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RESEARCH

A Comparison of Campfire Impacts and Policies in Seven Protected Areas

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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 fire sites and the amount of tree damage. Results indicate that unregulated campfire policies permitted substantial numbers of fire sites and tree damage in campsites, although fire bans did not eliminate or even substantially decrease these problems. A designated campfire policy was effective in decreasing number of fire sites, 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.

Land managers in the United States National Park Service (NPS) and Forest Service strive to balance the dual and often competing mandates of providing for recreational visitation while protecting resources. As managers strive to meet resource protection and recreational access mandates, the monitoring of resource impacts and efficacy of management actions has become an essential component of planning frameworks and land management decision making.

Included under the resource degradation heading are campfire-related impacts, which for 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 (Christensen and Cole 2000). Campfires result in aesthetic and ecologic impacts to protected natural 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 article, we provide a concise yet comprehensive review of the campfire impact literature to establish the ecologic and managerial significance of campfires in backcountry and wilderness settings. Visitor values related to campfires are also reviewed and include 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-related 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 decrease campfire impacts: No research has been undertaken to assess the efficacy of campfire management interventions. Such evaluations could offer managers insights regarding the merit of alternate campfire management policies. Towards this end, this article 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.

KEY WORDS: Campfire impacts; Camping impacts; Recreation impacts; Recreation ecology

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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). 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: fire site proliferation; overbuilt fire sites and associated seating arrangements; fuel wood depletion; sterilized soils; charred rocks and tree roots; ash and charcoal buildup; semimelted plastic, glass, and metal trash; chemical contamination of soils; unburned food, which attracts wildlife; tree damage and felling; and vegetation trampling associated with firewood collection (Bratton and others 1982; Cole 1995; Christensen and Cole 2000; Cole and Dalle-Molle 1982; Davies 2004; Fenn and others 1976; Hall and Farrell 2001; Hammitt 1980; Kendall 1999; Vachowski 1997).

A fire site 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 fire sites in many protected areas. For example, recent studies in the backcountry of Shenandoah and Great Smoky Mountains National Parks revealed a total of 216 and 563 fire sites, respectively (Williams and Marion 1995; Marion and Leung 1997). Similar studies in other areas of the United States have also revealed large numbers of fire sites. 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 fire sites. McEwen and others (1996) surveyed four wilderness areas in the central United States and found a total of 106 fire sites on open campsites. An additional 93 fire sites were located on unused and otherwise recovered campsites, demonstrating the long-term visible effects of fire scars.

Campfires alter soil properties. Fenn and others (1976) measured the effects of campfires on soil regimes and concluded that intense campfires can decrease organic matter content to a depth ≥10 cm. The researchers also found that campfires result in substantial alterations of soil chemistry. The decreases in organic matter and subsequent chemical changes diminish soil fertility and water- holding capacity and make the soil prone to erosion and compaction (Fenn and others 1976). Fire sites 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 fire site ashes. Davies (2004) analyzed gas emissions and ash content from 27 products commonly burned in campfires and found greatly increased levels of a variety of toxic materials including some that pose a threat to human health. Partially burned food items retain odors, thereby promoting attraction behavior among area wildlife.

Although not assessed empirically, land managers also cite broader resource-degradation issues associated with campfires. To accommodate large campfires or bonfires, visitors often build oversized fire rings that char excessive numbers of rocks or burn tree trunks and branches. Tree roots adjacent to fire sites 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 fire sites 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 fire sites migrate to multiple locations.

Firewood collection also degrades natural resources over a larger area for impacts such as vegetation trampling, tree damage, and felling of trees. Tree damage—including broken or cut limbs, 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 (Figure 1) (Cole and Dalle-Molle 1982). Felled trees related to wood-gathering efforts may decrease habitats for cavity-nesting birds while also affecting the 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, sur-

veyors 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 United States 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 examining 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 in 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 during a 50- to 70-year time frame but has negligible effects in the short term. A significant decrease 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 with 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 decrease in woody materials adjacent to campsites when compared with controls, but they only speculated about the potential ecologic effects of such decreases.

Monitoring studies often use the number of informal trails as an indicator of the extent of adjacent offsite 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, although studies in Great Smoky Mountains and New River Gorge have shown totals of 1087 and 221 informal trails, respectively (Marion and Leung 1997, 1998). Although 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.

