Campsite Impact on Three Western Wilderness Areas

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ABSTRACT / Campsites were studied in subalpine forests in the Eagle Cap Wilderness in Oregon, and in the Mission Mountains Tribal Wilderness and the Rattlesnake Wilderness in Montana. Research objectives were to examine ecological changes on these sites and the extent to which these changes become more pronounced as use increases. For most parameters measured, impact on campsites used for only a few nights per year exceeds threshold values beyond which further increases in use have little effect. Loss of litter, tree root exposure, and site enlargement are the major types of alteration that are more pronounced on sites occupied more frequently than several nights per year. In heavily used parts of backcountry areas, this suggests that ecological change can be minimized by limiting use to a small number of sites. In the three areas studied, campsite occupancy rates would probably have to be no higher than a few nights per year before dispersal of use among a large number of sites would be an ecologically sound strategy.

Of the many difficult tasks facing wilderness professionals, management of backcountry campsites is one of the most troublesome. The nature and severity of ecological impact on campsites are a function of the amount, frequency, timing, and type of use a site receives, as well as the characteristics of the site itself. All of these variables are subject to manipulation by the manager. A major challenge to wilderness research is to improve our understanding of these functional relationships to the point where managers can curtail site deterioration without unnecessarily detracting from the wilderness values of freedom and lack of regulation.

It has usually been assumed that the most important determinant of site impact is the amount or frequency of use that a site receives. Thus, many areas have attempted to reduce use in popular areas either by limiting use or by encouraging parties to camp in less popular areas. Research on this subject, however, is inconclusive. In what is now the River of No Return Wilderness in Idaho, Coombs (1976) found that frequently used sites had considerably less vegetation cover and more erosion pavement than infrequently used sites. In the more heavily used Boundary Waters Canoe Area in Minnesota, Frissell and Duncan (1965) found very little difference in understory vegetation cover between frequently and infrequently used sites. In the very heavily used Great Smoky Mountains National Park backcountry, Bratton and others (1978) report a strong positive correlation between amount of use and the areal extent of various types of site damage. They, however, were examining sites occupied almost every night by more than one party. The more heavily used sites have to accommodate more parties per night, so the size of the area affected is larger. This does not shed any light on how the frequency with which any site is used affects the severity of alteration on that site.

KEY WORDS: Wilderness; Backcountry management; Ecological impact; Campsites

This paper examines the relationship between frequency of campsite use (number of parties/season) and amount of impact on three separate wildernesses, two in western Montana and one in northeastern Oregon (Figure 1). The Montana and Oregon case studies were conducted independently and rather different field methods were used. The results of these studies have been combined in this jointly authored paper because the conclusions and implications of both studies were so similar despite differences in methods and environmental situations and because both studies posed the same two basic questions. Those questions were 1) how much change has occurred on campsites and 2) to what extent can differences in amount of change be related to differences in frequency of use.

The Study Areas

The Eagle Cap Wilderness is located in the Wallowa Mountains of northeastern Oregon. Almost 120,000 ha in size and the largest wilderness in Oregon, the Eagle Cap received about 100,000 visitor days of use in 1979. On a use per hectare basis, this is well below the average for the National Wilderness Preservation System as a whole (Hendee and others 1978). About 25 percent of the parties staying overnight have packstock, and about two-thirds of the use is during the summer months, June through August.

All of the campsites studied were located close to lakes, at elevations between 2,150 and 2,400 m. They were all located in forests, with an overstory primarily of *Abies lasiocarpa* and an understory of *Vaccinium scoparium* (Figure 2). Soils were coarse sandy loams derived from granitic bedrock. This limita-

Aldo Leopold Wilderness Research Institute: Publication # 116
CITATION : Cole, David N.; Fichtler, Richard K. 1983. Campsite impact on three western wilderness areas. Environmental Management. 7(3): 275-288.

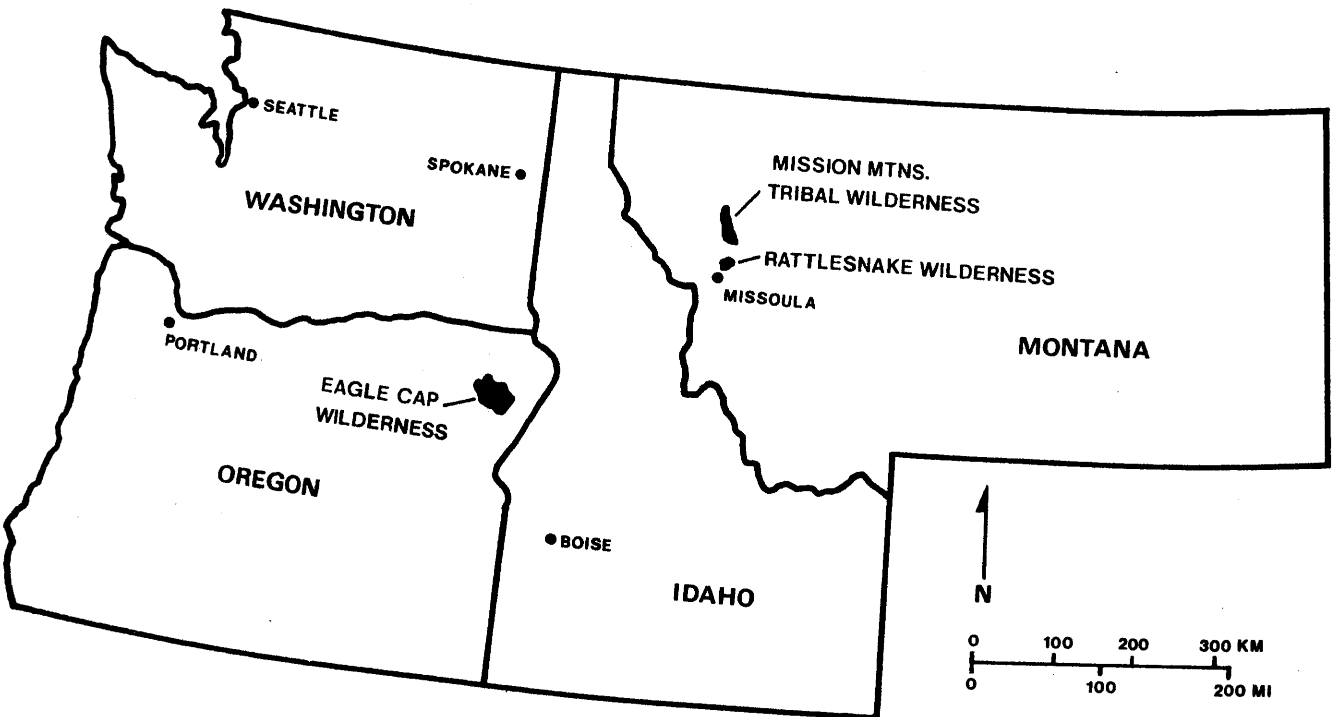

Figure 1. Location of the three study areas.

