RESEARCH REPORT

AN ASSESSMENT OF RECREATION IMPACTS TO CLIFF AND ROCK OUTCROP ENVIRONMENTS IN SHENANDOAH NATIONAL PARK

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Patuxent Wildlife Research Center
Virginia Tech Field Station

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EXECUTIVE SUMMARY

The rock outcrops and cliffs of Shenandoah National Park (SNP) provide habitat for several rare and endangered plant and animal species, including the federally endangered Shenandoah Salamander. The location of the well-known park tour road, Skyline Drive, along the ridgeline provides exceptional access to many outcrops and cliffs throughout the park for a large number of the park's 1.2 million annual visitors. Consequently, visitor use of cliff areas has led to natural resource impacts, including marked decreases in size and vigor of known rare plant populations. Despite the clear ecological value and potential threats to the natural resources at cliff areas, managers possess little information on visitor use of cliff sites and presently have no formal planning document to guide management. Thus, a park-wide study of cliff sites was initiated during the 2005 visitor use season. As part of this research effort, our study investigated recreation-related resource impacts to cliff and rock outcrop environments. This work was limited to cliff-top and cliff-base recreation sites, and associated trails, as these locations support the greatest visitor traffic and/or support the majority of rare plant communities. Procedures derived from campsite and trail impact studies were adapted and used to measure and characterize the amount of visitor-caused resource impact.

Of the 48 SNP cliff and rock outcrop study areas, this research conducted field investigations at 16, including nearly all sites where preliminary inventories found visitor-created informal trails and recreation sites. Field staff found 44 recreation sites, 10 campsites, and 60 informal trails, accounting for intensive visitor trampling over a total area of 56,249 ft^2, or 1.3 acres. Furthermore, recreation sites and campsites lost vegetation cover over an estimated 16,312 ft^2, including 10,100 ft^2 of exposed soil. Other impacts were somewhat less severe, including 23 damaged trees, 15 trees with exposed roots, and 9 tree stumps found on recreation sites and campsites. Consequently, as the resource data in this study show, large areas of bare soil and solid rock are already characteristic of the cliff-associated visitor use sites. Furthermore, assessments of site expansion potential, which examine barriers to future expansion based on topography and vegetation, suggest that substantial future expansion could occur.

The total lineal extent of the 58 informal trails assessed within the study areas was 7532 lineal feet (1.43 mi). Their mean width ranged from 14 to 45 inches and mean depth ranged from 0 to 8.8 inches. Mean cross sectional area (CSA) ranged from 0 to 401 in^2 with a total volume of soil loss estimated at 3,270 ft^3, though 2,023 ft^3 of this was from a single trail. Only five of the 58 trails were considered to be predominantly used by rock climbers and these represent a relatively small proportion of aggregate impact. One exception to this is the soil loss associated with the steep descent trail at Little Stony Man cliffs.

Research findings from companion social science surveys of rock climbers at Little Stony Man Cliffs (LSMC) and Old Rag Mountain (Lawson *et al.* 2006) reveal these two areas as the most popular for climbing, followed by White Oak Canyon and limited climbing at Blackrock/Split Rock, Mount Marshall, and Mary's Rock. Observation surveys at the heavily visited LSMC provides insights into factors that may be driving visitor-caused impacts at LSMC and other SNP cliffs. First, observers found that day hiking constitutes the majority of recreational activity at LSMC and that day hikers trampled soil and vegetation, as opposed to staying on rock, more

frequently than either rock climbers or backpackers. Given that LSMC is the most popular rock climbing area within the park this finding is likely to be even more applicable to other SNP cliffs. A noteworthy exception are the climbing areas on Old Rag Mountain, which require difficult bushwhacks to access and appear to receive no use by non-climbers.

A second important observation from LSMC is that hikers (hereafter to include walkers and backpackers) are predominantly drawn to cliff-top locations for the vistas they provide, while climbers spend most of their time at cliff-base sites. Also of importance was the finding that day hikers were more likely to disperse along the cliff edge during crowded periods to get a good view and/or find personal space. In contrast, climbers tend to cluster at the top and base of specific climbing routes, which limits the areal extent of their trampling impact. Such motives and patterns of use are also likely to be applicable to other cliffs. A principal management implication from these findings is that hikers are the probable primary contributors to the development of cliff-top recreational sites and associated cliff-top informal trails within SNP.

The findings from this study suggest that a management approach characterized by visitor education, some site hardening, and concentration of visitor use on durable surfaces, along with the installation of fixed anchors at the top of popular climbing routes is likely to have the greatest success at balancing visitor enjoyment with resource protection. Management planning and decision-making should begin with assessments of impact acceptability – some cliff-related impacts are unavoidable and/or acceptable if their recreation use as vistas or climbing-related sites are appropriate. Site management options include selecting or redesigning trails and sites to avoid or minimize impacts, installing facilities such as observation platforms, stone steps, or scree walls, and closing and restoring areas that are most sensitive to recreation impacts. Management recommendations are provided for these topics and for visitor management recommendations, including educational and regulatory actions for influencing visitor behavior to avoid or minimize impacts.

Finally, manuals for use by park staff in the future to assess and monitor visitor impacts to cliff-related recreation sites, campsites and trails are included in Appendices 1 and 2 and baseline data from their assessment as part of this study have been transferred to park staff for future use.

ACKNOWLEDGEMENTS

We wish to acknowledge and thank the National Park Service for sponsoring this study. We also thank Dr. Steve Lawson (Virginia Tech) and Dr. Aram Attarian (North Carolina State University) for their collaboration and assistance, and Steve Bair (National Park Service, Shenandoah National Park) for his substantial assistance, collaboration, and logistical support. Lastly, we would like to thank Kerry Wood, Aurora Moldovanyi and Alan Williams for field assistance, and the rattlesnake for not striking the senior author when he nearly stepped on it.

INTRODUCTION

The National Park Service (NPS) accommodates nearly 300 million visitors per year, visitation that presents managers with substantial challenges at some 388 park units. The increasing number of visitors inevitably contributes 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 2006, 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 2006).

The increasing popularity of the national park system presents substantial management challenges. Too many visitors may cause unacceptable impacts to fragile natural and cultural resources, and may also cause crowding and other social impacts which degrade the quality of the visitor experience. How many visitors can ultimately be accommodated in a park or related area? How much resource and social impact should be allowed? These and related questions are commonly referred to as carrying capacity (Manning 1999; Stankey and Manning 1986; Shelby and Heberlein 1986; Graefe et al. 1984).

Responding to these concerns, NPS managers at Shenandoah National Park sponsored this research to investigate visitation-related impacts to the park’s cliff and rock outcrop environments, which are important habitats for a number of rare plants and animals. Shenandoah National Park (SNP) encompasses 70 miles of ridge crest along the Blue Ridge Mountains of Virginia. Rock outcrops and cliffs punctuate the otherwise forested landscape, composing approximately 2% of the park’s 197,000 acres. These cliffs and rock outcrops are also highly accessible to the park’s 1.2 million annual visitors due to their proximity to Skyline Dr and the Appalachian Trail. Cliff-tops provide the only opportunities for vistas for day hikers and backpackers in this heavily forested landscape. Additionally, in the last several years, some cliff areas in the park have become increasingly popular for rock climbing. Consequently, visitor uses of cliff areas within the park have led to natural resource impacts such as vegetation damage and loss, and soil exposure, compaction and erosion. These impacts are occurring at in increasing number of informal (visitor-created) recreation sites, campsites, and trails (Hilke 2002).

Preliminary botanical surveys suggested that the rare and ecologically significant plant communities associated with SNP cliff and outcrop environments occur at cliff-top locations and are associated primarily with Greenstone rock strata. Furthermore, hikers far outnumber climbers in these environments and most hikers are drawn to cliff-tops for the vistas they provide. The majority of trampling associated with rock climbers occurs at cliff-base recreation sites, where staging and belaying activities occur. For these reasons park and research staff decided to focus this research on the cliff-top and cliff-base recreation sites, including all cliff-associated trails used for accessing these sites.

Despite the clear ecological value and potential threats to the natural resources at SNP cliff areas, managers possess little information on visitor use of cliff sites and presently have no formal planning document to guide visitor management of the park's cliff resources. Concerns over the effects of visitor-caused impacts to cliff areas have prompted park staff to initiate a study of cliff sites and to formulate a Cliff Resource Management Plan. As part of this research effort, the study presented in this report used an approach that integrates ecological and social science assessments and findings to help assess the effects of recreational use on the vegetation and soils at all cliff sites in the park that receive moderate to high visitation. In particular, this study integrates data from measurements of resource conditions on cliff-associated trails, recreation sites, and campsites (presented in this report) with social science information collected through direct observations and visitor surveys (presented in Lawson *et al.* 2006). The information from this integrated program of research will assist the park in managing visitor use and developing a plan that protects the park's cliff resources while providing sustainable opportunities for visitor enjoyment.

The study had two objectives:

Objective 1: Develop, pilot test, and refine cost effective and scientifically defensible trail, recreation site, and campsite condition assessment procedures.

Objective 2: Initiate a long-term visitor impact monitoring program by applying the procedures to cliffs and rock outcrop areas within Shenandoah National Park that receive sufficient recreational use to show permanent visitor-created trails and recreation sites. Prepare a technical report that compiles, analyzes, and presents results and management implications.

This report contains a review of the relevant scientific literature describing trail and recreation site impacts, criteria for selecting appropriate impact indicators, trail and recreation site impact assessment methods, and a review of the study area and methods employed in this study. The data collected from assessing trail and recreation site conditions are presented to characterize the distribution and extent of visitation-related impacts to SNP cliff resources. Management implications and options are also presented and discussed, including findings from collaborative social science investigations. Study implications and recommendations for park planning, management, and monitoring are provided. This information is useful in selecting and implementing effective site or visitor management actions. If park staff implement procedures developed from this research as part of a long-term monitoring program then comparisons to the baseline dataset provided by this study will allow the detection of trends and evaluation of the effectiveness of management interventions. Finally, these data support the selection of indicators and standards as part of a Cliff Management Plan based on the NPS Visitor Experience and Resource Protection (VERP) framework (described in the following section).

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 recreation site and 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 1995, 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.

External Mandating Documents

Several external documents also guide NPS management practices. Relevant external documents include the Wilderness Act of 1964 (PL. 88-577) and the National Environmental Policy Act of 1969 (42 USC 4321 et seq). For example, Congress intended the Wilderness Act to overlay park designation to protect roadless park areas singled out for exceptional ecological or social values. Parks with Wilderness designations are managed with additional protections of their natural resources, processes, and wilderness experiences.

Wilderness, as defined in the Wilderness Act of 1964 (16 USC 1131-1136), is:

> "an area where the earth and its community of life are untrammeled by man . . . which is protected and managed so as to preserve its natural conditions and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable. . . ."

The Wilderness Act established the same use and preservation management paradox implied by the Organic Act. Wilderness areas:

> "shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness and so as to provide for the

> protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness. . . ."

Finally, the National Environmental Policy Act of 1969 (42 USC 4321 *et seq*) directs federal agencies to use all practicable means to "attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences. . . ." Title I of the act requires that federal agencies "monitor, evaluate, and control on a continuing basis their agency's activities so as to protect and enhance the quality of the environment." This amendment also directs agencies to "promote the development and use of indices and monitoring systems to assess environmental conditions and trends, to predict the environmental impact of proposed public and private actions and to determine the effectiveness of programs for protecting and enhancing environmental quality."

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 2006* (NPS 2006) 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 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 extent practicable, adverse impacts on park resources and values. However, the laws do give the Service the management discretion to allow impacts to park resources and values when necessary and appropriate to fulfill the purposes of a park, so long as the impact does not constitute impairment of the affected 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. The enjoyment that is contemplated by the statute is broad; it is the enjoyment of all the people of the United States and includes enjoyment both by people who visit parks and by those who appreciate them from afar. It also includes deriving benefit (including scientific knowledge) and inspiration from parks, as well as other forms of enjoyment and inspiration. 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. (*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.

An impact to any park resource or value may, but does not necessarily, constitute an impairment. An impact would be more likely to constitute impairment to the extent that it affects a resource or value whose conservation is

- necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, or
- key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or
- identified in the park's general management plan or other relevant NPS planning documents as being of significance.

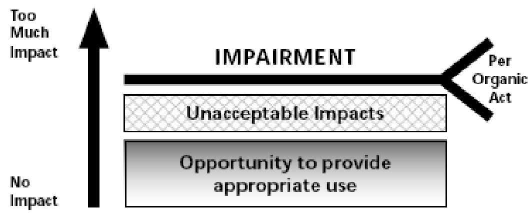
An impact would be less likely to constitute an impairment if it is an unavoidable result of an action necessary to preserve or restore the integrity of park resources or values and it cannot be further mitigated. (*Section 1.4.5*)

The impact threshold at which impairment occurs is not always readily apparent. Therefore, the Service will apply a standard that offers greater assurance that impairment will not occur. The Service will do this by avoiding impacts that it determines to be unacceptable. These are impacts that fall short of impairment, but are still not acceptable within a particular park's environment. Park managers must not allow uses that would cause unacceptable impacts; they must evaluate existing or proposed uses and determine whether the associated impacts on park resources and values are acceptable.

Virtually every form of human activity that takes place within a park has some degree of effect on park resources or values, but that does not mean the impact is unacceptable or that a particular use must be disallowed. Therefore, for the purposes of these policies, unacceptable impacts are impacts that, individually or cumulatively, would

- be inconsistent with a park's purposes or values, or
- impede the attainment of a park's desired future conditions for natural and cultural resources as identified through the park's planning process, or
- create an unsafe or unhealthful environment for visitors or employees, or

- diminish opportunities for current or future generations to enjoy, learn about, or be inspired by park resources or values, or
- unreasonably interfere with
  - park programs or activities, or
  - an appropriate use, or
  - the atmosphere of peace and tranquility, or the natural soundscape maintained in wilderness and natural, historic, or commemorative locations within the park.



(*Section 1.4.7.1*)

The fact that a park use may have an impact does not necessarily mean it will be unacceptable or impair park resources or values for the enjoyment of future generations. 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. For this reason, the Service will not knowingly authorize a park use that would cause unacceptable impacts.

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. When a use is authorized by law but not mandated, and when the use may cause unacceptable impacts on park resources or values, the Service will avoid or mitigate the impacts to the point where there will be no unacceptable impacts; or, if necessary, the Service will deny a proposed activity or eliminate an existing activity. (*Section 8.1.1*)

Superintendents must continually monitor and examine all park uses to ensure that unanticipated and unacceptable impacts do not occur. Superintendents should also be attentive to existing and emerging technologies that might further reduce or eliminate impacts from existing uses allowed in parks.

The National Park Service will always consider allowing activities that are appropriate to the parks, although conditions may preclude certain activities or require that limitations be placed on them. In all cases, impacts from park uses must be avoided, minimized, or mitigated through one or more of the following methods:

- visitor education and civic engagement
- temporal, spatial, or numerical limitations on the use
- the application of best available technology
- the application of adaptive management techniques

If, in monitoring a park use, unanticipated impacts become apparent, the superintendent must further manage or constrain the use to minimize the impacts, or discontinue the use if the impacts are unacceptable." (*Section 8.1.2*)

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 evaluate possible causes and effects of changes that might cause impacts on park resources and values. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions. (*Section 4.1*)
>
> Similarly, planning for park operations, development, and management activities that might affect natural resources will be guided by high-quality, scientifically acceptable information, data, and impact assessment. Where existing information is inadequate, the collection of new information and data may be required before decision-making. Long-term research or monitoring may also be necessary to correctly understand the effects of management actions on natural resources whose function and significance are not clearly understood. (*Section 4.1.1*)
>
> 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 NPS 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 provide reference points for comparison with other environments and time frames; and
> - use the resulting information to maintain – and where necessary restore – the integrity of natural systems." (*Section 4.2.1*).

The NPS has implemented a strategy designed to institutionalize natural resource inventory and monitoring on a programmatic basis throughout the agency. A servicewide Inventory and Monitoring Program ensures that the approximately 270 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 Park Vital Signs Monitoring, is the organization of park units into 32 monitoring regional 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. For additional information see: http://science.nature.nps.gov/im/monitor/index.htm.

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.

The NPS defines carrying capacity as "the type and level of visitor use that can be accommodated while sustaining the desired resource and visitor experience conditions in the park" (NPS 2001). Carrying capacity addresses issues related to the amount of visitation that parks can accommodate and the acceptability of associated degradation to resource and social conditions (Manning 1999, Stankey & Manning 1986, Shelby & Heberlein 1986, Graefe *et al.* 1984). The U.S. Forest Service addressed carrying capacity issues in wilderness areas by developing a planning and management decision making framework known as the Limits of Acceptable Change (LAC) (Stankey *et al.* 1985). The NPS developed a similar framework, Visitor Experience and Resource Protection (VERP) (see Figure 1), designed to guide decisions needed to protect park natural and cultural resources while maintaining the quality of the visitor experiences (NPS 1997).

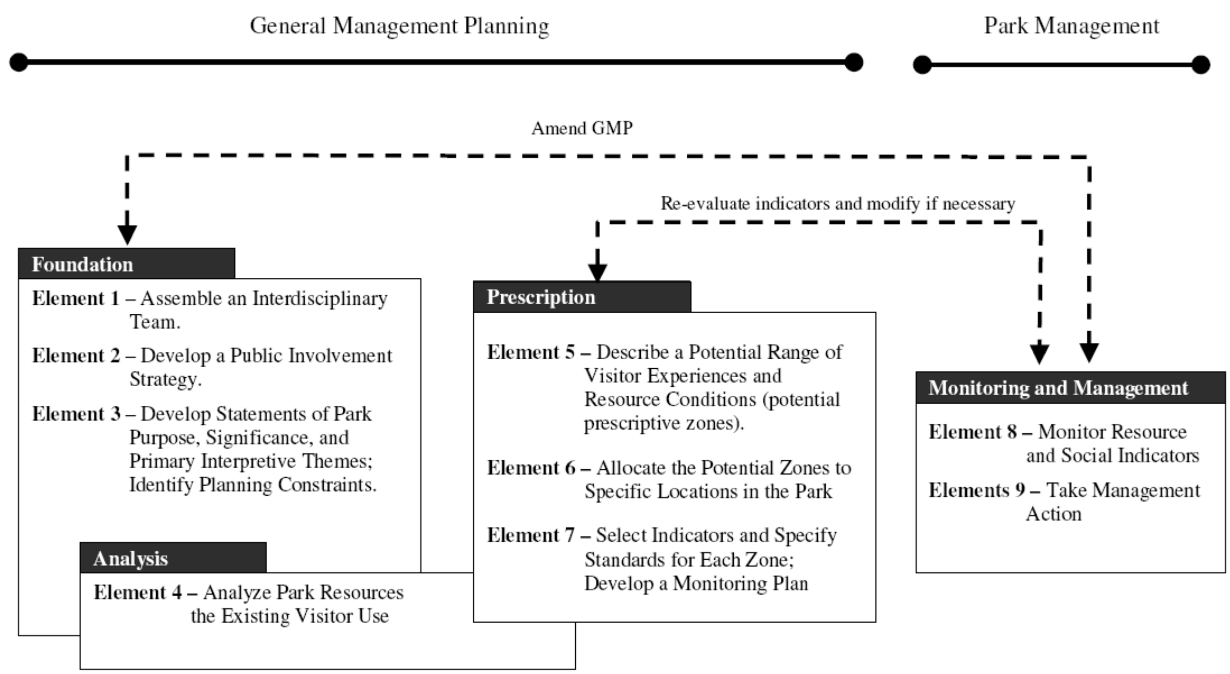


Figure 1. The NPS Visitor Experience and Resource Protection framework used to address carrying capacity decision making.

The NPS fulfills its legal mandate to address carrying capacity by incorporating VERP Elements 1-7 into its General Management Planning process, Elements 8 and 9 are included in ongoing park management. Research such as this study can assist managers with many elements of the VERP process. During the planning phase Element 4 requires an analysis of park resources and visitor uses. Assessments of visitor-related resource impacts can document baseline conditions for trails, recreation sites, and campsites and reveal the distribution of various types of visitor uses. These data can also provide partial input to the development of realistic resource condition prescriptions and their allocation through zoning to specific park locations (VERP Elements 5 & 6). Comprehensive assessments of visitor impacts can serve as a core source for selecting appropriate indicators and as a filter for identifying realistic standards. For example, preliminary indicator standards can be compared with baseline data to determine if current conditions exceed proposed standards and if so, to identify the specific locations so that decision makers could visit these sites to judge if they are appropriate.

