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Assessing Recreation Impacts to Cliffs in Shenandoah National Park: Integrating Visitor Observation with Trail and Recreation Site Measurements

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EXECUTIVE SUMMARY: The rock outcrops and cliffs of Shenandoah National Park provide habitat for several rare and endangered plant and animal species, including the federally endangered Shenandoah Salamander (*Plethodon shenandoah*; Ludwig et al., 1993). 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 used an integrative approach to study recreational use and visitor-caused resource impacts at one of the more heavily visited cliff sites in the park: Little Stony Man Cliffs (LSMC). In particular, this study integrated data from resource impact measurements and visitor use observation to help assess the effects of recreational use on the natural resources of LSMC.

Procedures derived from campsite and trail impact studies were used to measure and characterize the amount of visitor-caused resource impacts on LSMC (Marion & Leung, 2001; Marion, 1995). Visitor use observations were conducted on top of LSMC to document and characterize the type and amount of recreational use the cliffs receive and the behaviors of recreationists that may contribute to cliff-top resource impacts.

Resource impact measurement data show trampling disturbance present at LSMC, characterized by vegetation loss, exposed soil, and root exposure. Documentation of informal trails, soil erosion, tree damage, and tree stumps provide further indicators of resource damage at LSMC.

Results of visitor use observation offer several insights into contributory factors of cliff-top resource damage by showing differences in use and behavior between visitor types. 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.

KEYWORDS: Shenandoah National Park, rock climbing, cliff and rock outcrops, resource impact measurements, visitor use observation

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Introduction

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% (3920 acres) of the park's 197,000 acres. Previous Virginia Department of Conservation and Recreation (VADCR) survey work at a few of the park's larger rock outcrops documented the occurrence of 28 rare species, including the federally endangered Shenandoah Salamander (*Plethodon Shenandoah*; Ludwig et al., 1993). Furthermore, previous research identified a rare plant community type, the High Elevation Greenstone Outcrop Barren, believed to be endemic to the park (Hilke, 2002).

The location of the world-famous ridgeline parkway, Skyline Drive, makes many outcrops and cliffs within the park readily accessible to the park's 1.2 million annual visitors. Rock outcrops provide vistas for day hikers and backpackers along the park's 500 miles of trails, including the Appalachian National Scenic Trail, which parallels Skyline Drive for the length of the park. Additionally, in the last several years, some cliff areas in the park have become increasingly popular for rock climbing. Consequently, visitor use of cliff areas within the park has led to natural resource impacts such as vegetation damage and loss, soil exposure, compaction and erosion, proliferation of informal (visitor-created) trails, and illegal or poorly located campsites (Hilke, 2002).

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. Concern over the effects of visitor-caused impacts to cliff areas has prompted the park 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 paper used an approach that integrates social science and ecological data to help assess the effects of recreational use on the vegetation and soils at one of the most heavily visited cliff sites in the park, Little Stony Man Cliffs (LSMC). In particular, this study integrates data from measurements of resource conditions on cliff-associated trails, recreation sites, and campsites with information collected through direct observations of the amount and type of recreational use, and the behaviors of visitors that might contribute to resource impacts at LSMC. The information from this study 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.

Related Literature

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 nine 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 (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; McMillan & Larson, 1999; 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.

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 LSMC, a conclusion reached through intuition rather than empirical evidence. This letter prompted the park to initiate the study presented in this paper.

While the authors of this paper are aware of only one study examining the trampling effects of non-rock climbing recreational activities on cliff resources (Parikesit et al., 1995), a number of studies have been conducted to investigate soil and vegetation trampling impacts to trails and campsites (Cole, 1995; Leung & Marion, 2000; Marion & Cole, 1996). These studies reveal that most vegetation is lost on sites receiving even low levels of visitation, particularly in forested habitats. Procedures used to measure trampling disturbance on trails (Farrell & Marion, 2002; Marion & Leung, 2001) and campsites (Leung & Marion, 2000; Marion, 1995) are reasonably well-developed and are adaptable for measuring cliff-top, cliff-bottom, and descent trail impacts. Thus, procedures designed to measure the total area of trampling disturbance, vegetation loss, and soil exposure on campsites or day-use recreation sites are likely adaptable to measure these and other indicators on cliff-top and cliff-bottom recreation sites. Thus, despite an apparent lack of previous studies evaluating the effects of alternative recreation types on cliff sites, present study methodology and findings from both rock climbing cliff impact studies and trampling literature reviewed above may provide adequate tools for evaluation and documentation of cliff site impacts. This study is designed to adapt and apply these methods and knowledge to assess the extent of resource impacts at LSMC associated with all types of recreational uses, including, but not limited to, rock climbing.

