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Ecological Changes on Campsites in the Eagle Cap Wilderness, 1979 to 1984

David N. Cole

THE AUTHOR

DAVID N. COLE is a research scientist with Systems for Environmental Management, Missoula, MT. From 1978 to 1982 he had a temporary assignment with the Intermountain Research Station's Wilderness Management research work unit. Since then he has worked cooperatively with the research unit. Dr. Cole received his B.A. in geography from the University of California, Berkeley, in 1972. He received his Ph.D., also in geography, from the University of Oregon in 1977. He has written extensively on wilderness management, particularly the management of campsite impacts.

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RESEARCH SUMMARY

Twenty-two campsites in the Eagle Cap Wilderness were examined in 1979 and then reexamined in 1984 to compare the extent of ecological impacts. Of the 22 campsites, six had received low use, six moderate use, and 10 high use, Of the high-use sites, six had been closed to use in the late 1970's by a regulation prohibiting camping within 200 ft (61 m) of lakeshores. This stratification made it possible to evaluate whether or not change over time was related to amount of use. It was also possible to evaluate the effectiveness of campsite closures in promoting recovery.

Some types of impact worsened over this period; others remained stable. The most consistent and pronounced changes were increases in the size of the campsite and its devegetated core. On most campsites, exposure of mineral soil increased, as did the number of felled-trees. Vegetation cover and composition, and seedling density were stable.

Some campsites experienced recovery, at least for certain types of impact; on others, all types of impact became more severe. Amount of change did not differ significantly on campsites receiving different levels of use. The major finding related to use level was that conditions on low-use sites tended to either deteriorate or improve consistently over time; changes on high-use sites were less consistent. Similarly, the campsites most likely to deteriorate were those that were least impacted in 1979. This suggests that in attempting to avoid campsite deterioration, a high priority should be placed on management of campsites and destination areas that are receiving relatively low but consistent amounts of use.

High-use sites, once closed, did not recover much in 5 years. The most pronounced changes on open sites-expansion of the entire site and devegetated core-were less pronounced on closed sites. Nevertheless, exposure of mineral soil continued at the same rate as on open sites. More effective means of closing and rehabilitating sites are needed.

The results of this research have several important implications for management. Lightly impacted sites are most sensitive to changes in use intensity, and should be used as infrequently as possible. Low-impact camping techniques are particularly important in reducing the impacts on such sites. High-use sites will continue to deteriorate, but deterioration will be minor if site expansion and tree damage are controlled. In subalpine forests, site rehabilitation is a slow process that requires elimination of all use, including day use.

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Intermountain Research Station
324 25th Street
Ogden, UT 84401

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INTRODUCTION

Ecological impacts on campsites are common to most wilderness and backcountry recreation areas in the United States. The most obvious impacts occur in destination areas that have received heavy use for long periods of time. Managers are understandably concerned that such campsites may deteriorate to the point that they are no longer desirable places to camp. Two studies, both in car campgrounds, suggest that conditions on established campsites are relatively stable (Magill 1970; Echelberger 1971). For wilderness camp sites, however, there are few data available to determine whether or not long-term deterioration is likely to be pronounced.

In response to perceived campsite deterioration, managers may encourage visitors to use less-impacted sites, thereby reducing use levels on the more severely deteriorated sites. A sizable body of research suggests that such attempts will be futile because use levels must be reduced to very low levels-or eliminated entirely-before conditions are likely to improve substantially (Cole and Fichtler 1983; Marion and Merriam 1985; and others). Managers may also close severely impacted sites in an attempt to rehabilitate them. Two studies suggest that closure requires a prohibitively long time period to affect rehabilitation and that, where compliance with closure is poor, recovery may never occur (Stohlgren 1982; Cole and Ranz 1983).

