AN ADAPTIVE ASSESSMENT OF VISITOR IMPACTS TO PROTECTED AREAS

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
in
Forestry

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April 25, 2003
Blacksburg, VA

Keywords: adaptive management, visitor impacts, visitor impact management, recreation ecology

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ABSTRACT: As an applied approach to recreation management, adaptive management allows researchers and protected area managers to cooperatively improve management policies, and achieve the dual mandate to protect natural resources and provide high-quality recreational experiences. Through an evaluation of the efficacy of campsite and campfire management policies, this research provides land managers with an empirical assessment to aid in the adaptation and improvement of their visitor management strategies. Results from the Shenandoah National Park camping management study suggest that an established camping visitor containment strategy succeeded in reducing the areal extent of camping impacts while minimizing restrictions on visitor campsite selection options. Findings from the campfire research in seven protected areas indicate that current campfire policies have been largely ineffectual at reducing resource damage, and may exact a heavy toll in visitor experiences via campfire restrictions. The incorporation of resource and social research in this research offers a holistic approach to the evaluation of management objectives and affords protected area managers a more balanced perspective on the assessment of their policies. The conclusions reached by this integrated research will provide land managers with germane and timely information that will allow them to adapt their policies to better achieve their recreation management objectives.

ACKNOWLEDGEMENTS

First and foremost, I would like to extend my deepest gratitude to my advisor and committee chair, Dr. Jeffrey L. Marion, for his constant support, thoughtful advice and encouragement throughout my graduate work. I am honored to have had the opportunity to work with such a committed and professional mentor. I would also like to express my sincere appreciation to the following people: Dr. Joe Roggenbuck, who challenged me intellectually and motivated me with his appreciation of wilderness. Dr. Kevin W. Larkin, who guided me in qualitative interview methods and analysis, and offered valuable writing suggestions. Kerri Cahill, for her thoughtful reviews and sage advice during my graduate studies.

Finally, and especially, I thank my lovely wife and best friend, Ellen, who sacrificed so much while inspiring and supporting me during my graduate work. I would also like to acknowledge my father, mother and brother, who have stood by me forever.

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INTRODUCTION

The 1916 Organic Act (16 United States Code 1) created the National Park Service (NPS) and directed it 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 a manner and by such means as will leave them unimpaired for the enjoyment of future generations" (USDI NPS, 1994:28). The 2001 NPS Management Policies provided greater specificity by acknowledging that providing recreation is part of the Park Service's mission, but should only occur if it "can be sustained without causing unacceptable impacts to park resources or values" (USDI NPS, 2001:8.1).

The dual mandate to promote visitation while protecting park resources guides NPS planning and management efforts. Given that some degree of resource degradation is inevitable with recreational use, managers seek innovative approaches to balance park visitation and resource protection.

Included in this thesis are two papers: The first is an assessment of the success of Shenandoah National Park's established backcountry campsite management policy. The second is a comparison of campfire policies and impacts from seven protected areas. Both projects seek to provide useful information regarding the efficacy of management actions. The first research effort is part of an ongoing assessment mandated by the Shenandoah National Park Backcountry and Wilderness Management Plan and has immediate implications for campsite management in the park. The second project is broadly applicable to all protected areas and provides information to assist land managers in making more informed decisions about policies to reduce campfire impacts.

Overall, the goal of the research is to assess the effectiveness of management actions and benefit future land management decisions. The integration of social and ecological research provides land managers with a unique perspective regarding common recreation management problems. Combining resource-based and social science research offers a more holistic perspective on the effects of management efforts. Such integrated research is managerially relevant but rare in academic literature.

The knowledge gained from the campsite research will be immediately significant to Shenandoah National Park land managers. With the goals of improved resource conditions and visitor experiences, park managers intend to adapt their camping management prescriptions based on knowledge gained from this research. The iterative approach to management decisions, termed adaptive management, has been applied to a variety of natural settings and scales. An experimental management design is rare in the field of outdoor recreation, however, and represents an innovative approach to administrating recreational use while preventing resource degradation.

Although the Shenandoah research has been developed as a purposive experiment in recreation management, the campfire research utilizes existing data from seven protected areas and compares campfire policies and campfire-related impacts. The findings from this evaluation will not immediately change management policy but it provides managers with insight into the effectiveness of different campfire policies. Findings from the meta-analysis allow land mangers to consider approaches that minimize campfire impacts while allowing greater visitor freedom regarding campfire use. Managers can use this information to adapt campfire policies and better achieve the dual mandate of recreational use and resource protection.

LITERATURE REVIEW

Adaptive Management

Conceptually, adaptive management is an iterative process of planning, monitoring, researching and adjusting, with the ultimate goal of improving management efforts and achieving desired future conditions (Briassoulis, 1989; Lessard, 1998). Implicit in adaptive management is the idea that policies are implemented as experiments. Land managers adjust prescriptions based on observed trends or knowledge gained from resource monitoring.

The foundations of adaptive management can be traced to the field of industrial operations where unstable demand patterns prompted companies to apply adaptive production models (Adam and Ebert, 1986; Johnson, 1999). Holling (1978) and Walters (1986) first associated adaptive management with natural resource management in response to the comprehensive/rational and incremental planning approaches that dominated early natural resource planning and management efforts. The rational planning approach, driven by one-time assessments and decisions by scientists and experts, tends to overestimate scientific understanding and fails to account for the dynamic character of natural systems (Briassoulis, 1989). In contrast, adaptive management is conceptualized as an approach of prepared responsiveness, whereby planning and policy actions are integrated with feedback systems based on monitoring and evaluation (Holling, 1978; Lessard, 1998). Management policies are viewed as deliberately experimental, flexible and actively adaptive (Walters, 1986; Walters and Holling, 1990).

Conceptualizations of ecosystem management in natural resource planning include adaptive management as a fundamental tenet of the approach (Grumbine, 1994; Slocombe, 1993; Cortner and Moote, 1999). As a result, most research regarding adaptive management has focused on ecosystem-level management efforts, although such studies' scales and subjects vary dramatically. For example, Meretsky et al. (1999) studied the adaptive approach to planned flood releases in the Grand Canyon and the effect of these actions on endangered species. This research received significant public attention from both the scientific community and the mainstream press (Blakeslee, 2002). In other examples, Gilmour et al. (1999) reviewed the adaptive approach to suburban area water cycle management in New South Wales, Australia. Johnson and Williams (1999) assessed the application of adaptive management to waterfowl harvest regulations across North America.

Numerous studies of adaptive management exist, but a review of the existing literature revealed few instances in which adaptive management was applied to recreational management. One study concluded that the effects of rock climbing on cliff plant communities could be ameliorated through the application of an adaptive management strategy, but such a strategy was not assessed (Camp and Knight, 1998). Lawson et al., (2002) utilized computer modeling to facilitate carrying capacity decisions in Arches National Park. The research allowed land managers to simulate relationships between visitor use and social conditions and adapt visitor carrying capacity decisions accordingly (Lawson et al., 2002).

Although the implementation of the adaptive management concept has been used for a variety of purposes, it is still a work in progress (Johnson, 1999). Common problems with implementation include cost-prohibitive monitoring expenses, skepticism by affected constituents, limited control of data, and lack of commitment by involved land managers (Lee, 1999; Moir and Block, 2001). Other barriers identified by researchers are the use of non-dynamic linear systems models, the exclusive use of scientific forms of knowledge, and inadequate attention to the development of shared understandings among diverse stakeholders (McLain and Lee, 1996). By definition, adaptive management is an iterative process replete with uncertainty and incremental knowledge growth. However, a committed adaptive approach can improve the potential for effective correction and pre-emption by forcing land managers to gauge the success of their efforts and anticipate future trends based on current monitoring conclusions (Daneke, 1983).

Although the primary goal of the adaptive management approach is to assess, reverse and prevent unacceptable resource and social impacts by altering management prescriptions, what constitutes an unacceptable impact is ultimately a value judgment made by managers and participants in a facilitated planning process (Roggenbuck et al., 1993). Contemporary carrying capacity approaches in land management, such as the Limits of Acceptable Change (LAC), Visitor Experience and Resource Protection, Visitor Impact Management, Protected Area Impact Management and others, integrate the principles of adaptive management while recognizing that value judgments are inherent in any planning process. These associated planning schema incorporate the selection of impact indicators and standards and periodic monitoring to evaluate success in achieving management objectives.

Limits of Acceptable Change

LAC and other associated planning frameworks were developed in response to perceived limitations of the carrying capacity approach to land management, which originated in range and wildlife management (Wagar, 1964; Stankey et al., 1984). LAC was developed to direct managers' attention away from a targeted number of visitors and towards defined, desired ecological and social conditions (Stankey et al., 1984). The LAC process suggests that land managers monitor existing conditions then formulate strategies to bring unacceptable conditions into compliance with set standards (Cole and Stankey, 1997). Although the LAC framework was originally developed in the rational/comprehensive planning tradition, implementation of the concept has forced managers to recognize that land management is inherently experimental and that all management must be adapted to account for new information (McCool and Cole, 1997). The implementation of LAC has therefore evolved into an adaptive management process where monitoring results dictate alterations in policy and management actions.

The LAC-based planning framework represents an effort to ensure that public land management is adaptable and accountable (Goetz Phillips and Randolph, 2000; Stankey, et al., 1984). The selection of indicators, the development of standards, the assessment of conditions and the alteration of management prescriptions to comply with standards is at the core of each of the frameworks (Krumpe, 1999). This iterative pattern of assessing and changing management prescriptions until standards are met is innately adaptive, as is the attempt to identify and manipulate the causal factors of resource impacts.

The Role of Recreation Ecology and Social Science Research

Reflective the dual mandate of many land management agencies, the monitoring of recreational impacts occurs primarily in two forms: resource and social. Recreation ecology has been defined as the scientific study of visitor impacts to protected areas (Hammitt and Cole 1998; Liddle 1997; Leung and Marion, 2000). Recreation ecology can be understood more broadly as the study of the ecological interrelationships between humans and the environment in a recreation or tourism context (Leung and Marion, 2000; Leung and Marion, 1996; Wagar, 1964). Resource impacts may occur individually or collectively to soil, vegetation, wildlife and water. Impacts to these resources may depreciate resource quality, inhibit recreational resource functionality and compromise agency protection mandates (Leung and Marion, 2000).

Research from recreation ecology has shown that recreational use inevitably causes some degree of resource impact and that the use/impact relationship is generally curvilinear in nature (Hammitt and Cole, 1998; Cole, 1981, 1982, 1995; Marion, 1987; Cole and Marion, 1988; Marion and Cole; 1996). Most recreational impacts have been shown to occur at initial or low levels of use (Leung and Marion, 1996). Further use levels generally do not prompt a corresponding increase in impacts, but rather level off as near maximum impact levels are reached at moderate to high use levels (Leung and Marion, 2000). These findings suggest that protected areas experiencing moderate to high levels of recreational use can minimize the overall areal disturbance by concentrating visitors and their impacts in limited areas (Cole, 1995). Conversely, at low levels of visitation, a dispersal strategy will likely minimize disturbance.

Empirical research designed to assess the state of protected area resources plays an increasingly critical role in LAC-based land management and planning frameworks. Monitoring efforts have taken many forms - from informal management staff observations to formal, detailed quantitative and qualitative research- but the planning frameworks that utilize indicators and standards rely heavily on standardized empirical measures for their implementation (Cole, 1983; Cole 1989; Marion, 1991; Leung and Marion, 2000). Recreation ecology therefore plays an integral role in land managers' efforts to understand the nature, distribution and cause of recreational resource impacts.

In addition to resource monitoring, land managers and researchers have also studied the social aspects of outdoor recreation. Studies of visitor characteristics, preferences, behavior and attitudes remain the most frequently studied topics in the recreation social science field (Manning, 1999). Recreational carrying capacity and perceived crowding studies, which have assessed the point at which visitors become negatively affected by the presence of other visitors, are also relatively common (Manning and Lime, 2000). Efforts to determine the success of educational initiatives in conveying management policies to the public have also been conducted and have reached mixed conclusions (see Roggenbuck, 1992; Reid and Marion, 2002). Such research is potentially useful to land managers interested in assessing the relative value of outreach efforts.

CONCLUSION

An adaptive approach to recreation and land management allows managers in park and protected areas to develop their policies as research is implemented. To better assess recreation management policies, a holistic approach to research will yield more applicable and insightful results. Recreation ecology and social science research both provide important information for decisions regarding management policy. However, the integration of the two fields is rare in the academic literature. The integration of management policies and empirical research is also uncommon. Combining resource and social science research to provide an integrated assessment of management actions offers land managers a unique perspective of the efficacy of their efforts and will ultimately improve recreation management.

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CHAPTER II.

An Adaptive Management Assessment of New Camping Policies in Shenandoah National Park

ABSTRACT: The expansion and proliferation of backcountry campsites is a persistent problem in many parks and protected areas. This paper describes a longitudinal adaptive management assessment of new campsite management policies in Shenandoah National Park. Using an approach that combines resource assessments and visitor interviews, conclusions regarding the effectiveness of a visitor impact containment strategy involving an established site camping option are offered. This innovative management approach successfully reduced the number of campsites and aggregate measures of camping-related disturbance at SNP while minimizing the use of regulations, site facilities, and staff resources. Integration of resource and social research methods also provided a more holistic perspective to management policy assessments. Physical campsite measurements were combined with qualitative visitor interviews to address important dimensions of the park's success in implementing the new camping policies. Adaptive management research provides a timely evaluation of management success while facilitating effective modifications in response to unforeseen challenges.