Visitor Observation

As noted, previous studies of recreation-related cliff resource impacts lack a social science component. Thus, it is difficult to draw conclusions from these studies about the relative effect of varying amounts and types of recreational use on cliff resources. Furthermore, it is difficult to assess the extent to which cliff resource impacts might be explained by visitor behaviors. In this study, visitor observations were used to document the amount and type of recreational use of LSMC, and the frequency with which visitors engaged in behaviors that directly impact cliff resources (i.e., trampling soil and vegetation). While the authors know of no published applications of visitor observation methods to studies of cliff resource use in general and rock climbing in particular, a number of studies have documented direct observation procedures and methods designed to collect information about visitor use (e.g., amount, time, location of use, etc.) and visitor characteristics (e.g., type of use, group size, activities, etc.; Hendricks et al., 2001; Keirle, 2002; Muhar et al., 2002; Watson, 2000). Direct visitor observation methods have also been used to study visitors' behavior, including depreciative behavior (Gramann & Vander Stoep, 1986; Hockett, 2000) and visitor etiquette (Hendricks et al., 2001). Furthermore, direct observation methods have been used to study the extent to which visitors engage in behaviors that cause environmental impacts. For example, Johnson and Swearingen (1992) used unobtrusive observation methods to examine the extent to which visitors at Mt. Rainer National Park hiked off-trail, causing the formation of informal trails. Hendricks et al. (2001) conducted unobtrusive observations of mountain bikers on Mt. Tamalpais in Marin County, California to investigate stream protection behavior at a stream crossing. In particular, observers were stationed at the stream crossing and recorded for each passing mountain biker whether they rode through the stream or crossed the bridge spanning the stream.

The authors are aware of no other studies that have used unobtrusive observation methods in tandem with resource impact measurements to examine how information about visitor use and behavior might be used to explain the extent and character of resource impacts at recreational sites. Thus, the objectives of this study, which are applied and methodological in nature, are designed to address this gap in the literature. From a methodological perspective, the objective of this study is to build on the literature reviewed above by demonstrating a set of procedures to not only document the extent of recreation-related resource impacts associated with cliff recreation, but develop an understanding of visitor use and behavior that helps to explain the occurrence, extent, and location of resource impacts. From an applied perspective, the objective of this study is to integrate measures of resource impacts with information about visitor use and behavior obtained through direct observation to provide park managers with a more informed basis for developing resource protection strategies for LSMC than resource impact measurements or visitor observation behavior would provide alone.

Methods

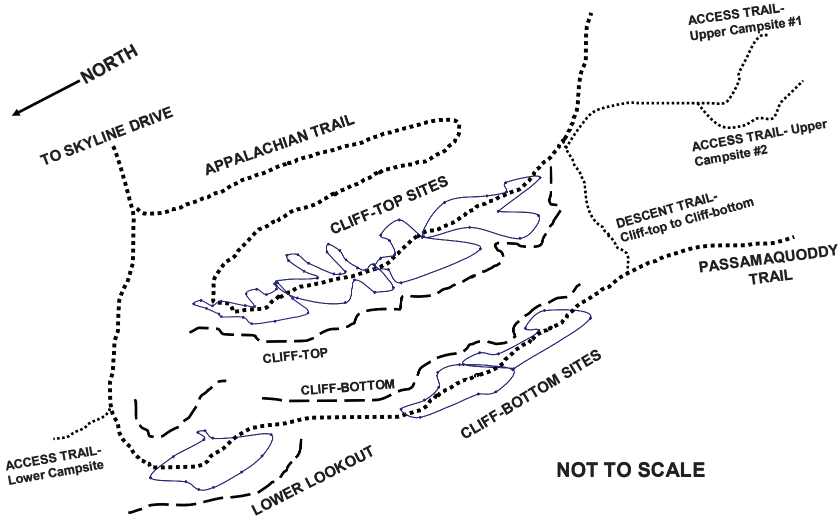
Study Area

The Little Stony Man Cliffs are one of many greenstone (metamorphosed basalt) cliff formations located within SNP. At an elevation of 3560 feet, these cliffs rise approximately 100 feet, providing visitors with a spectacular view of the Shenandoah Valley to the west and, on clear days, West Virginia. The cliffs are popular among day hikers and backpackers for the views they afford and among rock climbers, including organized groups, for the easily accessed beginner to intermediate climbing routes (Hilke, 2002). Most visitors access LSMC by taking a short hike on the Appalachian Trail from the Little Stony Man Cliffs trailhead on Skyline Drive (Figure 1). During the summer and fall of the 2002 visitor use season, trailhead registers were used to monitor the amount of use of LSMC. The trailhead register data suggested that an average of 49 people visit LSMC per day during the summer and fall seasons (Hilke, 2002). However, observation data collected during eight randomly selected days when trailhead registers were in place suggest that only about 59% of visitors signed in at the register. Thus, after adjusting for non-compliance with the trailhead register, it was estimated that approximately 84 people visit LSMC per day during the summer and fall seasons. While seasonal differences in visitor use levels may occur at LSMC, they were not reported in the study (Hilke, 2002).

The majority of the LSMC cliff-top is characterized by solid rock rising toward the cliff edge at varying heights with a few interspersed patches of vegetation and bare soil. Several day-use recreation sites located along and east of the rocky cliff edge are present on the cliff-top, characterized by a mix of bare soil and trampled vegetation. The Appalachian Trail runs the length of the cliff-top, bisecting the recreation sites which extend west to the cliff edge and east into the forest, and further south to the cliff descent trail and upper campsite access trails (Figure 1). The polygons in Figure 1 represent the recreation sites that were measured for recreation impacts as part of this study.