Visitor impact monitoring programs provide an essential component of such efforts. VERP and other similar frameworks (e.g., Limits of Acceptable Change), evolved from, and have largely replaced, management approaches based on the more traditional carrying capacity model (Marion *et al.* 1985). Under these newer frameworks numerical standards are set for individual biophysical or social condition indicators. These limits define the critical boundary line between acceptable and unacceptable conditions, establishing a measurable reference point against which future conditions can be compared through periodic monitoring. According to NPS *Management Policies*:

> “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 manage park uses that may unacceptably impact the resources and values for which the parks were established. Superintendents will identify visitor carrying capacities for managing public use. Superintendents will also identify ways to monitor for and address unacceptable impacts on park resources and visitor experiences.
>
> When making decisions about carrying capacity, superintendents must use 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 level of analysis necessary to make decisions about carrying capacities is commensurate with the potential impacts or consequences of the decisions. The greater the potential for significant impacts or consequences on park resources and values or the opportunities to enjoy them, the greater the level of study and analysis and civic engagement needed to support the decisions.
>
> The planning process will determine the desired resource and visitor experience conditions that are the foundation for carrying capacity analysis and decision-making. If the time frame for making decisions is insufficient to allow the application of a carrying capacity planning process, superintendents must make decisions based on the best available science, public input, and other information. In either case, such planning must be accompanied by appropriate environmental impact analysis, in accordance with Director’s Order #12.

> As park use changes over time, superintendents must continue to decide if management actions are needed to keep use at sustainable levels and prevent unacceptable impacts. 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 is acceptable 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 campsites, 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 campsites, particularly those in degraded condition, reminds visitors that others have preceded them. In remote areas even the presence of trails and campsites reduce perceived naturalness and can diminish opportunities for solitude. In accessible and popular areas the proliferation and deterioration of trails, recreation sites, and campsites present a “soiled” or “used” appearance, in contrast to the ideal of a pristine natural environment (Leung & Marion 2000).

Degraded resource conditions on trails and recreation sites can have significant utilitarian, safety, and experiential consequences for visitors (Leung & Marion 2000). Trails serve a vital transportation function in protected natural areas and their degradation greatly diminishes their utility for visitors and land managers. For example, excessive tread erosion or muddiness can render trails difficult and unpleasant to use. Such conditions can also threaten visitor or packstock safety and prevent or slow rescues, possibly increasing agency liability. Impacts associated with certain types of uses, such as linear rutting from bikes or vehicles or muddy hoof prints from horses, can also exacerbate conflicts between recreationists.

Visitors spend most of their time within protected natural areas on trails and recreation sites, so their perceptions of the area and its naturalness are strongly influenced by trail and site conditions. 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 campsite 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 campsite were rated as more important than many social indicators, including number of people seen while hiking and encounters with other groups at campsites. Hollenhorst and Gardner (1994) also found vegetation loss and bare ground on campsites 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 properly and with periodic reassessments, these programs produce a data base with significant benefits to protected area managers (Figure 2).

Data from the first application of impact assessment methods developed for a long-term monitoring program can objectively document the types and extent of recreation-related resource 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 resource assessments. It may detect 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 may be greatly reduced by shifting recreation sites or trails to more resistant and resilient vegetation types instead of more contentious limitations on 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 management standards for resource conditions.
- 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

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 recreation sites and trails are reviewed and prospective indicators and measurement units are presented. Common recreation site and trail impact assessment procedures are also reviewed.

Visitation-Related Resource Impacts

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 protected natural areas 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 trails and at recreation sites.

Trail Impacts

Resource impacts associated with trampling on trails include an array of direct and indirect problems (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). Visitors can also introduce and transport non-native plant species along trail corridors, some of which may out-compete undisturbed native vegetation and migrate away from trails (Cole 1987).

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

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

The exposure of soil on unsurfaced trails can lead to 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). 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).

Trails are generally regarded as an essential facility in protected natural areas, providing access to unroaded areas, offering recreational opportunities, and protecting resources by concentrating visitor traffic on resistant tread surfaces (Marion & Leung 2001). Unfortunately, many trails are 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.

Formal developed trail systems rarely access all the locations that visitors want to go so the establishment of informal visitor-created trails is commonplace in 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 informal trails 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, routing through fragile vegetation, substrates, sensitive wildlife habitats, and trampling or disturbance to rare flora, fauna, or archaeological sites. These design attributes also make informal trails far more susceptible to tread impacts, including expansion in width, soil erosion, and muddiness.

Trails near cliffs and rock outcrops are particularly prone to degradation due to steep terrain and thin soils. Climbing related trail impacts include the creation of trails that access the cliffs, run parallel to the cliff at cliff-top and cliff-base locations, and steep descent trails between the two where the cliff-line is interrupted or ends (Joshua Tree National Park *et al.* 2000). These problems are particularly pronounced on trails that are excessively steep – erosion up to four feet in depth was assessed on some climber's trails at Pinnacles National Monument in California (Genetti & Zenone 1987).

Many 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). Poorly located formal trails thus suffer from the same design problems described for informal trails. Even well-designed and managed trails are susceptible to the many forms of degradation described in Table 1.

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.

Recreation Site Impacts

Recreation sites and campsites are an additional recreation facility needed to protect resources when intensive day-use or overnight visitation is accommodated in natural settings (Leung & Marion 2004). In this study, recreation sites are predominantly caused by intensive trampling associated with cliff-top vistas, with smaller numbers created as campsites and recreation sites at the top or base of rock climbing routes. Most recreation sites, even those designated by land managers, were originally selected and created by visitors. As with trails, many recreation sites are poorly located with respect to resource protection considerations and are thus more susceptible to the environmental impacts of visitor use activities. Most visitor use impacts are caused by trampling and are similar to those previously described for trails (see Table 1). Differences include the nodal configuration of trampling disturbance and campfire-related impacts, including tree damage, fire sites, and offsite firewood collection trampling and wood removal (Reid & Marion 2005).

Recreation sites can range in size from several hundred to more than 8,000 ft^2 (Marion & Cole 1996), generally more than half of which is non-vegetated and more than one-quarter has also lost most organic litter. These larger expanses of exposed soil are generally in flatter terrain, though sheet erosion can remove large amounts of soil over time. Soil erosion is a more substantial problem when recreation sites are located along shorelines, where eroded soil from the site and steeper shoreline access trails can drain runoff directly into waterways. Other concerns related to their large size are the loss of woody vegetation and its regeneration over time. Gaps in forest canopies caused by these sites can alter microclimates and create sunny disturbed locations that give invasive vegetation a start.

Monitoring studies often use the number of informal trails connected to campsites as an indicator of the extent of adjacent off-site vegetation trampling. These trails may be used to access the site, water, other sites, restroom or firewood gathering areas, and scenic features. Census surveys of campsites in Great Smoky Mountains and New River Gorge have shown totals of 1087 and 221 informal trails, respectively (Marion & Leung 1997, Leung & Marion 1998).

Cliff Resource Impacts

Cliffs often support distinctly different plant communities than surrounding environments, largely due to the limited moisture availability, high winds, and limited supply of nutrients characteristic of cliff environments. These unique environmental attributes provide habitat for a relatively narrow range of species adapted to extreme environments (Farris 1998, Nuzzo 1996). While adapted to harsh cliff environments, cliff plant species' resistance to other forms of disturbance (e.g., trampling) may be limited (Farris 1998). Until recently, the inaccessibility and potential danger of most cliffs has provided a protective barrier between plant communities and potentially damaging human activities (Camp & Knight 1998, Kelly & Larson 1997, Krajick 1999). However, the growing popularity of rock climbing means that more people are accessing and using cliff sites, which may negatively affect cliff site plant communities (Camp & Knight 1998, Farris 1998, McMillan *et al.* 2003).

Despite the fact that over 9 million individuals are estimated to participate in rock climbing annually, rock climbing's effects on cliff site environments have received limited attention in the scientific literature (Cordell 2004, Farris 1998, McMillan & Larson 2002). The Access Fund (Pyke 2001) describes six zones that have the potential to be impacted by rock climbing activities: the approach (access trail), staging area (cliff-bottom), climb (cliff-face), summit (cliff-top), descent (descent trail or rappel route), and campsite. Existing cliff research has generally focused on studying rock climbing-related impacts in the cliff-top, cliff-bottom, and cliff-face zones. Results of these studies have documented negative effects of rock climbing on vascular plant density and/or species richness on cliff-faces (Camp & Knight 1998, Kelly & Larson 1997, Nuzzo 1995), on cliff-tops (Kelly & Larson 1997, McMillan & Larson 2002) and cliff-bottoms (Camp & Knight 1998). Additionally, Nuzzo (1996) found lichen cover and frequency to decrease on climbed cliff-faces.

Climbing impacts to the cliff-face include damage and loss of vegetation cover, including rooted vascular species, bryophytes (mosses, liverworts, and hornworts), and lichens attached to rock (Larson *et al.* 1999, McMillan 2000). These impacts are generally restricted to the immediate vicinity of well-used climbs, which can essentially be considered as vertical "trails." Difficult climbs have more limited impact due to their greatly reduced micro-topography, which support fewer plants and have limiting options for hand and foot-holds (Kuntz & Larson 2006a, 2006b). Conversely, impacts can be more widespread on cliffs used by beginners or below fixed rappel stations. Climbers may also purposefully "clean" vegetation and soils from cracks to improve hand or foot holds or provide access for the placement of protection devices such as cams or stoppers.

Visitors to cliffs can also disturb and potentially displace wildlife that live or nest in cliff habitats. At SNP, managers are concerned about possible disturbance to Shenandoah salamander (*Plethodon Shenandoah*), which prefers greenstone talus deposits (Ludwig *et al.* 1993). Another concern is the Peregrine Falcon (*Falco peregrinus*), which have been reared and released at Hawksbill Mountain within the park since 2000, with a pair nesting on Stony Man Mountain in 2006. Cliff-related recreational activities can disrupt raptor foraging, nesting activities, and cause abandonment of nests and breeding territories (Cymerys & Walton 1988, Camp & Knight 1998). Climbing management options to avoid or minimize impacts to raptors are described in Pyke (1997).

Whereas cliff-face impacts are associated with rock climbers due to technical skill and equipment requirements, the remaining zones are subject to impact by other recreationists such as hikers and backpackers. However, few studies have examined the relative effect of alternative types of recreational use on cliff resources (Parikesit *et al.* 1995). Rather, it is often inferred, without empirical evidence, that cliff-top and cliff-bottom trampling impacts are caused primarily by rock climbers (Camp & Knight 1998, Kelly & Larson 1997, McMillan & Larson 2002). For example, a letter from Virginia's Division of Natural Heritage describing the trampling and loss of globally significant cliff-top plant communities at SNP largely attributed the worst damage to "increased heavy use … by large rock-climbing groups" at Little Stony Man Cliff (LSMC), a conclusion reached through intuition rather than empirical evidence. This letter prompted the park to initiate the study presented in this report.

Climbing-related impacts include use of fixed anchors for protection, and chalk (carbonate of magnesia) that reduces sweat on hands to provide greater friction and grip on the rock.

Potential impacts from chalk use include its visibility, dissolution of carbonate rock minerals, and increase in pH that could adversely affect cliff vegetation (Jones 2004, Swineford 1994). Use of gray chalk can minimize visual impacts, which are limited to specific handholds. Chalk can raise the solubility of carbonate minerals in rocks such as dolomite and limestone, though this effect is likely negligible given the small amounts of chalk used. Similarly, the extent to which small amounts of chalk alters the pH of water runoff or affects cliff vegetation are likely minor, though this topic has not been investigated.

Installation of fixed anchors has been a particularly controversial issue for managers of federal wilderness areas, due to their permanency (Jones & Hollenhorst 2002). Anchors generally take the form of expansion bolts that are hammered into a hole drilled in the rock. Climbers attach their ropes to the anchors, which can arrest a fall when climbers are belayed from the cliff-base. Most management agencies have policies governing their installation and maintenance in wilderness, or their use is addressed in management plans. Their use does little damage to the rock (a drilled hole) and in some situations can avoid greater resource impact associated with tying ropes to trees, including trampling of plants and soil (Pyke 2001). Their use is also a subject of some debate between different types of climbers. Traditional climbers generally shun their use, preferring the challenge of placing removable protection devices in rock cracks. In contrast, sport climbers, who generally make face climbs that do not follow crack systems, require large numbers of bolts.

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 and recreation sites include:

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

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

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

Before a monitoring program can be developed, appropriate resource indicators must be selected. A single, direct measurement of a recreation site’s or 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 or recreation site that serve as indicators of that facility's condition. Cole (1989b), Marion (1991) and Merigliano (1990) review criteria for the selection of indicators (Figure 3), 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. Recreational trampling sufficient to expose a campsite's soil, for example, is aesthetically unappealing and renders the site vulnerable to soil compaction and erosion. Similarly, indicator measures should primarily reflect changes caused by the recreational activity of interest. For example, measures of tree damage should exclude damage caused by lightning strikes. However, soil erosion along the shorelines of campsites may be attributable to a combination of recreation use and natural forces, suggesting it would make a poor indicator in this particular setting. Indicators should be measurable, preferably at an interval or ratio scale where the distances between numeric values are meaningful, i.e. a trail that is 36 inches wide it twice the width as a trail with an 18 inch width. 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.

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?

Figure 3. Criteria for selecting indicators of resource condition. Adapted from Cole (1989b), Marion (1991a), 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. Accurate measurements correctly describe how much change has occurred; precise measurements permit objective comparisons of change over time (Cole 1989b, 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.

Some indicators are less appropriate than others. For example, indicators of depreciative behavior, such as tree damage, litter, and fire construction in areas were fires are banned, detract unacceptably from environmental or social conditions. Unfortunately, indicators that reflect depreciative behavior present difficulties for managers because the resource degradation is often attributable to a small number of visitors whose actions may be less responsive to traditional management actions. These, and other indicators that are temporally dynamic, are also difficult to monitor effectively. For example, the number of fire sites and extent of litter and improperly disposed human waste can vary considerably from one week or month to the next.

Preferred Indicators

From these indicator criteria and knowledge of how recreation affects soil, vegetation, and aesthetics, managers select preferred indicators of trail or recreation site conditions. Table 2 includes a listing of commonly employed indicators for assessing resource conditions on trails and recreation sites 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. Generally, travel time to the sampling locations is the most substantial portion of the time budget so assessing a few additional indicators is 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.

Two of the most common recreation site indicators are the number or density of visitor-created recreation sites and site size. For soil, the area of exposed soil and number of trees with exposed roots are indicators that represent the extent of organic horizon pulverization and loss, and the compaction and erosion of the underlying soil. Many studies have also shown the extent of exposed soil to be linearly correlated with amount of use (Hammitt & Cole 1998, Marion &

Merriam 1985). The area of vegetation loss is perhaps the best indicator of vegetation disturbance (Cole 1989a).

Although the dynamic nature of many aesthetic and behavioral indicators present assessment difficulties, those that have been shown to be most pertinent to management objectives and visitor concerns are often selected. These indicators include the number of trails extending from a recreation site, the number of damaged trees or stumps, and the presence of litter and improperly disposed human waste. Infrequent monitoring can provide a "snapshot" of the conditions for the most dynamic indicators but more frequent monitoring is required to characterize their true condition or to reliably evaluate the effectiveness of management actions.

For trails, the number, length, and density of visitor-created trails, along with tread width, are the most commonly used indicators. Soil erosion, an ecologically significant trail impact, can be assessed at sample points by measuring maximum incision or cross sectional area. An alternative “Problem Census” method assesses the lineal extent along trails of all occurrences of erosion that exceed a pre-defined level. Similarly, tread muddiness can be assessed at sample points as a percentage of tread width or as the lineal extent along trails through a problem census approach.

Table 2. Potential indicators of recreation site and trail conditions and measurement units.

Campsite Indicators	**Measurement Units**
Informal Recreation sites	#/unit area, #/unit length along formal trails
Recreation site Size	Max. value, value/unit area, aggregate value/unit area
Area of Vegetation Loss	Max. value, value/unit area, aggregate value/unit area
Area of Soil Exposure	Max. value, value/unit area, aggregate value/unit area
Damaged Trees	Max. value, value/unit area, aggregate value/unit area
Trees w/Exposed Roots	Max. value, value/unit area, aggregate value/unit area
Fire Sites	Max. value, value/unit area, aggregate value/unit area
Litter	Max. value, value/unit area, aggregate value/unit area
Human Waste	Max. value, value/unit area, aggregate value/unit area
Trail Indicators	**Measurement Units**
Informal Trails	Length/unit area, % of formal trail length, #/unit length on formal trails [PC]
Tread Width	Max. value, value/unit length, running avg./unit length [PS]
Maximum Incision	Max. value, value/unit length, running avg./unit length [PS]
Cross Sectional Area	Max. value, value/unit length, running avg./unit length [PS]
Excessive Erosion	Length/unit area, % of trail length, length/unit length along formal trails [PC]
Muddiness	Max. % of tread width, avg. %/unit length, running avg. %/unit length [PS]
Excessive Muddiness	Length/unit area, % of trail length, length/unit length along formal trails [PC]

PS = Point Sampling, PC = Problem Census

In summary, managers must consider and integrate a diverse array of issues and criteria in selecting indicators for monitoring impacts on recreation sites. 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.

Types of Trail Impact Assessment Systems

Formal trail surveys provide information for a number of important management needs. The location and lineal extent of formal and informal trails can be documented and monitored. The number, location and efficacy of trail maintenance features, such as water bars and drainage dips, can be assessed. Trail conditions may be assessed to identify the location, type and extent of trail resource impacts. Information on trail conditions 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 Coleman (1977), Cole (1983), and Leung and Marion (2000). At the most basic level, a trail inventory may be employed to locate and map trails and to document trail features such as type of use, segment lengths, hiking difficulty, and natural and cultural features. Trail location information can be accurately documented using a Global Positioning System (GPS) device, which can be input to a Geographic Information System (GIS) for display and analysis of trail attributes (Wolper *et al.* 1994, Wing & Shelby 1999).

Trail facility and maintenance assessments provide information on existing or needed trail maintenance features or work. These assessments may be used to develop databases on signs (e.g., location and text), existing facilities (e.g., bridges) and tread features (e.g., water bars, steps, bog bridging). Prescriptive trail maintenance work log assessments have also been developed to describe recommended solutions to existing tread deficiencies, such as installation of water bars and steps or trail rerouting (Birchard & Proudman 2000, Williams & Marion 1992). Data can be summarized to provide cost and staffing estimates and to direct work crews.

Trail condition assessments seek to describe resource conditions and impacts for the purpose of documenting trends in trail conditions, investigating relationships with influential factors, and evaluating standards or the efficacy of corrective management actions. Leung and Marion (2000) provide a classification of alternative trail impact assessment and monitoring methods. Sampling-based approaches employ either systematic point sampling, where tread assessments are conducted at a fixed interval along a trail (Cole 1983, Cole 1991), or stratified point sampling, where sampling varies in accordance with various strata such as level of use or vegetation type (Hall & Kuss 1989). Alternately, census-based approaches employ either sectional evaluations, where tread assessments are made for entire trail sections (Bratton *et al.* 1979), or problem census evaluations, where continuous assessments record every occurrence of predefined impact problems (Cole 1983, Leung & Marion 1999a, Marion 1994). These two approaches of assessment have been combined in an integrative survey (Bayfield & Lloyd 1973). More elaborate and time-consuming methods for accurately characterizing soil loss (Leonard & Whitney 1977) and vegetation changes (Hall & Kuss 1989) have also been developed.

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 census method is a preferred approach for monitoring trail characteristics that are easily predefined or infrequent (e.g., excessive width or secondary treads), particularly when information on the location of specific trail impact problems is needed.

Types of Recreation Site Impact Assessment Systems

Systems for assessing recreation site conditions differ significantly in the type of information collected, assessment methods, and assessment time. Three general approaches can be been applied:

1) *Photographic systems* - based on repeat photographs from permanent photo points.
2) *Condition class systems* - based on descriptive visual criteria of general site conditions.
3) *Multi-indicator systems* - based on individual measurements and appraisals of many specific indicators of resource condition.

A brief summary of these approaches and systems follows, see Cole (1989b), Marion (1991), and Leung and Marion (2000) for more comprehensive reviews of these systems.

Photographic systems were among the first applied to document the trampling effects of visitors (Magill & Twiss 1965). Photographic methods are generally easy to establish, require little time for repeat photographs, and yield easily understandable visual records of recreation site conditions. Disadvantages include poor comparability due to inconsistent photographic quality, lack of quantitative measurements for specific types of changes, and changes that are missed in areas hidden from view or not photographed. Additionally, assessment of photographic data requires extensive investment of time to handle and compare individual photographs.