More longitudinal data on campsite deterioration and recovery rates and on their relationship to use levels would make it easier to evaluate the efficacy and appropriateness of these responses. To meet some of these information needs, a long-term study of established campsites was initiated in 1979 in the Eagle Cap Wilderness, OR. Primary objectives were to describe trends in campsite condition over the 5 year period, 1979 to 1984, and to determine whether the amount of change that occurred was related to the amount of use the sites received. It was also possible to compare amount of change on heavily used sites that had been closed to use shortly before the **1979** season with neighboring heavily used sites that remained open to use. This permitted a further evaluation of the effectiveness of closures in the typical wilderness situation where management presence is low and voluntary compliance must be relied upon.

STUDY AREA AND METHODS

The study area and methods are described in considerable detail in Cole (1982), a report on the first year of fieldwork. That report described campsite conditions and estimated how much change had already occurred on campsites by comparing them with neighboring control sites. It reported that even lightly used sites were highly altered and that the only types of impact that were significantly more pronounced on more heavily used sites were change in species composition, exposure of mineral soil, decrease in duff depth, exposure of tree roots, and size of the barren campsite core.

Twenty-two campsites were examined in 1979 and again in 1984. All were around subalpine lakes at elevations between 7,050 and 7,800 ft (2 150 and 2 400 ml. All were located in forests with an overstory primarily of ***Abies lasiocarpa*** and a ground cover dominated by ***Vaccinium scoparium*,** on soils derived from granitic rocks. Six of the sites were at lakes that received little use; these lakes were located either in trailless basins or far from trailheads on rough trails. Use levels for these low-use sites were estimated at less than five nights per year; some of these sites are not used every year. Another six sites were at lakes that were not popular destinations although they could be reached on well-maintained trails. Estimated use levels for these moderate-use sites were 10 to 20 nights per year. Ten sites were located at very popular lakes-two at each of five lakes. Three of these lakes are in the Lake Basin, an area visited by one of every three visitors to the Wilderness in 1978. Use levels for these heavy-use sites were estimated to be 25 to 50 nights per year. At each lake, one site was open to use; the other was less than 200 ft (61 m) from the lakeshore and, therefore, not a legal place to camp. One of the five open sites was later closed to use so that by 1984 there were four open and six closed sites. Two of the six closed sites were partially revegetated with transplants between 1979 and 1984.

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 disturbed campsite and to the first significant amount of vegetation were measured along 16 transects. This defined the camp area and the devegetated central core area. Tree “seedlings,” 0.5 to 4.5 ft (15 to 140 cm) tall, were recorded within the camp area, excluding any untrampled "islands"; larger trees were counted within the entire camp area. Trees that had been damaged (for example, with trunk scars, nails, or broken branches), felled, or had exposed roots were counted. In 1984, the center point-a buried nail-was relocated. Distances to the edge of the disturbed campsite and to the first significant amount of vegetation were remeasured, and new camp and devegetated core areas were calculated. The boundaries of the 1979 camp area were reestablished; seedlings, damaged trees, felled trees, and trees with exposed roots were counted as in 1979.

On each campsite, approximately 15 quadrats, 3.3 by 3.3 ft (1 by 1 m), were located along four transects, originating at the center point and oriented perpendicular to each other. The canopy cover of total ground vegetation, exposed mineral soil, and each plant species was estimated for each quadrat. Coverages were estimated to the nearest, percent if under 10 percent, or if above 10 percent, in lo-percent coverage classes. The midpoints of each coverage class were used to calculate mean coverages for the campsite. The thickness of the organic horizons was measured at four points between 3.3 and 6.5 ft (1 and 2 m) from the center point along each transect. In 1984, nails at the end of each transect were relocated. This permitted precise relocation of the transects and quadrats. Coverages were estimated and organic horizon thickness was measured as in 1979.

On the control plots, which varied in size from 980 to 2,164 ft^2 (91 to 201 m^2), coverage of total vegetation, exposed mineral soil, and each plant species was estimated for the entire plot. Seedlings were counted on a 538-ft^2 (50-m^2) subplot placed in the center of the control. Organic horizon thickness was measured at four regularly distributed points. Measurements were repeated in 1984.