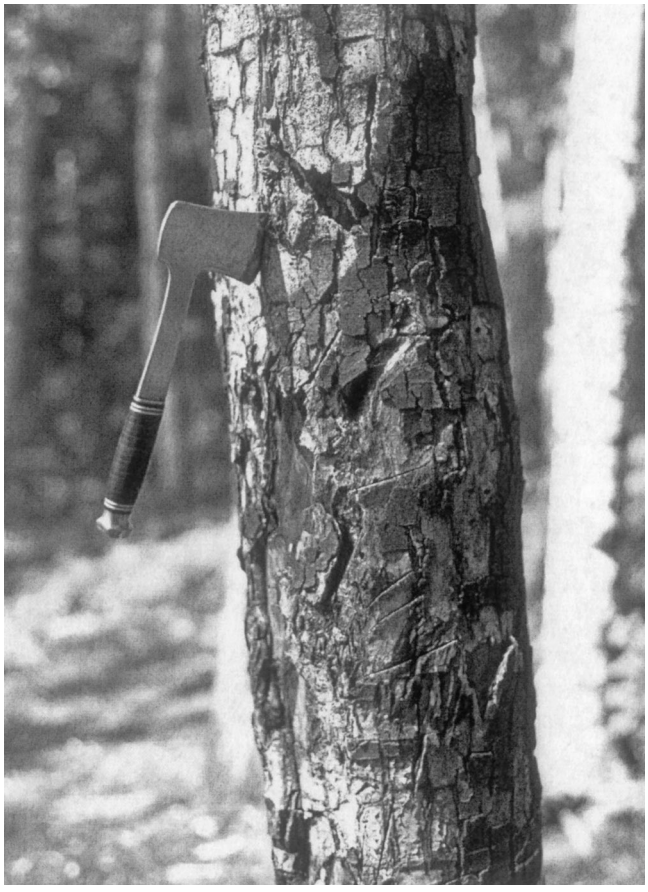

Figure 1. Severe tree damage, such as to this Paper Birch, is aesthetically displeasing to visitors and can kill the tree.

Visitor Values Related to Campfires

Campfires have a long tradition in recreational camping. Although many land managers consider fire sites a degradation of resource conditions, studies have shown that visitors consider a single fire ring to be a desirable campsite amenity (Lucas 1980; Shelby and others 1988; White and others 2001). 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% to 65% of them built at least one campfire during their trip (Christensen and Cole 2000). This study also found that between 41% and 60% of visitors in areas that allowed campfires had a fire for enjoyment purposes only. A study of Appalachian Trail users found that 72% of visitors surveyed opposed or strongly opposed campfire prohibitions (Manning and others 2000). A

survey of visitors to a popular Appalachian Trail camping area in Maryland found that 76% of campers rated having a campfire as a moderately or very important element of their camping experience (Daniels 2004). These findings suggest that campfires hold high value for visitors, even when they 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. For example, hunters and stock users were more accepting of substantial campfire impacts, whereas land managers and conservation group members showed 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 detract from visitors' enjoyment (Lee 1975). A study of eight United States wilderness areas found that only 25% to 50% of visitors believed there were problems with too many fire rings or built-up and trashy fire sites (Christensen and Cole 2000). Visitor-induced tree damage 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, whereas 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, and temporal. 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 and prohibit 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 fire site rehabilitation techniques. Vachowski (1997) summarizes products used to decrease campfire impacts (e.g., fire pans, fire blankets, and fire grates).

Table 1. Campfire-management strategies and actions

Spatial strategy
Established campfires: Permit fires only in established (existing) fire sites
Designated campfires: Require the use of anchored fire grates, fire rings or grills
Communal campfires: Require groups to share common designated fire sites
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 areawide
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
Fire-pan regulations: Require the use of portable fire pans for all fires
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

Adapted from Hammitt (1982) and Cole and Dalle-Molle (1982).

A 1993 survey of NPS backcountry managers found that 43% of managers surveyed reported that campfires 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, whereas 37% required cookstoves. In a similar survey of wilderness managers, Washburne and Cole (1983) found that the United States Fish and Wildlife Service and NPS prohibited campfires in 59% and 43% of their protected areas, respectively. Although the United States Forest Service and Bureau of Land Management rarely prohibited fires (1% and 0%, respectively, of areas), campfires were discouraged in 20% and 36% of areas, respectively (Washburne and Cole 1983).