The lower portion of LSMC is comprised of two separate areas, both accessed by the Passamaquoddy Trail - a lower lookout perched on top of a small cliff and the cliff-bottom (Figure 1). The lower lookout shares similar characteristics with the cliff-top - a large recreation site perched on top of a cliff. Few patches of vegetation are found at this site and it lacks a forest canopy. The main cliff-bottom is characterized by two recreation sites containing a mix of bare soil and trampled vegetation along with multiple

Figure 1
Little Stony Man Cliffs - Recreation Sites and Trails



informal trails diverging from the Passamaquoddy Trail to the cliff base.

Three visitor-created campsites are located close to LSMC, accessible by informal (visitor-created) trails connected to the Appalachian or Passamaquoddy Trails (Figure 1). Two of the campsites are located south of the cliff-top while the remaining campsite is located to the north of the lower lookout. Each campsite contains at least one core area of disturbance characterized by a combination of bare soil, organic litter and trampled vegetation.

In addition to informal trails associated with recreation sites, one informal descent trail located south and adjacent to LSMC provides quick access between cliff-top and cliff-bottom (Figure 1). This badly eroded trail follows a steep drainage ravine consisting of loose soil, rock, and other debris. The soil and rock eroded from this trail have accumulated in a large mound found at the base of the trail where it joins the Passamaquoddy Trail.

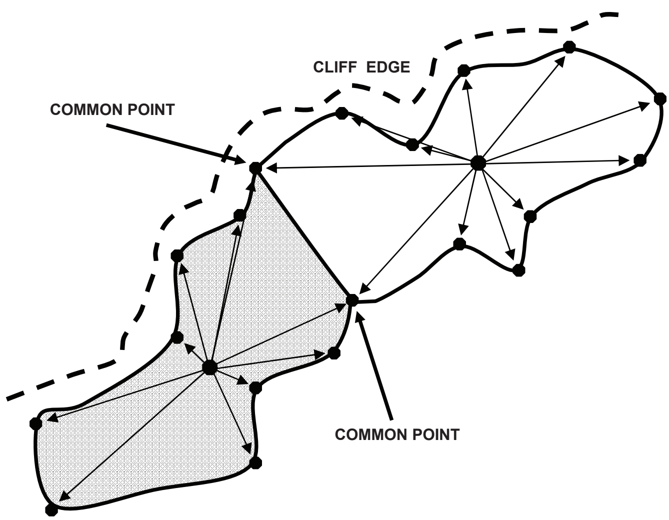
Several rare and endangered animal and plant species, and communities are found throughout the LSMC area. The highest occurrence of rare plant species and communities are on the cliff-top and surrounding upper ledges as most species are particularly adapted to the microclimate characteristic of these locations (Hilke, 2002; Nuzzo, 1995). Less frequent concentrations of rare plants are present on the lower lookout and along the cliff-top directly south of LSMC, along the edge of the two upper campsites (Figure 1). Furthermore, habitat for the globally rare Shenandoah Salamander is believed to be located within proximity of the descent trail to the south of LSMC (Hilke, 2002; Ludwig et al., 1993).

Resource Impact Measurement

In the study presented in this paper, procedures from campsite and trail impact studies were adapted to measure and characterize the extent of resource impacts associated with all types of LSMC recreational uses. Impact indicators assessed at cliff-top and cliff-bottom recreation sites and campsites included area of disturbance, vegetation loss, exposed soil, tree damage, tree stumps, root exposure, number of informal (visitor-created) trails, and expansion potential. Trail condition assessments were also performed on visitor-created trails at LSMC exceeding 10 feet in length (a decision rule to conserve assessment time).

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 site boundaries defined by trampling disturbance (Marion, 1995). Reference points were permanently marked and located using Global Positioning System (GPS) devices. Multiple radial transects that shared common points were used to accurately measure area of disturbance for long linear recreation sites present on both the cliff-top and cliff-bottom (Figure 2). Area of disturbance for each radial transect was calculated arithmetically from transect data using Excel spreadsheet formulas.

Figure 2
Modified Radial Transect Method Used to Measure Recreation Sites at Little Stony Man Cliffs



Ground vegetation on recreation sites and campsites and in 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 area of disturbance 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 area of disturbance.

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). 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. Informal trails that connected with each radial transect 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. Impact indicator values reported for LSMC reflect summed totals and mean percentages for all sites according to their location at LSMC (cliff-top, cliff-bottom, campsites, and lower lookout).