Figure 2. Two of the campsites sampled in the Eagle Cap Wilderness were located close to Mirror Lake.

tion of environmental variability was imposed so that differences resulting from amount of use could be more precisely delineated.

The Rattlesnake Wilderness, immediately to the north of Missoula in western Montana, became a classified wilderness in 1980. It is about 8,000 ha in size. Although no accurate use data are available, the Rattlesnake is almost certainly less heavily used than the Eagle Cap. During the summer of fieldwork, less than 5 percent of the parties using the study sites had packstock.

The campsites studied were located in subalpine *Abies lasiocarpa* forests around lakes. Elevations were between 1,800 and 2,250 m. The undergrowth on most sites consisted primarily of *Xerophyllum tenax* and *Vaccinium scoparium*.

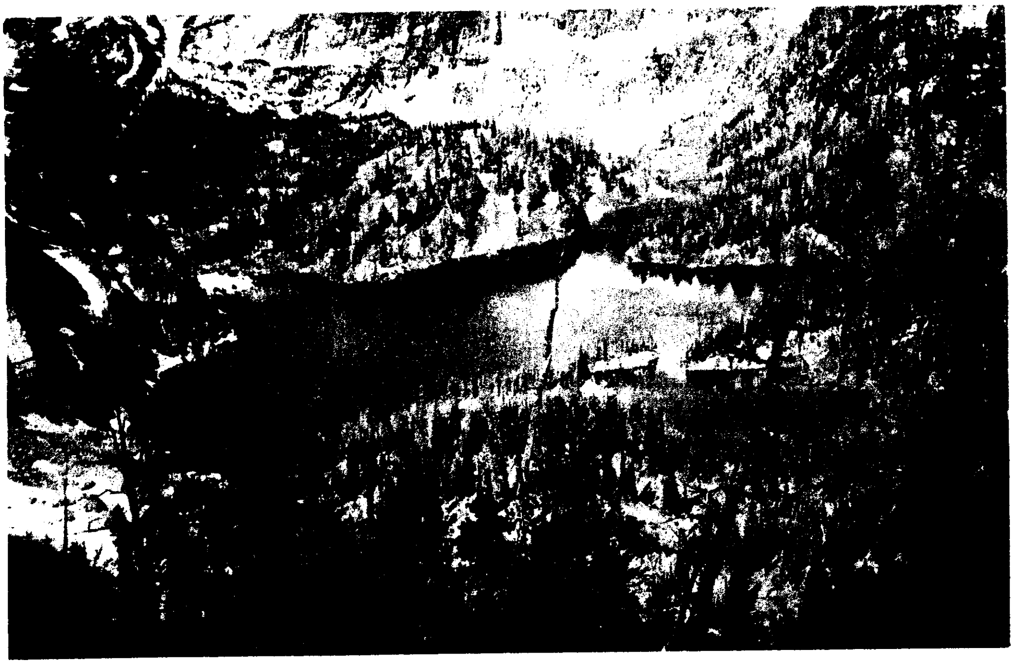

Figure 3. Two of the campsites sampled in the Mission Mountains Tribal Wilderness were located close to Cliff Lake.

On a few sites, the undergrowth was predominantly *Menziesia ferruginea* or lush forbs, such as *Senecio triangularis*. Soils were generally loams developed in volcanic ash deposits.

The Mission Mountains Tribal Wilderness is north of the Rattlesnake Wilderness in western Montana. Owned by the Confederated Salish and Kootenai tribes, this 38,000 ha area adjoins the 30,000 ha Mission Mountains Wilderness administered by the United States Department of Agriculture (USDA) Forest Service. Again no use data are available, but this area is probably the least heavily used of the three study areas. During the summer of fieldwork, about 15 percent of the parties using the study sites had packstock.

The campsites here were also located in subalpine *Abies lasiocarpa* forests around lakes, at elevations between 1,650 and 2,100 m (Figure 3). The undergrowth on most sites consisted primarily of *Menziesia ferruginea,* but the undergrowth on a few sites consisted of lush forbs, such as *Senecio triangularis.* Soils were generally loams developed in volcanic ash deposits.

Methods

The methods employed in the Eagle Cap study were somewhat different from those used in the other two areas. In the Eagle Cap, a total of 22 campsites were studied. Six sites were classified as light-use sites. Using permit data, personal observations, and discussions with rangers, we estimated that these sites are used less than 5 nights per year; some of them receive no use in some years. Estimated use frequencies were 10 to 20 nights per year for the six moderate-use sites, and 25 to 50 nights per year for the 10 heavy-use sites.

In the Missions and Rattlesnakes, visitor registration boxes were placed at each campsite. Use data were collected for one season and compliance was checked by observation. The light-use sites studied were used for 5 nights or fewer (<25 visitor days) during the year of study, while the more frequently used sites were used 10 to 21 nights (50–125 visitor days). Because these use frequencies correspond so closely to those of the light- and moderate-use sites in the Eagle Cap, the more frequently used sites will be considered only moderate-use sites. Six light-use and eight moderate-use sites were studied in the Mission Mountains; 12 light-use and nine moderate-use sites were studied in the Rattlesnake.