Condition class systems have been described by Frissell (1978) and Marion (1991). Such systems consist of a set of statements describing increasing levels of resource change. Observers compare site conditions to these descriptive condition classes and record the class that most closely matches the conditions of the site being assessed. This type of system is easy and quick to apply and provides a useful summary measure of resource condition. However, as with photographic systems, this approach does not provide quantitative measurements of specific resource changes. Furthermore, the visual criteria used in these systems are subjective and require careful training of personnel to achieve consistent results. Perhaps most importantly, the data collected allow for only limited analysis because the differences between condition classes are not related linearly. Instead, they are ordinally related. An ordinal relationship means that a condition class 2 site is not twice as degraded as a condition class 1 site.

Multi-indicator systems are based upon independent assessments of several inventory variables and condition indicators. Several different approaches, including rapid estimation techniques as well as more objective but time-consuming measurement-based approaches have been developed. Rapid estimation rating systems designed by Parsons and MacLeod (1980), Cole (1983), and Marion (1984) consist of 6 to 10 variables, each with 3 to 5 quantitatively defined rating categories reflecting the degree of change in a particular indicator. Evaluators assign ratings to each impact parameter based on estimates or quick measures of impacts and comparison to numerically defined impact categories. Ratings, rather than the measured values, are emphasized with these rapid assessment approaches due to the generally low accuracy of the assessment procedures. Marion (1991) has refined multi-indicator systems that emphasize more accurate area measurements of campsite condition. Measurements for many indicators are completed within permanently referenced campsite boundaries, allowing substantially greater precision.

STUDY AREA

Shenandoah National Park encompasses 70 miles of ridge crest along the Blue Ridge Mountains of Virginia. These mountains, and their exposed cliffs and outcrops, are comprised of granitic gneisses, greenstones, and metasedimentary rocks (Thornberry-Ehrlich 2005). The granitic rocks, found only on Old Rag Mountain, are the oldest formations exposed in the park, formed during the Proterozoic age some 1.1 billion years ago. The greenstone rocks are low-grade metamorphic remnants of basalt lava flows and intrusive dikes dating back to around 570 million years ago (Gathright 1976, Thornberry-Ehrlich 2005). At this time two large tectonic plates began to drift apart, allowing an upwelling of molten rock over several million years that covered over 4,000 miles of land. These flows, ranging from 20-100 feet thick are called the Catoctin Formation. Originally composed of black basalt, the rocks were metamorphosed, the intense heat and pressure allowing the growth of new minerals such as chlorite and epidote, that give the exposed rocks a grey and dark green color.

Rock outcrops and cliffs punctuate the otherwise forested landscape composing approximately 2% (3,920 acres) of the Park's 196,000+ acre area. The cliffs of SNP are some of the largest in the region and serve as islands of unusual habitat and species assemblages. The park's geology and soils are closely related since soils are derived from the underlying rock formations. Interestingly, strong correlations between rock type and flora and fauna have also been discovered. For example, Virginia Department of Conservation and Recreation (VADCR) surveys have found that high elevation greenstone cliff-top formations host a rare plant community type, the high elevation greenstone outcrop barren, believed to be endemic to the park (Fleming *et al.* 2004). The rare Shenandoah Salamander (*Plethodon* Shenandoah) prefers greenstone talus deposits for its habitat (Ludwig et al. 1993). The relatively high elevation of many rock outcrop areas in the park means that these areas also provide habitat for unique communities of boreal disjunct species. For example, the bearberry (*Arctostaphylos uva-ursi*) shrub is known from one outcrop area in the park, and is disjunct over 200 miles from its southern range limit. Previous VADCR survey work at a few of the park's larger rock outcrop and cliff communities has documented the occurrence of 28 rare species.

Existing SNP natural resources information regarding cliff-related flora and fauna are insufficient for management decision making. The best available park vegetation map lacks sufficient resolution to adequately locate and classify cliff and rock outcrop areas because of their small size and linear shapes. In addition, numerous outcrop and cliff areas within the park have never been visited by survey teams, and it is suspected that many more occurrences of rare botanical and zoological resources will be found if survey work is performed in these areas. Cliff and rock outcrop areas have been identified by the VADCR, Division of Natural Heritage, as some of the most important sites for immediate conservation action in the park (Smith 2002).

Unfortunately, cliffs are also popular destination features for thousands of park visitors, primarily by providing scenic vistas above forest canopies, waterfalls, and opportunities for climbing. The location of the world-famous park tour road, Skyline Drive, along the ridgeline provides exceptional access to many outcrops and cliffs throughout the park for a large number of the park's 1.7 million annual visitors. Walking, hiking and backpacking are perhaps the most popular recreational activities in the park. Visitation at one of the park's most accessible peaks averaged 980 people per week during the summer and fall of 2002 (Hilke 2002). This visitation occurred exclusively within an identified rare plant community. No visitation data is available for the park's most popular hike/climbing destination, Old Rag Mountain, a granitic peak served by a 250-car parking area often filled to capacity on weekends.

The popularity of the park for rock climbing and bouldering appears to have increased within the last 10 years, though rock climbing in the park remains a minor and low use recreational activity. Rock climbing is not monitored or actively managed by park staff; there are no climbing guidelines or registration procedures. Regardless, one climbing guide (Watson 1998) identifies 27 separate rock climbing areas within the Park, each area described in detail with numerous climbing routes. The most popular park climbing area is Little Stony Man cliffs, regularly used by nearby universities and outdoor organizations for climbing classes. Also of note are the cliffs on Old Rag Mountain (Hörst 2001), which are attractive to climbers because of their regionally rare granite rocks, though the long uphill hike makes them far less accessible than other cliffs in the park.

Many different types of climbing are practiced within SNP, each requires different types of cliffs or rock outcrops. Like other park visitors, climbers have varying levels of experience, skills, equipment, and activity preferences (Hollenhorst 1987, Merrill & Grafe 1997). The majority of climbing in the park is traditional or top-roped climbing, with some sport climbing, bouldering, rappelling, ice climbing, and limited aid climbing. Trad climbing involves scaling the cliff from the base, with the lead climber placing protective devices in cliff cracks attached to the climbing rope with a belayer positioned at the cliff base. The protection used is removable and does not damage the rock. The second climber is belayed from the top and removes the protection as they ascend. In top-roped climbing the belayer can be at the cliff top, or if the cliff is short cliff top anchors can be placed so that the belayer can be positioned at the base so they can better see the climber, with the rope extending up to the anchor and back down to the climber. Sport climbing involves the use of permanent or fixed protection, expansion bolts, that are hammered into holes drilled in the rock. While a few bolts can be seen on several SNP cliffs, most appear to receive little use. Bouldering involves climbing low to the ground without ropes, frequently above a large foam "crash pad" that fellow climbers reposition beneath the climber as they climb. Bouldering likely occurs at SNP cliffs and rock outcrops but the specific sites are generally not noted in the guidebooks and we neither found or heard of specific areas where it was a common activity. Rappelling is a method of descending a cliff on ropes following a climb, though some recreationists only rappel and do not climb. Ice-climbing generally can only occur at specific locations such as waterfalls or cliff-face seeps that create columns of ice that can be climbed with special ice-climbing gear. Finally, aid-climbing is practiced only by advanced climbers with gear that allows to traverse overhangs or difficult rock faces relying entirely on equipment rather than hand- and foot-holds. It is important for managers to understand these different cliff-related recreational activities when evaluating their associated resource impacts or considering management educational or regulatory practices.

Intense visitor use of cliff areas can lead to resource impacts such as soil compaction, erosion, vegetation damage and loss, informal trail development and proliferation, illegal or poorly located campsites, and human waste disposal issues. The vegetation communities that thrive on cliffs and rock outcrops can be susceptible to human impacts from hiking and climbing activities because in places they support delicate lichen growth and mats of vegetation growing on thin soil or in rock crevices. Lichens take decades to grow back once damaged, and vegetation recovers slowly because the soil needed for growth is often eroded by traffic, water, or high winds. VADCR, Department of Natural Heritage, botanists have noted degradation of several outcrop plant communities within the park over the last twenty years (Fleming 2003). Outcrop and cliff areas that were once pristine have been virtually denuded of lichen and vegetation cover. Known rare plant populations have exhibited marked decreases in size and vigor, and campsite and informal trail proliferation are occurring in one area occupied by the federally endangered Shenandoah Salamander. Old Rag Mountain had a pristine example of the high elevation acidic heath barren community on one of the mountain's two main summits. Within the last 20 years the area has become increasingly popular with hikers and has suffered severe trampling damage to vegetation and substantial soil erosion (Fleming 2003).

METHODS

Selection of Study Sites

SNP, VA DCR, and USGS staff assembled a listing of 48 possible study areas based on known cliff and rock outcrop sites, aerial photography, and ground truth surveys. Gary Fleming and Kevin Heffernan (VA DCR) and John Young (USGS) then used lines to delineate cliff and outcrop tops with 100 m buffers to form study area polygons for each site. Ground surveys of each study area by Gary Fleming and Eric Butler (NPS) noted the presence of permanent visitor impacts in the form of recreation sites at the tops or base of cliffs and/or informal trails. This information, along with NPS input and approval, led to the selection of 17 study sites for recreation impact assessments (Table 3). Field survey work was completed for 16 of these, omitting Old Rag–East (C37), due to limitations on field time. This selection is believed to include nearly all sites with permanent visitor-created informal trails and recreation sites, though we note the possibility of minor human impacts in some of the other study areas. The study areas generally have cliffs and rock outcrops comprised of Metabasalt, are located in the higher elevation zones, and VADCR biologists ranked their biological significance at high or intermediate levels (Table 3).

Table 3. Study area bedrock type, elevation zone, and biological significance ratings.

Study Area	Bedrock Type	Elevation	Biological Significance
Betty's Rock Overlook (C02)	Metabasalt	High	1
Blackrock Summit (C04)	Metabasalt	High	1
Calvary/Chimney Rocks (C08)	Sandstone	Moderate	3
Crescent Rock (C10)	Metabasalt	High	1
Franklin Cliffs Overlook (C16)	Metabasalt	High	1
Gooney Manor Overlook (C19)	Metabasalt	High	1
Hawksbill Summit (C22)	Metabasalt	High	1
Little Stony Man (C28)	Metabasalt	High	1
Loft Mountain Summit (C29)	Metabasalt	High	2
Mary's Rock Overlook (C31)	Charnockite	High	2
North Marshall Mtn. (C35)	Metabasalt	High	2
Old Rag: SE (C36)	Granite	Moderate	3
South Marshall (C46)	Metabasalt	Mod-High	2
Stonyman Cliffs (C47)	Metabasalt	High	1
Old Rag: Summit (C62)	Granite	High	2
Overall Falls Lookout (C63)	Metabasalt	Low	2

The outline of each study area was entered into a Global Positioning System (GPS) device so that we knew the study area boundaries during field survey work. Within each study area we hiked all formal park trails and looked for and walked all connecting visitor-created trails. Climbing guides weres also consulted to guide field searches at the top and base of described climbs (Horst 2001, Watson 1998). We also bushwacked to cliffs to search for trails and sites, including searches of cliff-top and cliff-base locations. We assessed each visitor-created trail, recreation site, or campsite found within study area boundaries, and in a few instances sites that were adjacent to but just outside boundaries but associated with cliff or outcrop features.

Recreation Site Procedures

Standardized procedures were developed, field tested and refined for assessing cliff-associated visitor impacts at recreation sites and campsites for incorporation into a long-term monitoring program. These procedures emphasize measurements over ratings but also incorporate condition class assessments and photographs from permanent photopoints. Photographs provide for visual comparisons of changes on individual sites over time. The field assessment manual containing detailed assessment procedures for all recreation site indicators is included as Appendix 1. Assessing impacts from climbing activities on the cliff-face was not an objective of this study.

Recreation sites and campsites were defined as areas of obvious vegetative or organic litter disturbance that in the judgment of survey staff was caused by visitor activities. Furthermore, the disturbance had to be of such extent to produce a discernable boundary between disturbed and undisturbed areas. Impact indicators were selected on the basis of earlier recreation ecology and visitor impact perception studies, indicator selection criteria, and discussions with park staff. Recreation site and campsite sizes were measured using a Variable Radial Transect method based on measurements of transect lengths and compass bearings radiating from a reference point to points selected along site boundaries (Marion 1995). Reference points were permanently marked and located using a GPS device (Garmin GPS Map 60C, accuracy between 10 and 50 feet) and referenced by compass bearings and distances to recognizable permanent features (see Appendix 1). Where necessary, multiple radial transects that shared common points were used to accurately measure area of disturbance for long linear recreation sites (Figure 4). Only two sites had to be split this way during the study; data for these sites were then combined to a common site for analyses. Site sizes were calculated arithmetically from transect data using Excel spreadsheet formulas.

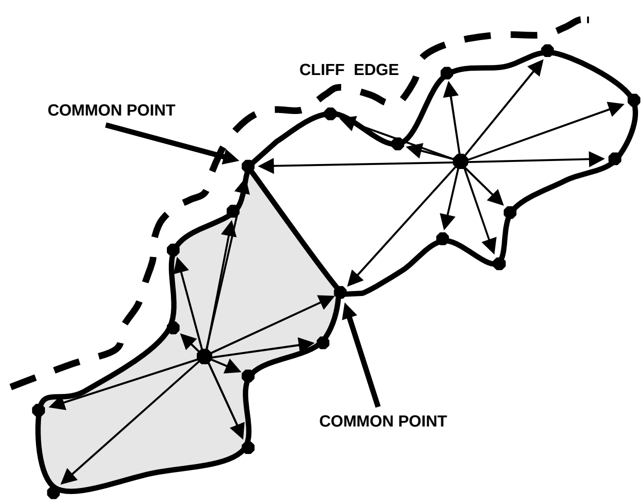


Figure 4. Modified Variable Radial Transect method used to delineate and measure the size of recreation sites and campsites.

For future reference we note that some of the Greenstone rock formations are sufficiently magnetic to alter compass readings. When this was noticed elevating the compass lessened the problem but in future surveys a lightweight aluminum stepladder is recommended to avoid any possible distortion. Visual checks of plotted recreation site boundaries failed to find any gross errors associated with this problem.

Conditions for most other indicators were assessed within the established boundaries for each site, with additional procedures allowing assessments of any "satellite" use areas. Fixing the area of interest within site boundaries increases the precision of assessments, however, this approach can reduce measurement accuracy. For example, counts of damaged trees and stumps conducted only within site boundaries increase the efficiency and precision of these assessments for future monitoring efforts but decrease the accuracy of assessing total or aggregate tree damage and felled trees.

Ground vegetation on recreation sites and campsites and in paired environmentally similar but undisturbed control sites, was assessed using six cover classes (Marion & Cole 1996). Vegetation loss was calculated by subtracting the onsite coverage class midpoint value from its paired control site coverage class midpoint value, resulting in a percentage of vegetation loss. This percentage value was multiplied by the corresponding site size to obtain an estimate of the area over which vegetation cover has been lost. The area of exposed soil was also assessed by multiplying the onsite coverage class midpoint value for exposed soil by the corresponding site size.

Tree damage and root exposure were recorded by category (none/slight, moderate, and severe) for each onsite tree and tree stumps were counted (Marion & Cole 1996). However, data are reported by summing trees assessed in the moderate and severe categories as “damaged trees” or “trees with exposed roots.” These indicators were assessed to evaluate potential damage to trees from climbing ropes being tied around them and from intensive foot traffic and associated soil loss around tree roots. Informal trails that connected with each site were counted, regardless of length. Site expansion potential was assessed for each site based on the extent to which expansion appeared to be inhibited by topography, rockiness, or dense woody vegetation.

Trail Assessment Procedures

Standardized procedures were also developed, field tested and refined for assessing all cliff-associated informal (visitor-created) trails exceeding 10 feet in length (a decision rule to conserve assessment time) within each study area. The field assessment manual containing detailed informal trail assessment procedures is included as Appendix 2. Informal trails were defined as lineal routes with obvious vegetative or organic litter disturbance that in the judgment of survey staff was caused by visitor activities. Faint trails that receive very little use were included, though routes receiving limited traffic would likely not lead to permanent or visible vegetation change and would be omitted from our survey. A GPS device was used to document each trail’s location.

The condition of informal trails was assessed using point sampling procedures modified from Farrell and Marion (2001) and Marion (2006), and included measurement of trail length, width, and soil loss since trail creation using a Cross Sectional Area (CSA) procedure (Figure 5). CSA was calculated using Excel spreadsheet formulas based on vertical measurements taken at 0.3 ft intervals along each trail transect. Trail condition measurements were taken at transects spaced at fixed intervals along each trail following a randomized start. The number of transects for each trail was proportional to the trail's length (see Table 1, Appendix 2). A trail measuring wheel was used to identify sample point locations. At each sample point, a transect was established perpendicular to the trail tread. Tread width was defined by boundaries at the most visually pronounced change in non-woody vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is minimal or absent, disturbance to organic litter. Such boundaries are intended to capture about 95% of all trail traffic. Trail width was roughly equivalent to tread width on informal trails with little or no erosion, though generally slightly longer as it was derived from CSA measurements taken every 0.3 ft. (V_1 to V_{16} in Figure 5). For more deeply incised trails, tread width was assessed only across the bottom of the eroded tread, excluding the steep sides that are not walked upon (depicted in Figure 5).

Trail condition measures were calculated for each trail and for all trails combined, including area of disturbance, CSA, and mean trail width, depth, and CSA (Table 4). For example, "area of disturbance," an estimate of the land area intensively disturbed by informal trail traffic, was calculated by multiplying trail length by mean trail width. CSA volume, an estimate of aggregate soil loss (CSA ft^3), was calculated by multiplying mean CSA (converted to ft^2) by trail length.

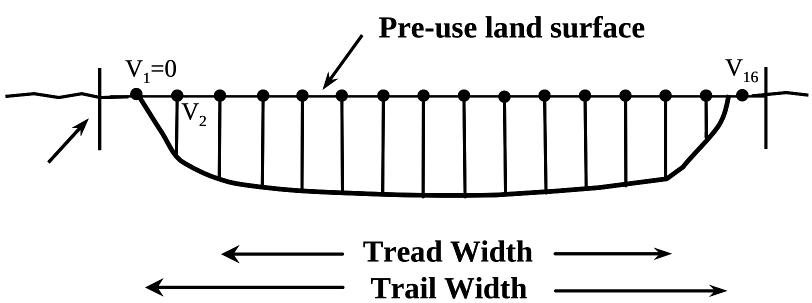


Figure 5. Cross Sectional Area (CSA) diagram illustrating measurement procedures for visitor-created trails.

Table 4. Description of trail impact indicators and calculation methods.

Trail Length	Length of informal trail, summed to obtain an aggregate measure for each study area.
Tread Width	Width of tread that captures about 95% of all traffic. Assessed at sample points along each informal trail and averaged for each trail to obtain mean trail width.
Trail Width	Width of trail, including tread and trail-sides up to pre-use land surface. Assessed at sample points along each informal trail and averaged for each trail to obtain mean trail width. Mean trail width for study areas was calculated as the area of disturbance for each trail divided by total length.
Area of Disturbance	The mean trail width times the trail length.
CSA	The cross sectional area from the pre-use land surface to the tread surface. Assessed at sample points along each informal trail and averaged for each trail to obtain mean CSA. Mean CSA for study areas was calculated as average of the CSA values measured at the sample points.
CSA Volume	The mean CSA for a trail times trail length – an estimate of the total volume of soil lost from a trail.
Mean Trail Depth	Calculated by dividing mean CSA by mean trail width.

RESULTS

Recreation Sites

Field staff found a total of 44 recreation sites at 15 of the 16 study areas visited (2.75 sites/study area), ranging from no sites at Gooney Manor Overlook to 7 sites at Little Stony Man (Table 5). Seven of the study areas had only two recreation sites. The majority of recreation sites (32, 73%) were judged to be used predominantly by hikers, all located at cliff-top locations and considered to be vista sites (Table 5). Type of use judgments were made based on patterns of trampling at each cliff site (e.g., the presence of cliff-base disturbance associated with the location of climbing routes described in climbing guidebooks), climbing guidebook information, and conversations with park staff and area climbers. Six sites (14%) were judged to be primarily climbing-related, five at cliff-base locations and one at cliff-top. These sites are found in two of the study areas on Old Rag (Table 6), sites that can only be accessed by steep downhill bushwhacks from the trail to the summit. An additional six sites were judged to be mixed hiking and climbing, three at cliff-base locations and three at cliff-top, all found in the Little Stony Man study area (Table 6). A substantial majority of the recreation sites (36, 82%) were located at the tops of cliffs, reaffirming their suspected use primarily as vista sites (Table 4). We note that rock climbers generally spend the majority of time at cliffs on the face or at cliff-base recreation sites. Though use data for these sites is unavailable, rough estimates based on dialogue with park staff and climbers, and by the site sizes and evidence of vegetative trampling, reveal that most (30, 68%) are believed to receive high use, with 7 each at medium and low use (Table 5).