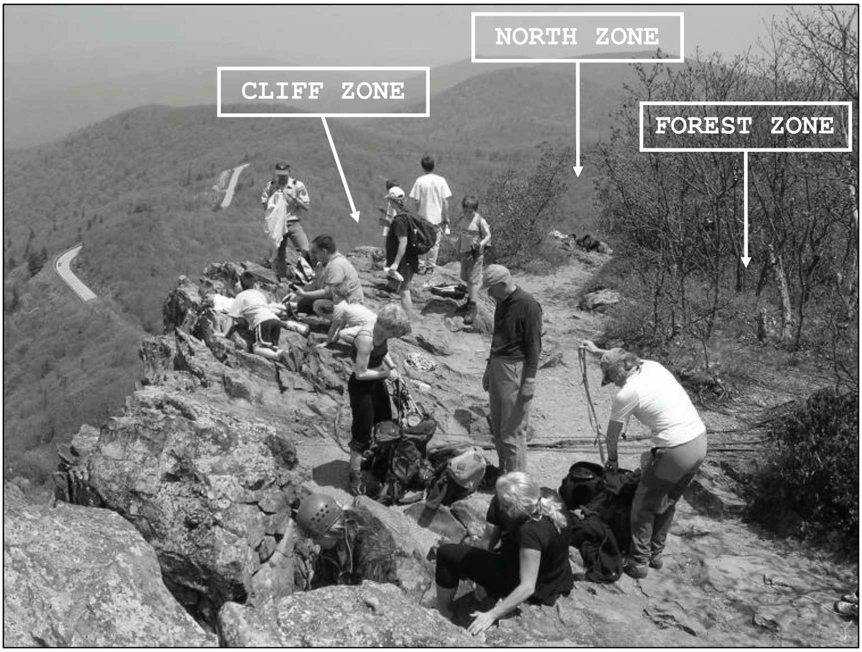
The condition of informal trails was assessed using point sampling procedures outlined in Farrell and Marion (2001) and Marion (2006), and included measurement of trail length, width, mean depth, and when depth exceeded one inch, assessments of soil loss since trail creation using a cross sectional area (CSA) procedure. These 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. GPS devices were also used to document each trail's location. Trail condition measures were calculated for each trail and for all trails combined, including mean CSA, trail width, and trail depth. Trail length was multiplied by mean trail width to produce estimates of the land area intensively disturbed by trail traffic. CSA soil loss measures at each transect were also extrapolated to provide aggregate estimates of soil loss (ft3) for each trail.

Visitor Observation

Unobtrusive visitor use observations were conducted on 14 randomly selected days between May 27, 2005 and September 10, 2005 on top of LSMC to document and characterize the type and amount of recreational use the cliffs receive and the behaviors of recreationists that may contribute to cliff-top resource impacts. Sampling days were stratified by day of the week and time of day, with morning sampling shifts conducted from 9:00 AM to 2:00 PM and afternoon sampling shifts conducted from 2:00 PM to 7:00 PM. For the purposes of conducting visitor use observations at

LSMC, three observation zones were defined: the North, Cliff, and Forest Zones (Figure 3). Data collectors were stationed in a fixed location on the cliff-top that provided a view of all three observation zones. Staff conducting the visitor use observations dressed to blend-in with visitors, concealed observation sheets, and conducted observations in a subtle manner to avoid altering visitor behavior.

Figure 3
Little Stony Man Cliffs Cliff-top Observation Zones, Looking North



During the sampling period, five types of visitor use information were collected through direct observation, including the number of people at one time (PAOT) in each of the three observation zones; occurrences of soil/vegetation trampling (Behavior Observations); total daily use of the cliff top (Total Daily Use); visitors' length of stay on the cliff top (Length of Stay); and supplemental observations concerning visitor use and behavior.

PAOT and Behavior Observations data were collected concurrently by a single data collector. At the start of each sampling day that PAOT counts and Behavior Observations were collected, the data collector conducted an instantaneous PAOT count and recorded the number and type (i.e., rock climber, day hiker, and backpacker) of visitors in each observation zone. Immediately following the first PAOT count, the data collector randomly selected one individual from among the visitors in the three observation zones. The data collector observed the behavior of the selected participant for five minutes or until he/she was no longer in any of the three observation zones. For the duration of the observation, the data collector recorded whether the individual being observed trampled soil/vegetation, and the location of each "trampling event" observed. At the conclusion of the Behavior Observation, the data collector recorded the type of visitor observed (i.e., rock climber, day hiker, backpacker) and the length of time of the observation. At five minutes after the first PAOT count, the data collector conducted a second PAOT count and then randomly selected the next subject for Behavior Observation. The data collector continued making PAOT counts every five minutes throughout the sampling day and Behavior Observations during the five minute intervals between PAOT counts.

Length of Stay observations were conducted in tandem with Total Daily Use observations by a single data collector. On each day that Length of Stay and Total Daily Use observations were conducted, the total number and type of visitors entering the study area were tallied and recorded. Visitors who left the observation area and returned at a later time were counted each time they entered the observation area unless the data collector recognized the visitor as having been counted earlier in the sampling shift. In addition, at the start of each sampling day that Length of Stay and Total Daily Use observations were conducted, the data collector selected the first visitor to enter any of the three observation zones. The data collector recorded the type of visitor selected and his/her point and time of entry into the study area. The data collector also recorded the visitor as part of the Total Daily Use count being conducted concurrently with Length of Stay observations, along with all subsequent visitors that entered any of the three study zones while Length of Stay observations were conducted. The data collector observed the selected visitor until he/she left the study area, at which time the data collector recorded the subject's exit point and time, and the total time the visitor was observed in the study area. The data collector then selected the next visitor to enter any of the three observation zones as the subject of the next Length of Stay observation. The process described above was repeated throughout the entire sampling period.