The amount of change that had occurred on campsites prior to 1979 was inferred from comparisons of campsites and controls. Absolute difference is the campsite measure minus the control measure. This was the preferred comparison except where variation between control sites was high; in this case relative difference (absolute difference divided by the control value) was calculated. Change in species composition was estimated by comparing the composition of campsites and controls. using the following coefficient of floristic dissimilarity:

$$FD = 0.5\Sigma \mid P_1 - P_2 \mid$$

where P_1 is the relative cover of a given species on the control and P_2 is the relative cover of the same species on the campsite.

The magnitude of change between 1979 and 1984 was expressed as the median difference between 1979 and 1984 values. To provide some perspective on the importance of this change, this difference is divided by 1979 values to obtain percent change. Counts of the number of sites that experienced either an increase or a decrease suggest how consistent changes were. For certain variables, change in both campsite and absolute or relative difference (the campsite-control comparison) measures are provided.

The statistical significance of these changes (that is, the extent to which the changes measured on these sample sites are applicable to other sites) was evaluated with the Wilcoxon matched-pairs, signed-ranks test. The Kruskall-Wallis analysis of variance test was used to test the null hypothesis that the amount of change between 1979 and 1984 was similar on low-, moderate-, and high-use sites. The Mann-Whitney test was used to test the null hypothesis that the amount of change on closed, former high-use sites was similar to that on open high-use sites (Siegel 1956). Null hypotheses were rejected if probability values were 0.05 or less. Nonparametric tests were selected because data for many variables were not normally distributed and the sample size was small. Although not reported, analogous parametric tests were also run to see if they provided different statistical interpretations; they provided similar inferences to nonparametric tests in all cases but one.

RESULTS AND DISCUSSION

Ecological Changes Between 1979 and 1984

The most consistent and one of only two statistically significant changes between 1979 and 1984 was an increase in campsite area (table 1). Fourteen of the 16

Table l.-Median change in size and tree damage on all 16 open campsites'

Statistic	Camp area	Devegetated core area	Damaged trees	Trees with exposed roots	Felled trees
	m2		Number		
Median					
1979	**198**	86	9.0	3.5	4.0
1984	233	104	7.5	3.5	5.0
Difference	22	5	0	0	1.0
Change (percent)	11	10	0	0	35
Number of sites					
increase	14	10	3	4	8
Decrease	1	5	6	3	4
Significance	<O.OOl	0.03	0.17	0.26	0.08

'Difference is the media: difference between 1979 and 1984. Change is difference as a percentage of 1979 values. Positive values indicate an increase between 1979 and 1984. The significance of differences between 1979 and 1984 was tested with the Wilcoxon matched-pairs, signed-ranks test.

sites increased in size. The median campsite-at about 2,500 ft^2 (233 m^2 in 1984-was 11 percent larger than it had been in 1979. One site increased over 1,600 ft^2 (152 m^2) to a total area in 1984 of over 7,500 ft^2 (712 m^2).

The other statistically significant change was an increase in the size of the devegetated central core of the campsite. Increases in area (loss of vegetation) occurred on twice as many sites as decreases (revegetation); the magnitude of increases was also much greater than the magnitude of decreases. The median devegetated area increased 10 percent over 5 years to over 1,100 ft^2 (104 m^2) in 1984. This increase is proportional to the increase in camp area; devegetated core still comprises about 45 percent of the total camp area.

Results for tree damage were mixed. The number of damaged trees tended to decrease, while the number of felled trees and trees with exposed roots increased. The decline in number of damaged trees generally resulted from felling of these trees-not recovery from tree damage. Changes in the number of damaged trees and trees with exposed roots were minor; median differences were zero. The number of felled trees increased 35 percent on the median site, however. On four sites, five or more trees were felled between 1979 and 1984. This suggests that the rate of tree felling is as great now as it has ever been, despite regulations and educational campaigns that ask visitors not to cut down trees. Such changes probably occur sporadically and do not occur on all sites-hence the lack of statistical significance. But because the impact of one ax-wielding party can last for a century, even small cumulative changes add up to pronounced long-term deterioration (fig. 1).