For those sites used by climbers (12, 28%), based on climbing guidebook descriptions and site observations the predominant type of climbing in the park is traditional or “trad” climbing, occurring at 10 sites, five of which also likely have some top-roped climbing (Table 5). One site was classified as mixed trad and sport climbing and one site as bouldering. The number of sites by study area and type of climbing is presented in Table 7.

The expansion potential of recreation sites was assessed by determining the extent to which further use and expansion in size would be limited by topography or dense vegetation. Most sites were judged to have moderate expansion potential (17, 39%), with 10 sites rated as having good expansion potential and 17 rated as poor (Table 5). Given their proximity to cliffs, it is not surprising to find that large numbers of the recreation sites had sloping terrain: 12 (27%) with slopes >10% and 17 (39%) with slopes of 5-10%. An important implication is that vegetation cover is generally largely removed on recreation sites and on steeper slopes soils not protected by vegetation cover and roots can quickly erode.

Appendix 3 contains study area maps that depict the spatial distributions of recreation sites, campsites, and trails within each study area. These were generated from GPS data collected during field surveys with reference point data for all recreation sites and campsites and track data for all informal trails. Furthermore, an Excel file containing the Variable Radial Transect data for all recreation sites and campsites and including a plotting of site boundaries from latitude/longitude coordinates has been provided to Shenandoah National Park staff as another product of this work. An illustrative example of simple study area maps that can be made from such data is presented in Figure 6 for the Little Stony Man Cliffs.

Table 5. Inventory indicator data for recreation sites found within the 16 study areas (park codes for the study areas appear in parentheses).

Inventory Indicators		Recreation Sites N	Recreation Sites %
Study Area	Betty's Rock Overlook (C02)	1	2
	Blackrock Summit (C04)	2	5
	Calvary/Chimney Rocks (C08)	2	5
	Crescent Rock (C10)	2	5
	Franklin Cliffs Overlook (C16)	2	5
	Gooney Manor Overlook (C19)	0	0
	Hawksbill Summit (C22)	4	9
	Little Stony Man (C28)	7	16
	Loft Mountain Summit (C29)	2	5
	Mary's Rock Overlook (C31)	2	5
	North Marshall Mtn. (C35)	3	7
	Old Rag: SE (C36)	4	9
	South Marshall (C46)	1	2
	Stonyman Cliffs (C47)	2	5
	Old Rag: Summit (C62)	6	14
	Overall Falls Lookout (C63)	4	9
Expansion Potential	Good	10	23
	Moderate	17	39
	Poor	17	39
Site Slope	<5%	15	34
	5-10%	17	39
	>10%	12	27
Type of Use	Mostly Climbing	6	14
	Mixed Climbing/Hiking	6	14
	Mostly Hiking	32	73
Site Use Level	High	30	68
	Medium	7	16
	Low	7	16
Site Location	Bottom	8	18
	Top	36	82
Type of Climbing	Bouldering	1	2
	Mixed Sport & Trad	1	2
	Mostly Trad	5	11
	Not Applicable	32	73
	Trad w/Top Rope	5	11

Table 6. Number of recreation sites by type of use and study area.

Study Areas	Type of Use		
	Mostly Climbing	Mixed Climbing/Hiking	Mostly Hiking
	sites (#)		
Betty's Rock Overlook	0	0	1
Blackrock Summit	0	0	2
Calvary/Chimney Rocks	0	0	2
Crescent Rock	0	0	2
Franklin Cliffs Overlook	0	0	2
Hawksbill Summit	0	0	4
Little Stony Man	0	6	1
Loft Mountain Summit	0	0	2
Mary's Rock Overlook	0	0	2
North Marshall Mtn.	0	0	3
Old Rag: SE	4	0	0
South Marshall	0	0	1
Stonyman Cliffs	0	0	2
Old Rag: Summit	2	0	4
Overall Falls Lookout	0	0	4

Table 7. Number of recreation sites by type of climbing and study area.

Study Areas	Type of Climbing				
	Climbing Not Evident	Bouldering	Mixed Sport & Trad	Mostly Trad	Trad & Top Rope
	sites (#)				
Betty's Rock Overlook	1	0	0	0	0
Blackrock Summit	2	0	0	0	0
Calvary/Chimney Rocks	2	0	0	0	0
Crescent Rock	2	0	0	0	0
Franklin Cliffs Overlook	2	0	0	0	0
Hawksbill Summit	4	0	0	0	0
Little Stony Man	1	1	0	0	5
Loft Mountain Summit	2	0	0	0	0
Mary's Rock Overlook	2	0	0	0	0
North Marshall Mtn.	3	0	0	0	0
Old Rag: SE	0	0	1	3	0
South Marshall	1	0	0	0	0
Stonyman Cliffs	2	0	0	0	0
Old Rag: Summit	4	0	0	2	0
Overall Falls Lookout	4	0	0	0	0

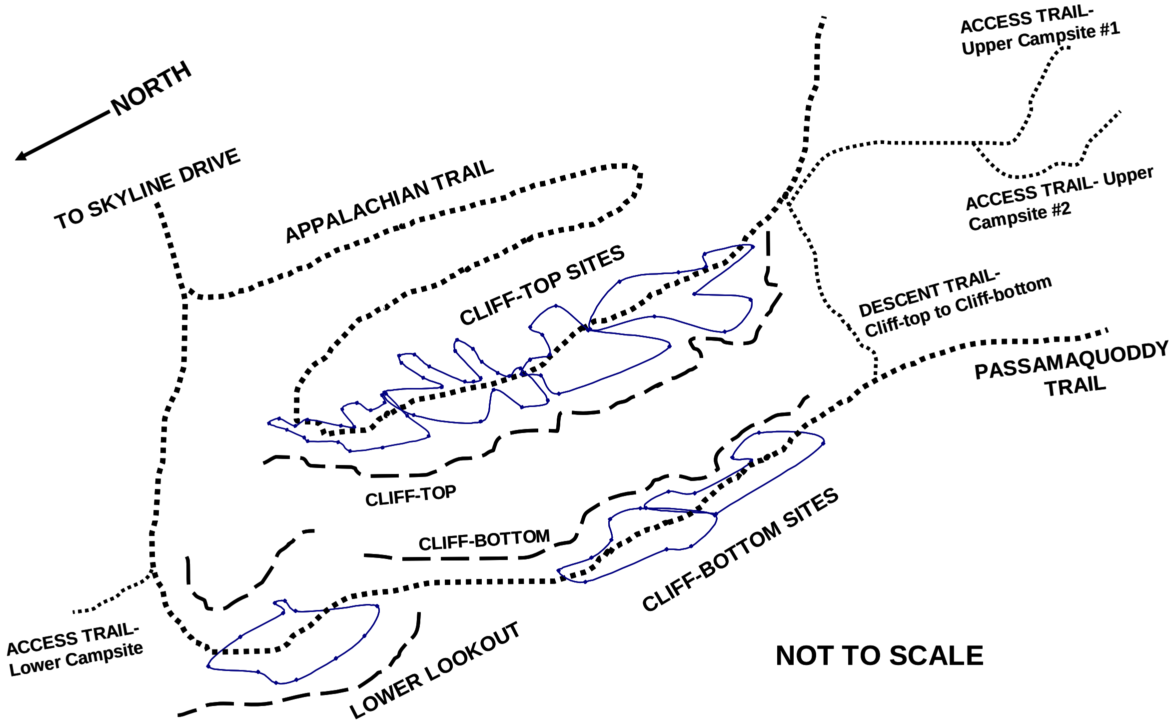


Figure 6. Recreation sites and formal/informal trails in the vicinity of the Little Stony Man Cliffs (from Wood, Lawson & Marion 2006).

Resource conditions at all recreation sites were assessed with a condition class rating system (Table 8) and through measurements for a number of specific indicators. Site numbers increased with condition class. These data suggest that while cliff-associated recreation sites are not very numerous in the park, their resource conditions are generally very poor. For example, 31 sites (70%) were rated class 4 or 5 (Table 9). Some of the quantitative data are included in Table 7 to characterize the condition class ratings. These data show that the majority of recreation sites have lost nearly all their vegetation and organic litter cover, exposing rock or soil, the latter being susceptible to erosion from wind or rain. Given that cliff-tops generally have very thin soils over bedrock, these levels of impact can be a significant threat to the protection of cliff-associated plant communities.

Table 8. Condition Class rating descriptions.

Class 1:	Site barely distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.
Class 2:	Site obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3:	Vegetation cover lost and/or organic litter pulverized on much of the site, some bare soil exposed in primary use areas.
Class 4:	Nearly complete or total loss of vegetation cover and organic litter, bare soil widespread.
Class 5:	Soil erosion obvious, as indicated by exposed tree roots and rocks and/or gullying.

Table 9. Number, percent, size, vegetation cover, and exposed soil of recreation sites by condition class.

Condition Class	**Sites** #	%	**Avg. Site Size** (ft^2)	**Avg. Vegetation Cover** (%)	**Avg. Exposed Soil** (%)
1	2	5	38	20	20
2	4	9	113	39	3
3	7	16	376	12	21
4	11	25	685	7	16
5	20	45	1353	5	42
All Sites	44	100	858	10	28

Table 10 presents mean and sum measures for nine specific resource condition indicators of recreation site condition by study area. Recreation site size ranged from 6-5683 ft^2 with a mean of 858 ft^2 and a sum of 37,738 ft^2 (0.87 acres). Twelve sites exceeded 1000 ft^2 in size, accounting for 27,555 (73%) of the total sum. The study areas with the largest areas of disturbance were Little Stony Man, Hawksbill Summit, Loft Mountain Summit, Stonyman Cliffs, and Old Rag Summit. Vegetation cover loss for sites ranged from 0-83% with a mean of 44%. Estimated area of vegetation loss ranged from 0-1703 ft^2 with a mean of 339 ft^2 and a sum of 14,907 ft^2. Only four study areas had areas of vegetation loss exceeding 1000 ft^2, totaling 10,216 ft^2, 69% of the total sum (Table 10). Percent exposed soil on recreation sites ranged from 3-86% with a mean of 28%. Estimated area of soil exposure ranged from 0-1171 ft^2 with a mean of 215 ft^2 and a sum of 9454 ft^2. Only two study areas had areas of soil exposure exceeding 1000 ft^2, totaling 5495 ft^2, 58% of the total sum (Table 10).

The number of damaged trees per recreation site ranged from 0-5 with a mean of 0.4 and a sum of 17. Eleven of these trees were located at the Little Stony Man Cliffs. Similarly, the number of trees with exposed roots ranged from 0-3 with a mean of 0.3 and a sum of 11. Tree stumps were relatively uncommon, ranging from 0-4 with a mean of 0.2 and a sum of 7, 5 of which were located at Little Stony Man Cliffs. Finally, the number of formal and informal trails connecting with recreation site boundaries ranged from 1-12 with a mean of 2.5 and a sum of 111. Three study areas had 15 or more trails, totaling 57 trails, 51% of the total sum. The six sites on the Old Rag Summit accounted for 25 trails, the highest density of any study area.

Table 10. Recreation site conditions as assessed by quantitative indicators summarized by study area. Numbers in parentheses following each study area refer to the number of recreation sites within that study area.

		Site Size (ft^2)	**Vegetation Loss** (%)	**Vegetation Loss** (ft^2)	**Exposed Soil Onsite** (%)	**Exposed Soil Area** (ft^2)	**Damaged Trees** (#)	**Trees w/Exposed Roots** (#)	**Tree Stumps** (#)	**Site Trails** (#)
Betty's Rock	*Mean*	1134	48	539	16	176	0	0	0	2
Overlook (1)	*Sum*	1134		539		176	0	0	0	2
Blackrock	*Mean*	814	24	147	20	85	0	0	0	3
Summit (2)	*Sum*	1628		293		169	0	0	0	5
Calvary/Chimney	*Mean*	349	37	150	9	37	0	0	1	2
Rocks (2)	*Sum*	697		299		74	0	0	1	4
Crescent Rock (2)	*Mean*	566	35	130	9	16	0	0	0	2
	Sum	1132		260		31	0	0	0	3
Franklin Cliffs	*Mean*	1302	30	292	9	79	0	0	0	4
Overlook (2)	*Sum*	2603		583		157	0	0	0	8
Hawksbill	*Mean*	1432	9	427	9	221	0	0	0	4
Summit (4)	*Sum*	5728		1706		886	0	0	0	15
Little Stony Man (7)	*Mean*	1415	49	650	32	433	2	0	1	2
	Sum	9908		4547		3029	11	2	5	17
Loft Mountain	*Mean*	2197	24	677	9	281	0	0	0	2
Summit (2)	*Sum*	4393		1354		562	0	0	0	4
Mary's Rock	*Mean*	418	72	335	51	319	0	0	0	2
Overlook (2)	*Sum*	836		669		638	0	0	0	3
North Marshall	*Mean*	73	52	30	14	22	0	0	0	1
Mtn. (3)	*Sum*	219		91		65	1	0	0	3
Old Rag: SE (4)	*Mean*	70	39	35	20	15	0	1	0	2
	Sum	280		140		60	1	3	0	8
South Marshall (1)	*Mean*	42	36	15	3	1	0	0	0	2
	Sum	42		15		1	0	0	0	2
Stonyman Cliffs (2)	*Mean*	1960	24	404	9	135	0	0	0	3
	Sum	3919		808		271	0	0	0	6
Old Rag: Summit (6)	*Mean*	621	71	435	60	411	0	1	0	4
	Sum	3724		2609		2466	2	4	1	25
Overall Falls (4)	*Mean*	374	66	248	57	217	1	1	0	2
	Sum	1495		992		869	2	2	0	6
Total (44)	*Mean*	858	44	339	28	215	0.4	0.3	0.2	2.5
	Sum	37,738		14,907		9454	17	11	7	111

Campsites

Field staff found an additional 10 campsites within 6 of the study areas (Table 11). These sites appeared to be used primarily as overnight campsites and were located near but set back away from cliff or rock outcrop features. The three sites located at Little Stony Man appear to be primarily used by climbing groups, but all other sites were judged to be used primarily by hikers (Table 11). Park staff, to protect adjacent cliff-top plant communities, have since closed two of the campsites at Little Stony Man. Nine of the sites have cliff-top locations and all were located under forest overstories, which ranged from 63% cover (1 site) to 98% (5 sites). In comparison to the recreation sites, campsites are located in flatter terrain with fewer limitations on site expansion and were judged to receive lower use (Table 11).

Table 11. Inventory indicator data for campsites found within the 16 study areas (park codes for the study areas appear in parentheses).

Inventory Indicators		**Campsites** N	%
Study Area	Calvary/Chimney Rocks	1	10
	Little Stony Man	3	30
	Loft Mountain Summit	2	20
	Mary's Rock Overlook	1	10
	North Marshall Mtn.	2	20
	South Marshall	1	10
Expansion Potential	Good	6	60
	Moderate	4	40
	Poor	0	0
Site Slope	<5%	7	70
	5-10%	3	30
	>10%	0	0
Site Use Level	High	2	20
	Medium	4	40
	Low	4	40
Type of Use	Mostly Climbing	3	30
	Mostly Hiking	7	70
Site Location	Bottom	1	10
	Top	9	90

Condition class ratings for the campsites ranged from class 2-4 with 7 sites rated class 3 (Table 8 and Table 12). Table 13 presents mean and sum measures for nine specific resource condition indicators of campsite condition by study area. The campsites are generally about half the size of the recreation sites, with a mean size of 430 ft^2. Site size ranged from 56 to 1488 ft^2 with a sum of 4297 ft^2. Two-thirds (68%) of the total area of disturbance for campsites is associated with the three campsites near the Little Stony Man cliffs (Table 13). Vegetation cover loss ranged from 0-83% with a mean of 41%, while the area of vegetation cover loss ranged from 0 to 376 ft^2 with a mean of 141 ft^2 and a sum of 1405 ft^2. Similarly, percent exposed soil on campsites

Table 12. Number, percent, size, vegetation cover, and exposed soil of campsites by condition class.

Condition Class	**Campsites** #	%	**Avg. Site Size** (ft^2)	**Avg. Vegetation Cover** (%)	**Avg. Exposed Soil** (%)
2	1	10	56	86	3
3	7	70	469	29	11
4	2	20	480	16	39
All Sites	10	100	430	32	16

Table 13. Campsite conditions as assessed by quantitative indicators summarized by study area. Numbers in parentheses following each study area refer to the number of recreation sites within that study area.

		Site Size (ft^2)	**Vegetation Loss** (%)	**Vegetation Loss** (ft^2)	**Exposed Soil Onsite** (%)	**Exposed Soil Area** (ft^2)	**Damaged Trees** (#)	**Trees w/Exposed Roots** (#)	**Tree Stumps** (#)	**Site Trails** (#)
Calvary/Chimney Rocks (1)	Mean	442	0	0	3	11	1	0	0	1
	Sum	442	0	0	3	11	1	0	0	1
Little Stony Man (3)	Mean	970	31	284	16	150	2	1	0	2
	Sum	2909	93	852	47	451	5	4	1	5
Loft Mountain Summit (2)	Mean	242	59	142	3	6	0	0	1	3
	Sum	483	118	284	5	12	0	0	1	5
Mary's Rock Overlook (1)	Mean	169	83	139	63	106	0	0	0	3
	Sum	169	83	139	63	106	0	0	0	3
North Marshall Mtn. (2)	Mean	111	30	43	20	32	0	0	0	1
	Sum	221	60	85	41	64	0	0	0	2
South Marshall (1)	Mean	73	61	44	3	2	0	0	0	1
	Sum	73	61	44	3	2	0	0	0	1
Total	Mean	430	41	141	16	65	0.6	0.4	0.2	1.7
	Sum	4297	413	1405	160	646	6	4	2	17

ranged from 3-63% with a mean of 16%, while the area of exposed soil ranged from 1-231 ft^2 with a mean of 65 ft^2 and a sum of 646 ft^2.

The number of damaged trees per campsite ranged from 0-3 with a mean of 0.6 and sum of 6, all but one were found on the Little Stony Man campsites (Table 13). Trees with exposed roots were less common, ranging from 0-2 with a mean of 0.4 and a sum of 4, all located on the Little Stony Man campsites. Only two tree stumps were found on campsites but the number of connecting trails ranged from 1-3 with a mean of 1.7 and sum of 17. Connecting trails were most numerous at Little Stony Man and the Loft Mountain Summit study areas, each with five trails (Table 13).

Informal Trails

Field staff located and measured 58 informal trails (7,532 lineal ft) within the 16 study areas (Table 14). Two study areas, Calvary Rocks and Overall Falls Lookout contained no informal trails. All but one area contained long segments of formal trails or roads (including the Appalachian Trail). Old Rag SE was the one area without any formal trails—but it did contain an informal trail leading to the base of a rock climb area (the trail had no erosion, Table 15).

The study area maps (Appendix 3) show the location of the informal trails within the 16 study areas. A visual inspection of the maps shows most of the informal trails are short offshoots from a formal trail or road to a cliff-top site that serves primarily as a vista. Overall, these 58 informal trails averaged 130 ft in length (Table 14). The area of disturbance from the informal trails ranged from no area of disturbance at the two sites with no informal trails, to 2,755 ft^2 at Little Stony Man and 3,963 ft^2 at Old Rag: Summit. The total area of disturbance associated with these informal trails is 14,214 ft^2. This area represents 0.1% of the 225 acres within the 16 study areas.

Five of the 58 informal trails lead to the base of rock climbs listed in the Hörst (2001) rock climbing guidebook. We considered those five informal trails to be predominantly used by climbers. These climber trails are the descent trail at the south end of the Little Stony Man overlook, the descent trail to the West face crags at Old Rag Summit, the loop descent trail to PATC Wall at Old Rag Summit and the two parts of the descent trail to the Reflector Oven area at Old Rag SE.

Trail erosion estimates are reported in Table 15. Human trampling, which reduces or removes ground vegetation cover and organic litter, exposes soils at higher levels of traffic, making them vulnerable to erosion from rainfall or wind. The amount of erosion on a trail was calculated from the average cross section of the trail at the sample points times the length of the trail. The majority (62%) of the trail erosion is from one area—Little Stony Man. Old Rag: Summit and Blackrock Summit contribute 18% and 12%, respectively, of the total erosion. The informal trails at Blackrock Summit are immediately adjacent to the motel/cabin area at Big Meadows. Little Stony Man is a short hike from Skyline Drive and just a couple of miles drive from the Skyland resort area. The hike to Old Rag Summit is one of the premier hikes on the east coast. The other 13 sites each contribute 2% or less of the total estimated erosion (Table 15).

To aid in comparison, erosion was standardized to a per mile value—the total erosion volume for each area was divided by the length of informal trails in the area to provide an erosion rate. By

Table 14. Informal trail conditions by study area, including trail numbers, length, width, and area of disturbance.