Data collectors recorded supplemental observations concerning visitor use and behavior at the end of each sampling period. Supplemental observations were made on the initial sampling day and on each subsequent sampling day in which previously unrecorded activities and/or behaviors were observed. Data collected as a result of supplemental observations included possible motivations for visitors trampling soil or vegetation. For example, non-rock climbing visitors were observed trampling soil or vegetation in the Forest Zone in an effort to seek shade from the sun and others were observed trampling soil or vegetation in the Cliff Zone to get a closer look at rock climbing activity. Supplemental observations also included notes describing behavioral responses of non-rock climbing visitors to the presence of rock climbing ropes and webbing placed across the Appalachian Trail on the cliff top. For example, observations of visitors stepping off of the Appalachian Trail into the Forest Zone in order to avoid having to step over the climbing ropes crossing the trail were noted. Data collectors also documented popular climbing routes at LSMC and the location of trees and boulders most often used to construct anchors for each climbing route.

During the first two days of visitor use observations, data were collected by pairs of observers in order to assess the reliability of observation data (excluding supplemental observations) and to make adjustments to data collection procedures as needed to increase the reliability of the observation data. In particular, results of observations from the paired observers were compared to determine whether they were the same or similar. Comparisons of the paired observers' results suggested that all of the measures were being recorded precisely the same by both observers, except measures of soil and vegetation trampling. Specifically, the procedures were originally designed to have observers record a soil trampling event or a vegetation trampling event when visitors stepped off the trail or bedrock, depending on whether they stepped onto soil or onto vegetation. This procedure was adjusted based on the results of the reliability assessments, which suggested that while it was not difficult for observers to determine when visitors stepped off the trail or bedrock surfaces, it was difficult to distinguish whether they had stepped onto soil or onto vegetation. Consequently, the procedures were revised to have observers record a soil/vegetation trampling event when visitors had stepped off the trail, but not to try to distinguish whether it was soil or vegetation that they had stepped onto. Comparisons of paired observations of the revised soil/vegetation trampling measure suggested that the measure was being recorded precisely the same by both observers.

Results

Resource Impact Measurement

The area of disturbance for LSMC recreation sites and campsites, characterized by bare soil and vegetation loss, total 12817 ft2 (Table 1). The highest percentage (42%) of trampling disturbance was found to occur on the cliff-top while the lower lookout accounted for the lowest percentage (15%). Conversely, percentage of exposed bare soil and vegetation loss estimates were lowest on the cliff-top while the lower lookout was the most heavily impacted site, containing roughly 63% bare soil and accounting for an 83% reduction in ground cover compared to the offsite control. The combined area of disturbance for campsites accounted for nearly 25% of trampling disturbance at LSMC, while percentages of both vegetation loss and bare soil were similar to the cliff-top.

All sites where resource impacts were measured contained trees, except the lower lookout site. Within cliff sites where trees are present, most observed tree damage was categorized as none/slight. However, some

Table 1
Impact Indicator Data for LSMC Recreation Sites

Impact Indicator	Cliff-top	Cliff-bottom	Campsites	Lower Lookout	Total
Area of Disturbance (ft^2) [a]	5338	2481	3139	1859	12817
Vegetation Loss (%) [b]	35	56	35	83	
Vegetation Loss (ft^2) [a]	1529	1367	962	1543	5401
Exposed Soil (%) [b]	16	16	21	63	
Exposed Soil (ft^2) [a]	827	943	538	1171	3479
Tree Damage (#)					
Slight	27	9	9	0	45
Moderate	2	6	5	0	13
Severe	0	3	0	0	3
Tree Root Exposure (#)					
Slight	28	14	10	0	52
Moderate	0	1	3	0	4
Severe	0	1	1	0	2
Tree Stumps (#)	4	1	1	0	6
Informal Trails (#)	2	0	4	0	6

[a] Values reported are sums
[b] Values reported are means

Table 2
Impact Indicator Data for LSMC Informal Trails

Impact Indicator	Cliff Descent Trail	Lower Campsite Trail	Upper Campsite Trail #1	Upper Campsite Trail #2	Totals
Trail Length (ft)	204	169	141	98	612
Trail Width (in)[a]	115	37	34	45	
Area of Disturbance (ft^2)[b]	1955	521	400	368	3243
Trail Depth (in)[a]	16.8	2	1.4	3.2	
Cross Sectional Area (CSA)					
(in^2)[a]	1747	49	38	144	
(ft^3)[b]	2288	440	21	54	2803

[a] Values reported are means
[b] Values reported are sums

moderate tree damage was found in all three sites that contained trees, while severe tree damage was observed only at the cliff-bottom. While tree stumps were also observed in all three sites that contained trees, the cliff-top contained the greatest number of stumps and only one stump was observed in each of the other sites. Root exposure was observed within all three sites, but only the cliff-bottom and campsites contained areas with moderate or severe root exposure.

Informal trails were found only on the cliff-top and at the three campsites. The two informal trails on the cliff-top and one informal trail at an upper campsite were less than 10 feet in length, thus condition assessments were not performed on them. However, condition assessments were performed for two informal trails observed at the upper campsites, one for the lower campsite, and the descent trail (Figure 1). The condition assessments found that informal trails used to access campsites at LSMC range from 98-169 feet in length, 34-37 inches in width, and have mean trail depths ranging between 1.4-3.2 inches (Table 2). Measurements of the descent trail indicate that the trail is 204 feet in length, has a mean width of 115 inches, and a mean trail depth of 16.8 inches. The total surface area of disturbance associated with informal trails is one-quarter (3243 ft2) the size of the total area of disturbance (12817 ft2) from recreation sites and campsites. Soil loss on the campsite trails was relatively low, as indicated by mean CSA, ranging from 49 in2 for the lower campsite trail and 38 in2 and 144 in2 for the upper campsite trails, #1 and #2 respectively. Soil loss on the cliff descent trail was much more pronounced, with a mean CSA of 1747 in2. Additionally, the descent trail made up roughly 82% (2288 ft3) of the total cumulative soil loss (2803 ft3) from all informal trails.