Eagle Cap Methods

Each sample site consisted of both a campsite and an undisturbed control site in the vicinity. The distances from an arbitrarily established center point to the edge of the campsite and to the first significant amount of vegetation were measured along 16 transects. This defined the campsite area and the area of the barren central core (bare area). Tree seedlings (15 to 140 cm tall) were recorded within the camp area, excluding any untrampled "islands"; larger trees were counted within the

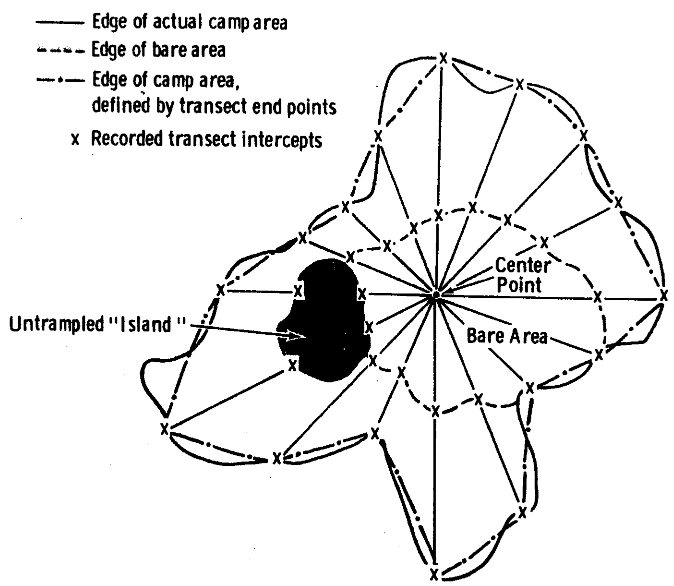

Figure 4. Example of transect layout used in the Eagle Cap to determine camp area and bare area.

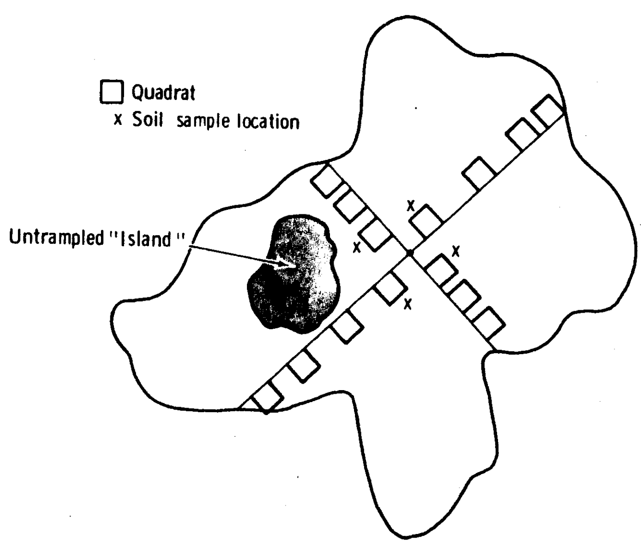

Figure 5. Example of quadrat layout and location of soil samples on an Eagle Cap campsite.

entire camp area (Figure 4). Any human damage to trees was noted.

On each campsite, approximately 15 quadrats, 1-m by 1-m square, were located along four transects, originating at the center point and oriented perpendicular to each other. The distance between successive quadrats decreased with distance from the center point, so that the central part of the site was not over sampled (Figure 5). In each quadrat, we estimated the

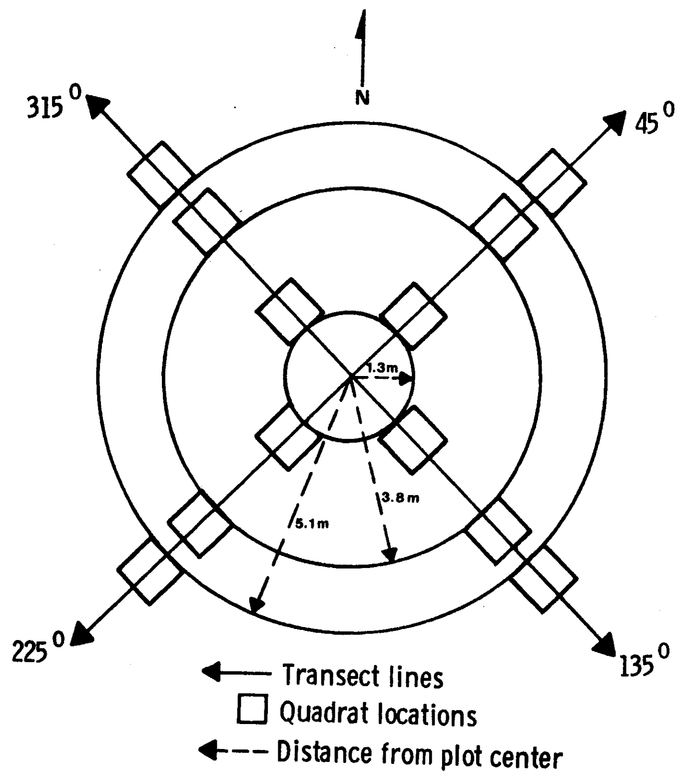

Figure 6. Example of quadrat layout used in the Mission Mountains and Rattlesnakes.

canopy cover of total ground vegetation, exposed mineral soil, each vascular plant species, and mosses collectively. Coverages were estimated to the nearest percent if under 10 percent or, in 10 percent coverage classes, between 10 and 100 percent. The midpoints of each class were used to calculate means for each variable.

We collected information on soil properties we thought might be affected by recreational use. Soils were sampled between 1 and 2 m from the center point along each of the four transects. The depth of the organic litter and fermentation (0) horizons (duff depth) was measured. The pH was determined by the colorimetric method in the field. Infiltration rates were measured with a double ring infiltrometer. The rate that the first cm of water entered the soil was called the instantaneous infiltration rate, while the rate for the first 5 cm was called the saturated rate. Both were expressed in cm/min. Volumes for bulk density calculations were determined by measuring the amount of water required to fill a hand-excavated, cellophane-lined hole 5-cm deep by about 9-cm in diameter. The excavated soil was removed in plastic bags for weight determination and other soil analyses. Bulk density and pH measurements were taken in the uppermost portion of the mineral soil, after the organic horizons had been removed.

Table 1. General characteristics of the campsites in the Eagle Cap Wilderness.

Camp area (m^2)	Bare area (m^2)	Injured trees (%)	Trees with exposed roots (%)	Felled trees (%)	Scarred trees (%)	Floristic dissimilarity[1] (%)
			Median			
193	87	96	32	28	25	59

[1]A measure of the percent change in species composition on the campsite relative to the paired control site.

On the control plots, which varied in size between 91 and 201 m^2, we estimated the coverage of total vegetation, exposed mineral soil, each vascular plant species, and mosses, for the entire plot. Seedlings were counted on a 50-m^2 circular subplot placed in the center of the control. Four sets of soil measurements and samples, identical to those on campsites, were taken.