Constructed campsite facilities of all types have been shown to assist managers with implementing impact-

containment strategies (Bratton and others 1978; Marion and Leung 1997; Marion and Farrell 2002). Fire sites 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 fire grates on campsites attracted and concentrated camping activities near the fire site, thereby shrinking campsite sizes. In contrast, nonpermanently fixed fire sites often migrate around a campsite or develop into multiple fire sites, 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 NPS 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. Study area descriptions were organized by their campfire policies: ''campfire ban'' reflected a policy prohibiting campfires, ''designated campfires'' connoted a restriction of campfires to provided or established fire grates or rings, and ''unregulated campfires'' indicated that visitors are free to select or construct their own campfire sites. Campfire policies have been consistent at each study site for at least the preceding 12 years, unless otherwise stated. More detailed information about the study areas, research methods, and findings may be obtained from the original research reports listed for each study area. The number of campsites included in this study may be a subset of campsites present in each study area.

Campfire Ban

Shenandoah National Park (SHEN) is a 79,061-ha forested linear park in north-central Virginia that receives 45,729 overnight visitors/y. Backpackers are the predominant users of undesignated campsites (N = 221), and campfires have been banned since 1974 (Williams and Marion 1995).

Big Bend National Park (BIBE) is a 324,21- ha park located in southwest Texas along the Mexican border. The park receives 50,193 overnight visitors/y. Monitoring data are presented only for backpacking campsites in the Chisos Mountains portion of the park and for undesignated trail-accessed campsites throughout the park (Williams and Marion 1996). Campfires have been prohibited at these campsites (N = 155) for at least 15 years before the monitoring assessment.

Isle Royale National Park (ISRO), located in northern Michigan, is a 231,39-ha island park that receives 46,625 overnight visitors/y. Backpackers and boaters camp at primitive shelters and designated campsites. Campfires are prohibited at 206 campsites (denoted ISRON) but are permitted in designated fire grills and communal fire rings at 38 sites (denoted ISROF) (Farrell and Marion 1998).

Designated Campfires

Isle Royale National Park, 38 campsites as previously noted. Delaware Water Gap National Recreation Area (DEWA) is a 28,328-ha river park located along the border of Pennsylvania and New Jersey. This park receives 33,184 overnight visitors/y. Campsite monitoring was restricted to the riparian zone and included 85 designated campsites used mostly by canoeists and some fishermen (Marion 1994). Campfires are permitted only within fire grates.

Unregulated Campfires

The New River Gorge National Park (NERI) in West Virginia is a 28,329-ha river park that receives 13,333 overnight visitors/y, mostly whitewater rafters, canoeists, and fishermen. Campsites are undesignated (N = 77), and there are no restrictions on campfires (Leung and Marion 1998).

The Forest Service–managed Jefferson National Forest (JNF) is located primarily in southwestern Virginia. Campsites were assessed in 11 wilderness areas (23,068 ha) where backpacking is the predominant overnight use (Leung and Marion 1995). Camping occurs on 168 undesignated campsites, and campfires are unregulated.

Great Smoky Mountain National Park (GRSM), in North Carolina and Tennessee, is a mountainous park with 208,367 ha and 96,459 overnight visitors/y. Backpackers are the primary overnight visitors, and they are required to camp at designated campsites (N = 221) (Marion and Leung 1997). Campfires are unregulated.

Methods

Selection of Indicators

Campfire impact indicators include the number of fire sites 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 fire sites is a direct measure of campfire impacts. The number of damaged trees reflects damage from the cutting or breaking of limbs for firewood as well as 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 of felled trees (stumps) were also assessed but were not reported because of the confounding influence of hazard tree removal work, which also occurs in some of the study areas but not in others.

Field Measurements

After undergoing 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. The objective at each study area was to conduct a census; field staff followed a uniform set of procedures for locating campsites that included consulting with knowledgeable managers and conducting exhaustive ground-based searches to locate all campsites. Campfire impact–indicator measurements were consistently applied across each area, except where noted. Quality assurance measures—including periodic comparative assessments, midseason evaluations, and alternation of field partners—were applied.

