descriptions</u>

Class R1 - I am spending more time off trails than on trails. It is difficult to piece together trails or routes that take me in the direction I want to travel and bushwhacking is often required.

Class R2 - I am walking on a trail most of the time, but I have to remain alert and make frequent choices about which trails to follow. Occasional short trail gaps may exist and periodic backtracking and/or bushwhacking are required.

Class R3 - I am generally always on a trail, and can easily navigate along trails in the direction I want to travel.

APPENDIX 2: TRAIL MONITORING WORK FLOW

This Appendix contains information to assist field staff in the collection of field data, specifically the pre-fieldwork set-up tasks and the post-fieldwork data processing tasks.

Data Dictionaries

Access.ddf

Line Transect Sampling.ddf

Census Mapping.ddf

Point Sampling.ddf

Pre-fieldwork Setup Tasks

1. Load necessary data dictionary(s) sample region and background data sets onto the Trimble GPS(s).
2. Ensure that batteries are charged and ancillary equipment is ready for use:
    a. External batteries,
    b. Antennas and leads,
    c. Backpack antenna mount,
    d. Clinometer, digital camera, and measurement tools as required by sampling protocol to be implemented,
    e. Logbook and forms as needed.
3. Create and print schematic/directions to get to sampling area (if needed).

Field Tasks

1. Navigate to the sampling location(s).
2. Implement required sampling protocols(s).
3. Fill in logbook indicating work completed, dates, and field staff names.
4. Return equipment to office with completed logbook and written summaries.

Data Post-Processing Tasks

This guidance provides an outline for post-processing GPS data and implementing an organized and easily transferable/updateable spatial database. Post-processing and creation/integration of spatial datasets should be done by a single person, preferably by a GIS staff member. When transferring the data to the GIS staff, field staff should include a brief narrative describing the GPS data. This narrative should include:

- Date(s) of collection
- Field staff names and contact information
- Type of survey(s) collected
- Area of collection
- Additional comments or notes that may be pertinent

Suggested Protocols

Use Trimble's Pathfinder Office software to post-process data (differentially correct, edit and convert to ESRI shapefiles). Staff should be careful to not create redundant datasets, and to name files using a system that allows for integration into existing park datasets.

- Always work in one Pathfinder Office Project (do not create a new project each time you correct data)
- Download data from GPS devices.
- Verify the contents vs. logbook and note any discrepancies (contact field staff to resolve).
- Differentially correct GPS data.
- Name Files appropriately and/or maintain a spreadsheet with a key to interpret default GPS rover/pathfinder file names.
- Export data to ESRI shapefile using a template that creates shapefiles with desired attributes and coordinate system. Clean up and recode attribute data, enter paper form data as needed.
- Integrate Shapefiles into existing ArcMAP Spatial Databases
- Use standardized file naming conventions with file storage in separate project folders and maintain appropriate back-up and archiving of datasets.

Monitoring Tasks

1. Create summary data (maps, tables, photo compilations).
2. Prepare comparisons between zones/areas of interest and across time
    a. Calculate % and absolute change/difference,
    b. Prepare maps to facilitate visual comparison of spatial data.
3. Update monitoring/sampling plans/zones:
    a. Based on datasets coming in and comparisons to other times and/or locations,
    b. Based on input from field staff, rangers, etc.

Route Finding Experience (RFE) Tasks

1. Coordinate sampling efforts/training with backcountry permit office:
    a. Provide written RFE/Garmin user instructions,
    b. Develop sampling schedule/plan,
    c. Distribute and collect Garmin GPS units from backcountry office.
2. Download and convert Garmin Data to GIS data (use MN DNR software).
3. Integrate field notes and attribute RFE point data as needed.
4. Prepare summary maps:
    a. Interpolate surface from data if sufficient points exist,
    b. Color code point data for visual comparison of RFE data,
    c. Calculate distance to nearest trail/road,
    d. Summarize distance(s) to RFE points by RFE class.
5. Maintain an appropriate back-up of datasets using appropriate naming conventions.
6. Integrate RFE data with IT spatial datasets (from other protocols above):
    a. Spatially analyze RFE data relative to IT networks and other park infrastructure,
    b. Compare data sets at differing times and varied locations within park.