INTRODUCTION

In parks and protected areas, backcountry recreation is typically focused on trails and campsites, which provide access to public lands, facilitate recreational opportunities, and concentrate traffic to protect natural resources. Campsites are of particular concern due to their extended duration of use and intensive trampling caused by overnight visitors, particularly associated with cooking, sleeping, and social activities. Managing campsites to limit the areal extent and severity of camping-related resource impacts is particularly challenging for U.S. National Park Service (NPS) managers, who operate under the guidance of the Organic Act (16 USC 1) and the Wilderness Act (16 USC 1131-1136). These laws direct the NPS to provide for recreational access to public lands in such a manner as will leave them unimpaired for future use and enjoyment (NPS 2001).

Empirical research has consistently shown that recreational use of public lands and campsites inevitably causes resource degradation, which can affect natural ecosystem functions and compromise the quality of visitor recreational experiences (Hammitt & Cole 1998; Leung & Marion 2000). Common campsite impacts include vegetation loss, exposed soil, erosion, tree damage and fire scars (Cole 1989a). Past research has also documented a curvilinear relationship between amount of site use and site condition. The majority of impacts occur with initial and low levels of use, while subsequent use adds minimally to cumulative degradation (Cole 1982, 1995; Cole & Marion 1988; Marion & Cole 1996, Newsome *et al.* 2002). Based on empirical studies and theoretical modeling, researchers have concluded that the most effective approach to minimizing camping impacts in moderate to highly visited areas is to concentrate use on a limited number of sites (Cole 1992, 1995; Leung & Marion 1999, 2000).

U.S. national park and wilderness managers perceive campsite expansion and degradation as problematic in "many" or "most" areas of their parks (Washburne & Cole 1983; Marion *et al.* 1993). A variety of management strategies have been applied to minimize camping-related impacts, including use restrictions and closures, visitor dispersal and containment, site design and management, and visitor education (Cole *et al.* 1997; Leung & Marion 1999, 2000; Marion & Cole 1996). Leung and Marion (1999) highlight four spatial strategies for managing impacts: spatial segregation, containment, dispersal and configuration, and note that a combination of strategies will often provide the most effective solution. Cole (1993) suggests three primary approaches to preventing campsite proliferation and deterioration: change site selection behavior, develop an active site management program, and improve visitor behavior at campsites. For example, an effective containment strategy should combine all three elements: 1) encourage visitors to camp only on well-established sites, 2) close and rehabilitate fragile, low-use, unacceptably impacted, or unnecessary sites, and 3) educate visitors to concentrate camping activities in core impacted portions of the site.

Evaluations of the effectiveness of camping policies in reducing resource degradation are uncommon, but have been undertaken in a few settings. Cole and Ranz (1983) found that closing wilderness campsites to facilitate recovery failed to improve overall resource conditions due to ineffectual closure, slow recovery rates, and development of new, visitor-created campsites. In an assessment of campsites in three western wilderness areas, Cole (1993) found that campsite dispersal policies often contributed to pervasive campsite proliferation problems. Marion (1995) monitored the effectiveness of a campsite containment strategy along an Eastern U.S. river that was accomplished primarily through the closure of unnecessary sites and the designation of resistant sites with anchored fire grates. These actions contributed to a 50% reduction in the cumulative area of disturbance, despite slight increases in degradation on campsites left open to visitors. In contrast, using pre-and post policy campsite condition assessments in two Oregon wilderness areas, Hall (2001) concluded that a designated-site management policy yielded mixed success. Although the containment strategy effectively reduced campsite proliferation, closed sites recovered minimally while designated sites deteriorated significantly. Research regarding visitor containment strategies has therefore shown conflicting results, suggesting that additional studies are needed to improve the understanding of campsite concentration policies.

Research Objectives

This study seeks to evaluate the effectiveness of an adaptive campsite management strategy in Shenandoah National Park (SNP). Adaptive management is an approach that recognizes policies as inherently experimental. Land managers implement policies and adjust prescriptions based on observed trends of change or knowledge gained from periodic monitoring efforts. Through an integrated approach using both quantitative resource assessments and qualitative visitor interviews, this study provides a more holistic assessment of the efficacy of a new campsite containment strategy implemented in the park. This application of adaptive management, integration of social and resource assessments, and longitudinal design is rare in the recreation resource management literature.

SNP managers implemented a multi-option backcountry camping policy in 2000 that includes camping containment with designated and established campsites, dispersed camping, and no camping options depending on management zone (SNP 1998). This study evaluates the success of the established site camping option within three park management zones selected to pilot test the new policies. Success is gauged through comparisons of campsite numbers and cumulative areal measures of disturbance, including campsite size and area of vegetation loss and soil exposure. A second study objective gauges the success of park education efforts in informing visitors about the new camping policy and their selection of appropriate campsites. Integrated findings from a resource assessment and visitor interviews are used to assess the efficacy of the park's established campsite policy.

Research Design Innovations

Adaptive Management

Adaptive management is described as an iterative process of planning, monitoring, researching and adjusting, with the ultimate goal of improving management efforts and achieving desired future conditions (Briassoulis, 1989; Lessard 1998). Holling (1978) and Walters (1986) first associated adaptive management with natural resource management in response to the shortcomings of the comprehensive/rational and incremental planning approaches. Adaptive management is an approach of prepared responsiveness, whereby planning and policy actions are integrated with feedback systems based on monitoring and evaluation (Holling 1978; Lessard 1998; Bellamy *et al.* 2001). Management policies are viewed as deliberately experimental, flexible and actively adaptive within a set of planned objectives (Walters 1986; Walters & Holling 1990). Despite a growing number of natural resource-oriented adaptive management studies, there are very few instances where this process has been applied to recreation management. One recreation study concluded that the effects of rock climbing on cliff plant communities could be ameliorated through the application of an adaptive management strategy, but such a strategy was not assessed (Camp & Knight 1998). Lawson *et al.* (*in press*) utilized computer modeling to facilitate carrying capacity decisions in Arches National Park. The research allowed land managers to simulate relationships between visitor use and social conditions and adapt visitor carrying capacity decisions accordingly (Lawson *et al. in press*).

Integration of Resource and Social Information

Reflecting the dual mandate for many land management agencies and the commonly utilized Limits of Acceptable Change planning framework, the monitoring of recreation impacts generally occurs in two forms: resource and social. Resource surveys commonly assess impacts such as vegetation damage and loss, and soil exposure and erosion, while social surveys tend to gauge levels of visitor crowding and conflict (Leung and Marion 2000; Manning 1999). However, multi-faceted methodological research approaches are necessary to better address the complex and multidimensional nature of recreation and leisure (Henderson 1991). Specifically, the integration of resource and social research has been recognized as important in recreation management (Clark *et al.* 2000), although such research is rare in the recreation literature. Cole *et al.* (1997) integrated recreation resource impact with visitor encounter and perception data to describe the recreation setting and potential management approaches in six high-use wilderness areas. Farrell and Marion (2000) correlated campsite density measures with perceptions of crowding and conflict, and concluded that higher campsite densities contributed to degraded social conditions. Using conjoint analysis, Newman *et al.* (2001) integrated resource, social and management conditions to offer a holistic assessment of carrying capacity decisions in Yosemite National Park.

Qualitative Research Methods

Visitor interviews were conducted for this study to offer additional insight into the effectiveness of the camping management policy. Qualitative research is an umbrella concept encompassing multiple types of studies that gather context-based information (Denzin & Lincoln 1994). Qualitative research approaches can assess individuals' experiences, often using subjects' own words (Merriam 1998). The strength of interview-based research is that it provides a rich, in-depth assessment of a specific topic and allows for direct quotes to illustrate empirical findings (Glaser 1967; Strauss & Corbin 1994). Participant interviews allow open-ended questions and follow up clarifications to better assess subjects' understandings of topics. However, when contrasted with quantitative data, which allows generalizations to an entire population, qualitative research offers detailed specifics regarding only those subjects interviewed.

METHODS

Study Area

SNP is a U.S. Department of the Interior-administered NPS unit located in central Virginia, within a one-day drive for 60% of the population of the United States. Given the number of backcountry overnight visits to the park (Table 1) and the land area (791 km^2), Shenandoah has one of the highest overnight use densities in the U.S. National Parks system (NPS 2002). SNP is a linear park, running north to south along the crest of the Central Appalachian Mountains. The climate is temperate, humid and continental, with precipitation spread fairly uniformly throughout the year. Elevations in the park range from 171 m to 1234 m and have a profound effect on local wind, temperature and precipitation patterns. A second-growth oak-hickory deciduous forest cover dominates the majority of the park, although cove hardwoods, maples, eastern hemlock, northern hardwood, pine-oak, beech and spruce-fir communities are also present.

Day hiking and backpacking are the primary backcountry recreational pursuits in the park, especially along the Appalachian Trail (AT) corridor. Although the AT receives significant attention and visitation, it comprises only 169 km of the park's 806 km trail network. Approximately 40% of SNP is federally designated wilderness.

Table 1. SNP backcountry visitation (nights/year) park-wide and in the three study areas.

Year	Park Totals	Big Run	Jeremys Run	Nicholson Hollow
1999	43,913	1020	1356	1245
2000	42,564	823	1297	1196
2001	42,966	990	1101	915
2002	39,960	766	1035	1125

Camping Policies in Shenandoah National Park

Camping management policies in SNP have changed considerably over the past 30 years. SNP originally allowed "at-large" camping in which visitors were allowed to camp anywhere in backcountry areas. In 1972, increasing resource impacts and visitation prompted managers to restrict backcountry camping to 39 locations. By 1974, resource and social conditions at many of these locations deteriorated to unacceptable levels as visitation increased substantially. In response, a dispersed camping policy was implemented, directing visitors to camp more than 25 feet from water and out of sight of trails and other campers. However, the dispersal policy resulted in the creation of approximately 1300 campsites by 1983, and due to declining visitation, 725 campsites in 1994 (Williams and Marion 1995). Furthermore, 68% of sites were illegal by the park's camping regulations in 1994.

In 1998, SNP completed a Backcountry and Wilderness Management Plan (SNP 1998). The plan, based on a Limits of Acceptable Change (LAC) framework, incorporated a multi-option camping policy recommended by a park-wide campsite research study completed in 1993 (Williams and Marion 1995). The new camping policies were implemented in June 2000. A containment strategy restricting campers to *designated* sites was applied in the most popular zones, such as near shelters along the Appalachian Trail. A limited number of signed and mapped campsites were constructed in sloping terrain using cut-and-fill practices to inhibit site expansion. A variation of the containment strategy offering greater visitor choice and more primitive sites was implemented for the majority of the backcountry. This *established* site camping option directs visitors to choose from previously used sites selected by managers but not signed or mapped. Visitors have the freedom to explore and select an existing campsite that appeals to them. This option qualifies as a containment strategy because managers selected a substantially reduced subset of the pre-existing campsites to remain open. *Dispersed* camping on pristine sites is also permitted when visitors in an established site camping zone cannot locate an open pre-existing campsite. Finally, some areas are *closed* to camping due to high levels of day use or sensitive flora and fauna.

In 1999 a campsite occupancy survey was conducted on six predominantly high use (not peak use) weekends in each study area. Park staff recorded the number of groups and occupied campsites. These statistics revealed that campsite numbers often substantially exceeded the number of groups within a basin, even on high use weekends. For example, more than 4 groups per night rarely visited one basin with 34 campsites (a 12% occupancy rate). In an effort to increase occupancy rates to approximately 33% and reduce the overall areal extent of camping impacts, managers selected a reduced number of campsites to leave open for established site camping. Previously, visitors were free to create new campsites or select any existing site that met park guidelines. Campsite proliferation problems resulted because three to five night's camping use per year in a deciduous forest is enough to establish a new site or keep existing campsites from recovering (Cole 1995; Marion and Cole 1996). The subset of existing campsites were chosen by managers based on criteria derived from research and experience with the goal of identifying resistant locations offering the greatest opportunity for solitude (Williams and

Marion 1995). Criteria included distance to park developments, water sources, trails and other campsites, expansion potential, slope, groundcover composition, forest type and aspect.

Study Focus

This research focused on evaluating the established campsite policy because it was less restrictive than the designated camping policy and managers felt that it offered the greatest opportunity for visitor confusion and non-compliance. Research questions included: Could criteria for selecting only the unmarked established sites be effectively communicated to visitors? Would the number of sites and total area of disturbance associated with camping decline? Would the selected sites expand in size and impact severity to unacceptable levels? This uncertainty underscored the need to evaluate success and provided the impetus for this adaptive management study involving park staff and scientists.