Soil samples were analyzed at the Montana Forest and Conservation Experiment Station, Missoula, Montana. Each sample was oven dried and weighed to determine bulk density. Nitrate (NO_3) content was determined before drying by using the Specific Ion Analyzer. The four soil samples for each campsite were then passed through a 2-mm screen and composited. Calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na) concentrations were determined by extraction in 1N ammonium acetate and analysis with the Atomic Absorption Spectrophotometer. Phosphate (PO_4) was extracted with dilute acid fluoride and its concentration determined by molybdenum blue stannous chloride color reaction; total nitrogen (N) was determined by using the modified microkjeldahl procedure (Hesse 1972). Organic matter content was determined by combustion at 525°C.

Change in species composition was measured with the following coefficient of floristic dissimilarity:

$$FD = 0.5 \sum |P_1 - P_2|$$

where P_1 is the relative cover of a given species on the control plot and P_2 is the relative cover of the same species on the campsite (Cole 1978).

Rattlesnake and Mission Mountain Methods

As in the Eagle Cap study, measurements were taken on both campsites and control plots. All trees (taller than 140 cm) on the campsite were counted and damage was noted. The length of exposed roots greater than 2.5-cm in diameter was measured on these trees and the percentage of the root bark that had been abraded was estimated. Seedlings (15 to 140 cm tall) were counted on 50-m^2 circular subplots, both on campsites and controls.

Soil compaction, mineral soil cover, vegetation cover, and species composition were studied on a series of 1-m by 1-m quadrats established on both campsites and controls. These quadrats were located 1.3 m, 3.8 m, and 5.1 m from an arbitrarily established center point, along transects oriented at 45°, 135°, 225°, and 315° from true north (Figure 6). Any quadrat that fell outside of the campsite was not included. Larger sites had the full 12 plots, while smaller sites had as few as four.

In each quadrat, we estimated the coverage of total vegetation, exposed mineral soil, each vascular plant species, and mosses, to the nearest 5 percent. Two soil compaction measurements on each quadrat were taken with a pocket soil penetrometer. Floristic dissimilarity was calculated as in the Eagle Cap study.

Although each of these studies used a different sampling design and measured different sets of parameters, the estimates of vegetation cover, mineral soil cover, and floristic dissimilarity should be directly comparable. Tree injury estimates are not comparable because trees with cut or broken lower branches were considered to be injured in the Eagle Cap study, but not in the Montana studies. Interpretation of the seedling data is also not comparable because in the Eagle Cap study only on-site seedlings were counted, while in the Montana study off-site seedlings were counted if they were within the 50-m^2 circular subplots centered on each campsite. All of the other parameters measured were unique to one of the studies.

Data Analysis

The amount of change that has occurred is inferred from comparisons of campsites and controls. We calculated both absolute change—the difference between the measure on the control site and the measure on the campsite—and relative change—the absolute change expressed as a percentage of the measure on the control site. Where control conditions are variable, relative change provides a more valid basis for site-to-site comparisons than absolute change. In both cases, negative values indicate higher values on the campsite.

Two different analyses were used to determine the statistical significance of results. The first analysis involved testing whether campsites were significantly different from controls. The Wilcoxon matched-pairs signed-ranks test (Siegel 1956) was used to test the null hypothesis that campsite characteristics were identical to controls. Standard parametric techniques

Table 2. Median conditions on campsites and controls in the Eagle Cap Wilderness and estimates of amount of change.[1]

	Seedlings	Vegetation	Mineral soil	Duff depth	Organic matter	Bulk density	Instantaneous infiltration rate
	(#/ha)	(%)	(%)	(cm)	(%)	(g/cm^3)	(cm/min)
Campsite	329	6	31	0.25	18	0.95	0.33
Control	2,647	61	1	.53	15	.88	.59
Absolute change	2,266	47	−25	.30	−2	−.11	.19
Relative change (%)	92	87	−1,598	51	−20	−15	29
Significance	<.001	<.001	<.001	<.001	.027[2]	.047	.003

[1]Absolute change is the control value minus the campsite value; relative change is the absolute change divided by the control value. Positive values indicate reduced campsite values and negative values indicate increases on campsites. Significance was tested with the Wilcoxon matched-pairs, signed-ranks test. Differences were considered significant if the level of significance was less than .05.

[2]Two-tailed tests were used because the direction of change was not predicted. All other tests were one-tailed.

were invalid because populations were not normally distributed and sample size was small. Medians are the primary measure of central tendency reported. Statistics depicting variability can be found in Fichtler (1980) and Cole (1982).

The second set of tests determined whether the amount of difference between campsites and controls was related to frequency of use. Two tests were used to examine the null hypothesis that frequency of use had no effect on differences between campsites and controls. For the Eagle Cap data, which had three use categories, we used Kendall's tau; the Mann-Whitney *U* test was used for the Mission Mountains and Rattlesnake data (Siegel 1956).

Amount of Change

Eagle Cap Results

If we use the median value for all sites, regardless of amount of use, as a measure of the average campsite, sites in the Eagle Cap are typically almost 200-m^2 in size (Table 1). Almost all of the trees on these sites have been injured. Although the damage to many of these trees is relatively minor, over one-half of the trees have been felled or have scars on their boles and about one-third of the trees have exposed roots.

Despite this high frequency of injury, there is little evidence of recreation-caused tree mortality or reduction in vigor, aside from outright felling and situations in which tying horses to trees has resulted in girdling. Much more significant is the elimination of more than 90% of the tree reproduction (Table 2). The few seedlings that have survived are confined to sites that are protected from trampling. Along with the loss of saplings to felling, this forecasts a lack of trees to replace the overstory trees when they eventually die. Continued replacement of trees will probably be one of the major challenges to long-term site maintenance.

The loss of undergrowth vegetation has also been severe: typically, 85 to 90% has been lost, leaving a sparse vegetation cover quite dissimilar in composition to undisturbed sites. The median measure of floristic difference between campsites and controls was 59% (Table 1). The central core of the campsite, which is completely devoid of vegetation, is typically about 90 m^2, almost one-half of the camp area (Figure 7).

In addition to removing vegetation, trampling has also broken up and eroded away much of the soil organic horizon. The mineral soil that is exposed typically covers over 30% of the campsite, despite being virtually absent on control sites. The depth of the remaining organic horizons (duff) is 50% less on campsites than on controls. Some of the organic matter pulverized by trampling must move down and accumulate in the uppermost mineral horizons, because the organic matter content of the upper 5 cm of the A horizon is 20% higher on campsites than on controls (Table 2).