Study Area	Trails (#)	Trail Length (ft)	Trail Length (%)	Mean Trail Length (ft)	Mean Trail Width (in)	Area of Disturbance (ft^2)
Betty's Rock Overlook (C02)	2	209	3	105	16.7	291
Blackrock Summit (C04)	3	451	6	150	36.0	1355
Calvary Rocks/C. Rocks (C08)	0	-	-	-	-	-
Crescent Rock (C10)	2	199	3	100	21.1	350
Franklin Cliffs Overlook (C16)	1	382	5	382	25.7	818
Gooney Manor Overlook (C19)	1	146	2	146	10.0	122
Hawksbill Summit (C22)	4	366	5	92	24.6	750
Little Stony Man (C28)	6	726	10	121	45.5	2755
Loft Mountain Summit (C29)	1	52	1	52	36.0	156
Mary's Rock Overlook (C31)	4	582	8	146	14.1	685
North Marshall Mtn. (C35)	9	938	12	104	15.9	1239
Old Rag: SE (C36)	2	896	12	448	14.5	1084
South Marshall (C46)	2	126	2	63	28.8	302
Stonyman Cliffs (C47)	4	233	3	58	17.7	343
Old Rag: Summit (C62)	17	2226	30	131	21.4	3963
Overall Falls Lookout (C63)	0	-	-	-	-	-
Means & Totals:	58	7532	100	130	22.6	14,214

Table 15. Informal trail conditions by study area, including trail depth and soil loss.

Study Area	Trails (#)	Mean Trail Depth (in)	Mean CSA (in^2)	Trail Erosion Volume (ft^3)	Trail Erosion Volume (%)	Trail Erosion Volume (ft^3/mi)
Betty's Rock Overlook (C02)	2	0.3	5	7	0	169
Blackrock Summit (C04)	3	3.4	124	388	12	4541
Calvary Rocks/C. Rocks (C08)	0	0.0	0	0	0	0
Crescent Rock (C10)	2	1.6	35	48	1	1273
Franklin Cliffs Overlook (C16)	1	0.9	23	62	2	858
Gooney Manor Overlook (C19)	1	0.0	0	0	0	0
Hawksbill Summit (C22)	4	0.4	11	28	1	402
Little Stony Man (C28)	6	8.8	401	2023	62	14,715
Loft Mountain Summit (C29)	1	0.0	0	0	0	0
Mary's Rock Overlook (C31)	4	0.2	3	13	0	122
North Marshall Mtn. (C35)	9	0.5	8	54	2	305
Old Rag: SE (C36)	2	0.0	0	0	0	0
South Marshall (C46)	2	1.9	55	48	1	2001
Stonyman Cliffs (C47)	4	0.3	6	9	0	208
Old Rag: Summit (C62)	17	1.8	38	590	18	1400
Overall Falls Lookout (C63)	0	0.0	0	0	0	0
Means and Totals:	58	2.8	5	3270	100	2293

this measure the trails at Little Stony Man average 14,715 ft^3/mile of erosion, with Blackrock Summit having the second largest rate of erosion at 4,541 ft^3/mile.

Another way to look at informal trail impacts is to compare informal trails that are predominantly used by rock climbers to all informal trails. Table 16 summarizes the five climber trails. Table 17 compares these climber trails to the list of all 58 informal trails.

Table 16. Informal trails serving climbing areas.

Study Area	**Trail Length** (ft)	**Mean CSA** (in^2)	**Mean Trail Width** (in)	**Area of Distur bance** (ft^2)	**Erosion Volume** (ft^3)	**Erosion Rate** (ft^3/mile)	**Trail Description**
Little Stony Man	204	1311	96	1624	1858	48,081	South end of climb area
Old Rag summit	313	97	23	610	211	3,560	Summit area crag-west face
	835	16	19	1294	93	586	PATC Wall-descents, base
Old Rag SE	81	0	13	88	0	0	Beyond Strawberry Fields
	815	0	15	996	0	0	Descent to Strawberry Fields
Means and Totals:	2248		24.6	4613	2161	5057	

Climbers are the predominant users of only one of the six informal trails at Little Stony Man. This trail is by far the most heavily eroded trail of all 58 measured. Two of the 17 trails at Old Rag Summit and the two trails at Old Rag SE, are predominantly used by climbers. Two items of interest stand out in the Table 17 comparison of climber trails with all informal trails. The first is that climber trails are generally much longer than multi-use informal trails (mean length of 450 ft vs. 130 ft). Second, when considering all five climber trails, the rate of erosion (5,057 ft^3/mile) is more than two times the average for multi-use informal trails.

When considering the maps of the 16 study areas (Appendix 3), it appears that the original trail designers routed the formal trails right to or very close to most of the cliff-top scenic overlooks (e.g., consider cliff-top site #239 at North Marshal Summit). A hiker only needs to make a short informal trail to enjoy the view. While the tops of the climbs at Little Stony Man and Old Rag are reasonably well served by the formal trail network, climbers required much longer informal trails to reach the base of the climbs (450 ft vs. 130 ft average trail length).

The rate of erosion for the 5 climber trails is very heavily skewed by the extreme erosion on the climber descent trail at Little Stony Man cliffs. This trail is a special case that requires substantial reconstruction or closure. When that trail is removed from the calculation, the rate of erosion on climber trails drops to one third (34%) of the rate for all informal trails (Table 17).

Table 17. Informal trails serving climb areas in relation to all informal trails.

Indicator	Trails (#)	Trail Length (ft)	Mean Length (ft)	Area of Disturbance (ft^2)	Erosion Volume (ft^3)	Erosion Rate (ft^3/mile)
All informal trails	58	7532	130	14214	3270	2295
Climber trails	5	2248	450	4613	2161	5057
% of total	9%	30%		32%	66%	220%
Climber trails w/out LSM	4	2044	510	2988	304	784
% of total	7%	27%	-	21%	9%	34%

In summary, based on the spatial distribution of the informal trails, most of the informal trails are directly related to formal trails—the informal trails provide the final link to cliff-related scenic overlooks, recreation sites, and campsites. In some instances, it may be beneficial to incorporate some informal trails into the formal trail system (this appears to have been done at Calvary Rocks). Further discussion on this option is provided in the Discussion and Management Recommendations section.

The three study areas with the most informal trail erosion may each be a special case—each is very accessible and heavily used. Blackrock Summit is the only area with multiple trails to the same destination areas, suggesting "avoidable" impact that could be addressed by closing "duplicate" trails. However, with its location close to the Big Meadows lodging area, this may be more a "playground" area where youth can explore close to park lodging. One trail at Blackrock contributes 10% of the total erosion measured in this study (Table 18). Another trail at Old Rag Summit contributes 6% of total erosion. The most eroded trail by a large margin is the descent trail at Little Stony Man at the south end of the overlook. Focusing on just these three trails would address 73% of the total erosion associated with informal trails.

Table 18. The four trails with largest amount of soil erosion.

Study Area	Trail Length (ft)	Area of Disturbance (ft^2)	Erosion Volume (ft^3)	% of Total
Little Stony Man	204	1624	1858	57%
Blackrock (central)	112	790	329	10%
Old Rag Summit	313	610	211	6%
Little Stony Man	98	323	99	3%

One concern that led to the initiation of this study was recreation impact to the cliffs and rock outcrops within the park. The 16 areas we studied were selected by the overall project as areas of concern. One particular concern was rock climbers using these cliff-associated features—climbers have the unique ability to impact the cliff-top, cliff-bottom, and the cliff-face. One climbing guidebook, The Virginia Climber's Guide, lists several hundred climbs in the park (Watson 1998). This guide lists 144 climbs (Table 19) in or near our 16 study areas along Skyline Drive, with additional climbs on Old Rag Mountain. This represents a large amount of potential impact, though evidence from this study reveals that climbing use and impact are minor at the present time.

In addition to documenting impacts along trails and at overlooks and campsites, we specifically looked for impacts in the climb areas Watson describes. Other than the climbing impacts at Little Stony Man and Old Rag, we did not find any appreciable climbing impact in the study areas. This suggests that the majority of climbs that Watson lists receive little to no use currently. These findings were confirmed through a number of informal interviews with area climbers, guides, group leaders, and outdoor store owners. To summarize, as the maps show, recreation impacts in the 16 study areas are concentrated in a very small percent of the overall area. Further, the visitors to these areas generally are not straying very far from formal roads and trails.

Table 19. Climb areas and number of climbs listed in Watson (1998).

Climb Area Name	Mile Marker	Climbs (#)
Mount Marshall	15.9	16
Overall Run Falls	22.2	3
Mary's Rock	31.5	36
Little Stony Man Cliffs	39.1	31
Crescent Rocks	44.0	2
Hawksbill Mountain	45.6	28
Franklin Cliffs	48.7	0
Blackrock	51.2	22
Loft Mountain	79.5	6
Calvary Rocks	90.0	0
Chimney Rocks	90.0	0
	Total:	144

DISCUSSION AND MANAGEMENT RECOMMENDATIONS

This section will review and summarize the principal research findings and discuss implications for managers. Site and visitor management recommendations are offered for improving management of recreation sites, campsites, and trails to accommodate and sustain a variety of visitor uses while protecting the park's natural resources.

Research Summary and Management Implications

Park managers are continually challenged to protect the natural and cultural resources under their stewardship while also providing for appropriate types and levels of visitation. As previously noted, SNP cliffs and rock outcrops support unique and rare communities of flora and fauna, and in places, heavy recreational use. Walking, hiking, backpacking and rock climbing have been traditional recreational activities in the park and managers are striving to preserve opportunities for these pursuits in the future. To some degree, resource impacts associated with recreational activities are inevitable. The principal challenge for park managers is to avoid impacts where possible, particularly within rare communities of flora and fauna, and to reduce unavoidable impacts to minimal and/or acceptable levels.

Of the 48 SNP cliff and rock outcrop study areas, this research conducted field investigations at 16, including nearly all sites where preliminary inventories found visitor-created informal trails and recreation sites. Field staff found 44 recreation sites, 10 campsites, and 60 informal trails, accounting for intensive visitor trampling over a total area of 56,249 ft^2, or 1.3 acres. Furthermore, recreation sites and campsites lost vegetation cover over an estimated 16,312 ft^2, including 10,100 ft^2 of exposed soil. Other impacts were somewhat less severe, including 23 damaged trees, 15 trees with exposed roots, and 9 tree stumps found on recreation sites and campsites. Consequently, as the resource data in this study show, large areas of bare soil and solid rock are already characteristic of the cliff-associated visitor use sites. Furthermore, assessments of site expansion potential, which examine barriers to future expansion based on topography and vegetation, suggest that substantial future expansion could occur.

The total lineal extent of the 58 informal trails assessed within the study areas was 7532 lineal feet (1.43 mi). Their mean width ranged from 14 to 45 inches and mean depth ranged from 0 to 8.8 inches. Mean CSA ranged from 0 to 401 in^2 with a total volume of soil loss estimated at 3,270 ft^3, though 2,023 ft^3 of this was from a single trail. Only five of the 58 trails were considered to be predominantly used by rock climbers and these represent a relatively small proportion of aggregate impact. One exception to this is the soil loss associated with the steep descent trail at Little Stony Man cliffs.

Research findings from the companion social science studies also have relevance to the interpretation and management implications of these resource assessment findings (Lawson *et al.* 2006). Visitor use observation work at the heavily visited Little Stony Man Cliffs (LSMC) provides insights into factors that may be driving visitor-caused impacts at LSMC and other SHP cliffs. First, observers found that day hiking constitutes the majority of recreational activity at LSMC and that day hikers trampled soil and vegetation, as opposed to staying on rock, more frequently than either rock climbers or backpackers. Given that LSMC is the most popular rock climbing area within the park this finding is likely to be even more applicable to other SNP cliffs. A noteworthy exception are the climbing areas on Old Rag Mountain, which require difficult bushwhacks to access and appear to receive no use by non-climbers.

A second important observation from LSMC is that hikers (hereafter to include walkers and backpackers) are predominantly drawn to cliff-top locations for the vistas they provide, while climbers spend most of their time at cliff-base sites. Also of importance was the finding that day hikers were more likely to disperse along the cliff edge during crowded periods to get a good view and/or find personal space. In contrast, climbers tend to cluster at the top and base of specific climbing routes, which limits the areal extent of their trampling impact. Such motives and patterns of use are also likely to be applicable to other cliffs. A principal management implication from these findings is that hikers are the probable primary contributors to the development of cliff-top recreational sites and associated cliff-top informal trails within SNP.

Results from the survey of rock climbers at LSMC and Old Rag Mountain (Lawson *et al.* 2006) reveal these two areas as the most popular for climbing, followed by White Oak Canyon and limited climbing at Blackrock/Split Rock, Mount Marshall, and Mary's Rock (*Note*: our careful inspections of the White Oak Canyon climbing sites revealed no permanent evidence of climbing impacts, other than some faint informal trails). About 62-73% of the climbers are day use visitors and most (77-85%) are with family and/or friends. About one-quarter of the climbers to LSMC are organized groups, often with beginners. A majority of climbers (56-64%) have climbed previously in the park, most visiting 2-5 times previously. Fall is the most popular climbing season, followed by summer and spring. Most have been climbing for about 2-5 years and consider themselves as intermediate to advanced climbers. A majority of climbers (75-88%) rate themselves as having intermediate or better knowledge of minimum impact rock climbing practices. Most climbers (44-49%) described themselves as traditional climbers, though sport climbers and indoor/gym climbers were also well represented.

A majority of climbers rate the natural and cultural resource impact issues considered in this study as little or no problem in SNP. Over 75% of climbers supports having park staff provide more information regarding minimum impact climbing practices. There was also broad support for placing fixed anchors at the top of climbs to minimize resource impacts, requiring a permit to place fixed protection, and for limiting fixed protection to specified areas. Climbers also strongly supported resource protection measures, such as requiring climbers to use designated access trails, closing cliffs during critical wildlife seasons, and closing climbing routes in areas with sensitive rare plants.

These findings suggest that SNP climbers are relatively unaware of visitation-related impacts to the parks cliff-associated rare flora and fauna. Such information needs to be communicated more effectively to climbers, and likely to hikers as well. Survey results also suggest that climbers are relatively well versed in minimum impact climbing practices, support efforts to provide additional information, and when necessary, would support seasonal or permanent closure of climbs to protect rare flora and fauna.

Evaluating Impact Acceptability

An important first step in management decision making is making judgments about the acceptability of existing cliff-associated recreation impacts. Such judgments can be made by examining the results of this report and other SNP cliff research studies that document the presence, rarity, and sensitivity of flora and fauna. Carrying capacity based decision frameworks, such as the NPS Visitor Experience and Resource Protection (VERP) framework provide a more formal process for making impact acceptability decisions.

Managers should first consider the management zone and associated objectives where the visitor impacts are occurring. Impacts occurring in pristine areas where preservation values are paramount are less acceptable than when located in areas that are intensively developed and managed for heavy recreation use. Secondly, managers should consider environmental and cultural factors. Visitor impacts occurring within rare, sensitive or fragile communities of flora or fauna or cultural resources are less acceptable than when located in areas that lack such attributes. Informal trails that directly ascend steep slopes or are prone to muddiness and widening are less acceptable than trails with a dry side-hill alignment.

Finally, managers should consider use-related factors. Visitor impacts resulting from illegal or inappropriate types of uses are less acceptable than when caused by permitted or appropriate types and levels of recreational activities. Is visitor behavior a factor? Impacts caused by visitors seeking to shortcut a longer, more resistant route are less acceptable. Impacts that can be easily avoided are less acceptable – such as when three informal trails in close proximity to each other access a location that could be accessed by a single trail. Similarly, are three vistas present when one could suffice, or could a 3000 ft^2 vista be reduced to 1000 ft^2 and serve the same purpose?

A careful consideration of these and other relevant factors (e.g., visitor safety) can assist managers in making inherently value-laden decisions regarding the acceptability of visitor impacts. The acceptability of visitor impacts, in turn, guides decisions about the need for and selection of appropriate and effective management interventions.

No actions are needed for visitor impacts found to be acceptable to managers. As previously noted, visitation to parks is an important mandate and some degree of degradation is an inevitable consequence. Formal trails and recreation sites are never sufficient by themselves for sustaining all forms of park visitation. Dispersed off-trail traffic that can lead to the development of informal (visitor-created) trails and recreation sites are necessary for accessing and using less visited locations, like vista or rock climbing sites. Some degree of visitor impact associated with dispersed use activities simply must be tolerated. Fortunately, managers have some powerful site and visitor impact management strategies and actions available for avoiding or minimizing such impacts. The following sections review site management and visitor management options, and provide specific recommendations relevant to cliff-associated recreational activities.

Site Management Recommendations

Site management actions fall into three general categories: redesign trails and sites, install facilities, and close and restore areas.

Redesign Trails and Sites

Informal (visitor-created) trails frequently follow shortest-distance “fall-line” (parallel to landform slope) alignments, often with steep grades. In contrast to constructed side-hill trails, such attributes make informal trails that receive heavy use susceptible to rapid erosion and permits trail widening and proliferation of braided or alternate treads. Under conditions of low use such trails may not present a resource protection concern. Additionally, visitors do not recognize or avoid rare or sensitive communities. For these reasons, protected area managers should evaluate the alignments of informal trail networks and seek to manage them to avoid or minimize associated impacts.

Informal trails created by illegal users, trails with poor designs, trails that threaten rare or sensitive resources, and trails that are unnecessary and/or represent avoidable impact should be considered for closure and restoration (see section below on area closure). Again, level of trail use is a factor, lightly used informal trails that are narrow and retain vegetation or organic litter ground cover are often of less concern. When visitor access to the area in question is acceptable, then a qualified trail management professional should identify an alternate route. An existing trail or previously disturbed route is always preferable when available. Leaving a trail in a poor alignment is only acceptable if there are no resource protection concerns or if management actions (e.g., installation of tread drainage or rockwork) will effectively resolve existing problems and sustain future use. If a trail runs too close to a patch of rare plants, a few well-placed large rocks or logs, or a short scree wall, can safely route traffic to avoid the plants. In some instances, relocation to an improved alignment will be a more cost-effective and sustainable long-term solution, even though pristine terrain may be impacted. The ability to effectively close and rehabilitate the existing informal trail is also an important consideration. When rerouting trails, trail design and maintenance staff should carefully consider and integrate their prescriptions with biological resource assessments. Important design considerations include trail alignment to the slope (favoring side-hill designs over “fall-line” alignments), trail grade (<15%), and substrates (favoring rocky soils).

Similarly, informal (visitor-created) recreation sites may also be poorly located, for example, within a sensitive or rare plant community. However, while a trail may be successfully relocated, there may be fewer options for relocating recreation sites when they are attraction feature destinations. As an example, consider the current situation at Little Stony Man Cliffs (LSMC) (Figure 6), which includes a number of cliff-top recreation sites and informal trails located within a rare plant community. A substantial majority of visitors to these recreation sites are day hikers arriving via the Appalachian Trail (AT) from Skyline Drive for viewing scenic vistas. These cliff sites are numerous and large (9908 ft^2) and have lost an estimated 49% of their vegetation cover. VADCR monitoring has shown that the cliff-top sites have been expanding laterally along the cliff top where the rare species are most concentrated. Furthermore, a substantially eroded descent trail on the south end of the main cliffs has lost an estimated 1858 ft^3 of soil (57% of total soil loss for all informal trails, Table 15).

The authors, Dr. Steve Lawson, Virginia Tech students, park staff, and climbing and hiking representatives visited this site in August and November 2006, to examine management alternatives to reduce visitor impacts. One option under consideration involves relocating a section of the AT to avoid the cliff-top sites; routing visitors seeking a vista to the Lower Lookout site along the Passamaquoddy Trail instead (Figure 6). The portion of the AT accessing the cliff-top sites could be signed as open only to rock climbers to protect cliff-top rare plant communities. The Lower Lookout site is sufficiently large, has durable substrates, has a safer configuration, and its size is topographically limited to constrain further expansion. Under the guidance of International Mountain Biking Association trail design consultant Rich Edwards, Virginia Tech students were able to demonstrate with temporary flagging the potential for a sustainable new alignment of the Appalachian Trail.

If park managers close and stabilize the highly eroded descent trail some climbers may be unwilling to use the much longer Appalachian/Passamaquoddy Trail route. One climber suggested installation of a formal rappel station with double anchors, which could reduce the amount of climber traffic on trails. Another option is leaving the descent trail open and installing rockwork and steps, provided impacts to rare species can be avoided.

NPS staff have already closed the cliff-top campsites within this study area. Campsites could be closed in the remaining study areas if they are located near rare plants. There are many other opportunities for hikers to camp elsewhere along the AT, and climbers could use somewhat more distant sites, park campgrounds, or cliff-base campsites, where rare plants are generally not found. NPS staff could also proactively create cliff-base side-hill campsites at cliffs that receive heavy rock climbing use, a design that uses topography to limit campsite size (Daniels and Marion 2006, Marion 2003).