SNP Site Management and Education

The study was limited to three park travel zones, essentially three drainage basins, located within designated wilderness. SNP staff selected the highest use travel zone managed under the established site camping policy within each of the three park districts. High-use zones were selected to ensure a sufficient number of campsites for investigation. Managers and researchers also expected that success in the high-use areas would imply similar or greater success in less-visited, established camping travel zones. Working within the three districts distributed the monitoring efforts and staff time and ensured greater variation in environments, visitation, and evaluations of park-wide visitor education efforts. The three study areas include Jeremys Run in the North District of SNP, Nicholson Hollow in the Central District, and Big Run in the South District (see Table 1 for use data).

No site management work was done on campsites selected for inclusion in the established campsite zones, with the exception of dismantling any fire sites that appeared (campfires have been prohibited in SNP since 1974). Campsites not selected were closed and rehabilitated by piling organic debris such as leaves, branches, and logs onto the sites. More dramatic techniques such as “ice-berging” rocks or posting closure signs are future options but were not applied in this study. Park managers conducted a late-season trip through each travel zone once annually to locate campsites and repeat this work on all sites selected for closure that had experienced subsequent use. The type, extent, location and time required for all rehabilitation work was documented. For the purposes of this study in which closed sites were located but not measured, “recovered sites” are the sites that have not received enough camping use to retain visually obvious campsite boundaries (based on vegetation cover and undisturbed leaf litter).

To facilitate the policy change adopted in 2000, park managers initiated an education campaign to inform park visitors about the new camping policy. Backcountry camping permits have been required in SNP since 1974, and park staff estimate that 90-95% of visitors comply with the backcountry permit requirement. Visitor education regarding the current campsite policies has been achieved principally through the permit distribution process. Visitors obtain permits prior to entering the backcountry via mail, self-served kiosks, or ranger issuance at a visitor center. Campsite policies are printed on the back of each permit, in distributed brochures, on trailhead bulletin boards, and on SNP’s website. Rangers also convey camping policies during routine visitor contacts.

Campsite Assessment Procedures

The primary focus of this study is an assessment of campsite conditions in the three study areas before and after implementation of new camping policies in January 2000. Thorough off-trail searches were conducted to locate all campsites within the study areas during the summers of 1999 and 2002. Site locations were documented with Global Positioning Satellite receivers and when needed, data was used to relocate all campsites and rehabilitated sites from prior surveys. Campsite assessments were consistently conducted late in the use season to minimize variability related to seasonal differences in visitation and vegetative growth patterns.

Trained field staff applied campsite condition assessment procedures adapted from Marion (1991). Utilizing buried metal markers as a permanent reference point, the variable radial transect method (Marion 1995) was applied to outline previous campsite boundaries and to alter them only when there was a compelling reason to do so. This procedure minimizes measurement errors associated with subjective determinations of campsite boundaries. Visually distinct differences in vegetation cover, height, disturbance or composition, and surface organic litter served as the basis for flagging campsite boundaries. The transect distance and compass bearing to each boundary flag was input to a computer program for area calculations and all adjacent satellite camping areas were also measured and included.

Indicators of Site Condition

Ten indicators of campsite condition were assessed in 1999 and 2002; three indicators relating specifically to the type and extent of ground cover disturbance are presented in this paper. Campsite area is considered the most important indicator of camping impacts because it reflects the overall areal extent of resource disturbance and is responsive to changes in visitation and management (Cole 1989a; Marion, 1991). The area of vegetation loss is another highly responsive indicator, particularly at low to moderate use levels, that has ecological and social significance (Cole 1989b). Non-woody vegetative ground cover was estimated in percentage categories (0-5, 6-25, 26-50, 51-75, 76-95, 96-100) within site boundaries and in adjacent, undisturbed off-site "control" areas with similar environmental attributes. Mid-point values for onsite cover categories were then subtracted from comparable offsite values, divided by 100, and multiplied by the campsite area to yield area of vegetation loss. This measure provides an estimate of the area over which vegetation cover has been lost on a campsite.

More intensive trampling removes vegetation cover to expose organic litter and soils; further trampling pulverizes and removes these materials to expose mineral soil. The extent of bare mineral soil exposure has been identified as a good indicator of campsite condition on highly used sites (Cole 1982; Marion & Merriam 1985). On-site exposed soil, defined as areas with very little or no organic matter or vegetation cover, was estimated for each campsite using the percentage-based categories employed for vegetation loss. Mid-point values were divided by 100 and multiplied by campsite area to determine area of exposed soil.

Inter-Campsite Visibility

Cole et al. (1987) suggested that the number of visitor encounters at campsites can determine perceived levels of crowding, especially in designated wilderness areas. As a result, Farrell and Marion (2000) used an inter-campsite visibility indicator and the distance between campsites to assess the potential for visitor encounters at campsites. As indicators of the potential for solitude while camping, the distance and visibility between campsites were each assessed for this study.

Qualitative Methods

Participant interviews helped provide insight into visitors' understanding and compliance with camping management policies. Visitor interviews occurred at campsites in the three study areas during the resource assessments fieldwork. All available campsite visitors were approached in their campsites and asked to participate in a fifteen-minute interview. Open-ended interview questions gauged visitors' understanding and articulation of the SNP established-site camping policy, including the nature and location of the educational message conveyed to them, and the rationales for their campsite selection. Cross-validated content analysis, as described by Neuendorf (2002), was performed to categorize interview findings. Used in a variety of settings from cultural studies to mass communications research, content analysis is a quantitative approach to qualitative data that involves categorizing subject statements into broad themes, then counting the number of comments under each theme (Manning & Cullum-Swan 1994).

For this research, which utilized a convenience sample, the unit of analysis was the number of times a concept was mentioned by interview subjects, rather than the number of individuals who articulated it. The number of "mentions" or "response units" indicates the degree to which interviewees focus on a particular aspect of the SNP camping policy and suggests the cognitive retention of certain concepts over others. Tallies for each topic are expressed as a percentage of the total response units under each broader theme. For example, a tally of 25 statements pertaining to campsite convenience under the total of 50 responses to site selection criteria would yield a "50% of mentions" result. To ensure consistent interpretation and analysis of the qualitative data, inter-rater reliability procedures were applied, in which independent reviewers performed content analyses and then compared their results for consistencies and discrepancies. Conclusions from the analysis are drawn only from those themes and comments consistently identified by both reviewers. The inter-rater reliability measure indicating the percentage of agreement between independent interview analyses, was 93%.

RESULTS

Campsite Assessments

Following a thorough search of the study areas, field staff located and assessed 73 campsites in 1999. Managers selected 41 of these sites to leave open when the established campsite policy was initiated in June of 2000 (Table 2). The remaining 32 campsites were considered illegal, and efforts were made to close them and enable natural recovery to occur. In 2002, field staff relocated all 73 former campsites and searched for new sites. Only 37 campsites exhibited signs of use and identifiable disturbance-related boundaries in 2002, a 49% reduction in site numbers from 1999 (Table 2). These included 21 of the 41 campsites left open for established site camping and 3 new visitor-created sites that met site legality criteria. Of the 13 remaining campsites, 5 had been present in 1999 and became illegal in 2000 and 8 were new visitor-created illegal campsites. Seventeen additional campsites left open for established site camping in 2000 were not counted as campsites in 2002 because they had no appearance of use and lacked disturbance-related boundaries.

The area of disturbance attributed to camping activities, which is reflected by the campsite size indicator, was reduced by 51% (2122 to 1049 m^2) (Table 2). The majority of this reduction is attributable to the greatly reduced number of campsites, though mean size for illegal sites fell from 30 to 20 m^2. Legal sites grew slightly in size, from a mean of 28 to 33 m^2, though aggregate disturbance for legal sites fell by 32% (Table 2).

Aggregate area of vegetation loss decreased 44% during the study period (524 to 293 m^2) (Table 2). Legal campsites experienced a slight increase in mean area of vegetation loss (8 to 9 m^2) though the aggregate measure declined 29%. On illegal sites, area of vegetation loss decreased 64%, from 225 to 82 m^2 (Table 2). Area of exposed soil also decreased during the study period, but the reduction (184 to 155 m^2, 16%) was not as dramatic as for vegetation loss or campsite area. A 67% reduction in exposed soil on illegal sites was offset by an increase in exposed soil on legal sites (92 to 125 m^2, 36%), attributable to an increase in mean area of exposed soil (2 to 5 m^2). For 21 campsites that were legal and established in both 1999 and 2002, mean campsite area increased slightly from 33 m^2 to 34 m^2, while the mean area of exposed soil increased from 3 m^2 to 5 m^2, and area of vegetation loss grew from 8 m^2 to 9 m^2.

When broken down on a study-site basis, Big Run and Nicholson Hollow experienced substantial reductions in the number of campsites and corresponding aggregate campsite areas. By contrast, the number of campsites and aggregate campsite area in Jeremys Run decreased marginally. Overall average campsite size increased in Jeremys Run and Big Run, but decreased in Nicholson Hollow. Average area of vegetation loss in Jeremys Run increased markedly, while similar measures in Big Run and Nicholson Hollow increased slightly. Average area of exposed soil increased in all three study areas, although aggregate area of exposed soil increased in Jeremys Run and decreased in the other two basins.

To understand changes in campsite use and condition affected by the new campsite policies, an average per-site visitation figure was calculated based on permit data reflecting annual visitation and average group size for each study area. The number of backcountry visits for each basin was divided by the average overnight group size for that basin to obtain average nights camped per basin. An estimate of annual per-site visitation was calculated by dividing annual sums by campsite numbers. Estimated annual visitation on study area campsites was 19 nights in 1999 and 29 in 2002, a 53% increase we attribute to implementation of the established campsite policy.

Table 2. Findings for aggregate campsite indicators for all areas and in each study area[1].

Indicators & Year		*Legal*			*Illegal*			**Total**		
		n	*Avg.*	*Sum*	*n*	*Avg.*	*Sum*	*n*	*Avg.*	*Sum*
All Areas										
Campsite Size (m^2)	'99	41	28	1161	32	30	961	73	29	2122
	'02	24	33	787	13	20	262	37	28	1049
Vegetation Loss (m^2)	'99	40	8	299	32	7	225	72	7	524
	'02	24	9	212	13	6	82	37	8	293
Exposed Soil (m^2)	'99	40	2	92	30	3	92	70	3	184
	'02	24	5	125	13	2	30	37	4	155
Big Run										
Campsite Size (m^2)	'99	19	25	482	15	21	318	34	24	799
	'02	8	31	251	5	18	90	13	26	341
Vegetation Loss (m^2)	'99	18	8	149	15	5	74	33	7	223
	'02	8	8	65	5	3	15	13	6	81
Exposed Soil (m^2)	'99	18	3	48	14	2	21	32	2	69
	'02	8	4	31	5	<1	3	13	3	35
Jeremys Run										
Campsite Size (m^2)	'99	8	20	156	3	13	38	11	18	194
	'02	4	29	115	5	11	53	9	19	168
Vegetation Loss (m^2)	'99	8	5	39	3	5	16	11	5	55
	'02	4	7	29	5	5	23	9	9	82
Exposed Soil (m^2)	'99	8	<1	6	3	2	5	11	1	11
	'02	4	4	16	5	2	8	9	3	23
Nicholson Hollow										
Campsite Size (m^2)	'99	14	37	524	14	43	606	28	40	1129
	'02	12	35	421	3	39	118	15	36	539
Vegetation Loss (m^2)	'99	14	8	111	14	10	135	28	9	246
	'02	12	10	117	3	14	43	15	11	161
Exposed Soil (m^2)	'99	14	3	38	13	5	65	27	4	104
	'02	12	7	78	3	7	20	15	7	97

[1] For comparison purposes, 1999 data reflect site legality designations associated with the new camping policies implemented in June 2000.

The potential for campers to find solitude while camping was evaluated by assessing the number of other visible campsites from each campsite. In 1999, the number of campsites visible from a given site ranged from 0 to 5 with a mean of 1 and a sum of 71 for all sites. In 2002, this measure ranged from 0 to 5 campsites visible with a mean of 0.4 and a sum of 13. Distance to the nearest other campsite was also assessed and this measure increased from a mean of 15 m in 1999 to 18 m in 2002.

Rehabilitation Efforts

Rehabilitation efforts within the three study areas were performed once annually during the study period to discourage use of illegal sites by covering them with organic debris. Although 32 campsites in the three study areas were not selected and would become illegal in June of 2000, only 17 sites received rehabilitation work late in 1999 (Table 3). SNP staff was unable to perform rehabilitation work in Jeremys Run in 1999. Nine sites were rehabilitated in 2000 and 8 sites were rehabilitated in 2001. During the study period, a total of 29 hours of staff time were dedicated to rehabilitation efforts, with an average of 52 minutes of work/site.

Table 3. Campsite rehabilitation efforts in SNP, with number of campsites rehabilitated, aggregate time and average time (hours) per campsite.