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

Tree damage was assessed for all trees located within or on campsite boundaries at each study area. Tallies were recorded for each damaged tree, defined as ''numerous small trunk scars and/or nails, one moderate-sized scar, or any complete girdling of tree (cutting through bark and outer wood all the way around tree)'' (Marion and Leung 1997). The same set of color photographs with descriptive text was used for training and field reference to illustrate qualifying tree damage. We note that the qualifying damage almost always resulted from the use of axes, hatchets, and saws, implements associated with firewood collection and preparation.

Data Analysis

Measures of indicators were numerically transformed to standardize the data to permit appropriate comparisons among study areas. Comparison of fire sites was performed using data from all surveyed campsites. To facilitate comparison, campsites containing more than four fire sites were categorized into one class of greater than four. Tree damage indicators were computed only for campsites that contain trees within their boundaries. One potential study limitation is that campsite sizes varied between study areas and this may have affected tree-damage measures. A direct comparison of tree damage can therefore be misleading. Similarly, tree density within a given area will also determine the number of trees that could potentially be damaged. These problems were addressed by calculating the number of damaged trees per hectare for each campsite based on its size and presenting a frequency distribution of these data for each study area. The actual number, average, and percent of damaged trees per campsite were also reported by study area. For all campfire-impact indicators, the numbers of campsites in each prospective category were reported as percentages to permit appropriate comparisons between areas with varying numbers of campsites. Inferential statistical testing is inappropriate for evaluating differences in these data because they are derived from a census; field staff located and assessed all campsites in each study area.

Results

Number of Fire Sites

The numbers of fire sites were decreased, but not eliminated, by prohibiting campfires. For the three areas with a campfire ban, the mean number of fire sites ranges from 0.01 to 1.0 (average 0.5), and the percentage of campsites with one or more fire sites ranged from 11% to 66% (average 35%) (Table 2). Under the designated campfire policy, the mean number of fire sites per campsite was 1.1, and 93% of the campsites had one or more fire sites (92% have 1 or no fire sites) (Table 2). Under the unregulated fire site policy, the mean number of fire sites ranged from 1.1 to 1.7 (average 1.5, indicating that an unregulated campfire policy may lead to multiple fire sites on campsites). The percentage of campsites with one or more fire sites ranges from 89 to 99% (average 95%) (Table 2).

Tree Damage

For the standardized number of damaged trees per hectare measure, results indicated that campfire bans do not even approach the elimination of tree damage (Figure 2a). SHEN and BIBE had the highest per-

Table 2. Fire site measures: number, average per campsite, and percentage of campsites with one or more firesites

	Campfire ban			Designated campfires		Unregulated camfires		
Indicator	BIBE (N = 155)	SHEN (N = 221)	ISRON (N = 206)	DEWA (N = 85)	ISROF (N = 38)	GRSM (N = 327)	JNF (N = 168)	NERI (N = 111)
No. fire sites	40	216	24	92	38	563	192	192
Arg. no. of fire sites	0.3	1.0	0.01	1.1	1.0	1.7	1.1	1.7
Firesites (%)[a]	23	66	11	91	100	99	92	89

[a]Percentage of campsites with one or more firesites.

BIBE = Big Bend National Park; DEWA = Delaware Water Gap National Recreation Area; GRSM = Great Smoky Mountains National Park; ISROF = Isle Royale National Park, fires permitted; ISRON = Isle Royale National Park, fires prohibited; JNF = Jefferson National Forest; NERI = New River Gorge National Park; SHEN = Shenandoah National Park.

centage of campsites with no tree damage—61% and 58%, respectively—whereas ISRON had the lowest (43%) (Figure 2a). Areas with designated campfire policies did have somewhat greater levels of tree damage; at ISROF, 42% of campsites lacked damaged trees compared with 25% at DEWA (Figure 2b). However, the areas with campfire bans had more campsites with higher densities of damaged trees (compare Figures 2a and 2b). These findings were similar to those in areas with unregulated campfires; JNF had 68% of its sites with no damaged trees compared with 38% at NERI and 33% at GRSM (Figure 2c).

Nonstandardized statistics for the number, average, and percent of damaged trees on a per-campsite basis provided an alternative context for examining tree damage (Table 3). Findings revealed that 511 damaged trees were found on campsites in the three areas with campfire bans (1.6 damaged trees/site), clearly indicating that a campfire ban is ineffective in eliminating damage to campsite trees. Data for the percentage of damaged trees on campsites in areas with campfire bans ranged from 28% to 78%, supporting this assertion (Table 3). Mean number of damaged trees increased substantially to 4.2 trees/site for areas with designated campsites, although the percentage of damaged trees was roughly equivalent to areas with a fire ban (59% to 77%) (Table 3). Areas with unregulated campfire policies also had a high mean number of damaged trees (3.8 trees/site), but the percentage of damaged trees was somewhat lower (35% to 52%).