Soil has also been compacted on campsites, where bulk densities are typically about 15% higher and infiltration rates are about 30% lower than on controls (Table 2). The magnitude of these changes was much less than expectations based on the results of other studies (for example, Brown and others 1977; Monti and Mackintosh 1979; James and others 1979). High organic matter and sand content may make the soil relatively uncompactable and naturally hydrophobic (Singer and Ugolini 1976).

Finally, several statistically significant changes in soil chemistry were found (Table 2). Soil pH increased slightly from median values of 5.13 on controls to 5.48 on campsites. Mg and Ca concentrations doubled and Na concentration increased significantly on campsites. Concentrations of NO_3, K, and total N also increased, but the results were so variable that a significant difference could not be established. PO_4 content did not differ. These nutrient increases probably result from the scattering of materials, such as campfire ashes, excess food, and

Table 2. (Continued)

Saturated infiltration rate	pH	NO_3	K	Mg	Ca	Na	PO_4	Total N
(cm/min)		(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
0.16	5.48	7.6	195	61	528	53	14	3,193
.25	5.13	3.6	167	39	287	45	11	2,342
.09	−.50	−4.1	−40	−23	−300	−6	.8	−165
33	−9	−68	−28	−107	−101	−13	2	−5
<.001	$.003^2$	NS^2	NS^2	$.001^2$	$.002^2$	$.014^2$	NS^2	NS^2

Figure 7. This campsite at Chimney Lake illustrates the tree damage, lack of vegetation, and patchy duff cover that are characteristic of most campsites.

soap, as well as from reduced leaching as a result of slower infiltration rates (Young and Gilmore 1976).

Mission Mountain and Rattlesnake Results

On Mission Mountain and Rattlesnake campsites about two-thirds of the trees had bole injuries or had been felled (Table 3). Trees with cut or broken lower limbs were not considered to be injured, so the percent of trees that were injured was less than in the Eagle Cap study, where trees with cut or broken branches were considered to be injured.

Tree root exposure is also prevalent on Mission Mountain and Rattlesnake campsites, as it was in the Eagle Cap. Typically, the length of exposed roots over 2.5-cm in diameter is low, 56-cm per site in the Mission Mountains, and 20-cm per site in the Rattlesnake. Extent of exposure is highly variable, however; some sites have over 500-cm of exposed roots. The extent to which the bark on exposed roots has been

Table 3. General characteristics of the campsites in the Mission Mountains Tribal and Rattlesnake Wildernesses.

Mission Mountains Tribal Wilderness				Rattlesnake Wilderness			
Injured trees (%)	Root exposure (cm)	Root bark removed (%)	Floristic dissimilarity[1] (%)	Injured trees (%)	Root exposure (cm)	Root bark removed (%)	Floristic dissimilarity[1] (%)
Median							
71	56	2	48	60	20	1	27

[1]A measure of the change in species composition on the campsite.

abraded is also quite variable. On most sites essentially no bark removal was found; on a few, as much as 40 to 50% of the bark had been removed.

Seedling loss on the Mission Mountain and Rattlesnake sites has been high; a typical site has lost over two-thirds of its seedlings (Table 4). This measure of loss would certainly have been even greater (as it was in the Eagle Cap) if seedlings in untrampled areas off the campsite, but within the 50-m^2 sample plot, had not been counted.

Loss of vegetation has been pronounced, but less so than on Eagle Cap campsites. Mission Mountain campsites have typically lost 72% of their cover, while Rattlesnake sites have lost 55%. These differences reflect differences in the susceptibility of the vegetation to trampling damage. *Xerophyllum tenax,* the most abundant undergrowth species on most of the Rattlesnake campsites, is highly resistant to trampling. Even where trampling is severe enough to break off most of the straplike leaves, resistant clumps survive. *Menziesia ferruginea,* dominant on most of the Mission Mountain campsites, has brittle, easily broken branches and stems, although the large size of these plants provides some protection. However, *Vaccinium scoparium,* dominant on the Eagle Cap campsites, has brittle stems and branches and is low growing; it has been almost eliminated.

The resistance of the understory dominants also influences the magnitude of change in species composition. Floristic dissimilarity values are highest in the Eagle Cap and lowest in the Rattlesnake. The median floristic dissimilarity value of 27% for the Rattlesnake sites is not higher than typical values for stand-to-stand variability (Cole 1978), suggesting that there has been very little change in species composition as a result of recreational use.

Increased exposure of mineral soil occurred on campsites, but the median absolute increases of 6% in the Mission Mountains and 11% in the Rattlesnake were less pronounced than the 25% increase in the Eagle Cap. This could reflect either less litter production or more use of the Eagle Cap campsites. *Abies lasiocarpa* forests with *Vaccinium scoparium* undergrowth are generally less productive than forests with *Xerophyllum tenax* or *Menziesia ferruginea* undergrowths (Pfister and others 1977). The importance of amount of use is evaluated later in this paper.

Penetration resistance (soil compaction) typically increased 1.4 kg/cm^2 on both the Mission Mountain and Rattlesnake campsites. The severity of this change cannot be compared to change on the Eagle Cap sites because penetration resistance values respond much more dramatically to compaction than bulk density values.

Relation between Use and Impact

Although the changes that have occurred on these campsites are pronounced (that is, differences from unused control sites are highly significant), the amount of change varies greatly from site to site. For parameters that exhibit significant differences between campsites and controls, we examined the extent to which this variability was related to differences in the amount of use each site received. In Tables 5 and 6, amount of use is compared to existing site conditions, the absolute change that has occurred on each site, and the relative change that has occurred on each site.

On Eagle Cap campsites, there were significant correlations between the amount of use a site receives and size of bare area, percent of trees with exposed roots, floristic dissimilarity, seedling loss, vegetation loss, exposure of mineral soil, and duff depth. The only significant difference related to amount of use on the Mission Mountain sites was in the amount of exposed mineral soil; no parameters differed significantly on the Rattlesnake sites.

In the Eagle Cap, the percentage of trees with exposed roots increased from 3% on light-use sites to 33% on moderate-use sites and to 39% on heavy-use sites (Table 5). However, the length of exposed roots and the percent of bark removed, variables measured in the Mission Mountain and Rattlesnake studies, did not differ significantly between use categories (Table 6).