Year	Big Run			Jeremys Run			Nicholson Hollow			Total		
	n	*Time*	*Avg.*	*n*	*Time*	*Avg.*	*n*	*Time*	*Avg.*	*n*	*Time*	*Avg.*
1999	10	8.1	.8	0	0	0	7	6	.9	17	14.1	.8
2000	2	.9	.5	3	3.5	1.2	4	5	1.3	9	9.4	1.0
2001	6	2.4	.4	1	1.3	1.3	1	2	2	8	5.7	.7

In addition to the rehabilitation efforts performed by park staff, a lack of visitor use and natural events, including tree falls from forest fire and insect infestations, resulted in the closure and unassisted recovery of additional campsites (Table 4). These numbers reflect campsites that lacked evidence of use and disturbance-related boundaries. From a management perspective this was defined as successful recovery, though we recognize that many years of closure to use will be required to achieve ecological recovery. During 1999, field staff found only 2 sites that had recovered in a prior year, while 24 sites lacking evidence of reuse were found in 2002. Fifteen illegal sites lacking evidence of rehabilitation work and reuse were located in 2002. As previously noted, 17 campsites were left open for use in 2000 but never used – these were recovering and lacked disturbance-related boundaries in 2002.

Table 4. Numbers of actively and naturally recovered campsites by year.

Site Legality and Rehabilitation Status	1999	2002
Illegal Rehabilitated Campsites (#)	2	24
Illegal Non-rehabilitated Campsites (#)	-	15
Legal Non-rehabilitated Campsites (#)	-	17

Interview Results

Thirty-three visitors were interviewed to evaluate their understanding and compliance with the new camping policies. Study participants' ages ranged from 9 to 50, with group sizes ranging from 1 to 8 visitors. Although the majority of respondents were Virginia residents, others were from Maryland, Pennsylvania, Ohio and the District of Columbia. A wide range of outdoor experience was represented, from novices participating in their first overnight trip to visitors with twenty years of backpacking experience. Of the thirty-three visitors interviewed, only one individual had not obtained the required backcountry camping permit.

Participants were asked what prompted them to select the campsite they chose. Their preferences were divided into three broad themes: convenience, aesthetics and campsite qualities. Campsite qualities, such as flat ground, available “bear hang trees,” campsite size, and a lack of rocks, composed the primary consideration for most respondents, including 47% of mentions. Aesthetic factors, including nearby waterfalls, “fishing holes,” cliff faces, and “quiet spots” were of secondary consideration at 29%. Convenience considerations such as the distance to the trailhead, the timing of the day and fatigue accounted for 24% of mentions. For example, one participant mentioned all three selection themes in stating, “We were looking for flat space, and I guess a fishing spot. We were hiking and it just felt like it was the right time to stop.”

Interview participants were also asked to articulate their understanding of SNP’s camping policy. Of the thirty-three visitors interviewed, 97% were able to successfully describe some aspect of SNP’s camping policy and 33% of the interviewees specifically mentioned camping on pre-existing or established campsites. More specifically, the distance of campsites to park trails and the *Leave No Trace* minimum impact message were the primary concepts mentioned at 19% and 18% of mentions, respectively. Distance to water source directives were of secondary importance at 14% of response units with camping in established campsites and bear precautions close behind at 13% each. On a tertiary level, the distance to other campers, park structures, park roads and boundaries, and the fire prohibition were also mentioned at 5-7% of response units each. When asked to describe SNP’s camping policy, one participant stated, “They tell you…there are certain rules about, you need to be a certain distance from a trail or park boundary, a building…um more than fifty feet from a historical building. And try to pick a campsite that has already been cleared by someone else. Try not to create your own.”

Those subjects who successfully articulated the established campsite policy were also asked to identify factors that allowed them to identify an established site. Bare ground was the most commonly cited identification method at 34% of response units. Flat ground, fire rings and tent sites were secondary methods for campsite identification at 18%, 16%, and 14%, respectively. Access trails and trash were of lesser importance at 9% of mentions each. One visitor described his search for a campsite as the following: “Off the main trail, I saw a small foot path and I was hoping that it was going to lead to a nice little spot to pitch my tent. And as I went back, as I said, there was just a small opening, a small clearing. The ground was completely dirt. It was packed down and it was level."

When asked to identify their source for information regarding the park's campsite policy, interviewees cited two primary sources: the camping brochure that accompanies permits at 41% of mentions and park rangers at 33%. Prior knowledge of the area and suggestions by others were also important sources at a combined 14% of response units, with the internet, books and trailhead signs comprising the remaining responses at 6%, 4%, and 2% of mentions, respectively. Said one respondent, "We got it off the internet. She's my daughter and she got the information and we read it together and then, we also have a hiker's book that reiterated the policy. And then, from the National Park when we got the ticket…to register. Um, they read it to us again. So it was threefold."

DISCUSSION

The objective of a containment strategy for minimizing camping impacts is to concentrate overnight use onto a minimum number of sites, and on each site, to minimize the extent of disturbance by spatially concentrating traffic (Leung & Marion 1999; Marion & Farrell 2002). Due to the curvilinear nature of the use/impact relationship, campsites receiving more intensive visitation and traffic will suffer only marginal increases in size and loss of vegetation cover and organic litter (Cole 1982, 1992). By increasing visitation to selected campsites, other sites may be closed, resulting in reductions in the areal extent of indicator measures at a travel zone or protected area scale. These anticipated findings were validated by results from this study, which documented results from a combined management strategy that included established site camping regulations, visitor education and site rehabilitation. Substantial reductions occurred in the aggregate extent of the three primary campsite impact indicators--campsite area (51%), area of vegetation loss (44%) and area of exposed soil (16%) (Table 2). Under the former dispersal strategy, 2122 m^2 of disturbed area were contained in the 73 campsites. The established campsite policy yielded 1049 m^2 of disturbed area over 37 campsites. These reductions are primarily attributed to a 49% reduction in the number of campsites, most of which were effectively closed due to rehabilitation work and natural causes.

Other factors may also have contributed to these reductions in areal measures of camping disturbance. Overnight backcountry use levels park-wide and within the three study areas declined slightly during the study period (Table 1). Reductions in use could help to explain why only 24 of the 41 legal campsites left open by managers were used heavily enough by visitors to remain open and established (Table 2). Natural disturbances in the form of wildfire and parasitic insects may have also contributed to reductions in camping impacts. An autumn 2000 wildfire burned part of the Nicholson Hollow study area, killing some trees in the basin and opening the overhead canopy. The subsequent deadfall and increased sunlight contributed to the closure and recovery of some sites in the basin. Similarly, recent losses of eastern hemlocks from the Asian hemlock woolly adelgid may have caused similar effects. These natural events prompted the closure of several sites, as evidenced by the large number of recovered sites that received no active rehabilitation work (Table 4).

Illegal sites declined in number (32 to 13), mean size (30 to 20 m^2) and aggregate area (961 to 262 m^2) (Table 2). These findings suggest that park efforts to educate visitors to select only the established sites and site closure and rehabilitation work have been effective. Rehabilitation data indicates that visitors pushed aside the organic debris piled on closed campsites only 9 times in 2000 and 8 times in 2001 (Table 3).

Although somewhat counterintuitive, the reduced number of campsites selected by managers to remain open to use did not deteriorate substantially, despite an estimated 53% increase in average visitation (from 19 to 29 nights/year). Mean campsite size, area of vegetation loss and exposed soil increased only marginally (Table 2). A comparison of conditions on 21 legal campsites assessed in 1999 and 2002 revealed small increases in campsite area (33 to 34 m^2) and somewhat larger increases in the area of vegetation loss (8 to 9 m^2) and area of exposed soil (3 to 5 m^2). These results follow the theoretical campsite impact model offered by Cole (1992). The surprisingly small increase in campsite area may be attributed to the selection of campsites with low expansion potential due to topographic limitations, rockiness or dense vegetation. Expansion potential was a primary selection criterion to favor retention of campsites that would inhibit site expansion pressures under sustained high use. Although campsite size was not a selection criterion, the closure of large sites close to trails or water sources could also contribute to these findings. From a managerial standpoint, the limited deterioration of legal established campsites is acceptable because, from an aggregate perspective, they are more than offset by reductions in impacts on sites no longer in use.

Closure and Rehabilitation Success

The rehabilitation efforts in the three study areas were integral to the success of the management policy because poorly located and fragile campsites were effectively closed to visitor use through the placement of organic debris. The effort devoted to the rehabilitation efforts was consistent annually, but was also realistic based on SNP's budget and staffing. We also note that the number of illegal sites dropped sharply (from 32 in 1999 to 13 in 2002) during the study, suggesting that following the initial transition period that ongoing rehabilitation work will be more manageable. Although this study did not include assessments of vegetative recovery on closed sites, undisturbed leaf litter and/or vegetative growth covered them and complete ecological recovery will occur if the closures remain successful.

These findings contrast sharply with those of Cole and Ranz (1983) and Hall (2001) in which campsite closure efforts were largely unsuccessful in western U.S. wilderness areas. The success of site closures in this study can be attributed to the persistent rehabilitation efforts of SNP managers and the recovery of many sites through natural causes such as downed trees and fallen leaves. The resilience of the SNP environment, especially when compared to the western, high-altitude study areas of other studies, is also a likely contributing factor. Marion and Cole's (1996) research on eastern U.S. riparian campsites closed to use showed extremely high recovery rates, in part due to the favorable growing conditions. SNP's soils and growing conditions are generally less favorable than those, but they are likely more favorable to plant recovery than those in most western areas.

Education Efforts

Visitor interviews revealed that managers have successfully reached visitors with campsite selection messages, but could improve efforts to convey the established campsite aspect of the policy. Although many visitors successfully articulated park policies regarding campsite distances from trails, water, park buildings and other visitors, the distances cited were often vague, confused or inaccurate. Since the park brochures and permits list these distances, visitors are able refer to the provided literature to obtain accurate values when necessary. Since all of the legal sites left open by park managers met the distance requirements, visitors who chose an established site would inevitably meet the criteria regardless of their knowledge level. Nonetheless, SNP managers could improve the educational message by simplifying the educational content and focusing on the primary policy goals, like selecting an established campsite.

Balancing Resource Protection and Visitor Experience Mandates

A principal challenge in camping management decision-making is balancing the protection of natural resources with the provision of high quality camping experiences. In SNP's high use areas, problems with campsite proliferation and site expansion are addressed through the use of well-marked designated campsites constructed using cut-and-fill techniques in sloping terrain (Marion & Farrell 2002). Limiting the number of sites in each area and providing adequate separation between campsites provides greater opportunities for visitor solitude. However, while this strategy effectively limits resource impacts, visitors lose campsite choices and must be prepared to hike farther to find an open site.

The established campsite policy was developed as a tradeoff - an effort to restrict camping to a limited number of resistant campsites while maintaining visitor flexibility and choice in campsite selection. Prior to the study, campsite occupancy rates in the study areas averaged 16%. Based on the 1999 campsite occupancy survey, site numbers were reduced to levels so that occupancy rates on average high use weekends (not peak use) would approximate 33%. This would permit an average of three campsites from which visitors could choose, while substantially reducing the aggregate extent of impact associated with an unregulated camping option. However, with the recovery of 17 legal campsites that managers left open in 1999 (Table 4), campsite occupancy rates for legal campsites in the study rose to 50%.

Inter-campsite visibility and distance measures, which reflect the potential for visitor solitude, also improved following the implementation of the established campsite policy. By decreasing the number of campsites and mean number of visible sites from 1 to .4, while increasing the mean distance between adjacent campsites from 15 to 18 meters, SNP managers increased the potential for visitor solitude while camping. This figure can be compared with Farrell and Marion's (2000) findings that campsites in Isle Royale National Park averaged 1.8 visible sites and a mean distance between adjacent sites of 23 meters. SNP park managers have effectively reduced inter-campsite visibility and marginally increased mean distance between sites. This success can be attributed to the reduction in campsite numbers and to selection criteria that included inter-campsite visibility and distances. We also note that managers left 17 additional established campsites that recovered because visitors did not find and use them (Table 3). Most of these campsites were more remote from trails and other campsites and offered visitors greater solitude than those that many selected and used.

Notably, SNP's established campsite policy and the closure of unneeded campsites was accomplished through relatively non-restrictive regulations (to select an existing campsite), careful site selection, visitor education, and site rehabilitation. In particular, visitors are likely unaware of the management attention that has gone into the selection of resistant, well-spaced campsites or of the ongoing efforts to close poorly located or unnecessary campsites. Such work is largely transparent to visitors, in comparison to alternative restrictive regulations (reserved designated sites), campsite signs/facilities, and mapped site locations. Under the established campsite policy visitors retain a significant degree of choice in their campsite selection, including the ability to search out and discover 'natural' unmarked sites that suit their needs.

SNP managers could have designated a much smaller number of campsites and operated a reservation system to ration their use. While this option could have further minimized the area of camping disturbance, such enhanced protection would have "cost" visitors their ability to have flexible itineraries and select campsites of their choosing. Alternately, managers could have designated the campsites with posted signs and symbols on maps without a reservation system. This option would likely reduce the extent of site rehabilitation needed but would reduce the naturalness of wildland environments and visitors' campsite choices and sense of discovery to explore and find a primitive unmarked campsite.

CONCLUSION

A visitor impact containment strategy and established campsite policy successfully reduced the number of campsites and aggregate measures of camping-related disturbance at SNP while minimizing restrictive regulations, site facilities, and staff resources. While campsite monitoring will be continued to validate this initial success, SNP managers are planning to continue its implementation and expand site containment and rehabilitation efforts to other park areas. Park staff are also evaluating these findings and their implications and may modify the policy or educational messaging when full implementation occurs. For example, temporary closure signs may be placed on the campsites that experience repeated reuse. Ice-berged rocks in the best tenting spots offer a more natural alternative.