Visitor Observation

Results of pairwise comparisons of average daily use by type of visitor suggest that significantly more hikers ($t=5.43$; $p<0.01$) and backpackers ($t=3.96$; $p<0.01$) visit LSMC during weekdays than rock climbers (Table 3). On weekend days, the number of day hikers who visit LSMC is significantly greater than the number of backpackers ($t=-8.60$, $p<0.01$) and rock climbers ($t=10.87$, $p<0.01$) who do so. Furthermore, while average daily backpacking and rock climbing use did not differ significantly between weekend days and weekdays, day hiking use of LSMC was found to be significantly higher on weekends than during the mid-week ($t=-5.41$, $p<0.01$).

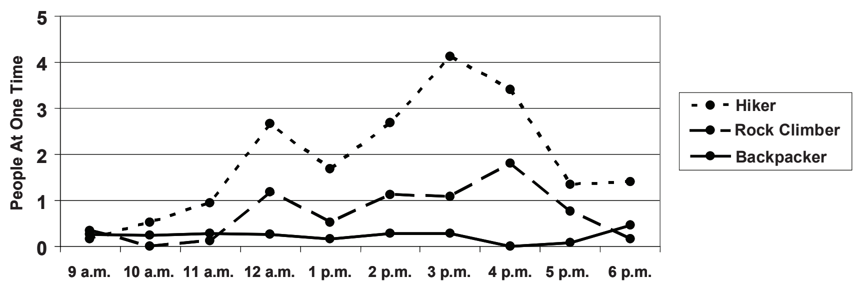
Day hiking use of LSMC was found to not only be concentrated more on weekends than weekdays, but also to be unevenly distributed across the hours of the day (Figure 4). In particular, day hiking use tends to be bi-modally distributed, with peaks at noon and mid-afternoon. Rock climbing use was observed to follow a similar but less pronounced trend across the hours of the day, whereas backpacking use of LSMC stayed relatively consistent and low throughout the day.

Table 3
Mean Total Daily Use on LSMC CLiff-top, by Day of Week and Type of Visitor

	Weekday	Weekend	Pairwise t - tests of weekday vs. weekend daily use	
Rock Climber	0.3[a]	2.7[a]	t=-1.64;	p=0.58
Hiker	14.5[b]	48.8[b]	t=-5.41;	p<0.01
Backpacker	8.0[b]	7.2[a]	t=0.67;	p=0.98

Note: Within each column, means with different superscripts are significantly different at α=0.05.

Figure 4
Mean Number of People At One Time (PAOT) on Little Stony Man Cliffs Cliff-Top, by Type of Visitor and Time of Day



Results of a one-way ANOVA comparing day hikers, rock climbers and backpackers with respect to mean length of stay indicate that the amount of time visitors spend on the cliff-top varies significantly by type of use ((F=10.62; p<.01). Post hoc tests (Tukey's HSD) suggest that rock climbers, with an average length of stay of 24 minutes, spend significantly more time on the cliff-top than day hikers, who average 9 minutes on the cliff-top, or backpackers, who spend an average of 5 minutes on the cliff-top. Day hikers and backpackers were not found to differ significantly with respect to the amount of time they spend on the cliff-top.

The likelihood of visitors to trample soil and vegetation on the LSMC cliff-top was found to differ by type of visitor (x^2=10.68; p<0.01; Table 4). In particular, 39% of day hikers observed during the study stepped on soil or vegetation, compared with 29% of rock climbers and 16% of backpackers.

Within each of the three observation zones, day hikers accounted for the majority of soil and vegetation trampling observed, however, rock climbers accounted for about one-quarter of all observations of soil and vegetation trampling in the Forest Zone (Table 5). In all three observation zones, backpackers accounted for the least amount of soil and vegetation trampling observed.

Table 4
Percent of Observed Visitors Seen Trampling Soil/Vegetation, by Type of Visitor

Rock Climber (n=62)		Hiker (n=224)		Backpacker (n=51)	
Trampling	No Trampling	Trampling	No Trampling	Trampling	No Trampling
29%	71%	39%	61%	16%	84%

x^2=10.68; p<0.01

Table 5
Percent of Observations of Soil/Vegetation Trampling, by Observation Zone and Type of Visitor

Cliff Zone (n=28)			Forest Zone (n=64)			North Zone (n=30)		
RC	H	BP	RC	H	BP	RC	H	BP
7%	89%	4%	27%	67%	6%	0%	90%	10%
X^2=7.19; P=0.03			X^2=6.99; P=0.03			X^2=9.38; P=0.01		

Note: RC=Rock Climber; H=Hiker; BP=Backpacker

Discussion and Management Implications

Resource impact measurement data show trampling disturbance present at all four LSMC sites (i.e., cliff-top, cliff-bottom, lower lookout, and campsites), characterized by vegetation loss, exposed soil, and root exposure. Documentation of informal trails, soil erosion, tree damage, and tree stumps provide further indicators of resource damage at LSMC. Of most concern are areas of disturbance at the cliff-top, the lower lookout, and the upper two campsites due to the substantial vegetation loss (including rare plants) and degradation/loss of habitat for the rare Shenandoah Salamander (Hilke, 2002; Smith, 2002). The presence of rare plants was noted near the boundaries of each site surveyed and some were located at protected locations within site boundaries. Earlier rare plant surveys had noted substantial expansion of the campsites and vista viewing areas over time and park managers are concerned about continued expansion into known endangered species habitat.