Given the challenges of successfully closing cliff-top recreation sites, another alternative is to redesign traffic patterns to limit traffic to exposed rock surfaces and/or to limit their size. Access to these sites should be restricted to a single trail that enters the site perpendicular to the cliff edge and ends at that location, rather than running along the cliff-top. The access trail should direct traffic to the portion of the cliff-top that has the most exposed rock and fewest rare plants and/or to a location that topographically constrains and concentrates traffic to a limited area. Park staff can further constrain traffic through some site management actions, including: 1) dragging large logs or dead cedar trees and anchoring them to block lateral cliff-top traffic, 2) constructing scree walls to block lateral traffic, and 3) installing educational signs to discourage use of closed site areas or trails. Without an educational sign to clarify management intent, visitors may not understand, and may even dismantle, site management work.

Install Facilities

Another management strategy for avoiding or minimizing visitor impacts is the installation of primitive or developed facilities to attract and concentrate use to a specific intended use location. A new well-designed and constructed formal trail might replace several poorly located and rapidly degrading informal trails. Even additional maintenance or blazing on an existing formal trail may be sufficient to attract and retain use or to provide a clear distinction with informal trails the park seeks to close. In backcountry or wilderness zones, facilities are less appropriate, though primitive rockwork, scree walls, or log borders can be very effective in guiding and concentrating visitor traffic to intended use areas (Figure 7a). For example, the retaining wall in Figure 7a was constructed to restore and protect soil around exposed tree roots and to provide a small level belay site at the base of a cliff. In developed park areas, construction of observation platforms at the best viewpoints may be appropriate (Figure 7b). Such facilities attract and concentrate visitor traffic and reduce impacts elsewhere along the cliff. Facility sizes should be matched to inherent site capacities or sustainable use levels. For example, observation at LSMC revealed that site expansion pressures were most evident during times of peak use. Reducing the size of the parking lot, or preventing cars from parking along the adjacent road, could substantially reduce site expansion pressures.


a)


b)

Figure 7. In backcountry settings, site management practices such as installing crude stone steps and rock retaining walls (7a, Carderock Cliffs, MD) armor the site, attract and concentrate use to resistant locations, and protect the soil from eroding in high traffic areas. In frontcountry settings, observation platforms (7b, Hawksbill Mountain) can concentrate visitor traffic, reducing the areal extent of trampling impact.

Data from the LSMC observation study revealed that rock climbers frequently constructed climbing anchors using trees, with ropes stretched across the A.T. However, resource impact measurements revealed bark abrasion and damage to be quite minor, in contrast to findings of more substantial climbing-related damage by Kelly and Larson (1997). Thus, efforts to reduce rock climbing-related impacts at LSMC should focus on reducing soil and vegetation trampling at the cliff-top. For example, the installation of fixed anchors on the cliff-edge would eliminate a substantial amount of trampling traffic associated with the need for rock climbers to use somewhat distant cliff-top trees to construct anchors. In addition, installing fixed anchors on LSMC could minimize damage to cliff-top trees and cliff-edge vegetation caused by rope abrasion (Baker 1999). Park staff should collaborate with climbing organizations to develop practices for insuring the appropriate placement, safety, and replacement of all fixed protection (bolts) within the park.

Close and Restore Areas

As previously noted, trails or recreation sites that represent avoidable impacts, result from illegal uses, are poorly designed, or threaten rare or sensitive resources should be considered for closure and restoration. Give consideration to how closures will affect recreational opportunities, including what alternative access routes or sites are available, if visitors will find them acceptable, and how information about closures and alternatives will be communicated. Working directly with the affected recreational groups to evaluate problems and alternatives, and implement appropriate solutions, is always preferable and provides the most effective outcome. There are numerous options for closing informal trails or recreation sites; generally, an incremental approach is followed. Sometimes, merely improving a designated trail or preferred informal trail may sufficiently reduce use on unnecessary trails to allow their recovery. Improvements may include vegetation trimming, tread drainage, rockwork, or graveling to create a more usable or visually obvious route. The same is true for recreation sites, designating and clearly marking intended use areas or even improving them to attract and concentrate visitor use.

However, improving formal trails and recreation sites is only effective if visitors can *easily* distinguish between formal trails or sites and the informal trails/sites that managers wish to close. Clear marking with paint blazes can help visitors make such distinctions. Even a well-blazed trail may be insufficient; what appears clear to managers if often unclear to visitors. Official recreation sites can be identified by blazed trails leading to them or by posting a site sign.

Trails and recreation sites to be closed should be hidden and "disimproved" by raking organic debris such as leaves onto them, along with placement of rocks and dead branches to hide and deter use. These actions also lessen soil erosion and speed natural recovery. Logs large enough to deter their removal by visitors can also be placed along the beginning of the trail or across the recreation site. Heavy brushing with materials that a single person cannot easily remove can be effective, but may also simply shift traffic around them. A study that evaluated the effectiveness of using brush to close informal trails along the Blue Ridge Parkway found that twelve of fourteen brushings were dismantled by visitors within two months (Johnson *et al.* 1987). The two successful brushings actually diverted hikers directly through pristine rare plant habitats. The investigators stressed that managers need to focus on addressing the causes for the off-trail traffic, i.e., visitor's desire to access a particular location. Contributing factors cited include:

- Lack of knowledge about the rare plant habitat and its fragility
- Lack of adequate signing to direct visitors to the official trailhead
- Confusion about the trail locations and destinations
- The challenge of rock climbing and the desire to explore
- Blueberry picking

Other site management options include "ice-berging" large rocks to block access or render the area more difficult to use. Rock scree walls across a site can clearly define the portions intended for visitor use and those that are "off-limits." Again, signing is critical to communicating management intent and the specific areas closed to use.

When all else fails, trail or site borders or barriers of various types can be installed. Low borders of rocks or logs are less obtrusive than high barriers yet provide an obvious visual cue to guide visitor traffic. Higher barriers such as scree walls and low or high fencing physically block access and provide indisputable evidence of management intent. Fencing can include inexpensive nylon string stretched between trees, rope strung through steel or wooden stakes, log barriers, and various types of manufactured fencing (Figure 8). Tall fencing is generally the only highly effective solution, but even these must have clear signage to prevent passage over or around the fence. Barriers can be temporary, effectively altering visitor distribution patterns until vegetative recovery occurs. However, it is critical that management actions effectively address the original cause for the feature's creation; otherwise, it may simply reappear.

Active restoration efforts involving the return of native soils and plantings may be needed to ensure recovery by the original rare plant community. Consultations with botanists and restoration specialists are recommended to ensure that native and genetically appropriate plant materials are used. Factors to consider include season of year for plantings, use of transplants versus greenhouse stock, soil preparation, fertilization and watering (Cole & Spildie 2007, Therrell *et al*. 2006). Restoration should generally not be initiated unless effective actions have been implemented to address the original causes of the trampling damage, otherwise the restored area may receive further damage during or after restoration work. In addition, vegetative recovery, particularly when soils are thin and dry, occurs very slowly even in the absence of visitor traffic. Even light levels of traffic may prevent vegetative recovery from occurring (Cole *et al*. 1987, Cole 1992, Leung & Marion 2000).

Figure 8. Low symbolic post and rope fencing is substantially more effective than signs alone and has been shown to deter nearly all off-trail traffic (Park *et al*. 2006). Low fencing is also less visually obtrusive than taller fencing.

Visitor Management Recommendations

Visitor management options avoid or minimize impacts by altering behavior through educational messages or regulations. For example, educational messages on trailhead displays can inform visitors about the presence of rare plants and need to stay on formal trails and recreation sites to prevent their trampling (Cole *et al*. 1997, Marion & Reid 2007). Alternately, regulations could prohibit off-trail hiking or limit the type or amount of visitation. Unfortunately, as noted in the preceding section, studies reveal that education or regulations would need to eliminate nearly all trampling from environments with low resilience (ability to recover), including most cliff-associated plant communities. This is quite challenging given that education-induced behavior change is voluntary and the effectiveness of regulatory approaches depends on the frequency of patrolling by agency law enforcement officers (Marion & Reid 2007).

To protect cliff-associated communities, the objective of visitor management efforts should be to increase the spatial containment of visitor trampling on a limited number of small well-defined and resistant locations (Cole 1992, Leung & Marion 1999b, Marion & Farrell 2002). Educational options are often tried first, and can be integrated with site management work. For example, off-trail hiking can be reduced by communicating *Leave No Trace* low impact hiking practices to visitors (www.LNT.org; Cole *et al.* 1987). In high use areas, these messages can ask visitors to concentrate traffic on formal trails and recreation sites. In low use areas, messages can ask visitors to restrict traffic to trampling-resistant natural surfaces or on the bare substrates of already established formal or informal trails and sites. Educational messages are generally communicated by signs placed at trailhead or cliff-site locations, or by personal communication through park staff or volunteer trail stewards. Educational signs placed in backcountry settings are generally limited to those deemed critical to resource protection efforts and are generally for short-term use, giving restoration and vegetative recovery a chance to take hold. The "costs" associated with use of artificial signs or site management work (described below) should be evaluated against the expected "benefits" of enhanced protection of natural resources.

An inexpensive educational method is to install small "prompter" signs, such as a 3x3 inch symbolic sign showing a Vibram boot print with a red slash symbol superimposed (Figure 9). These can be screwed onto a log pulled across an informal trail or site, mounted on a short well-anchored stake, or posted in a decal version on a Carsonite post (sources: www.rockartsigns.com, www.vosssigns.com, www.carsonite.com, and www.rhinomarkers.com). For trails or sites that are difficult to close, an effective method is to cover initial portions with peat moss and jute netting and install a restoration sign (Figure 9). Visitors who see an earnest attempt to restore a trail or site damaged by foot traffic will be less willing to "ruin" that effort by walking on it. Another option is an effectively worded educational sign. Signs that clearly define the appropriate behavior and provide a compelling rationale are more effective than a simple plea statement. For example, a simple sign of this type might say "Please Do Not Leave Designated Trails to Preserve Sensitive Vegetation," a more compelling trailhead educational sign based on social science research and theory (Cialdini 1996, Cialdini *et al.* 2006, Johnson & Swearingen 1992, Vande Kamp *et al*. 1994, Winter 2006) is included in Figure 9. This type of sign seeks to educate visitors about how their personal actions contribute to a significant management problem, providing a rationale for altered behavior. However, such signs are only effective if visitors can *easily* distinguish between official and visitor-created trails or recreation sites. Clear marking with paint blazes can help visitors distinguish between formal and informal trails. Even a well-blazed trail may be insufficient; what appears clear to managers if often unclear to visitors. Official recreation sites can be identified by blazed trails leading to them or posted with a site sign.

Figure 9. Examples of trail or recreation site closure signs.

It is worthwhile to consider how some of these visitor management recommendations might be applied to the heavily visited Little Stony Man cliffs. Educational efforts could employ both trailhead and onsite signs (Figure 9) designed to convey low-impact visitor behaviors to minimize soil and vegetation trampling. If site management work was conducted to restrict visitor traffic to a single vista location then educational signs would be needed to inform visitors of the need to restrict their traffic to the intended use areas. Climbing could continue, provided non-climbing participants stay at cliff-base sites and belayers stay on rock surfaces. Including good *Leave No Trace* low impact hiking and climbing practice information in the climbing guidebooks for the area is perhaps the best way to inform climbers. A park climber's pamphlet and information on a separate "climbers" section of the park website are other options. If climbing continues then park staff would need to communicate targeted messages to climbers that such guidance does not apply to them – they would need to venture "off-trail" to access their climbs. A rock climbers brochure could be developed to communicate specialized information, including: 1) basic park-wide climbing guidance, 2) information about cliff-associated rare plant communities and their fragility, 3) basic low-impact climbing practices (see the *Leave No Trace* Skills & Ethics booklet on climbing), and 4) where necessary, specific guidance for different cliffs within the park. At LSM, park staff know most of the organized groups who use this site and personal contacts can be used to communicate and reinforce the guidance in onsite signs and the pamphlet.

Park staff are also considering use of personal communications through a "Mountain Steward" program using volunteers or park staff. Similar to the Appalachian Trail Ridgerunner program, these personnel could contact visitors to communicate messages at parking lots or along trails. Communication messages could focus on *Leave No Trace* practices, the rarity and fragility of cliff-associated vegetation, and visitor safety.

CONCLUSION

This report seeks to inform SNP park planning and management decision making regarding the resource impacts of cliff-associated recreational activities. This was accomplished by measuring trampling impacts to cliff-related trails, recreation sites, and campsites, and in a companion study, by incorporating visitor observation to gain greater insights into how different use types and behaviors contribute to cliff resource impacts. Documentation of resource impacts provides a detailed characterization of current conditions, which can also provide a baseline for comparison with future monitoring. Visitor observation offers several insights into contributory factors of cliff-top resource damage by showing differences in use and behavior between visitor types. In particular, in the absence of this observational work, park staff may have incorrectly limited climbing activity, which our observations revealed was concentrated at a limited number of climb sites. Day hikers were revealed to be the primary cause for the expansion of the cliff-top vista sites, particularly during peak-use periods when visitors dispersed along the cliff-top to avoid crowding. The findings from this study suggest that a management approach characterized by visitor education, some site hardening, and concentration of visitor use on durable surfaces, along with the installation of fixed anchors at the top of popular climbing routes is likely to have the greatest success at balancing visitor enjoyment with resource protection at LSMC.

Land managers can gauge the effectiveness of implemented actions informally, but standardized resources assessments as part of a monitoring program can provide a more objective alternative. Objective monitoring will be needed if any potentially controversial management actions may be needed (e.g., use restrictions or high fencing). In exceptionally high use areas with sensitive resources there is a good probability that such actions will be necessary. For example, a combination of signs and restoration work may be able to keep 95% of visitors on a designated trail but 5% of 2000 visitors/day is 100 visitors/day, and that is easily sufficient to create entirely new trails. Resource monitoring of selected indicators and standards of quality are an essential component of LAC and VERP decision frameworks. Monitoring provides feedback for gauging the success of management interventions in keeping conditions within acceptable limits. In lieu of LAC or VERP frameworks, this report also contains substantial guidance for selecting relevant indicators and monitoring protocols for adaptive management programs. For example, managers could monitor he areal extent or trampling at recreation sites or along informal trails. A documented failure of one intervention can be used to justify the use of a more obtrusive or expensive intervention. More importantly, the data provides an objective evaluation of management's success in balancing recreation provision and resource protection objectives.

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APPENDIX 1: CLIFF SITE MONITORING MANUAL

Cliff Site Visitor Impact Monitoring Manual

Shenandoah National Park[1,2]

(*version 6/23/05*)

This manual describes procedures for conducting inventories and resource condition assessments necessary to document changes in the condition of cliff resources from hiking and climbing activities. It was developed for assessing conditions at cliff sites within Shenandoah National Park. Three general approaches are used for assessing cliff site conditions: 1) photographs from permanently referenced photo points, 2) a condition class assessment determined by visual comparison with six described levels of trampling impact, and 3) predominantly measurement-based assessments of several impact indicators. Additional monitoring practices are described in an associated Trail Monitoring Manual for assessing associated trail impacts.

For the purposes of this manual, cliff sites are defined as backcountry areas of disturbed vegetation, surface litter, or soils caused by human use at the base or top of cliffs, excluding associated trails. In areas with multiple sites or use areas there may not always be undisturbed areas separating sites and an arbitrary decision may be necessary to define separate sites.

Monitoring measurements should be taken near the middle or end of the visitor use season but before leaf fall. Site conditions generally recover during the fall/winter/spring periods of lower visitation and reflect rapid impact during early season use. Site conditions are more stable during the mid- to late-use season and reflect the resource impacts of that year's visitation. Subsequent assessments should be completed as close in timing to the original year's measures as possible. Generally monitoring should be replicated at 3-5 year intervals, unless conditions are changing rapidly.

Materials

(Check before leaving for the field)

- Topographic maps (1/24,000) with copier enlargements of areas with dense concentrations of sites (cut out and copy scale bars with enlargements)
- Compass, peephole type (not corrected for declination) and/or KVH Data Scope, digital compass
- Tape measure (100 ft. <u>in tenths</u>) and/or Sonin Combo Pro distance measuring device
- Field forms, maps, and photographs from previous surveys
- Flagged wire pins (25 minimum w/additional set of different color for remeasurement)
- Large steel reference point stake
- Digital camera, w/batteries, charger, extra memory cards or computer/cords to download images
- Aluminum numbered tags, 4 in. galvanized steel nails
- Clipboard, monitoring manual, blank field forms (some on waterproof paper), pencils
- Backpacking trowel
- Magnetic pin locator (site remeasurement only)

1 - Developed by Dr. Jeff Marion, USGS Patuxent Wildlife Research Center, Cooperative Park Studies Unit, Virginia Tech/Department of Forestry (0324), Blacksburg, VA 24061 (540/231-6603) email: jmarion@vt.edu.

2 - Photographs illustrating site boundaries, boundary flag placement, vegetative ground cover classes, soil exposure, tree damage, and root exposure are part of this manual. High quality reproductions of these photographs, some of which are in color, may be found in: Marion, Jeffrey L. 1991. Developing a natural resource inventory and monitoring program for visitor impacts on recreation sites: A procedural manual. USDI, National Park Service, Natural Resources Report NPS/NRVT/NRR-91/06, pages 46-51.

General Cliff Site Information

1) **Site Number**: Each site must have a unique aluminum tag number. Refer to site maps and forms from earlier surveys to identify if the site has been previously surveyed. If it has, follow the site remeasurement procedures below. If the site has not been previously surveyed then assign a new number from an aluminum tag and record it on the form. Criteria for locating the permanent reference point are provided in the Variable Radial Transect section of the manual. If it is impossible to bury an aluminum tag (e.g., due to bedrock), the same numbering system as above should be applied as if aluminum tags were used. If a tag is not buried it should be separated and disposed of to avoid confusion at subsequent sites. If it is a shelter site, bury the tag adjacent to the left front shelter corner post, just under the shelter. Regardless, remarks should be made on the field form indicating whether and/or where a tag was buried.

   Site remeasurement **-** Examine mapped site locations and field forms to determine if each site was present during the previous survey. Relocate permanent reference points with information from the form and the pin locator and verify site numbers by digging up the number tags. If the site has been previously surveyed but you are unable to locate the nail and tag then record the old number (if positively known) with a note that the nail and tag could not be found. If the reference point can be accurately identified from the previous survey form information and photo then do so, noting this on the new form. Use a new site tag and number, however, and record both old and new numbers on the form. If the reference point cannot be identified then proceed as if the site had never been surveyed before, recording new reference site information and the old and new tag numbers.

   Note – Guidance for odd situations: 1) A satellite use area has become the main site and the previous site is now a satellite site or has recovered. Use the same site number from the earlier survey. Relocate and dig up the nail and tag from the old site. Rebury the nail in the original location, moving the tag along with a new nail to a permanent reference point location on the current site (which was formerly a satellite site). Complete all procedures on the current site. Describe the situation in the comments section. 2) The site was rehabilitated by park staff or has recovered on its own. Complete a new form to allow an evaluation of site recovery for any sites that you can find. Take a photo from previous survey photo points.

2) **Site Type**: Record the most specific applicable code: **L -** current site, also present in last survey; **N -** new site; **S** - current site, satellite in last survey; **RL** - rehabilitated, present in last survey; **RN -** rehabilitated, new site; **SRE -** site is recovered, rehab work evident; **SRN -** site is recovered, no rehab.

3) **Location**: a) Record the cliff code (e.g., C62), and b) Record the cliff name.

4) **UTM Coordinates**: Record the location of the permanent reference point using a GPS device. If necessary do an offset to get an accurate site location.

5) **Date**: Month, day, and year the site was evaluated (e.g. July 1, 2005 = 06/01/05).

   Site remeasurement **-** Due to phenological and site use changes which occur over the use season, it is critical that sites be re-measured as close to the initial assessment month and day as possible, preferably within 1 to 2 weeks if early in the use season, 3 to 4 weeks if later.

6) **Inventoried by**: Identify the field personnel responsible for site.

Locate/Label Site on Topographic Map - Mark the topographic map with a dot precisely indicating the site's location and label with its site tag number. Be as accurate as possible. At 1/24,000 scale 1/4 inch on map = 500 ft. on ground. Accurate site location descriptions are critical to site relocation. For dense clusters of sites use 150% copier enlargements so that sites can be more accurately mapped.

Describe Location - Describe the site location using local geographic features (trail intersections, large boulders or trees) and paced (or measured) distances. Record the distance of your pace in parentheses, for example: 18 paces (5.5'), each time you record a paced distance. Conversions will be done in the office. Verify your pace periodically. Use sufficient descriptive detail and additional local area maps as so that someone else years later can relocate the site.