This study sought to integrate resource and social research to provide a more holistic perspective to management policy assessments. Physical measurements evaluated the potential for camping solitude, while visitor interviews addressed important dimensions of the park's success in implementing the new camping policies. Such studies are rare, though they hold significant promise for supporting more informed decision-making. Furthermore, the adaptive management collaboration between scientists and managers provided improved knowledge for selecting and implementing effective camping policies. Adaptive management research also provides more objective and timely evaluations of management success and facilitates effective modifications that are responsive to unforeseen problems. Objective documentations of such "real world" management case studies can also improve technology transfer to inform other managers and scientists.

An established campsite policy allows protected area managers to effectively contain camping impacts to selected resistant sites that enhance the potential for solitude, while providing visitors with the option to choose a primitive campsite. Application of the established campsite policy to other parks and protected areas would require similar camping regulations, education messaging, low to moderate use levels, and the ability to sustain ongoing site rehabilitation work. An established campsite policy also requires a greater number of campsites and resource disturbance than a designated site policy, particularly those with site reservations. This trade-off reflects the effort to balance resource protection with the provision of high quality recreation opportunities.

Future research efforts could apply a similar camping strategy to other areas to assess whether less resilient areas or those with different visitation patterns would experience the same level of success found at SNP. One problem with adaptive management research is its potential to constrain experimental designs. In this study reducing overnight visitation was a confounding influence and we were unable to randomize the selection of study sites. Extended longitudinal studies of management success with alternate camping policies are needed to evaluate their sustainability. An improved understanding of rehabilitation options and recovery on closed campsites is also needed to gauge long-term success and recovery rates. Several social science topics also require an improved understanding. Visitor preferences for alternate camping policies and their perceptions of resource and social conditions on campsites under different policies are a critical need.

ACKNOWLEDGEMENTS

This research was funded by the U.S. National Park Service. We extend our thanks to the staff of Shenandoah National Park, especially Steve Bair and Mary Cottone. We also appreciate the thoughtful guidance and thorough reviews of Kevin Larkin and Joe Roggenbuck.

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CHAPTER III.

A Comparison of Campfire Impacts and Policies in Seven Protected Areas

ABSTRACT: Using resource monitoring data from seven protected areas, the effectiveness of three campfire policies: campfire ban, designated campfires, and unregulated campfires, were assessed based on the number of firesites and the amount of tree damage. Results indicate that unregulated campfire policies permitted substantial numbers of firesites and tree damage in campsites, while fire bans did not eliminate or even substantially reduce these problems. A designated campfire policy was effective in reducing number of firesites, but little difference was found among policies regarding tree damage. Given the importance of campfires to visitor experiences, campfire prohibitions could be viewed as unnecessarily restrictive based on their limited success in preventing resource damage. Conclusions encourage protected area managers to consider designated campfire policies and prohibitions on axes, hatchets and saws to better meet resource protection and visitor experience mandates.

INTRODUCTION

Land managers in the National Park Service (NPS) and U.S.D.A. Forest Service strive to balance the dual and often competing mandates of providing for recreational visitation and protecting the resource. Recreation ecology research consistently shows that recreational use inevitably causes some degree of resource degradation. As managers strive to meet resource protection and recreational access mandates, the identification and monitoring of resource impacts has become an essential component of planning frameworks and land management objectives.

Included under the resource degradation heading are campfire related impacts, which to many represent a significant deterioration of resource qualities in protected areas. Campfires are an especially challenging issue for public land managers because fires remain an important aspect of many visitors' camping experience, despite recent findings that show an increasing preference for cookstoves for cooking purposes (Cole 2000). Campfires result in both aesthetic and ecological impacts to protected areas. Although the most obvious impacts tend to be focused on specific areas within campsite boundaries, wood collection and wildfire impacts resulting from campfires are more broadly distributed and affect larger areas. In this paper, we provide a concise yet comprehensive review of the campfire impact literature to establish the ecological and managerial significance of campfires in backcountry and wilderness settings.
Visitor values related to campfires are also reviewed, including visitors' perceptions of campfire-related resource impacts and the importance of campfires to wildland recreational experiences.

Many land managers have implemented restrictive campfire policies (e.g., fire bans, fires restricted to designated sites) in their efforts to avoid or minimize recreation-based resource impacts. These prohibitions may run counter to wilderness and backcountry ideals, which emphasize visitor freedom and minimal management intervention. There is also little evidence that such policies successfully reduce campfire impacts - no research has been undertaken to assess the effectiveness of campfire management interventions. In addition, no empirical study has compared campfire policies and associated impacts across several protected areas. Such an evaluation would offer managers insights regarding the efficacy of alternate campfire policies for reducing campfire impacts. Towards this end, this paper reviews campfire management strategies and actions to classify the range of management interventions possible and presents campfire impact–related data from six NPS units and one National Forest to evaluate the efficacy of three standard campfire management policies: campfire prohibition, campfires at designated sites, and unregulated campfires.

The impacts assessed in this study are based on preexisting monitoring data from the seven protected areas. The monitoring of resource impact indicators is an essential role for land management agencies concerned with preserving resource and social conditions while providing for public visitation. Impact indicators are commonly selected for management planning and decision making frameworks. This process requires the selection of indicators and the establishment of standards that, when exceeded, prompt management actions to ameliorate impacts (Stankey and others 1985, NPS 1997). Sustained monitoring of selected indicators documents long-term trends in resource conditions but also provides a measure of management success in achieving objectives. Similarly, the data used in this study reflect the degree to which alternate campfire policies have succeeded in their intent. A comparison across several areas with various campfire policies provides insights to managers for selecting a management approach that maximizes resource protection while minimizing visitor restrictions.

LITERATURE REVIEW

Recreation ecology is defined as the study of visitor impacts to protected areas (Hammitt and Cole 1998, Liddle 1997, Marion 1998). Recreation ecology research has shown that wildland recreation inevitably contributes to changes in the biophysical components of protected areas (e.g., soil, vegetation, wildlife and water). Public land managers commonly use techniques developed by recreation ecologists to monitor and assess resource condition indicators in places that receive intensive recreational use. Understanding recreation-related resource degradation, as influenced by use-related, environmental and management factors, can help managers select more effective impact management strategies and actions.

Types of Campfire Impacts

Research literature and management experience regarding campfire impacts reveals an extensive list of resource damage attributed to campfires, including: firesite proliferation, overbuilt firesites and associated seating arrangements, fuelwood depletion, sterilized soils, charred rocks and tree roots, ash and charcoal build-up, semi-melted plastic and metal trash and associated chemical contamination of soils, unburned food that attracts wildlife, tree damage and felling, and vegetation trampling associated with firewood collection (Cole and Dalle-Molle 1982, Cole, 1995, 2000, Fenn and others 1976, Bratton and others 1982, Kendall 1999, Hammitt 1980, Vachowski 1997, Hall and Farrell 2001). Managers consider these campfire-related resource impacts sufficiently problematic that 43% of NPS managers have prohibited campfires parkwide (Marion and others 1993). The same study also found that 23% of managers consider multiple firesites a significant problem in many or most backcountry areas of their parks.

A firesite is an obvious location where a campfire has burned, typically with a rock or metal fire ring and pile of charcoal with partially burned wood (Marion 1994). Census data from several monitoring efforts have revealed a substantial number of firesites in many protected areas. For example, recent studies in the backcountry of Shenandoah, Great Smoky Mountains and New River Gorge National Parks revealed a total of 216, 563 and 151 firesites, respectively (Williams and Marion 1995, Marion and Leung 1997, Leung and Marion 1998). Similar studies in other areas of the United States have also revealed large numbers of firesites. In a study of three western wilderness areas, Cole and others (1997) found that two basins in the Three Sisters Wilderness area contained a total of 209 firesites. McEwen and others (1996) surveyed four wilderness areas in the central U.S. and found a total of 106 firesites on open campsites. An additional 93 firesites were located on unused and otherwise recovered campsites, demonstrating the long-term visible effects of fire scars.

Campfires have also been shown to dramatically alter local underlying soil properties. Fenn and others (1976) measured the effects of campfires on soil regimes and concluded that intense campfires can reduce organic matter content to a depth of 10 cm or more. The researchers also found that campfires result in substantial alterations of soil chemistry. The reductions in organic matter and subsequent chemical changes diminish soil fertility and water holding capacity, making the soil prone to erosion and compaction (Fenn and others 1976).

Although not assessed empirically, land managers also cite broader resource degradation issues associated with firesites. To accommodate large campfires or bonfires, visitors often build large fire rings thereby charring excessive numbers of rocks or rock overhangs. Tree roots adjacent to firesites are also burned, and can ignite and start wildfires. Charcoal, buildup of ash and partially burned wood from campfires are an aesthetic concern for managers and visitors alike (Lee 1975) and can prompt the creation of other firesites or the displacement of visitors to alternate campsites. Makeshift furniture that accompanies campfires also concern managers, especially those who manage wilderness areas where human-constructed facilities are prohibited. Soil compaction and exposure of bare soil from intensive visitor traffic around campfires is also an issue, particularly when firesites migrate to multiple locations. Firesites also attract litter and garbage when visitors attempt to dispose of wastes through burning. The combustion of plastic, paper and metal garbage can contribute chemical contaminants to firesite ashes. Partially burned food items retain odors, thereby promoting attraction behavior among area wildlife.

At a somewhat larger spatial scale, firewood collection leads to secondary campfire impacts such as tree damage and visitor-felled trees. Tree damage, including broken or cut limbs, driven nails, hatchet wounds and girdling, is an aesthetic impact associated with campfires, but such wounds make trees more susceptible to insect and fungal attacks that can lead to tree mortality (Cole and Dalle-Molle 1982). Felled trees due to wood gathering efforts may reduce habitat for cavity-nesting birds while also affecting aesthetic qualities of an area (Cole and Dalle-Molle 1982).

Campsite monitoring surveys have consistently shown significant levels of tree damage and felling associated with campfire use. In censuses of campsites in Great Smoky Mountains, Shenandoah and Isle Royale National Parks, researchers found the total number of damaged trees associated with campfires to be 1,128, 190 and 281, respectively (Marion and Leung 1997, Williams and Marion 1995, Farrell and Marion 1998). In the same studies, the total numbers of tree stumps were 724, 159 and 389, respectively. In off-site areas at Great Smoky Mountains National Park, surveyors found an additional 1,249 damaged trees and 2,642 stumps. In a survey of four wilderness areas in the south-central United States, McEwen and others (1996) found a total of 268 damaged or felled trees. A similar survey in the Mount Jefferson Wilderness area in the northwestern U.S. revealed 1056 damaged trees and 745 felled trees (Cole and others 1997), suggesting that campfire-related tree damage is pervasive in many protected areas.

Studies that have examined the effects of firewood collection on forest nutrient cycling have yielded mixed results. The majority of forest nutrients are contained in the soil, and in tree leaves, needles and twigs, suggesting that the gathering of medium sized firewood (between 2.5 and 10 cm diameter) has a limited effect on forest nutrient cycling (Bratton and others 1982, Weetman and Webber 1972). Bratton and others (1982) investigated the effects of trampling and firewood gathering in Great Smoky Mountains National Park and concluded that the collection of downed wood likely affects nutrient cycling over a 50-70 year timeframe, but has negligible effects in the short term. A significant reduction in smaller dead tree stems was offset by no overall change in the total basal area of trees. The researchers therefore concluded that visitors were removing smaller standing dead trees for campfires, but larger trees were being left (Bratton and others 1982). The researchers also concluded that a long-term increase in tree mortality would result from an increase in the number of damaged trees. Other studies have also shown that tree damage is cumulative over time, suggesting that older campsites tend to have higher levels of tree damage (Marion and Merriam 1985). Hall and Farrell (2001) assessed the extent of woody material depletion in the Cascade Mountains of Oregon and found a significant reduction in woody materials adjacent to campsites when compared to controls, but only speculated about the potential ecological effects of such reductions.

Monitoring studies often use the number of informal trails as an indicator of the extent of adjacent off-site vegetation trampling. Managers consider larger densities of such trails to be closely associated with firewood gathering activities. McEwen and others (1996) found a total of 167 informal trails associated with campsites, while studies in Great Smoky Mountains and New River Gorge have shown totals of 1087 and 221 informal trails, respectively (Marion and Leung 1997, Leung and Marion 1998). While informal trails associated with campsites may be used for firewood gathering, they are also used to access the site, water, other sites, restroom areas and scenic features. Therefore, it is difficult to attribute informal trail development solely to firewood gathering.

Visitor Values Related to Campfires

Campfires have a long tradition in recreational camping. Although many land managers consider firesites a degradation of resource conditions, studies have shown that visitors consider a single fire ring to be a desirable campsite amenity (Lucas 1980, White and others 2001, Shelby and others 1988). Lucas (1980) found that visitors used stoves for cooking, and fires as the center of conversation and sociability. Surveys of visitors to five wilderness areas revealed that although visitors prefer cookstoves for cooking, 50-65% of them built at least one campfire during their trip (Cole 2000). This study also found that between 41-60% of visitors in areas that allowed campfires had a fire for enjoyment purposes only. A recent study of Appalachian Trail users found that 72% of visitors surveyed opposed or strongly opposed campfire prohibitions (Manning and others 2000). These findings suggest that campfires hold high value for visitors, even if campfires are not used for cooking purposes.