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, with JNF and NERI placing the least focus on education during the year preceding data collection. There was no coherent pattern to the distribution of campfire impacts based on these three educational-effort groupings.

Discussion

Number of Fire Sites

As might be expected, campfire bans greatly increase the proportion of campsites with no fire sites, but they do not eliminate fire sites. Given the intent of the policy to decrease the number of fire sites to zero, these data suggest that campfire bans are not very successful. For example, field staff at SHEN found 216 illegal fire sites, and one or more fire sites were present on 66% of the campsites. However, management success was somewhat better at BIBE and ISRON (Table 2). The designated campfire policy greatly increased the proportion of campsites that have no more than one fire site. The two parks implementing this policy have successfully limited the number of fire sites to one or fewer at 92% of the campsites. An unregulated campfire policy increases the proportion of campsites that have more than one fire site. Proliferation of fire sites is clearly problematic for managers at GRSM and NERI, where 35% and 39% of campsites, respectively, contain multiple fire sites.

Damaged Trees

Areas with campfire bans still have damaged trees (Figure 2a). However, areas with campfire bans also tend to have a greater proportion of campsites with no damaged trees than areas with other campfire policies. The exception to this finding was JNF, an area with unregulated campfires in which 68% of campsites surveyed had no damaged trees (Figure 2c). Although use figures are unavailable for JNF, most of its wilderness areas receive limited visitation. With the exception of JNF, areas with either designated or unregulated campfire policies had higher percentages of campsites, in the range of 1 to 250 damaged trees/ha, than did campsites without tree damage (Figures 2b and 2c). These results suggest that in areas where campfires are permitted, more campsites will experience low levels of tree damage.

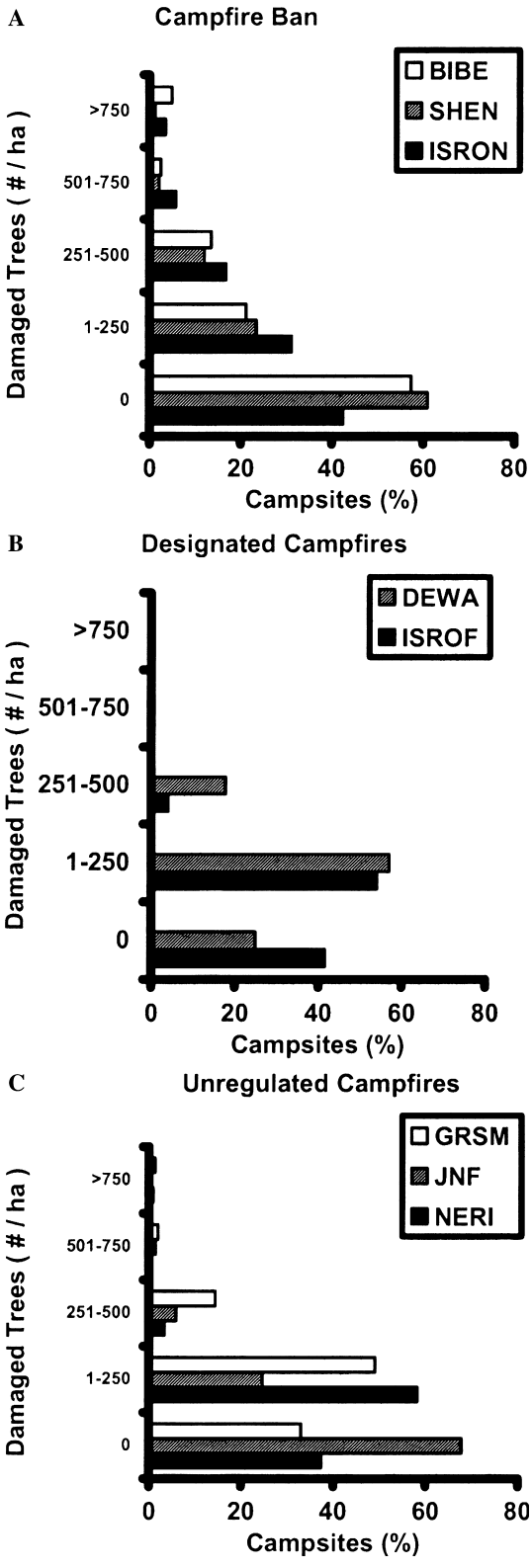

Figure 2. Damaged trees in (a) areas with a campfire ban policy, (b) areas with a designated campfire policy, and (c) areas with an unregulated campfire policy.