The tendency for the frequency of root exposure to increase on more heavily used sites probably results from increased loss of the surface organic horizons on these sites; decreases in duff depth and increases in the amount of exposed mineral soil are

Table 4. Median conditions on campsites and controls in the Mission Mountains Tribal and Rattlesnake Wildernesses and estimates of amount of change.[1]

	Mission Mountains Tribal Wilderness				Rattlesnake Wilderness			
	Seedlings	Vegetation	Mineral soil	Soil compaction	Seedlings	Vegetation	Mineral soil	Soil compaction
	(#/ha)	(%)	(%)	(kg/cm^2)	(#/ha)	(%)	(%)	(kg/cm^2)
Campsite	336	27	7	2.1	550	44	13	2.6
Control	1,200	85	1	.9	1,950	91	1	1.4
Absolute change	800	62	−6	−1.4	1,160	53	−11	−1.4
Relative change (%)	68	72	−975	−139	67	55	−1,400	−89
Significance	.003	<.001	<.001	<.001	<.001	<.001	<.001	<.001

[1]Absolute change is the control value minus the campsite value; relative change is the absolute change divided by the control value. Positive values indicate reduced campsite values and negative values indicate increases on campsites. Significance was tested with the Wilcoxon matched-pairs, signed-ranks test. Differences were considered significant if the level of significance was less than .05.

usually more pronounced on frequently used sites (Figure 8). In the Eagle Cap, mineral soil coverages on control sites were no more than a few percent; median absolute increases in exposure of mineral soil were 5% on light-use sites, 26% on moderate-use sites, and 32% on heavy-use sites. Absolute increases in the Mission Mountains were 2% on light-use sites and 15% on moderate-use sites. Differences were not significant in the Rattlesnake study.

Duff depth was only measured in the Eagle Cap study. Median duff loss was 3% on light-use sites, increasing to 21% on moderate-use sites and to 68% on heavy-use sites.

Vegetation cover decreased from 9% on light-use sites to 4% on heavy-use sites in the Eagle Cap. This represents a loss of 71% of the cover on light-use sites and 94% of the cover on heavy-use sites. In comparison to the extreme amount of vegetation loss resulting from even light use, these differences due to increasing frequency of use are scarcely noticeable. Differences between light-use and moderate-use sites in the Mission Mountain and Rattlesnake Wildernesses are not even statistically significant. Most vegetation is lost after a site is used a few times per year; further increases in use cause little additional loss (Figure 9).

Although percent vegetation loss did not vary between sites receiving different amounts of use, the size of the area devoid of vegetation (bare area) did. In the Eagle Cap, the bare area of light-use sites (19 m^2) was much smaller than that of moderate- and heavy-use sites, which had median bare area measures of 122 m^2 and 93 m^2, respectively. The size of the camp area was also much smaller on the light-use sites, and again, there was little difference between the size of moderate- and heavy-use sites (Figure 10). Consequently, the proportion of a site that has been devegetated is remarkably constant across all use categories.

Apparently light use is sufficient to eliminate most of the vegetation on a campsite, but the area affected is much larger on moderate- and heavy-use sites. Thus, both visitors and managers may find light-use sites considerably less obtrusive, despite the fact that vegetation loss per unit area is as great as on the more frequently used sites. When moderate- and heavy-use sites are compared, however, there are no significant differences even in the area affected.

The seedling loss data for the Eagle Cap campsites are more difficult to interpret because densities on controls are so highly variable. Seedling densities on the controls associated with heavy-use sites are abnormally high. Consequently, the absolute loss of seedlings—the difference between densities on campsites and controls—has been greatest on heavy-use sites, despite these same sites having the highest on-site seedling densities.

Relative change measures, which compensate for variability in conditions on control sites, are fairly constant across all use categories. Clearly, seedlings are almost entirely eliminated on campsites, regardless of the amount of use they receive. Being highly susceptible to trampling damage, any consistent use is sufficient to kill most seedlings. The number of seedlings surviving on a campsite is probably more a function of the number of protected germination sites than the amount of use the site receives. This conclusion is supported by the insignificant differences in seedling loss on Mission Mountain and Rattlesnake campsites.

The extent of tree damage was not related to use intensity in any of the study areas. In all three areas, the percent of injured trees increased slightly on the more frequently used sites, but these differences were dwarfed by site-to-site variability. In the Eagle Cap, felled trees were most abundant on light-use sites and scarred trees were most abundant on moderate-use sites.

Table 5. Relationship between impact and frequency of use in the Eagle Cap Wilderness.

Change parameter	Light-use sites (N = 6)	Moderate-use sites (N = 6)	Heavy-use sites (N = 10)	Kendall tau (α = .05)
		Median		
Camp area (m^2)	48	224	205	NS
Bare area (m^2)	19	122	93	.30
Injured trees (%)	74	85	97	NS
Trees with exposed roots (%)	3	33	39	.41
Felled trees (%)	43	12	34	NS
Scarred trees (%)	3	37	11	NS
Floristic dissimilarity (%)	31	60	64	.33
Seedlings[1]				
campsite (#/ha)	174	299	335	NS
absolute (#/ha)	1,113	1,825	3,727	.57
relative (%)	73	92	89	NS
Vegetation cover[1]				
campsite (%)	9	6	4	−.41
absolute (%)	37	30	60	.29
relative (%)	71	71	94	.29
Mineral soil cover[1]				
campsite (%)	14	20	35	NS
absolute (%)	−5	−26	−32	−.34
relative (%)	−529	−1,595	−3,293	−.43
Duff depth[1]				
campsite (cm)	.15	.45	.15	−.35
absolute (cm)	.06	.15	.35	.40
relative (%)	3	21	68	.36
Organic matter[1]				
campsite (%)	12	14	18	NS
absolute (%)	−5	−4	−2	NS
relative (%)	−19	−26	−20	NS
Bulk density[1]				
campsite (g/cm^3)	.95	.90	.95	NS
absolute (g/cm^3)	−.13	−.08	−.14	NS
relative (%)	−16	−11	−16	NS
Instantaneous infiltration rate[1]				
campsite (cm/min)	.54	.19	.28	NS
absolute (cm/min)	.07	.46	.05	NS
relative (%)	8	57	12	NS
Saturated infiltration rate[1]				
campsite (cm/min)	.23	.12	.14	NS
absolute (cm/min)	.01	.12	.09	NS
relative (%)	−2	39	42	NS
pH[1]				
campsite	5.25	5.25	5.55	NS
absolute	−.15	−.25	−.60	NS
relative (%)	−3	−5	−11	NS
Mg[1]				
campsite (ppm)	34	67	61	NS
absolute (ppm)	−18	−28	−35	NS
relative (%)	−41	−109	−108	NS
Ca[1]				
campsite (ppm)	280	755	528	NS
absolute (ppm)	−216	−483	−300	NS
relative (%)	−105	−160	−30	NS
Na[1]				
campsite (ppm)	54	53	51	NS
absolute (ppm)	−8	−15	−5	NS
relative (%)	−25	−33	−10	NS

[1]The three measures of change for these parameters are existing campsite conditions, absolute change (difference between campsites and controls), and relative change (absolute change as a percent of control conditions). A positive change represents a decrease in that measure on the campsite.