Inventory Indicators

7) **Site Expansion Potential**: P = Poor expansion potential - off-site areas are completely unsuitable for any expansion due to steep slopes, rockiness, dense vegetation, and/or poor drainage, M = Moderate expansion potential - off-site areas moderately unsuitable for expansion due to the factors listed above, and G = Good expansion potential - off-site areas are suitable for site expansion, features listed above provide no effective resistance to site expansion.

8) **Site Slope**: Record the site slope category (F = <5% M = 5-10% S = >10%)

9) **Tree Canopy Cover**: Imagine that the sun is directly overhead and estimate the percentage of the site that is shaded by the tree canopy cover. Note: use category 5 for nearly full to full tree canopy cover over the site; use category 6 only if the cover is fairly dense or thick.
(1 = 0-5% 2 = 6-25% 3 = 26-50% 4 = 51-75% 5 = 76-95% 6 = 96-100%)

10) **Use Type**: Mixed Climbing/Hiking = MCH, Mostly Climbing = MC, Mostly Hiking = MH

11) **Use Level**: Low = L, Moderate = M, Heavy = H

12) **Cliff Location**: Top = T, Base = B

13) **Climbing Type**: Mixed Sport/Trad = MST, Mostly Sport = MS, Mostly Trad = MT, or NA

14) **Climbs**: Record the number of different climbs in the immediate vicinity of the impacted area.

Impact Indicators

The first step is to establish the sites' boundaries and measure its size. The following procedures describe the use of the **Variable Radial Transect Method** for determining the sizes of sites. This is accomplished by measuring the lengths of linear transects radiating from a permanently defined reference point to the site boundary. **If the site has previously been assessed with the Variable Radial Transect Method, then skip to the Site Remeasurement procedures below.**

Step 1. Identify Site Boundaries and Flag Transect Endpoints. Walk the site boundary and place flagged wire pins at locations which, when connected with straight lines, will define a polygon whose area approximates the site area. Include the shelter within site boundaries. Use as few pins as necessary, typical sites can be adequately flagged with 10-15 pins. Look both directions along site boundaries as you place the flags and try to balance areas of the site that fall outside the lines with off-site (undisturbed) areas which fall inside the lines. Pins do not have to be placed on site boundaries, as demonstrated in the diagram in Figure 1. Project site boundaries straight across areas where trails enter the site. Identify site boundaries by pronounced changes in vegetation cover, vegetation height/disturbance, vegetation composition, surface organic litter, and topography (refer to photographs following these procedures). Many sites with dense forest overstories will have very little vegetation and it will be necessary to identify boundaries by examining changes in organic litter, i.e. leaves which are untrampled and intact vs. leaves which are pulverized or absent. In defining the site boundaries be careful to include only those areas that appear to have been disturbed from human trampling. Natural factors such as dense shade can create areas lacking vegetative cover. Do not include these areas if they appear "natural" to you. When in doubt, it may also be helpful to speculate on which areas typical visitors might use based on factors such as slope or rockiness. If you cannot discern trampling-related disturbance boundaries for most of the site then skip this procedure, record a 0 for site area (#28) and move on to #14.

Step 2. <u>Establish Site Reference Point.</u> Select a site reference point which is preferably: a) visible from all the site boundary pins, b) close to and easily referenced by distinctive permanent features such as boulders or trees, and c) in a spot permitting the burial of the reference point nail and site tag. Reference this point to at least three relatively permanent and distinctive features. If trees are used select ones that are healthy and unique to the site area, such as an uncommon species or with unique physical characteristics (forked trunk or large size). Try to select reference features in three opposing directions, as this will enable future workers to triangulate the reference point location. Also take the reference point photograph(s) and reference the photopoint(s) as described at the end of this manual.

For each reference feature, take a compass bearing (nearest degree) and measure the distance (nearest 1/10th foot) from the feature (center of trees or the highest point of boulders) to the site reference point. Also measure the approximate diameter of reference trees at 4.5 ft above ground (dbh). <u>Be extremely careful in taking these bearings and measurements as they are critical to relocating the reference point in the future.</u> Record this information on the back of the form.

Examples:
1) Red Maple, 2.9 ft. dbh, 8.9 ft. at 195° (largest tree on site)

2) Boulder, 7.9 ft. at 312°, (distance and bearing to highest point)

3) Sycamore, 1.8 ft. dbh, 8.4 ft. at 78°, (only Sycamore in the area)

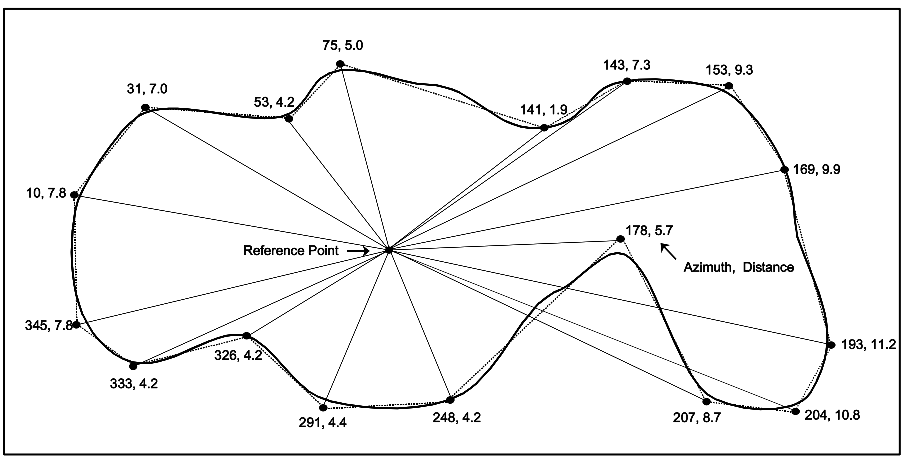

Figure 10. Variable radial transect method.

<u>Options</u>: Some sites may lack the necessary permanent reference features enabling the point to be accurately relocated. If only one or two permanent reference features are available, use these and take additional photographs from several angles. If you are unable to bury a nail and tag (e.g. bedrock) then select a permanent feature (e.g., some obvious bedrock feature) and use it as a reference point. Complete procedures to reference its location, including photographs. <u>Note your actions regarding use of these options in the Comments section</u>.

Step 3. <u>Record Transect Azimuths and Lengths.</u> Standing directly over the reference point, identify and record the compass bearing (azimuth) and distance to each site boundary pin working in a clockwise fashion (in the exact order you would encounter them if you were walking the site boundary). Be careful not to miss any pins hidden behind vegetation or trees. Be extremely careful in identifying the correct compass bearings to these pins as error in these bearings will bias current and future measurements of site size. If a tape measure is used, anchor the end to the large steel reference point stake and route it via the shortest distance around trees or other obstructions. Record the length of each transect (nearest 1/10th foot), starting with the same boundary pin and in the same clockwise order as before. Be absolutely certain that the appropriate pin distances are recorded adjacent to their respective compass bearings. Leave boundary pins in place until you finish all other site measurements.

Step 4. Measure Island and Satellite Areas. Identify any undisturbed "islands" of vegetation ($ 3x3 feet) inside site boundaries (often due to clumps of trees or shrubs) and disturbed "satellite" use areas ($ 3x3 feet) outside site boundaries (often due to tent sites or cooking sites). Use site boundary definitions for determining the boundaries of these areas. Use the **Geographic Figure Method** to determine the areas of these islands and satellites (refer to the Figure 3 diagrams at the end of the manual). This method involves superimposing one or more imaginary geometric figures (rectangles, circles, or right triangles) on island or satellite boundaries and measuring appropriate dimensions to calculate their areas. Record the types of figures used and their dimensions on the back of the form; the sizes of these areas should be computed in the office with a calculator. Also, record the compass bearing and distance from the center of each island or satellite site to the site reference point. Remove the reference point stake. Place a 4 inch long galvanized steel nail through the hole in the site number tag and bury at the reference point so that the tag is 3 inches deep.

Site Remeasurement - Relocate the reference point using point references, photos, and a magnetic pin locator. Typically the photo will get you in the right area and the pin locator will allow you to pinpoint the buried nail and tag. If you cannot find it then search for the three reference features, go to each and shoot the back azimuth (small number scale in the peep hole compass viewfinder). Use the tape measure to determine the correct distance and draw an arc on the ground. If the pin locator still does not register then repeat procedure from the other reference features and reestablish the reference point with a new tag and nail (note new site number on form and in database). Insert the large steel stake at the reference point location and reestablish all former site boundary pins using the previous transect data compass bearings and distances. Place wire flags on a single color at each the transect endpoints. Next, reassess these previous boundary locations using the following procedures (illustrated in Figure 2). Place wire flags of a different color at the end of each reassessed transect, both pre-existing and new (including transects whose length has not changed).

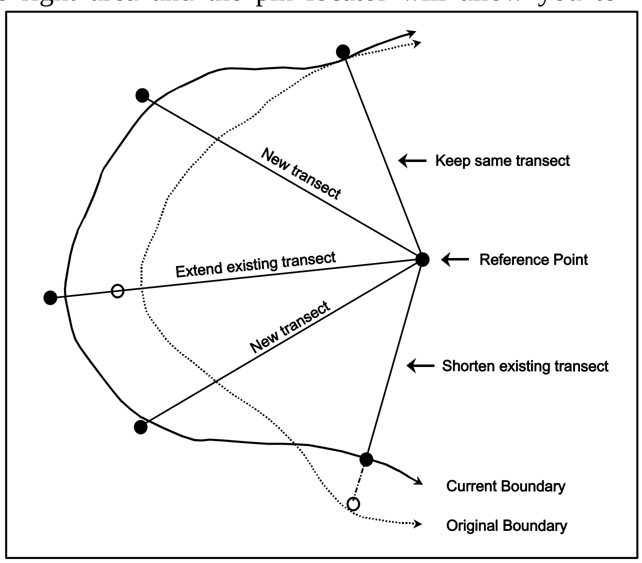

Figure 2. Transect site remeasurement procedures.

a) Keep the same transect length if that length still seems appropriate, i.e. there is no compelling reason to alter the initial boundary determination.

b) Record a new transect length if the prior length is inappropriate, i.e. there is compelling evidence that the present boundary does not coincide with the pin and the pin should be relocated either closer to or further from the reference point along the prescribed compass bearing.

c) Repeat earlier Steps 1 and 3 to establish additional transects where necessary to accommodate changes in the shape of site boundaries. Also repeat Step 4 to account for changes in island and satellite sites. If satellite areas are no longer disturbed, i.e. condition class 0, then note this in the Comments and do not remeasure their size.

d) Take and record new distances and compass bearings for transects that have changed in length and for new transects using the flags denoting current site boundaries. For transects that have not changed in length, copy the old transect data to the new forms (reassessing these would introduce measurement error). Record all transect data on the new form in the exact order you would encounter each transect if you walked the site boundary in a clockwise direction.

These procedures are designed to eliminate much of the measurement error associated with different individuals making subjective judgments on those sites or portions of sites where boundaries are not pronounced. These procedures may only be used for sites whose reference points can be relocated.

15) **Condition Class**: Record a site Condition Class using the descriptions below. If a site is underlain entirely by bedrock record "-1" for this item and items 15 - 17 as they are not applicable for bedrock sites. Include an explanation in the field form under Comments.

Class 0: Site barely distinguishable; no or minimal disturbance of vegetation and /or organic litter. Often an old site that has not seen recent use.
Class 1: Site barely distinguishable; slight loss of vegetation cover and /or minimal disturbance of organic litter.
Class 2: Site obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3: Vegetation cover lost and/or organic litter pulverized on much of the site, some bare soil exposed in primary use areas.
Class 4: Nearly complete or total loss of vegetation cover and organic litter, bare soil widespread.
Class 5: Soil erosion obvious, as indicated by exposed tree roots and rocks and/or gullying.

16) **Vegetative Ground Cover On-Site**: An estimate of the percentage of live non-woody vegetative ground cover (including herbs, grasses, and mosses and excluding tree seedlings, saplings, and shrubs) within the flagged site boundaries using the coded categories listed below (refer to photographs following these procedures). Include any disturbed "satellite" use areas and exclude undisturbed "islands" of vegetation. For this and the following two indicators, it is often helpful to narrow your decision to two categories and concentrate on the boundary that separates them. For example, if the vegetation cover is either category 2 (6-25%) or category 3 (26-50%), you can simplify your decision by focusing on whether vegetative cover is greater than 25%.

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

Site remeasurement - Also evaluate vegetative ground cover within the site boundaries identified during the last measurement period.

17) **Vegetative Ground Cover Off-Site**: An estimate of the percentage of live non-woody vegetative ground cover (including herbs, grasses, and mosses and excluding tree seedlings, saplings, and shrubs) in an adjacent but largely undisturbed "control" area. Use the categories listed above. The control site should be similar to the site in slope, tree canopy cover (extent of sunlight penetration), and other environmental conditions. The intent is to locate an area which would closely resemble the site area had the site never been used. 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 have selected a site with the least amount of vegetation.

Site remeasurement - Start by reexamining the off-site vegetative cover estimate from the last measurement period. Use this value only if it remains an appropriate estimate.

18) **Exposed Soil**: An estimate of the percentage of exposed soil, defined as ground with very little or no organic litter (partially decomposed leaf, needle, or twig litter) or vegetation cover, within the site boundaries and satellite use areas (refer to the photographs following these procedures). Dark organic soil, the decomposed product of organic litter, should be assessed as bare soil when its consistency resembles peat moss. Assessments of exposed soil may be difficult when organic litter forms a patchwork with areas of bare soil. If patches of organic material are relatively thin and few in number, the entire area should be assessed as bare soil. Otherwise, the patches of organic litter should be mentally combined and excluded from assessments. Soil covered by a shelter should be counted as exposed soil. Code as for vegetative cover above.

Site remeasurement - Also evaluate exposed soil within the site boundaries identified during the last measurement period.

19-21) **Tree Damage**: Tally each live tree (>1 in. diameter at 4.5 ft.) within or on site boundaries to one of the tree damage rating classes described below (refer to the photographs following these procedures). **Include** trees within undisturbed "islands" and **exclude** trees in disturbed "satellite" areas. Assessments are restricted to all trees within the flagged site boundaries in order to ensure consistency with future measurements. Multiple tree stems from the same species that are joined at or above ground level should be counted as one tree when assessing damage to any of its stems. Assess a cut stem on a multiple-stemmed tree as tree damage, not as a stump. Do not count tree stumps as tree damage. Take into account tree size. For example, damage for a small tree would be considerably less in size than damage for a large tree. Where obvious, assess trees with scars from natural causes (e.g., lightning strikes) as None/Slight.

None/Slight ..... No or slight damage such as broken or cut smaller branches, one nail, or a few superficial trunk scars.
Moderate......... Numerous small trunk scars and/or nails or one moderate-sized scar.
Severe............. Trunk scars numerous with many that are large and have penetrated to the inner wood; any complete girdling of tree (cutting through tree bark all the way around tree).

Site remeasurement - begin by assessing tree damage on all trees within the site boundaries identified in the last measurement period. Place boxes around each tally for trees in areas where boundaries have moved closer to the reference point, i.e., former site areas which are not currently judged to be part of the site. Next, assess tree damage in areas where boundaries have moved further from the reference point, i.e., expanded site areas that are newly impacted since the last measurement period. Circle these tallies. These additional procedures are necessary in order to accurately analyze changes in tree damage over time.

22-24) **Root Exposure**: Tally each live tree (>1 in. diameter at 4.5 ft.) within or on site boundaries to one of the root exposure rating classes described below. **Include** trees within undisturbed "islands" and **exclude** trees in disturbed "satellite" areas. Assessments are restricted to all trees within the flagged site boundaries in order to ensure consistency with future measurements. Where obvious, assess trees with roots exposed by natural causes (e.g., stream/river flooding) as None/Slight.

None/Slight ..... No or slight root exposure such as is typical in adjacent offsite areas.
Moderate......... Top half of many major roots exposed more than one foot from base of tree.
Severe............. Three-quarters or more of major roots exposed more than one foot from base of tree; soil erosion obvious.

Site remeasurement - Begin by assessing root exposure on all trees within the site boundaries identified in the last measurement period. Place boxes around each tally for trees in areas where boundaries have moved closer to the reference point, i.e., former site areas which are not currently judged to be part of the site. Next, assess root exposure in areas where boundaries have moved further from the reference point, i.e., expanded site areas that are newly impacted since the last measurement period. Circle these tallies. These additional procedures are necessary in order to accurately analyze changes in root exposure over time.

25) **Number of Tree Stumps**: A count of the number of tree stumps (> 1 in. diameter at ground and less than 4.5 feet tall) within or on site boundaries. **Include** trees within undisturbed "islands" and **exclude** trees in disturbed "satellite" areas. Do not include windthrown trees with their trunks still attached or cut stems from a multiple-stemmed tree.

Site remeasurement - begin by assessing stumps within the site boundaries identified in the last measurement period. Place boxes around each tally for stumps in areas where boundaries have moved closer to the reference point, i.e., former site areas which are not currently judged to be part of the site. Next, assess stumps in areas where boundaries have moved further from the reference point, i.e., expanded site areas that are newly impacted since the last measurement period. Circle these tallies. These additional procedures are necessary in order to accurately analyze changes in stumps over time.

26) **Access Trails**: A count of all trails leading away from the outer site boundaries. For trails that branch apart or merge together just beyond site boundaries, count the number of separate trails at a distance of 10 ft. from site boundaries. Do not count extremely faint trails that have untrampled tall herbs in their tread.

27) **Human Waste**: Follow all trails connected to the site to conduct a quick search of likely "toilet" areas, typically areas just out of sight of the site. Count and record the number of individual human waste sites, defined as separate locations with human feces present. The intent is to identify the extent to which improperly disposed human feces is a problem.

28) **Total Site Area**: Using a computer program (contact Jeff Marion), compute the site size using the transect data. Using a calculator, compute and sum the area of each island and satellite site (see the *Geometric Figure Method* sheet for procedures and formulas). Record these values in the spaces provided on the back of the form and calculate the Total Site Area. Record this value on the front of the form to facilitate computer data entry.

Comments: An informal list of comments concerning the site: note any assessments that you felt were particularly difficult or subjective, problems with monitoring procedures or their application to this particular site, suggestions for clarifying monitoring procedures, descriptions of particularly significant impacts beyond site boundaries (quantify if possible), excessive litter, human waste, or any other comments you feel may be useful.

Site/Reference Point Photographs: If the site has been previously surveyed, relocate the photo point and use it again. Frame your photo and adjust zoom lens to include the same area depicted in the earlier photo(s). If the site has expanded to areas that are not visible in the viewfinder then turn the camera to capture these areas or move back if necessary (and remeasure photo point distance). If the site has not been previously surveyed, select a vantage point that provides the best view of the site and reference point location. Try to select a location that clearly shows the reference point location in relation to nearby trees or boulders. It is best to have a person stand at the reference point with no one else in the photo. Also take a separate reference point photograph from a closer position that clearly identifies this point in relation to permanent site features. Place the tape measure or some other object against the reference point stake so that it is clearly visible in the camera viewfinder. For both photos leave the camera lens set at a 35-38mm focal length. Take photos with the camera pointed camera down to include as much of the site groundcover as possible. If a camera with a date/time recorder is used (preferred), record the date/time on the field form. ***Photo description procedures***: Use the photo description space to record the photo numbers and to write something unique about the photo that will allow someone to recognize and label the photo for this site. Also record the date and time the photo was taken.

Record the compass bearing and distance from the permanent reference point to the site photopoint (you may be able to use one of the site boundary flags as the photopoint). The intent is to obtain a photograph that includes as much of the site as possible to provide a photographic record of site conditions. The photo will also allow future workers to make a positive identification of the site and assist in relocating the permanent reference point. The location of the reference point photo does not need to be measured or recorded. At the earliest possible time, label the backs of 3x5 prints with the site number, date, film roll number, photograph number, bearing, and distance. Also, label and store the negatives. Store the photographs separately from the survey forms. An opaque plastic box should be used for long-term photo and negative storage.