Several studies have assessed visitors' perceptions of campfire impacts. Shelby and others (1988) concluded that impact standards (e.g., fire ring size and number) are different for various experiences and locations. These findings suggest that different levels of campfire impacts are acceptable in different locations or by visitors seeking different experiences. Various interest groups have been shown to value fire rings differently, with hunters and stock users accepting more substantial campfire impacts while land managers and conservation group members showing acceptance of only minimal levels of campfire-related impacts (Shelby and Shindler 1992). Although simple fire rings are often considered desirable, elaborately constructed or litter-filled fire rings have been shown to detract from visitors' trip enjoyment (Lee 1975). A more recent study of eight wilderness areas in the United States found that only one-quarter to one-half of visitors felt that there were any problems with too many fire rings, or built-up and trashy firesites (Cole 2000). Tree damage (such as scarring or nails in trees) has been found to negatively affect visitors' experience quality (Roggenbuck and others 1993), but nails in trees have also been shown to be a positive site attribute (White and others 2001). Based on these findings, visitors who perceive resource impacts appear willing to accept some degree of campfire-related damage based in part on the importance of campfires to their experience.

Campfire Management Strategies

Managerial responses to perceived campfire impacts are variable, depending on management objectives. Some park managers have sought to eliminate campfire impacts by banning campfires, while others have sought to minimize campfire impacts through a variety of regulations, site management actions, and educational practices. Table 1 presents potential campfire management actions arranged by general strategy: spatial, behavioral, temporal and facility. The management approach for a single area could include components from each of these strategies. For example, managers might only permit communal campfires in designated sites during seasons of low fire danger while prohibiting axes and saws to limit tree damage. Cole and Dalle-Molle (1982) provide guidance in selecting an appropriate campfire management strategy, review minimum impact campfire practices and describe firesite rehabilitation techniques. Vachowski (1997) summarizes products used to reduce campfire impacts (e.g., fire pans, fire blankets and fire grates).

A 1993 survey of National Park Service backcountry managers found that 43% of managers surveyed reported that ground fires were banned parkwide, and 83% indicated that cutting standing deadwood was also prohibited (Marion and others 1993). Forty-five percent of managers also encouraged the use of cookstoves in lieu of campfires, while 37% required cookstoves. In a similar survey of wilderness managers, Washburne and Cole (1983) found that the US Fish and Wildlife Service and National Park Service prohibited fires in 59% and 43% of their protected areas, respectively. Although US Forest Service and Bureau of Land Management rarely prohibited fires (1% and 0% of areas), campfires were discouraged in 20% and 36% of areas, respectively (Washburne and Cole 1983).

Table 5. Campfire management strategies and actions.

Spatial Strategy
Established Campfires - permit fires only in established (existing) firesites **Communal Campfires** - require groups to share common designated firesites **Vegetation Type Zoning** - restrict campfires in areas with sensitive vegetation or permit them only in types with sufficient fuels **Site Zoning** - prohibit fires near historic and/or park structures, or in fuel-limited areas **Elevational Zoning** - ban fires in high elevation areas **Shoreline Zoning** – restrict fires to below high tide or below seasonal high water mark **Unregulated Campfires** - no restrictions
Behavioral Strategy
Campfire Ban - prohibit fires area-wide **Education Programs** - encourage minimum impact visitor behavior including the use of stoves, existing firesites, collection of dead and downed wood, and burning of all wood to ash **Tool Restrictions** - prohibit the possession or use of axes and saws **Firewood Restrictions** - prohibit the cutting of live or standing dead trees, or require the importation of firewood from outside the protected area
Temporal Strategy
Temporal Zoning - allow fires only after dark or at certain times of day **Seasonal Zoning** - restrict fires to winter and cooler seasons, or to times of low wildfire danger **Rationing** - ration fires to a portion or percentage of the nights camped
Facility Strategy
Designated Campfires - require the use of anchored fire grates, fire rings or grills **Fire Pan Regulation** - require the use of portable fire pans for all fires

Adapted from: Hammitt 1982, Cole and Dalle-Molle 1982.

Constructed campsite facilities of all types have been shown to assist managers with implementing impact containment strategies (Bratton et al. 1978, Marion and Leung 1997, Marion and Farrell 2002). Firesites, in particular, have been shown to spatially concentrate visitor activity to one area of a campsite (Marion 1995, Marion and Cole 1996). For example, Marion (1995) speculated that new firegrates on campsites attracted and concentrated camping activities near the firesite, thereby shrinking campsite sizes. In contrast, non-permanently fixed firesites often migrate around a campsite or develop into multiple firesites, thereby expanding the areas of visitor activity and impact (Cole and Dalle-Malle 1982).

STUDY AREAS

This study evaluated secondary data on campfire impacts from six National Park Service units and one National Forest in the eastern and central United States. The data were collected along with numerous other campsite condition indicators during backcountry campsite monitoring surveys between 1991 and 1996. The following study area descriptions are organized by their campfire policies: "No Fires" reflects a fire ban policy, "Designated Fires" connotes a policy of campfires only in provided or established fire grates or rings, and an "Unregulated Fire" label indicates an undesignated fire policy (Table 2).

Shenandoah National Park (SHEN) is a forested linear park in north-central Virginia, 40% of which is included in the National Wilderness Preservation System. Backpacking on undesignated campsites is the primary overnight use. Campfires have been banned since 1974.

Big Bend National Park (BIBE) is located in southwest Texas along the Mexican border. Monitoring data are presented only for the Chisos Mountains portion of the park and for undesignated trail-accessed campsites throughout the park. Campfires have been prohibited at these campsites for at least 15 years prior to the monitoring assessment.

Isle Royale National Park (ISRO), located in northern Michigan, is an island park, 99% of which is designated wilderness. Primary overnight visitation includes backpackers and fishermen. ISRO is located in the northern boreal forest, consisting of balsam fir, white spruce, paper birch and aspen. Camping occurs in primitive shelters and on designated campsites, most of which do not allow campfires. However, campfires in designated fire grills and communal fire rings are permitted at 38 sites. For the purposes of this paper, ISRON denotes areas in Isle Royale National Park with a fire ban, while ISROF is used for Isle Royale areas that permit fires in designated firesites.

Delaware Water Gap National Recreation Area (DEWA) is a river park located within 100 km of New York City. Campsite monitoring was restricted to the riparian zone, which contains eastern deciduous forests dominated by white ash, silver maple and river birch. Fishermen and novice canoeists dominate the overnight visitation. Campsites are designated and fires are permitted only within fire grates.

The New River Gorge National Park (NERI) in West Virginia is also a river park, but the primary overnight visitation is by whitewater rafters. Similar to DEWA, campsites are located in a deciduous riparian forest with river birch, silver maple and sycamore. Campsites are undesignated and there are no restrictions on campfires.

The U.S.D.A. Forest Service manages the Jefferson National Forest (JNF), located primarily in southwestern Virginia. Campsites were monitored in eleven wilderness areas, and backpacking is the predominant overnight use. Vegetation in the JNF is predominantly deciduous hardwoods, including oak, poplar, and hickory. Camping occurs on undesignated campsites, and campfires are unregulated.

Table 6. Description of study areas and campfire policies

Protected Area	Area (ha)	Overnight Visits/year	Campsites[1] (#)	Campfire Policy	Citation
Shenandoah NP, VA (SHEN)	79,061	45,729	221	Campfire Ban	Williams and Marion 1995
Big Bend NP, TX (BIBE)	324,219	50,193	155	Campfire Ban	Williams and Marion 1996
Isle Royale NP, MI (ISRO)	231,395	46,625	244	Campfire Ban & Designated Campfires	Farrell and Marion 1998
Delaware Water Gap NRA, NJ/PA (DEWA)	28,328	33,184	85	Designated Campfires	Marion 1994
New River Gorge NR, WV (NERI)	2,509	13,333	77	Unregulated Campfires	Leung and Marion 1998
Jefferson National Forest, VA (JNF)	279,336	--	168	Unregulated Campfires	Leung and Marion 1995
Great Smoky Mountains NP, TN/NC (GRSM)	208,367	96,459	221	Unregulated Campfires	Marion and Leung 1997

1 - Number of campsites monitored that include assessments of firesites and tree damage, often a subset of all campsites for a given area.

Great Smoky Mountain National Park (GRSM), in North Carolina and Tennessee, is a mountainous park with vegetation that includes mountain top heath balds, spruce-fir forests and deciduous hardwood. Backpackers are the primary overnight visitors, and they are required to camp in designated campsites. Campfires are unregulated.

Study Area Educational Efforts:

Although each area included in the study utilized visitor education to convey park campfire policies, the emphasis on educational efforts varied. The four areas requiring camping permits (SHEN, BIBE, ISRO and GRSM) print campfire regulations on the permits. JNF, DEWA and NERI do not require camping permits and dissemination of educational materials is limited. Trail maps distributed at visitor centers and elsewhere also contained campfire regulations for GRSM and SHEN. DEWA and BIBE distributed park-produced pamphlets detailing campfire regulations. All of the study areas also conveyed campfire policies to visitors via informal ranger contacts. SHEN was unique among the areas in broadcasting the campfire prohibition on the park informational radio station.

METHODS

Selection of Indicators:

Campfire impact indicators include the number of firesites and damaged trees within campsite boundaries. Both measures are commonly used in campsite impact monitoring programs as the best available indicators of campfire-related damage. The number of firesites is a direct measure of campfire impacts. The number of damaged trees reflects damage from the cutting or breaking of limbs for firewood, but also malicious damage from axes, hatchets and saws. Visitors would not generally be carrying these implements unless they intended to use them for campfire-related wood collection and preparation. The number felled trees (stumps) were also assessed but are not reported due to the confounding influence of hazard tree removal work, which also occurs in some of the study areas but not others.

Field Measurements:

Following intensive training, field staff performed campsite surveys in each of the study areas during the summer months for the years indicated: DEWA-1991; SHEN-1992; GRSM and BIBE-1993; JNF-1994; NERI-1995; and ISRO-1996. Two-person crews dedicated full-time to campsite monitoring gathered descriptive data for each site using detailed procedural field manuals. Campfire impact indicator measurements were consistently applied across each area, except where noted. Quality assurance measures were applied, including periodic comparative assessments, mid-season evaluations and the alternation of research partners.

For each campsite included in the survey, the number of firesites within campsite boundaries and satellite areas was counted. A firesite is defined as an obvious location where a campfire has burned, typically with a rock or metal fire ring and a pile of charcoal with partially burned wood. Older, inactive firesites as exhibited by blackened rocks, charcoal or ashes were included in the tally, but field staff was instructed to distinguish between actual firesites and places where ash or charcoal had been dumped or scattered to ensure conservative estimates of firesite numbers.

Tree damage was assessed for all trees located within campsite boundaries at each study area. Damage to trees was categorized into three classes: *None/Slight* was defined as “No or slight damage such as broken or cut smaller branches, one nail, or a few superficial trunk scars”; *Moderate* was defined as “Numerous small trunk scars and/or nails or one moderate-sized scar”; *Severe* was defined as “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)" (Marion and Leung, 1997). In ISRO, the scars were further defined as: "superficial trunk scars total less than 2 square inches, moderate trunk scars total more than 2 square inches but less than 36 square inches, and severe trunk scars total more than 36 square inches" (Farrell and Marion 1998). Color photos with descriptive text were used for training and field reference to illustrate tree damage categories. We note that most damage qualifying as moderate and severe resulted from the use of axes, hatchets and saws, implements associated with firewood collection and preparation; knife damage was generally less common and substantial, and was rated in the None/slight class.

Data Analysis

Measures of indicators were numerically transformed to standardize the data to enable appropriate comparisons among study areas. Comparison of firesites was performed using data from all surveyed campsites. To facilitate comparison, campsites containing greater than four firesites were categorized into one class of greater than four. Tree damage indicators were computed only for campsites that contain trees within their boundaries. Due to possible variation in campsite sizes between study areas, tree damage measures were computed on a per hectare of campsite area basis.

A weighted tree damage index was calculated by summing the number of trees with none/slight damage, 2x moderately damaged trees, and 3x severely damaged trees, based on the premise that severe and moderate tree damage have greater ecological and managerial relevance (Cole and Marion 1988). This value was standardized by dividing by the total number of trees onsite and expressed on a per hectare basis for inter-area comparisons. These figures were then divided into 500 unit categories to illustrate tree damage distributions for each area.

The final calculation was tree damage per hectare. To compute this value, trees rated as moderate and severe were combined as a single measure of damaged trees and expressed on a per hectare basis. For all campfire impact indicators the numbers of campsites in each prospective category are reported as percentages to enable appropriate comparisons between areas with varying numbers of campsites.