Seedling densities actually increased on half of the campsites between 1979 and 1984 (table 2). But the increase on the median site was only 0.4 seedling per acre (one seedling per hectare). Moreover, the median percentage of seedlings lost on campsites (relative difference, as inferred from comparisons with controls) remained

Figure 7.-Between 1979 and 1984 this lodgepole pine **was** *girdled with an axe* **and** *died, an example of needless impacts that warrant control.*

Table 2.-Median change in seedling density and ground cover conditions on all 16 open campsites[1]

Statistic	Seed-lings/ hectare	Seed-ling loss	Vege-tation cover	Vege-tation loss	Mineral soil exposure	Mineral. soil increase	Organic horizon thickness	Organic horizon loss
	No.	Percent					cm	
Median								
1979	273	92	7.2	84	24	17	0.2	0.3
1984	302	92	7.5	85	42	29	0.1	0.3
Difference	1	0	0.3	1	5	5	0	0
Change (percent)	0	0	17	1	32	38	0	0
Number of sites								
Increase	8	4	9	8	12	12	6	6
Decrease	4	6	6	7	4	4	7	7
Significance	0.35	0.22	0.20	0.23	0.06	0.07	0.30	0.39

[1]Seedling and vegetation loss are relative differences (control value minus campsite value, divided by control); mineral soil increase and organic horizon loss are absolute differences (control value minus campsite value). Difference is the median difference between 1979 and 1984. Change is difference as a percentage of 1979 values. Positive values indicate an increase between 1979 and 1984. The significance of differences between 1979 and 1984 was tested with the Wilcoxon matched-pairs, signed-ranks test.

at 92 percent in 1984, the same as in 1979. No substantial improvement ordeterioration in the status of tree reproduction on campsites occurred (fig. 2a).

Vegetational cover also increased slightly over the 5-year period, from a median of 7.2 percent to 7.5 percent. The largest increase was 9.0 percent; the largest decrease was 7.3 percent. This general increase in cover on campsites reflects either a tendency to make higher percentage cover estimates in 1984 or more favorable climatic conditions, because cover also increased slightly on controls (fig. 2b). The median percentage of vegetation loss (relative difference) remained at about 85 percent. As with tree reproduction, vegetation conditions for all sites are neither improving nor deteriorating.

Changes in mineral soil cover are more pronounced and consistent. Mineral soil exposure increased on 12 of the 16 sites and, on the median campsite, increased 32 percent between 1979 and 1984. This change is considerably more substantial than the change on controls (fig. 2c). By 1984, mineral soil was exposed over 42 percent of the median campsite. The four sites on which soil exposure decreased were the sites with the most soil exposure in 1979. Even with the decreases that occurred between 1979 and 1984, these sites had a median exposed soil cover of 53 percent. Apparently; soil exposure only stabilizes after it reaches a level of 50 to 60 percent on most of these campsites.

Although the median thickness of organic horizons decreased from 0.10 inch (0.2 cm) to 0.04 inch (0.1 cm), the median change was zero. Thickness decreased on six sites and increased on seven sites. No changes were recorded on controls (fig. 2d), so absolute decreases in thickness also changed little.

The thickness of organic horizons was measured about 5 ft (1.5 m) from the center of the campsite. At this central location, most losses had already occurred by 1979. The sizable increases in mineral soil exposure-a result of loss of organic horizons-occurred primarily on quadrats located farther from the center of the site. Along with the increases in camp and devegetated core area, this suggests that the major changes over time are expanding zones of disturbance. Although such parameters as percentage of vegetation cover and organic horizon thickness remained relatively constant at the places where they were measured (fig. 3), impact upon them slowly spread over a larger area.