Findings from the visitor use observation work provide insights into factors that may be driving visitor-caused impacts at LSMC and, coupled with the resource impact measurement data, are suggestive of potential management solutions. Roughly one-third of all day hikers and rock climbers observed on the cliff-top of LSMC were seen trampling soil or vegetation. Consequently, as the resource data in this study show, large areas of bare soil and solid rock are already characteristic of the cliff-top. Furthermore, assessments of site expansion potential, which examine barriers to future expansion based on topography and vegetation, suggest that substantial future expansion could occur. Previous recreation ecology research suggests that attempting to address these impacts through use limits would require substantial reductions in use or closure to improve resource conditions under these circumstances (Cole et al., 1987; Cole, 1992; Leung & Marion, 2000). Conversely, educating visitors about rare plants inhabiting LSMC and the consequences of trampling cliff-top vegetation may reduce the amount of travel off existing trails and sites (Cole et al., 1997; Marion & Reid, in press). For example, reduction of instances of trampling may be achieved by communicating minimum impact hiking practices such as Leave No Trace to visitors (www.LNT.org; Cole et al., 1987). Concentrating visitor use on trampling-resistant natural surfaces or on core bare substrates of existing recreation sites through spatial containment strategies may also reduce the extent of trampling impacts (Cole, 1992; Leung & Marion, 1999; Marion & Farrell, 2002).

Results of the visitor observation work in this study suggest day hiking use constitutes the majority of recreational activity at LSMC and is particularly concentrated on weekends and in the afternoon. Furthermore, day hikers were observed trampling soil and vegetation in all three observation zones more frequently than either rock climbers or backpackers. In addition, supplemental observations found that most day hikers entered

LSMC from the north on the Appalachian Trail (Figure 1), with many entering the lightly impacted North Zone because it offered the first cliff-top vista. Supplemental observations also suggest that while rock climbers tend to cluster at the top of climbing routes, day hikers were more likely to disperse along the cliff edge during crowded, peak use periods and are the probable cause of the site expansion noted by prior rare plant surveys. Thus, day hikers may have been more likely to trample soil and vegetation in the Cliff Zone as they sought a place to enjoy the cliff-top view away from other visitors. These findings suggest that educational efforts designed to promote low-impact visitor behaviors to minimize soil and vegetation trampling in the North and Cliff Zones might be most productive if they are focused particularly on day hiking visitors. This would require the placement of educational signs onsite, though trailhead placement could also prove effective.

While representing the lowest percentage of overall visitor use of LSMC, rock climbers' generally spend more time on the cliff-top than day hikers or backpackers. Eighty-nine percent of all trampling by rock climbers observed in this study occurred in the Forest Zone. Supplemental observation data suggest the high percentage of trampling by rock climbers in the Forest Zone is largely due to time spent constructing climbing anchors using trees. Resource impact measurements provide additional evidence in support of this explanation for the high percentage of trampling by rock climbers occurring in the Forest Zone. In particular, virtually all bark damage on cliff-top trees occurred at the base of trees and was mostly due to abrasion from ropes used for climbing anchors. However, in contrast to findings of Kelly and Larson (1997), no severe tree damage was found on the LSMC cliff-top as a result of rock climbing use. Thus, efforts to reduce rock climbing-related impacts at LSMC should focus on reducing soil and vegetation trampling in the Forest Zone. For example, the installation of fixed anchors on the cliff-edge would eliminate the need for rock climbers to use trees in the Forest Zone to construct anchors and could therefore substantially reduce trampling in the Forest Zone. In addition, installing fixed anchors on LSMC could minimize damage to cliff-top trees and cliff-edge vegetation caused by rope abrasion (Baker, 1999).

Visitor use of LSMC was found to be unevenly distributed, with day hiking, and to a lesser extent, rock climbing use particularly concentrated on weekends and during the afternoons. Enforcement of and perhaps a reduction in parking capacity at the Skyline Drive parking lot might help reduce use density during peak hours. These actions, combined with site management actions that concentrate use to already impacted locations on the cliff-top, may reduce the lateral expansion of trampling along the cliff-top.

In contrast to day hikers and rock climbers, results of this study suggest backpackers are less frequent LSMC visitors, spend the shortest length of time at the cliffs, and are less likely to trample soil and vegetation than day hikers and rock climbers. These findings are consistent with the general nature of backpacking, in which people are typically covering relatively long hiking distances and thus may occasionally stop to enjoy the view from LSMC, but often continue down the trail without spending sustained time at the cliffs. Thus, management actions designed to minimize visitor-caused impacts at LSMC should focus primarily on day hikers and rock climbers as described above.