Management Implications

The different campfire policies and large number of campsites investigated in this study prompted the expectation of substantial differences in campfire-related impacts from contrasting campfire policies. However, study findings found no clear policy that effectively limited fire site proliferation and tree damage. Campfire bans were somewhat to largely ineffective in deterring visitors from building campfires or damaging trees. Furthermore, the repeated creation, destruction, and relocation of fire sites in areas with fire bans exacts a heavy toll in resource damage and staff time. A designated campfire policy appears to constrain the proliferation of fire sites but provides no obvious advantage with regard to limiting tree damage. An unregulated campfire policy and heavy visitation will likely result in higher levels of 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 decrease 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 visitors' freedom to have campfires. When such policies are ineffective, they fail to protect natural resources. However, 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 decreases fire site proliferation while retaining visitors' freedom to have a campfire. Well-anchored fire sites also decrease 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 used metal fire grates or rings, some managers believe that

Table 3. Damaged tree measures: total number, average number per campsite, and percentage of total on-site trees

	Campfire ban			Designated campfires		Unregulated campfires		
Indicator	BIBE (N = 40)[a]	SHEN (N = 168)	ISRON (N = 101)	DEWA (N = 78)	ISROF (N = 12)	GRSM (N = 242)	JNF (N = 75)	NERI (N = 103)
No. of damaged trees	64	190	257	359	24	1128	135	335
Avg. no. of damaged trees	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

[a]For all areas, number of campsites surveyed that have trees within site boundaries.
BIBE = Big Bend National Park; DEWA = Delaware Water Gap National Recreation Area; GRSM = Great Smoky Mountains National Park; ISROF = Isle Royale National Park, fires permitted; ISRON = Isle Royale National Park, fires prohibited; JNF = Jefferson National Forest; NERI = New River Gorge National Park; SHEN = Shenandoah National Park.

using such facilities in wilderness, although 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 ''iceberging'' or implanting large, oblong rocks in a preferred location. To ensure the consistent placement of migrating or proliferating fire sites, field staff could also carry photo documentation of campfire locations. In all cases, metal or rock fire sites should be limited in size to encourage smaller campfires, which should decrease firewood demand and are easier to clean.

An unregulated campfire policy maximizes visitors' ability to enjoy a campfire, but this review suggests that fire site proliferation and tree damage could be high. Problems with multiple and migrating fire sites will increase the area affected by camping disturbance. Managers may then be challenged with multiple options: leave all fire sites, dismantle all but one fire site, dismantle all fire sites and rebuild one in a durable location, or remove all fire sites to discourage campfires by less committed or interested visitors. Campfire-related impacts are rarely substantial under conditions of low visitation, as was seen with 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. We suggest that if there is a high expectation that visitors will frequently rebuild dismantled fire sites, then managers should leave one well-located fire site on each campsite and ''iceberg'' rocks and/or use photo documentation to promote its consistent use. Managers could promote an ''established fire site'' policy to visitors, i.e., ask them to use only existing fire sites and not to create new fire sites or move existing fire sites. If visitors are less committed to campfires, then dismantling all fire sites may further decrease the frequency of campfire building. However, those fire sites that are rebuilt will likely appear in different locations with 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 is a common practice for vehicle-supported campers, boaters, and horse packers. Backpackers can even carry lightweight fire pans, although this practice remains rare. Construction of mound fires is an alternate low-impact practice advocated by the United States. Leave No Trace program (www.LNT.org). Campfires are built on a thick pad of mineral soil, which protects vegetation and organic layers, and this 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. Furthermore, few of the strategies we have 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. Although 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 decreased tree damage impacts. Thus, limiting one nonessential 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, campsite sizes, and education efforts. 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 with 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 protected-area 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, particularly campsite 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. Although these are regulatory approaches, they appear to 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, thus enabling them to protect natural resources and the quality of visitors' experiences.

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