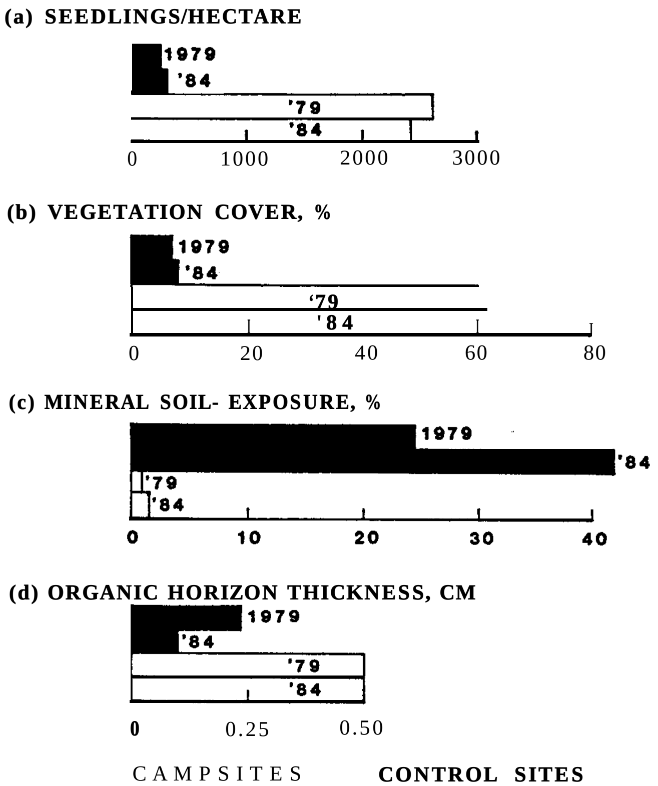

Figure 2.-Median (a) seedling density, (b) vegetation cover, (c) mineral soil exposure, and (d) organic horizon thickness, on campsites and control sites in 1979 and 1984.

Figure J.--Between 1979 (top) and 1984 (bottom) little change occurred, in terms of vegetational cover or mineral soil exposure, close to the center of the campsite at Wild Sheep lake.

Changes in vegetational composition were examined in a number of ways. Generally, compositional changes were minor. Floristic dissimilarity-an index of difference in composition between campsites and controls-increased on 10 sites (table 3). Despite this consistency, increases were generally small; dissimilarity increased only 3 percent on the median campsite between 1979 and 1984. When the vegetational composition of each campsite in 1984 and 1979 were compared, the median dissimilarity was 21 percent. This is virtually identical to the median difference in composition of control plots (20 percent) over this same time period. We therefore can conclude that recreational use effected little change in vegetational composition over the 5-year period.

Two indexes of diversity were also virtually unchanged (table 3). The median difference in number of species per campsite (species richness), between 1979 and 1984, was zero. The number of species increased on six sites and decreased on six sites. The Simpson index indicates the extent to which the vegetation is dominated by one or a few species (Simpson 1949). It varies between 0 and 1, with larger numbers indicating increased dominance. Dominance (or-loss of diversity) does tend to increase over time, from a median of 0.19 in 1979 to 0.25 in 1984, but this increase is small and the number of sites with increases and decreases is about the same.

Table X-Median change in indexes of species composition and diversity on all 16 open campsites[1]

Statistic	Floristic dissimilarity	Species richness	Simpson's index
	Percent	*No.*	
Median			
1979	50	11.5	0.19
1984	50	10.5	0.25
Difference	2	0	0.02
Change (percent)	3	0	3
Number of sites			
Increase	10	6	8
Decrease	4	6	7
Significance	0.17	0.33	0.77

[1]Floristic dissimilarity is a measure of difference in composition between campsiteand control; richness is number of species per campsite; Simpson's is an index of dominance. Difference is the median difference between 1979 and 1984. Change is difference as a percentage of 1979 values. Positive values indicate an increase between 1979 and 1994. The significance of differences between 1979 and 1984 was tested with the Wilcoxon matched-pairs, signed-ranks test.