The incidence of informal trails at LSMC is low and accounts for relatively little disturbance with the exception of the descent trail south of the cliffs. The descent trail is characterized by a high rate of erosion resulting in substantial soil loss, the trailside presence of rare plants, and possible degradation of Shenandoah Salamander habitat (NPS, personal communication). Several factors exist that explain such large scale erosion, most importantly its direct ascent/descent alignment to the topography and steep grade, both of which are influential factors in trail erosion (Cole et al., 1987; Marion & Leung, 2001). Given the substantially degraded state of the descent trail and its unsustainable alignment, one possible management response would be to close the trail. However, it is likely that illegal use of the trail would occur unless an alternate but sustainable route was constructed on the opposite end of the cliff. Installation of rock steps would require importing rock from a distance as native rocks in the area provide habitat for the Shenandoah Salamander. Development of a rappel station with a permanent anchor could also help to reduce descent trail traffic and impact.

While characterized by less severe erosion than the descent trail, informal trails on the cliff-top are cause for concern as they may provide impetus for further site expansion and deterioration of areas containing rare plant populations such as the North Zone (Cole, 1993; Cole et al., 1997; Leung & Marion, 2000). To prevent further site expansion associated with the use of informal trails on the cliff-top, managers might use rocks, natural vegetation, and wood debris to barricade these trails from use by visitors. Educating visitors about the importance of staying on formal trails may also discourage off-trail hiking.

Resource impact data show campsites are large contributors to overall site disturbance at LSMC, accounting for nearly 25% of the total area of disturbance in the study area. Past efforts to reduce or eliminate use of the upper campsites through voluntary compliance have been unsuccessful (NPS, direct communication). Thus, effective reduction of impacts associated with campsite use at LSMC might instead require both limiting the number and size of overnight groups and restricting their use to designated, sustainably designed campsites (i.e., sidehill campsites) located away from the rare plant community along the cliff-top (Hilke, 2002; Leung & Marion, 1999; Marion & Farrell, 2002; Smith, 2002).

From a methodological perspective, standard point sampling trail condition assessment methods were readily adapted for documenting the extent and condition of cliff-related informal trails. The shorter lengths of these trails required the use of variable sampling intervals to match trail length to sampling intensity. Standard campsite condition assessment procedures were also adaptable in measuring cliff-related recreation sites. The linear spatial arrangement of these sites required use of multiple, arbitrarily defined, recreation sites with findings aggregated by cliff location (e.g., cliff-top, cliff-bottom) for presentation. Use of permanently marked recreation site reference points and GPS technology also enables accurate repeat measurements for the purpose of monitoring changes in these conditions over time. Furthermore, to the best of the authors' knowledge, this is the first study to have adapted visitor observation methods to document recreational use and behavior to help determine the causes of resource impacts in a cliff environment or any other type of recreational area. In particular, techniques used to observe the amount and type of cliff-top recreational use were combined with methods to study LSMC visitor behaviors. Further, supplemental observations were recorded to help explain the quantitative observation results. Findings from the quantitative and supplemental observation data provide a means for interpreting the results of resource impact measurements, resulting in an integrative assessment of cliff resource conditions and recreational use at LSMC.

While this study provides managers quantitative measures of resource impacts at LSMC and insights into visitor use and behaviors that might help explain the extent and character of those resource impacts, there are at least two limitations of the integrative approach used in this study. First, the findings from this study do not provide managers with information about the social acceptability of those resource impacts. Previous studies have examined visitors' perceptions and acceptability ratings of resource impacts; however, this research has focused primarily on resource conditions at backcountry campsites (Farrell, Hall, & White, 2001; Shelby, Vaske, & Harris, 1988). Thus, additional research on public perceptions and the social acceptability of resource impacts is warranted, particularly efforts to extend this work beyond studies of backcountry campsite impacts. Furthermore, this is an area of research that may be particularly well suited for coupling resource impact assessments with social science research, an integrative research approach advocated for in this paper. For example, Farrell, Hall, & White (2001) examined the relationship between campsite conditions as measured through resource impact assessments and campers' ratings of resource conditions at the campsites in the Mount Jefferson Wilderness, Oregon. Second, while the results of this study inform managers about the probable relative effect of rock climbing, day hiking, and backpacking use on cliff resources at LSMC, the data do not provide a basis for developing a quantitative relationship between the amount and type of recreational use of the LSMC cliff-top and resource degradation. Thus, additional research using experimental methods to establish quantitative relationships between recreational behavior and cliff resource impacts may be warranted. For example, additional studies could be developed by adapting experimental methods for studying vegetation trampling to application at cliff sites (Cole & Bayfield, 1993).

Conclusion

The research presented in this paper addressed important gaps in previous cliff impact studies by broadening the scope to include assessing the effects of non-climbers. This was accomplished by measuring trampling impacts to cliff-related trails, recreation sites, and campsites, and by incorporating visitor observation to gain greater insights into how different use types and behaviors contribute to cliff resource impacts. The documentation of resource impacts, particularly those which threaten rare and endangered species inhabiting LSMC provides a detailed account of present site conditions in addition to indicators of future conditions if visitor use of the cliff-top proceeds without intervention. 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.

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