RESULTS

Number of Firesites

The majority of campsites in areas with a fire ban have one or no firesites (Figure 1a). Specifically, BIBE and ISRON tend to have a similar distribution of firesites per campsite, with 99% of campsites containing one or fewer firesites. In contrast, SHEN has a broader distribution, with 22% containing two or more firesites (Figure 1a). The mean number of firesites for the three areas ranges from 0.01 to 1.0 with an average of 0.5, and the percentage of campsites with one or more firesites ranges from 11 to 66% with an average of 35% (Table 3). Under the designated campfire policy, the distribution of the number of firesites per campsite is narrower. At ISROF, 100% of the campsites (N=38) contain only one firesite, while DEWA has a broader distribution of firesites, with 8% containing two firesites, and 4% in the three or four firesite categories (Figure 1b). The mean number of firesites per campsite for this campfire policy is 1.1 and 93% of the campsites have one or more firesites (Table 3). Under the unregulated firesite policy, all three areas have a wider distribution of firesites per campsite (Figure 1c). GRSM, in particular, has more multiple-firesite campsites than any other study area. Only 56% of campsites in GRSM have one or fewer firesites. NERI also has a high percentage (39%) of campsites with more than one firesite. In contrast, 83% of campsites in JNF contain one or fewer firesites (Figure 1c). The mean number of firesites range from 1.1 to 1.7 with an average of 1.5 and the percentage of campsites with one or more firesites ranges from 89 to 99% with an average of 95% (Table 3).

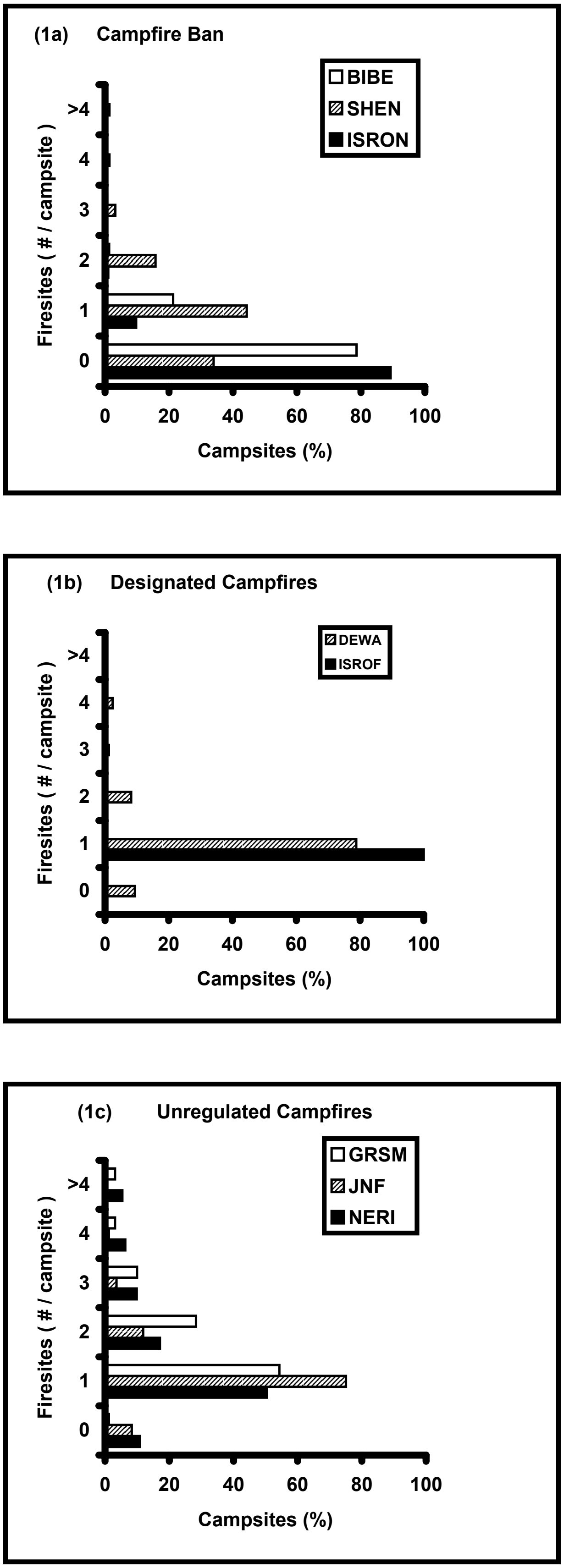

Figure 1. The number of firesites per campsite in: a) areas with a campfire ban policy, b) areas with a designated campfire policy, and c) areas with an unregulated campfire policy.

Table 7. Firesite measures: Number, average per campsite and percentage of campsites with one or more firesites.

Indicator	Campfire Ban			Designated Campfires		Unregulated Campfires		
	BIBE (n=155)	SHEN (n=221)	ISRON (n=206)	DEWA (n=85)	ISROF (n=38)	GRSM (n=332)	JNF (n=168)	NERI (n=111)
Firesites (#)	40	216	24	92	38	559	192	192
Firesites (Avg.)	0.3	1.0	0.01	1.1	1.0	1.7	1.1	1.7
Firesites (%)[1]	23	66	11	91	100	99	92	89

1 – Percentage of campsites with one or more firesites.

Tree Damage Index

The tree damage index computations reveal patterns in the distribution of tree damage across the seven study areas (Figure 2). Of the areas which ban campfires, ISRON has the highest scores in the tree damage index, with 58% of its campsites ranked in the highest three categories. In contrast, 40% of BIBE's campsites and 36% of SHEN's sites are in the three highest damage index categories (Figure 2a). In areas with designated campfire policies, ISROF has a very narrow and low tree damage index distribution, while DEWA's distribution is wider. For example, 33% of ISROF's campsites are in the three highest index categories, compared to 64% in DEWA (Figure 2b). Among unregulated campfire policy areas, GRSM has the highest scores in the tree damage index, with 54% of its campsites in the highest three categories. This figure can be compared with NERI and JNF at 24% and 23%, respectively (Figure 2c).

Tree Damage

For the tree damage per hectare measures, results indicate a relatively consistent distribution of the number of damaged trees in the areas with campfire bans (Figure 3a). SHEN and BIBE have a similar percentage of campsites with no damaged trees (61% and 58%, respectively), while ISRON has the lowest percentage of campsites with no tree damage (43%) (Figure 3a). Of the areas with designated campfire policies, ISROF has less tree damage on a percentage basis than DEWA. Forty-two percent of ISROF's campsites have no damaged trees compared with 25% in DEWA. (Figure 3b). In areas with unregulated campfires, JNF has 68% of its sites with no damaged trees, as compared with 38% at NERI and 33% at GRSM (Figure 3c). The distribution of GRSM's damaged trees tends to be skewed towards the higher numbers, with 18% of its sites in the three highest tree damage categories. This figure can be compared with 7% at JNF and 4% at NERI (Figure 3c).

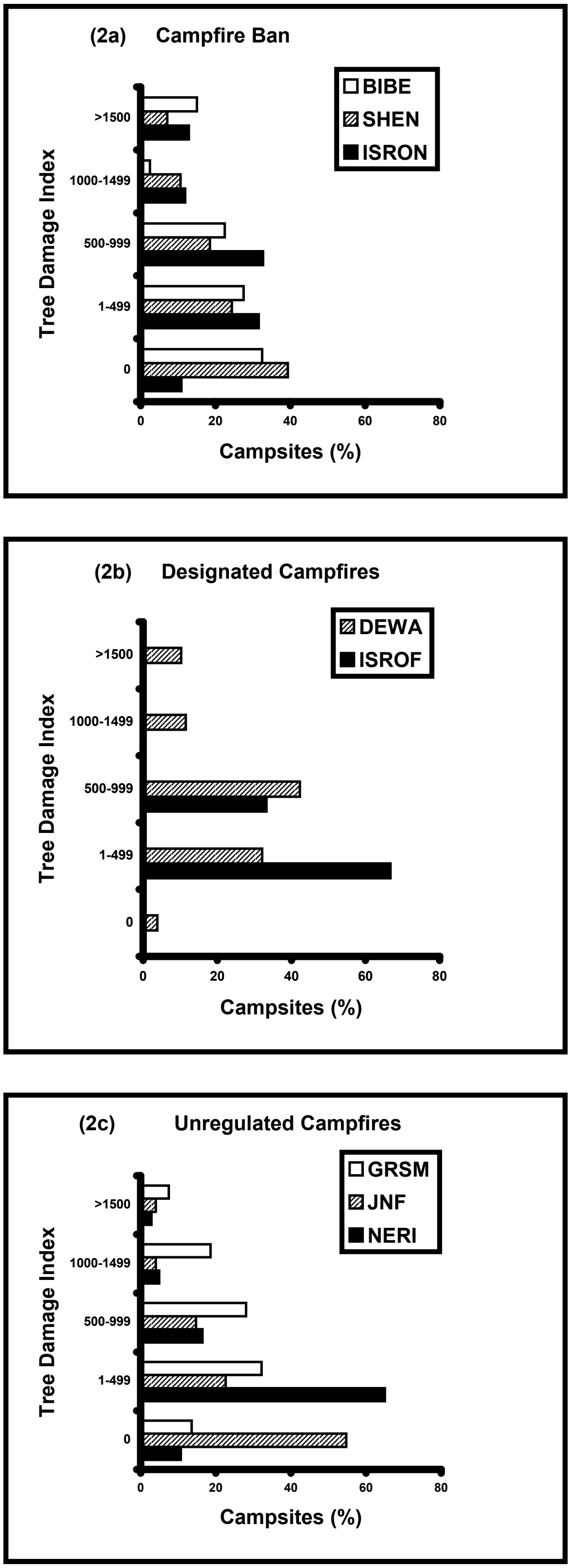

Figure 2. Tree damage index values for: a) areas with a campfire ban policy, b) areas with a designated campfire policy, and c) areas with an unregulated campfire policy.

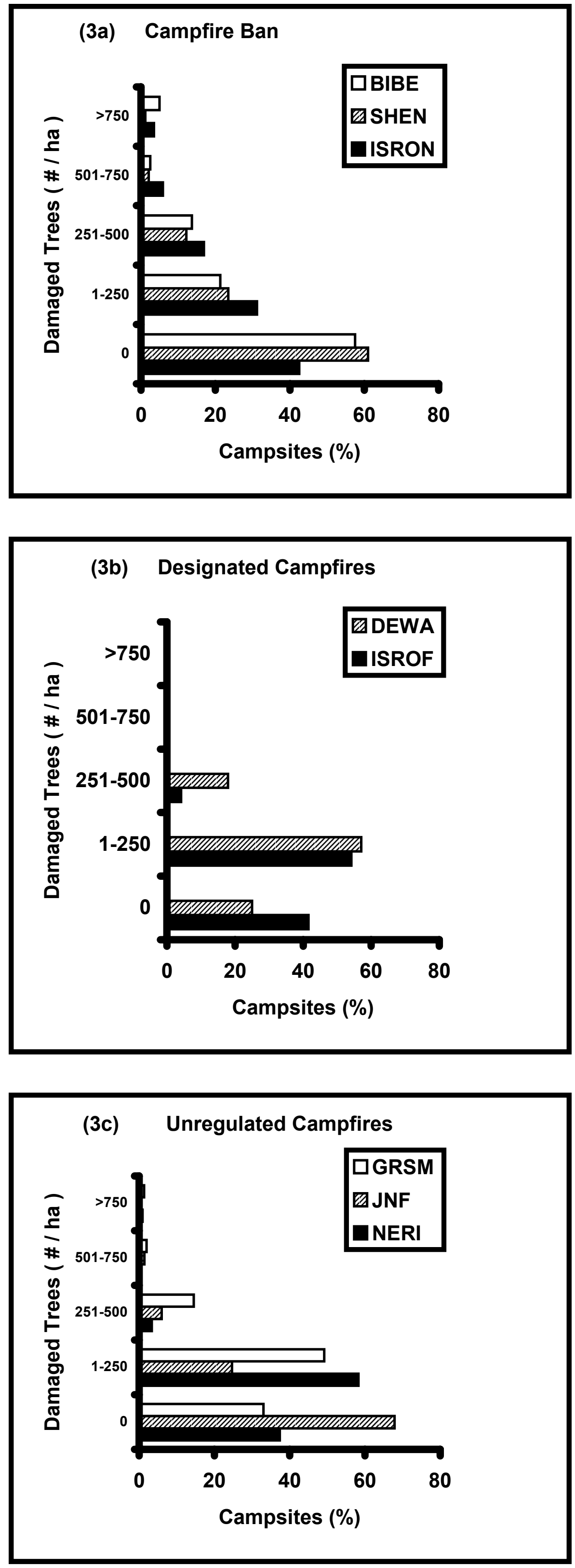

Figure 3. Damaged trees for: a) areas with a campfire ban policy, b) areas with a designated campfire policy, and c) areas with an unregulated campfire policy.

Although the tree damage expressed on a per hectare basis provides one measure for the amount, degree and pattern of campfire-related tree damage, non-standardized statistics for the number, average and percent of damaged trees on a per campsite basis provide an alternative context for examining actual tree damage in each area. These data are provided in Table 4. Readers should be cautioned that the numbers of trees on campsites is a function of both campsite area and tree distribution and density. Since the average campsite area varies widely among these study sites, a direct comparison of tree damage can be misleading. Similarly, tree density within a given area will also determine the number of trees that could potentially be damaged. When comparing these findings across different areas, readers should be aware of the limitations of such data.