The relative cover of the four most common species on campsites and controls changed little between 1979 and 1984 (fig. 4). (Relative cover is the cover of a given species expressed as a proportion of the combined cover of all species.) In 1984, as in 1979, *Juncus parryi* (Parry rush) and *Carex rossii* (Ross sedge) were considerably more prominent on campsites than on controls, while *Vaccinium scoparium* (grouse whortleberry) and *Phyllodoce empetriformis* (red mountain heath) were less prominent on campsites. *Juncus parryi* and *Carex rossii*, along with several other grass, sedge, and rush species, and an occasional low-growing forb, such as *Sibbaldia* ***procumbens*** (creeping sibbaldia), remained the most resistant species on campsites (refer to appendix for data on other species). They are not becoming more prominent on campsites, however. The relative cover of resistant species was as likely to decrease between 1979 and 1984 as it was to increase. The same was true for more susceptible species, such as ***Vaccinium scoparium*** and ***Phyllodoce empetriformis.***

Only two species, both present on only one campsite in 1979, were absent in 1984. One species-the exotic *Trifolium repens* (white clover)-was found on campsites for the first time in 1984. The total number of exotic species increased from two to three; the number of campsites with exotics also increased from two to three. Yet the total cover of exotics had decreased markedly by 1984 on the only campsite on which the cover of exotics exceeded 1 percent. Although a new exotic species had appeared on a new campsite, there was little evidence to

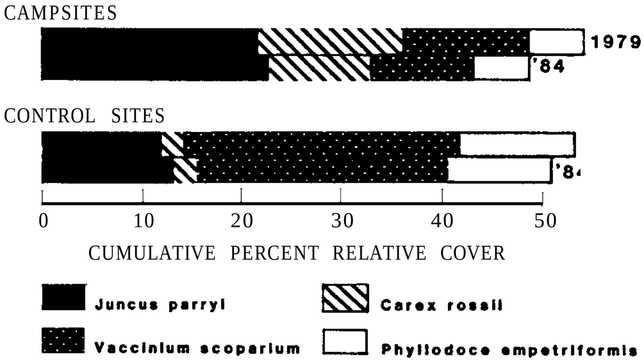

Figure 4.-Median relative cover of four common species, on campsites and control sites. in 1979 and 1984.

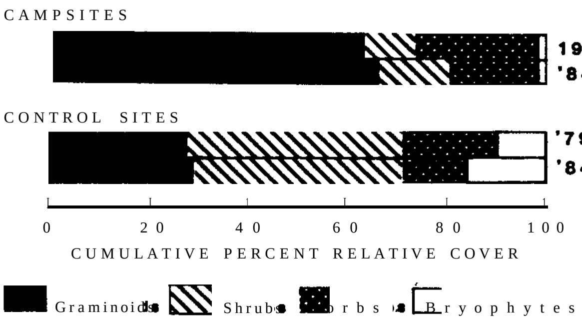

Figure 5.-Median relative cover of growth forms, on campsites and control sites, in 1979 and 1984.

suggest that exotics were spreading on these subalpine sites. This reflects the fact that at high elevations conditions are generally unfavorable for the growth of exotics.

The lack of change in vegetational composition is also apparent in a comparison of the relative cover of different growth forms in 1979 and 1984 (fig. 5). Differences on campsites are generally no more pronounced than those on controls. In 1984, as in 1979, the more resistant growth forms were graminoids and forbs. Graminoids increased slightly between 1979 and 1984; forbs decreased substantially, but no more than on controls.

Shrubs and bryophytes were the susceptible growth forms. Shrubs increased slightly between 1979 and 1984, but the relative cover of bryophytes remained unchanged.

Ecological Changes on High- and Low-Use Campsites

The magnitude of change between 1979 and 1984 did not differ significantly between use categories for any impact parameter (table 4). This lack of significance was surprising given the sizable differences between use cate gories in certain median difference values. With a small sample size, differences must be quite pronounced and consistent to establish statistical significance.