Table 6. Relationship between impact and frequency of use in the Mission Mountains Tribal and Rattlesnake Wildernesses.

	Mission Mountains Tribal Wilderness			Rattlesnake Wilderness		
Change parameter	Light-use sites (N = 6)	Moderate-use sites (N = 8)	Significance (α = .05)	Light-use sites (N = 12)	Moderate-use sites (N = 9)	Significance (α = .05)
		Median			Median	
Injured trees (%)	61	71	NS	60	66	NS
Tree root exposure (cm)	76	30	NS	15	23	NS
Root bark removed (%)	2	2	NS	1	1	NS
Floristic dissimilarity (%)	38	49	NS	39	22	NS
Seedlings[1]						
campsite (#/ha)	300	500	NS	300	800	NS
absolute (#/ha)	700	900	NS	1,300	850	NS
relative (%)	75	65	NS	67	56	NS
Vegetation cover[1]						
campsite (%)	34	25	NS	42	44	NS
absolute (%)	61	62	NS	50	53	NS
relative (%)	65	74	NS	53	55	NS
Mineral soil cover[1]						
campsite (%)	3	16	.003	14	9	NS
absolute (%)	−2	−15	.01	−14	−9	NS
relative (%)	−300	−2,750	NS	−800	−1,600	
Soil compaction[1]						
campsite (kg/cm^2)	1.7	2.5	NS	2.6	2.5	NS
absolute (kg/cm^2)	−1.1	−1.6	NS	−1.4	−1.0	NS
relative (%)	−109	−145	NS	−122	−80	NS

[1]The three measures of change for these parameters are existing campsite conditions, absolute change (difference between campsites and controls), and relative change (absolute change as a percent of control conditions). A positive change represents a decrease in that measure on the campsite.

Most tree damage is probably caused by a few destructive parties, making the frequency of use by parties that are not destructive irrelevant.

None of the changes in characteristics of the mineral soil was significantly related to amount of use. Although soil compaction was pronounced on the campsites, bulk densities on the heavy-use Eagle Cap sites were no higher than those on light-use sites, and infiltration rates on the heavy-use sites were only slightly slower than those on light-use sites. Penetration resistance on the Mission Mountain moderate-use sites was higher than on the light-use sites, but this difference was not statistically significant. Variations in the magnitude of chemical changes in the soil also showed no pattern that could be related to amount of use.

Despite pronounced ecological changes on campsites, we must conclude, for the sites we examined, that amount of change is not much greater on frequently used sites than on infrequently used sites. For most parameters measured, impacts on campsites used only a few nights per year already exceed threshold values, beyond which further increases in use have little effect on the severity of these impacts.

By the time a campsite has been used a few nights per year, most of the trees have been injured; most of the seedlings have been eliminated; most of the vegetation cover has been lost; soils have been compacted resulting in slower infiltration rates; and pronounced increases in soil pH, organic matter content, and nutrient content have occurred. Campsites used 10 to 20 nights per year differ from the light-use sites in the following ways: they are much larger, as is the area devoid of vegetation; exposure of tree roots becomes pronounced; duff (litter) is lost, exposing mineral soil; and changes in the species composition of the undergrowth have been more extreme. The only pronounced difference that we found between these moderate-use sites and sites used 25 to 50 nights per year is that the more frequently used sites have lost significantly more of their organic horizons.

Management Implications

The major management implications of this research are that in ecosystems as fragile as the subalpine forests of the Northern Rocky Mountains and northeastern Oregon, considerable site degradation is inevitable, even at very low use intensities. Impacts will occur wherever people camp, so the primary effects of manipulating use distributions will be on

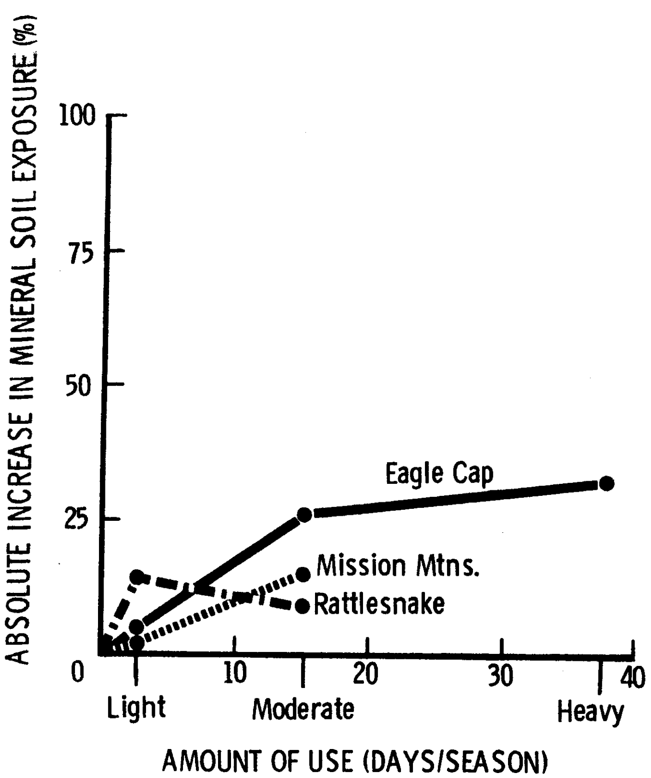

Figure 8. Median values of absolute increase in mineral soil exposure have been plotted in relation to amount of use in the Eagle Cap, Mission Mountain, and Rattlesnake study areas. For the Eagle Cap campsites, the numerical use frequencies are estimates.