Bearing such cautions in mind, however, the results suggest a number of patterns among different areas with different campfire policies. In areas with campfire bans, ISRON has the highest number of damaged trees for all three measures (Table 4). Among areas with a designated campfire policy, DEWA has the highest raw and average number of damaged trees while ISROF has a higher percentage of damaged trees per campsite. Findings from areas with an unregulated campfire policy indicate that GRSM has the highest number of damaged trees for all three measures. NERI also has a relatively high tree damage count and average (Table 4).

Table 8. Damaged tree measures: total number, average number per campsite and percentage of total on-site trees.

Indicator	Campfire Ban			Designated Campfires		Unregulated Campfires		
	BIBE (n=40)[1]	SHEN (n=168)	ISRON (n=101)	DEWA (n=78)	ISROF (n=12)	GRSM (n=242)	JNF (n=75)	NERI (n=103)
Damaged Trees (#)	64	190	257	359	24	1116	135	335
Damaged Trees (Avg.)	1.6	1.1	2.5	4.6	2.0	4.6	1.8	3.3
Damaged Trees (%)	57	28	78	59	77	58	35	52

1 – Number of campsites surveyed that have trees within site boundaries.

DISCUSSION

Number of Firesites

Based on the number of firesites per campsite, the designated campfire policy is the most effective in reducing firesite proliferation. Both DEWA and ISROF have successfully limited the number of firesites to one or fewer per campsite (85% and 100%, respectively) (Figure 1b). As might be expected, areas that prohibit campfires have the most campsites with no firesites. However, given that the intent of the policy is to reduce the number of campfires to zero, the policy can hardly be considered successful. At SHEN, 66% of campsites have illegal firesites, along with 23% in BIBE and 11% in ISRON (Figure 1a). Although areas with designated firesites empirically and logically have more firesites than those with fire bans, the repeated creation, destruction and relocation of firesites in areas with fire bans exacts a heavy toll in resource damage and staff time. Areas permitting unregulated campfires clearly have the most campsites with more than one firesite (Figure 1c). Particularly in GRSM and NERI, where 35% and 39% of campsites contain multiple firesites, respectively, proliferation of firesites is clearly problematic for managers (Figure 1c).

Tree Damage Index

The use of a weighted tree damage index was designed to quantify and characterize the amount and severity of tree damage across the study areas. Results generally reveal internal agreement among areas with similar campfire policies, but there are a few dramatic differences among policy groupings (Figure 2). ISROF shows a very limited distribution in the tree damage index measure, though the sample size of campsites decreased to only 12 due to the omission of campsites lacking trees (Figure 2b). It is notable that with respect to the tree damage index, all three areas that prohibit campfires have greater percentages of campsites with high index values than the three areas with unregulated campfire policies. ISRON, BIBE and SHEN have higher percentages of campsites in the three highest tree damage index categories (58%, 40% and 36%, respectively) than GRSM, NERI and JNF (54%, 24% and 23%, respectively) (Figures 2a and 2c). This finding suggests that a policy that bans campfires may be less effective at preventing overall tree damage than an unregulated campfire policy. Notably, DEWA, which has a designated campfire policy, has the greatest percentage of campsites in the three highest tree damage index categories (64%) (Figure 2b). This finding is likely the result of the high number of damaged trees per campsite (4.6) (Table 4). Park managers speculate that this high level of tree damage is a function of mostly novice visitors, who often try to burn green wood, and of visitors who are unaware of the area's campfire and wood gathering policies. Camping permits are not required in DEWA, which effectively limits managers' opportunities to educate visitors about campfire practices and policies.

Damaged Trees

The number of damaged trees per hectare measure provides a non-weighted approach for assessing levels of campfire-related tree damage. Areas with campfire bans (Figure 3a) tend to have more campsites with no damaged trees than areas with other campfire policies. The exception to this finding is JNF, an area with unregulated campfires, in which 68% of campsites surveyed have no damaged trees (Figure 3c). Though use figures are unavailable for JNF, most of its wilderness areas have very limited visitation. With the exception of JNF, areas with either designated or unregulated campfire policies have higher percentages of campsites in the 1-250 damaged trees per hectare range than campsites without tree damage (Figures 3b and 3c). These results suggest that in areas where campfires are permitted, more campsites will experience low levels of tree damage. Paradoxically, areas with campfire bans had more campsites with no tree damage, but also had more sites with higher levels of tree damage. ISRON, BIBE and SHEN had 9%, 9% and 3% of sites in the two highest tree damage categories, respectively (Figure 3a). This result can be compared with similar measures at NERI (1%), JNF (1%) and GRSM (3%) (Figure 3c). The two areas with designated campfire policies had no campsites in those categories. This finding may suggest that select visitors in ISRON and BIBE exhibit depreciative behavior that damaged a large number of trees on several sites.

Damaged tree measures reported in Table 4 provide some additional insights, particularly that within policy differences are as pronounced as between policy differences. For areas that prohibit campfires, ISRON had a large average number (2.5) and percent (78%) of damaged trees, compared with SHEN (1.1 and 28%, respectively). For areas with designated campfires, DEWA had a very large average number (4.6) yet lower percent (59%) of damaged trees, compared to ISROF (2.0 and 77%, respectively). And for areas with unregulated campfires, GRSM had a large average number (4.6) and percent (58%) of damaged trees, compared to JNF

(1.8 and 35%, respectively). Comparisons of table values present no compelling support for any single policy.

A Comparison of Two River Parks

The two river parks, NERI and DEWA, provide an interesting case study comparison because they have similar vegetation types and campsite numbers but different campfire policies. Results show that NERI has a higher percentage of campsites with multiple firesites (12% at DEWA, 39% at NERI) (Figures 1b and 1c). This finding again suggests that a designated campfire policy effectively reduces firesite proliferation. However, NERI's unregulated campfire policy has been more successful in reducing tree damage than DEWA's designated campfire policy. At NERI, 76% of campsites are in the lowest two tree damage index categories, compared to 36% at DEWA (Figures 2b and 2c). Values are more similar for tree damage per hectare measures, 96% of NERI campsites are in the lowest categories compared with 82% for DEWA.

Area educational differences

The seven areas in this study implemented a variety of visitor education strategies. In particular, SHEN, GRSM and BIBE devoted the most resources to visitor education, followed by ISRO and DEWA. Of the areas studied, JNF and NERI placed the least focus on educational efforts. There is no coherent pattern to the distribution of campfire impacts among the educational effort groupings, hence little indication that education effectively reduced campfire related impacts. Certainly, the role of educational programs regarding campfire impacts is difficult to assess from these types of comparisons. Future campfire impact studies should consider the role of education in shaping visitor behavior.

Land Manager Considerations

The different campfire policies and large number of campsites investigated in this study prompted the expectation of dramatic differences in campfire-related impacts from contrasting campfire policies. However, the overall findings from this study suggest that there is no clear policy that effectively limits campfire resource damage. Campfire bans may limit the number of firesites and tree damage but they are far from successful in eliminating these impacts. Campfire bans appear to be largely ineffective in deterring visitors from building campfires or damaging trees. A designated campfire policy appears effective in constraining the proliferation of firesites but provides no obvious advantage with regards to limiting tree damage. An unregulated campfire policy, particularly under higher levels of visitation, will result in high levels of both campfire proliferation and tree damage.

Based on these findings and the diverse strategies and actions available to address campfire impacts (Table 1), what are some preferred campfire management approaches? Selection of a preferred approach should be based on specific area objectives, which may vary by management zone. For example, permanent campfire bans in areas with insufficient wood production (e.g., deserts, high elevations) or temporal bans during times of high fire danger are prudent and more easily justified. However, this review offers little empirical evidence that fire bans will substantially reduce campfire related impacts. We speculate that this is largely a function of the apparent importance of campfires to visitors, i.e., they are willing to violate regulations to have a campfire. Poor communication of policies may also be a factor, particularly relating to the conveyance of credible rationales for prohibiting campfires. Regardless, the limited success of campfire prohibition policies appears to unnecessarily constrain visitor freedom to have campfires. When such policies are ineffective, they fail to protect natural resources. Yet such policies also prevent visitors from having campfires, which appear to be a desirable and important element of a high quality camping experience.

In contrast, a designated campfire policy effectively reduces firesite proliferation while retaining visitor freedom to have a campfire. Well-anchored firesites also reduce campsite sprawl by concentrating visitor activity to their immediate vicinity (Cole 1992, Marion 1995), and can address campsite proliferation problems by clearly identifying preferred or designated campsites. Although the areas assessed in this study utilized metal fire grates or rings, some managers feel that using such facilities in wilderness, while legal and present in several areas, compromises the philosophy that limits man-made structures. In such instances we suggest that rock campfire rings could be made more permanent by 'ice-berging' or implanting large oblong rocks in a preferred location. To ensure the consistent placement of migrating or proliferating firesites, field staff could also carry photo documentation of campfire locations. In all cases, metal or rock firesites should be limited in size to encourage smaller campfires, which should reduce firewood demand and are easier to clean.

An unregulated campfire policy maximizes visitors' ability to enjoy a campfire, but this review reveals that firesite proliferation is also maximized and tree damage remains high. Problems with multiple and migrating firesites will increase the area affected by camping disturbance. Managers may then be challenged with multiple options: leave all firesites, dismantle all but one firesite, dismantle all firesites and rebuild one in a durable location, or remove all firesites to discourage campfires by less committed or interested visitors. Campfire-related impacts are rarely substantial under conditions of low visitation, as revealed for most of the JNF wilderness areas in this study. In areas of moderate to high visitation, the problems of campsite proliferation and poor location will likely confront managers. If there is a high expectation that visitors will frequently rebuild dismantled firesites, then managers should leave one well-located firesite on each campsite and 'iceberg' rocks and/or use photo documentation to promote its consistent use. Managers could promote an "established firesite" policy to visitors - asking them to use only existing firesites, not to create new firesites or move existing firesites. If visitors are less committed to campfires, then dismantling all firesites may further reduce the frequency of campfire building. However, those firesites that are rebuilt will likely be in different locations over time, a practice that may promote unnecessary and long lasting resource disturbance. Additional research on these topics is needed to provide more definitive guidance.

A number of supporting actions may also contribute to the success of these general strategies and actions. Campfire impacts have been avoided or minimized in some areas by restricting campfires to metal fire pans carried by visitors. This practice is common along rivers with boaters and in areas with horse packers. Backpackers can even carry lightweight fire pans, though this practice remains rare. Construction of mound fires is an alternate low impact practice advocated by the U.S. Leave No Trace program (www.LNT.org). Campfires are built on a thick pad of mineral soil, which protects vegetation and organic layers, and is returned to its source after the fire is completely out. Other low impact campfire practices include using small-diameter dead and down wood, burning all wood to ash, and not burning trash or food in campfires.

No strategy or action investigated in this study effectively avoided or minimized damage to trees, which was extensive in some of the study areas. Further, few of the strategies we've highlighted hold great promise for addressing tree damage impacts. Asking visitors to collect only dead and down wood that can be broken by hand is a start, but its efficacy has not been demonstrated. Leave No Trace educational messages have also advocated leaving axes, hatchets and saws at home. While such efforts should be expanded and continued, we suggest that regulations prohibiting axes, hatchets and saws may be a more effective and justifiable option. Such implements are not essential to having a campfire in areas with sufficient wood to support a campfire policy. Managers would be more likely to support campfire policies if prohibition of these implements successfully reduced tree damage impacts. Thus, limiting one non-essential freedom (carrying such implements) could preserve what seems to be a more important freedom (having a campfire).

CONCLUSION

This meta-analysis and comparison of campfire policies and impacts at multiple sites was conducted to gauge the success of three common campfire policies. We recognize the unavoidable limitations associated with confounding variables such as differing visitor characteristics, use levels, education efforts, forest types and length of time a policy is in effect. We also note that tree damage indicators may reflect the actions of a few visitors practicing depreciative behavior rather than those of most visitors. Notwithstanding these limitations, this study investigated campfire-related conditions at seven separate areas and 1171 campsites, providing a comprehensive review and assessment of alternative campfire policies.

Campfires remain an important part of visitors' camping experiences and an important challenge with which land managers must cope. Findings from this study suggest that restrictive campfire policies such as prohibitions have not succeeded in preventing campfire impacts. Similarly, unregulated campfire use prompts excessive campfire-related resource damage and affects broader campsite impact issues including site expansion and proliferation. Managers seeking a balance between resource protection and visitor experience mandates should consider a designated campfire policy and prohibitions on axes, hatchets and saws. While these are regulatory approaches, they hold the greatest promise for avoiding and minimizing campfire-related resource impacts while preserving the opportunity for visitors to have campfires.

Regardless of the campfire management strategy employed, monitoring efforts can help to assess the extent to which management objectives are being achieved. Longitudinal research and adaptive management case studies can also improve our understanding of resource degradation patterns caused by alternative campfire impact management approaches. Such work can also assist managers in selecting effective management interventions, enabling them to protect natural resources and the quality of visitor experiences.

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