*** Bury reference point nail and tag about 3 inches deep, compact soil with foot. Collect all site boundary pins, the reference point stake, and all other equipment.**

Equipment Use Procedures

Use of Peep Hole Compasses: Hold the compass level with the viewfinder close to your eye and away from any metal objects. The top of the white floating scale should be centered in the viewfinder. With your chin over the reference point, align the object with the vertical black line in the viewfinder. Hold the compass very steady, allowing the compass scale to come to a rest. Read and record the bearing to the nearest degree. <u>Be careful in reading the bearing from the scale, use large numbers (small numbers are the back azimuth) and note that scale values decrease from left to right.</u> Large-scale interval is 5 degrees, smallest interval is 1 degree. Practice and periodically compare compass readings with your partner to verify their accuracy. (Cost: $42)

Use of KVH Datascope: Read Datascope manual. We will only use the compass bearing function (the distance function is intended only for estimates of long distances). Remove and safely store both lens caps. Hold the datascope approximately level (though it is gimballed for tilt angles up to "20$^{o)}$ and away from metal objects. Focus on target by turning rubber eyecup. Turn unit on by pressing any button (it shuts off automatically after 2 minutes of inactivity). If necessary, press the white “mode” button until you see the “Bearing” mode inside viewfinder. Push both green and black buttons so that the word “Bearing” begins flashing, it is now in continuous scanning and averaging mode. Sighting through the unit, superimpose the vertical line on your target, hold the unit very steady. Read and record the compass bearing to the nearest ½ of a degree. Replace lens caps and store in protective case following use. Accuracy is "0.5^{o}, *if used correctly*. The Datascope is waterproof and shockproof but lets not do any product testing - be careful! **Batteries**: Carry spare batteries (3 3-volt #2025 lithium). Unit must be recalibrated each time batteries are replaced or used in a location where the magnetic field is widely different from where it was last calibrated - see manual for procedures. (Cost: $470)

Use of Sonin Combo Pro: Read the Sonin manual. We will only use it in the target or dual unit mode. Turn main “receiver” unit on by pressing switch up to the double icons, turn “target” unit on and slide the protector shield up. The units power down automatically after 4 minutes of inactivity. Position units at opposite ends of segment to be measured, pointing the receiver sensors in a perpendicular orientation towards the target sensors. **Note:** The measurement is calculated from the base of the receiver and the back of the target, position units accordingly so that you measure precisely the distance your intended. Press and hold down the button with the line over the triangle symbol. The receiver will continue to take and display measurements as long as you depress the button. Wait until you achieve a consistent measurement, then release the button to freeze the measurement. Measures initially appear in feet/inches. To obtain conversions, press and hold the “C” button until the measure is converted to the units you want (tenths of a foot). Turn both devices off and store in protective case following use. Unit range is supposed to be 250 ft.; be careful and take multiple measures for distances over 100 ft. Under optimal conditions accuracy is within 4 in. at 60 ft. Device can be affected by temperature, altitude and barometric pressure, and noise (even strong wind). The units are not waterproof. **Batteries**: Carry spare batteries (2 9-volt alkaline). (Cost: $185)

Geometric Figure Method

This method for determining the area of sites, disturbed "satellite" sites, and interior undisturbed "island" sites is relatively rapid and can be quite accurate if applied with good judgment. Begin by carefully studying the site's shape, as if you were looking down from above. Mentally superimpose and arrange one or more simple geometric figures to closely match the site boundaries. Any combination and orientation of these figures is permissible, see the examples below. Measure (nearest 1/10th foot) the dimensions necessary for computing the area of each geometric figure. It is best to complete area computations in the office with a calculator to reduce field time and minimize errors.

Good judgment is required in making the necessary measurements of each geometric figure. As boundaries will never perfectly match the shapes of geometric figures, you will have to mentally balance disturbed and undisturbed areas included and excluded from the geometric figures used. For example, in measuring an oval site with a rectangular figure, you would have to exclude some of the disturbed area along each side in order to balance out some of the undisturbed area included at each of the four corners. It may help, at least initially, to place plastic tape or wire flags at the corners of each geometric figure used. In addition, be sure that the opposite sides of rectangles or squares are the same length.

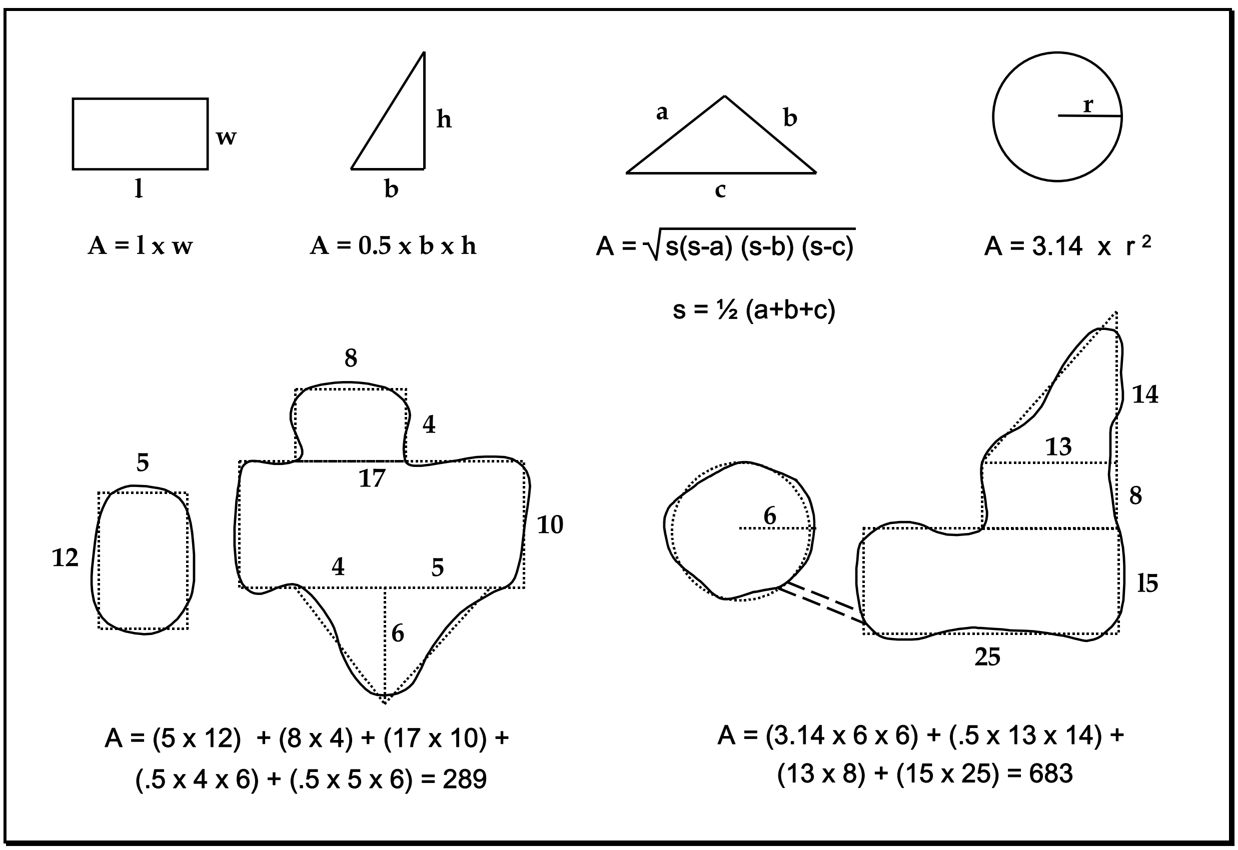

Figure 3. Geometric figure method for assessing site sizes.

Cliff Site Visitor Impact Monitoring Form, Shenandoah NP

ver. 6/23/05

General Site Information

1) Site Tag No. ___ ___ ___ ___   2) Site Type _____   3) Location Code/Name _________________

4) UTM Coordinates ____________________

5) Date _ _ / _ _ / _ _   6) Inventoried by: ______________   Locate/Label Site on Map _____

Describe Location: ____

____

____

Inventory Indicators

7) Site Expansion Potential: P M G ______

8) Site Slope: (**F** = <5% **M** = 5-10% **S** = >10%) ______

9) Tree Canopy Cover: (**1**=0-5% **2**=6-25% **3**=26-50% **4**=51-75% **5**=76-95% **6**=96-100%) ______

10) Use Type: Mixed Climbing/Hiking = MCH, Mostly Climbing = MC, Mostly Hiking = MH ______

11) Use Level: Low = L, Moderate = M, Heavy = H ______

12) Cliff Location: Top = T, Base = B ______

13) Climbing Type: Mixed Sport/Trad = MST, Mostly Sport = MS, Mostly Trad = MT, or NA ______

14) Climbs: ______

Impact Indicators

-- Apply Variable Radial Transect Method --

15) Condition Class (0 to 5) ______ ***Previous B.***

16) Vegetative Ground Cover On-Site (Use categories below) ______ ______

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

17) Vegetative Ground Cover Off-Site (Use categories above) ______ ______

18) Exposed Soil (Use categories above) ______ ______

19-21) Tree Damage None/Slight ____________________ Moderate ______________________ Severe _________

22-24) Root Exposure None/Slight ____________________ Moderate ______________________ Severe _________

25) Tree Stumps (#)________________________ ______

26) Access Trails (#) ______

27) Human Waste (#) ______

28) Total Site Area (Office) ______ft^2

Cliff Site Visitor Impact Monitoring Form, Shenandoah NP

ver. 6/23/05

Comments/Recommendations:____

____

____

Site Photo: Photo # ____ Bearing ____ Distance _____ ft Date/time: _____________

Description: ____

Ref. Pt. Photo #: ____ Description ____

Site Reference Point Information

1)

2)

3)

Bury Nail/Tag ___

Satellite Site Dimensions	Bearing	Distance

Island Site Dimensions	Bearing	Distance

Area from computer program ________

+ Satellite Area ________

! Island Area ________

= Total Site Area ________ ft^2

Transect Data

	Bearing	Distance (ft)
1)		
2)		
3)		
4)		
5)		
6)		
7)		
8)		
9)		
10)		
11)		
12)		
13)		
14)		
15)		
16)		
17)		
18)		
19)		
20)		
21)		
22)		
23)		
24)		
25)		

APPENDIX 2: CLIFF TRAIL MONITORING MANUAL

Cliff Trail Monitoring Manual

Shenandoah National Park[1]

(*version 6/29/05*)

This manual describes standardized procedures for conducting an assessment of resource conditions on recreation trails used to access cliffs. The principal objective of these procedures is to document the number and lineal extent of visitor-created cliff-access trails and to monitor changes in their condition. All continuous visitor-created trails to cliffs and in the vicinity of cliffs will be surveyed and GPS devices will also be used to record their location for computer mapping. These procedures rely on a sampling approach to characterize trail conditions from measurements taken at transects located every 300 ft (91 m) along selected trail segments. For trails less than 2400 ft (.45 miles) consult Table 1 for reduced sample point interval distances necessary to accurately characterize conditions on shorter trails. Values are calculated to include about 8 sample points for each trail segment (fewer for the shortest distances). Distances are assessed with a measuring wheel.

Trail condition measurements are applied at sample points to document the trail's width, depth, substrate, grade, and other characteristics. These procedures take about 2 minutes to apply at each sample point. Data is summarized through statistical analyses to characterize resource conditions for each trail segment. During future assessments it is not necessary to relocate the same sample points for repeat measures. Survey work should be conducted during the middle or end of the primary use season and during the growing season. This is necessary because determinations of trail boundaries are based on trampling-related disturbance to ground vegetation and leaf litter. Subsequent surveys should be conducted at approximately the same time of year.

Table 1. Sample point intervals for trails <2400 ft (.45 mi).

Interval (ft)	Trail Length (ft)
300	>2400
250	1801-2400
175	1201-1800
100	601-1200
75	301-600
50	51-300
1	<51

Materials

This manual and supply of data forms (some on waterproof paper), pencils, clipboard with compartment for forms, measuring wheel (one that removes distance when backed up), topographic and driving maps, clinometer, 12 ft tape measure (25 ft for wide trails), metal stakes (3), compass, 25 ft of thick non-stretchable line marked off every 0.3 feet on a spool.

Point Sampling Procedures

Trail Segments: Assess all visitor-created trails that are readily discernable, generally based on vegetation and/or organic litter trampling that has occurred during the survey year. In some places there are single trails that access a cliff top or base or a campsite. In others there is a network of trails, often interconnected and accessing the same destinations.

1 - Developed by Dr. Jeff Marion, USGS Patuxent Wildlife Research Center, Cooperative Park Studies Unit, Virginia Tech/Department of Forestry (0324), Blacksburg, VA 24061 (540/231-6603) email: jmarion@vt.edu.

1) **<u>Trail Segment Code:</u>** Record a unique trail segment code based on the cliff code.

2) **<u>Cliff Name:</u>** Record the name for the cliff area.

3) **<u>Surveyors:</u>** Record initials for the names of the trail survey crew.

4) **<u>Date:</u>** Record the date (mm/dd/yr) the trail was surveyed.

5) **<u>Use Type</u>**: Mixed Climbing/Hiking = MCH, Mostly Climbing = MC, Mostly Hiking = MH, MB = Mostly Biologists

6) **<u>Use Level</u>**: Low = L, Moderate = M, Heavy = H

<u>Starting/Ending Point:</u> Use a GPS device to assess and record UTM waypoint data for each trail segment's start and end points, except for trails <25 ft where only a single point is recorded where the trail departs from the initial trail. Turn on the GPS's tracking feature and leave it on for the duration of the survey work.

Measuring Wheel Procedures: Either wheel or pace each trail segment to determine its length, then refer to Table 1 for the sample point interval. For trails <51 ft select a "typical" sample point that is representative of the trail segment. For trails >50 ft select a random number from 1 to the selected interval distance. Record this number on the first row of the form. This will be the first sample point, from which all subsequent sample points will be located at whatever the specified interval is. This procedure ensures that all points along the trail segment have an equal opportunity of being selected.

*** At the first sample point, reset the wheel counter and use it to stop at points separated by your sample interval distance thereafter.**

Push the measuring wheel along the middle of the tread so that it does not bounce or skip in rough terrain. Lift the wheel over logs and larger rocks, adding distance manually where necessary to account for horizontal distances. Your objective is to accurately measure the distance of the primary (most heavily used) trail tread. Monitor the wheel counter and stop at your sample interval to conduct the sampling point measures. If you go over this distance, back the wheel up to the correct distance. If the wheel doesn't allow you to take distance off the counter then stop immediately and conduct your sampling at that point, recording the actual distance from the wheel, not the "missed" distance. Continue to the next "correct" sample point (as though you had not missed the last one).

Rejection of a sample point: Given the survey's objective there will be rare occasions when you may need to reject a sampling point due to the presence of boulders, tree falls, trail intersections, road-crossings, stream-crossings, bridges or other odd "uncharacteristic" situations. The data collected at sample points is intended to be roughly "representative" of the sections of trail on either side of the sample point. Use your judgment but be conservative when deciding if a sample point should be relocated. The point should be relocated by moving forward along the trail an additional 20 ft, this removes the bias of subjectively selecting a point. If the new point is still problematic then add another 20 ft, and so on. Record the distance of the actual point and continue on to the next "correct" point (as though you did not need to move the last one).

For the following data, in the field or office: If an indicator cannot be assessed, e.g., is "Not Applicable" code the data as -9, code missing data as -1.

7) **<u>Distance:</u>** Measuring wheel distance (ft) from the beginning of the trail segment to the sample point.

8) **<u>Trail Position (TP):</u>** Use the descriptions below to determine the trail position of the sampling point. Record the corresponding letter code in the TP column.
   R - Ridge: Ridge-top or high plateau position, **M** - Midslope/Sideslope: Mid-slope positions
   CB - Cliff base, **V** - Valley Bottom: Flatter valley bottom terrain

9) **<u>Trail Grade (TG):</u>** The 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.

10) **<u>Trail Alignment (TA):</u>** Assess the trail's alignment angle to the prevailing land-form in the vicinity of the sample point. Sight a compass along the trail from a point about 5ft before the transect to about 5ft past the transect, record the compass azimuth (0-360, not corrected for declination) on the left side of the column (it doesn't matter which direction along the trail you sight). Next face directly downslope, take and record another compass azimuth - this is the aspect of the local landform. The trail's alignment angle ($<90^0$) can be computed by these two azimuths.

11) **<u>Tread Width (TW):</u>** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized) (see photo illustrations in Figure 1, placed at the end of the manual). The objective is to define the trail tread that receives the majority (>95%) of traffic, selecting the most visually obvious outer boundary that can be most consistently identified by you and future trail surveyors. In places where the trail boundary is indistinct at the sample point project the boundary to the sample point from immediately adjacent areas. Measure and record the length of the transect (the tread width) to the nearest inch (don't record feet and inches). Note that for deeply incised trails, tread width is likely to be assessed only across the flatter bottom areas, excluding the steep eroded trail sides that generally receive little or no traffic (see Figure 2).

12) **<u>Rock (R):</u>** Record the percentage of rock (bedrock, rock and large gravel) present along the transect. Use 10% categories, 5% where needed.

13) **<u>Cross-Sectional Area (CSA):</u>** The objective of the CSA measure is to estimate soil loss from the tread at the sample point following trail creation. Place two stakes and the transect line to characterize what you judge to be the pre-trail or original land surface. Place the left-hand stake beyond the trail boundary so that the 1st mark on the transect line will fall on what you believe was the "original" ground surface but at the edge of any tread incision, if present (see Figure 2 at end of section). Thus, the transect incision value you record for the 1st mark (V_1) must be 0. Stretch the transect line (marked in 0.3 ft intervals) tightly between the two stakes - any bowing in the middle will bias your measurements. Insert the other stake just beyond the first transect line mark on the other side of the trail that is on the original ground surface and will be measured as a 0. The distance between the first and last vertical measures that are "0" is the trail width (V_1 to V_{16} in Figure 2). The transect line should reflect your estimate of the pre-trail land surface, serving as a datum to measure tread incision caused by soil erosion and/or compaction.

    Note: If the line cannot be configured properly at the sample point due to rocks or obstructing materials that cannot be moved, then move the line forward along the trail in one-foot increments until you reach a location where the line can be properly configured.

Measurement Procedure: On the CSA data form, label a new row with the measuring wheel distance for the transect (e.g., D=600 ft). Starting on the left side record a 0 for the 1st mark on the line (0.3 ft), followed by the measurement for the 2nd mark perpendicular to the transect line down to the ground surface (nearest 1/4 in, e.g., .25, .5, .75). Record this as V_2. Proceed to the third mark and record the vertical for this as V_3. Record the values on the data sheet next to their labeled numbers (e.g., V_1, $V_2 \ldots V_n$). Continue measuring each vertical until you reach the far side of the trail and obtain a measure of 0 when the original (non-eroded) ground is reached. ***Note:*** The transect line is not likely to be "level" so be cautious in measuring vertical transects that are *perpendicular* to the horizontal transect line. Contact Jeff Marion for a spreadsheet that calculates CSA for this data.

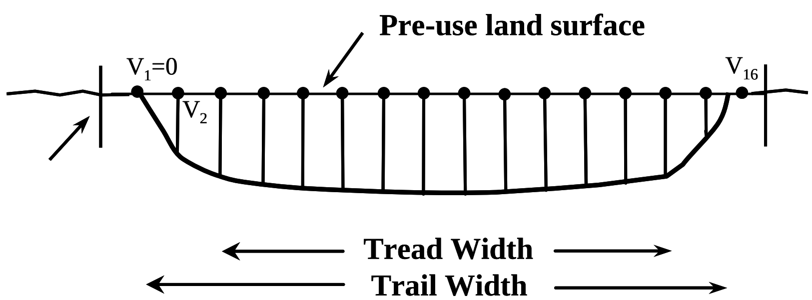

Figure 2. Cross sectional area (CSA) diagram illustrating measurement procedures for visitor-created trails.

14) **Comments:** Record any relevant comments.

Collect all equipment and move onto the next sample point.

Figure 1. Photographs illustrating different types of boundary determinations. Trail tread boundaries are defined as the most pronounced outer boundary of visually obvious human disturbance created by trail use (not trail maintenance like vegetation clearing). These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized). The objective is to define the trail tread that receives the majority (>80%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by you and future trail surveyors.

Cliff Trail Visitor Impact Form, Shenandoah NP

(ver. 6/29/05)

Surveyors ___________________ Date ______________________ **Note:** For each cliff area record the cliff name and code on a blank line.

Wpt	UT	UL	Dist	TP	TG	TA	TW	R	CSA	P#	Comments
						/					
						/					
						/					
						/					
						/					
						/					
						/					
						/					
						/					
						/					
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						/					
						/					
						/					
						/					

Wpt = Waypoint
UT = Use Type
UL = Use Level
Dist = Wheel Distance (include end distance)
TP = Trail Position (R, CB, M, V)
TG = Trail Grade (%)
TA = Alignment (Trail° / Landform°)
TW = Tread Width
R = Rock
P# = Photo no.
CSA (calculated from data form)

Cross Sectional Area Data Form							
T=							
D=							
V1=							
V2=							

Note: Record Trail Code (T), Distance (D) of transect along the trail, perpendicular vertical measures (nearest .25 in), and at the end of data for verticals leave 2 spaces, the first to record the CSA from the spreadsheet calculation.