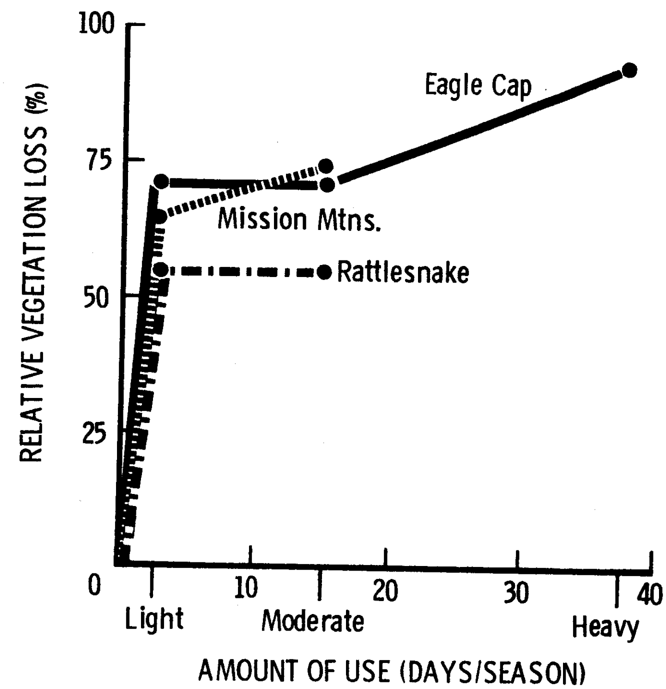

Figure 9. Median values of relative vegetation loss have been plotted in relation to amount of use in the Eagle Cap, Mission Mountain, and Rattlesnake study areas. For the Eagle Cap campsites, the numerical use frequencies are estimates.

how many sites are impacted and where these sites are located, rather than how severely individual sites are altered.

In the areas studied, reducing visitor use to the point where campsite occupancy rates are only about 10 nights per year would do little to improve site conditions other than to allow an increase in duff depth. Limiting campsite occupancy rates to a few nights per year would do more; sites would probably be smaller and duff loss and tree root exposure would be minimal. Most other types of impact, however, would only be affected if occupancy rates were much lower—probably less than one night per year.

Because use density is variable in most backcountry areas, managers may want to pursue different campsite management strategies in different parts of each backcountry area. In consistently used parts of areas as fragile as those studied (many of the trail corridors and destinations in the higher elevation wildernesses in the West) limiting use to a few sites would result in less impact than dispersing use among a large number of sites. Few sites would be impacted, and the amount of impact on each site could be minimized through improved site selection, visitor education, prohibitions on particularly destructive types of use, and site maintenance and rehabilitation. Solitude could also be enhanced by dispersing these sites locally. This would leave the vast majority of the wilderness in a near-pristine condition.

In more remote areas where campsite occupancy rates could be very low—less than 1 night per year in the areas we studied—dispersal of camping might be more appropriate. For this strategy to work, campers must know minimum impact camping techniques and be willing to camp on apparently unimpacted sites. Many areas may receive too much use for this strategy to be feasible, and even in lightly used areas it is not clear that visitors will voluntarily use unimpacted sites and eliminate all signs of their use (Canon and others 1979).

Monitoring of impacts is particularly important in remote areas where dispersal is promoted because of the potential for increased use or inappropriate visitor behavior to cause widespread deterioration. These are the areas that still provide opportunities for finding solitude and visiting essentially unaltered ecosystems, and their preservation should be a top priority. If the demand to visit these remote areas increases, preservation may be difficult, given that it takes only a few campers per year to cause large amounts of change. In such situations, use limitations in remote, near-pristine areas may

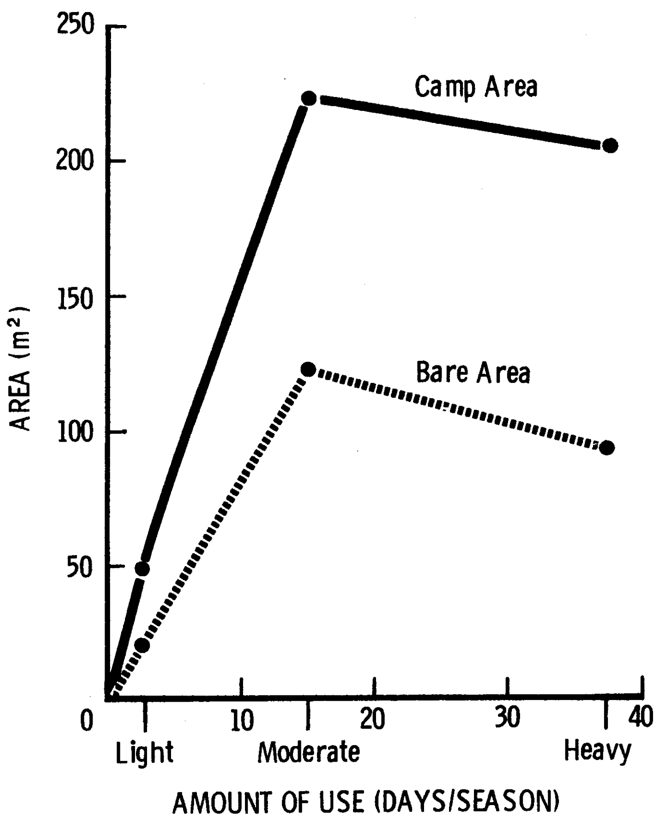

Figure 10. Median values of camp area and bare area in relation to estimated amounts of use in the Eagle Cap study area.

be required even before limitations are required in popular areas where use is concentrated.

Although these conclusions may be disturbing to those who want absolutely pristine wildernesses, the finding that constantly used sites are not much more severely altered than sites used a few times per year is encouraging. Concentration of use in popular areas will not lead to ever-increasing amounts of deterioration, provided that sites are well located and inappropriate visitor behavior is discouraged. Moreover, as long as most people want to visit these popular places—and most currently do—natural conditions will prevail throughout most of the wilderness; opportunities for solitude and unconfined recreation will be preserved; and the need to manipulate visitor distributions and behavior, which results in a loss of freedom and spontaneity, will be minimized.

Further Research

Where to encourage people to use a few frequently used sites and where to encourage them to use a large number of infrequently used sites is a critical management concern. It seemed significant to us that both of the studies reported here found that on sites used only a few nights per year, most types of impact already exceeded thresholds beyond which increased use had little effect on amount of impact. However, similar studies are needed to define similar thresholds in other parts of the country, particularly in ecosystems that are less fragile and more resilient than those studied here. Ideally, such studies should also be supported by experimental studies in which use is applied in carefully controlled amounts.

Acknowledgments

We are grateful to the following people for help in data collection and analysis: Jim Benedict, Newman Brozovsky, Sue Lindgren, Nancy Richardson, Leslie Underhill, and Randel Washburne. Helpful criticisms of this paper were provided by Susan Bratton, Robert Frenkel, James Habeck, and Robert Lucas.

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