To evaluate whether there might be subtle differences that might have been significant with a larger sample size, differences between 1979 and 1984 for each use category are presented graphically in figure 6. All graphs show tremendous variability in amount of change within most use categories; differences between use categories are small in relation to this variability. These data do show that, on the-sites examined, more highly used sites tended to experience larger increases in camp area, devegetated core area, and number of felled trees. Some what surprisingly, vegetational cover was more likely to increase and mineral soil cover was more likely to decrease on high-use than on low-use sites. None of these differences were statistically significant, however.

Clearly, there were no consistent and pronounced differences in amount of change that could be related to the amount of use a site receives. There appears to be a slight tendency for the areal extent of disturbance to increase more on more frequently used sites. The more often a site is used, the more likely it is to be used by a particularly large party that disturbs the perimeter of the site. More frequent use also increases the likelihood of use by a party that will fell trees. On the other hand, high-use sites are less likely than low-use sites to experience further loss of vegetation or increase in mineral soil exposure on already highly impacted parts of the site.

As a final attempt to identify any relationship between amount of change and amount of use, I constructed a synthetic index of amount of change. The index was based on differences, between 1979 and 1984, in eight impact parameters: camp area, devegetated core area, number of trees that were either damaged or felled, seedling density, vegetational cover, mineral soil cover, organic horizon thickness, and floristic dissimilarity. The index was:

$$CI = (a-b) / (a+b)$$

where a is the number of impact parameters for which 1984 campsite conditions were better than in 1979, and b is the number of parameters for which 1984 conditions were worse. The index ranges from -1.0 (where all types of impact became more severe) to 1.0 (where all types of impact became less severe).

For example, the campsite at Tombstone Lake experienced an increase in camp area, mineral soil cover, and floristic dissimilarity, and a decrease in vegetation cover and organic horizon thickness-five deteriorating parameters. Two improving parameters were a decrease in devegetated core area and an increase in seedling density. There was no change in number of damaged or felled trees. The change index for the Tombstone Lake site is:

$$(2-5) / (2+5) = -0.43.$$

Table 4.--Relationship between amount of use and amount of change[1]

Impact parameter	Low use 1979	Low use 1984	Low use Diff.	Moderate use 1979	Moderate use 1984	Moderate use Diff.	High use 1979	High use 1984	High use Diff.	Significance
	Median									
Camp area (m^2),	66	137	10	224	291	32	212	267	37	0.59
Devegetated core area (m^2)	36	27	1	122	132	9	89	112	26	.33
Damaged trees (number)	3.0	3.0	0	17.5	14.0	-1.5	14.5	14.5	-3.0	.50
Trees with exposed roots (number)	0.5	0.5	1.0	9.5	8.5	0	5.5	8.5	1.0	.17
Felled trees (number)	2.5	3.5	0	3.5	7.0	3.0	7.5	7.5	1.0	.47
Seedlings/hectare	225	275	0	526	461	22	206	229	23	.99
Seedling loss (percent)	82	81	0	92	88	-2	96	95	0	.63
Vegetation cover (percent)	8.6	13.6	-1.0	6.1	5.7	1.1	6.1	6.5	1.0	.58
Vegetation loss (percent)	78	73	2	75	79	3	91	87	-2	.57
Mineral soil exposure (percent)	29	41	4	24	29	6	43	53	2	.94
Mineral soil increase (percent)	3	13	9	22	26	5	42	50	3	.99
Organic horizon thickness (cm)	0.20	0.20	0	0.50	0.25	-0.10	0.10	0	-0.10	.74
Organic horizon loss (cm)	0.10	0.10	0	0.15	0.35	0.10	0.30	0.40	0.10	.83
Floristic dissimilarity (percent)	29	32	2	60	67	1	48	56	4	.87
Species richness (number)	9	8	0	11	11	0	12	13	-1	.93
Condition class	3.3	3.3	0	4.0	4.0	0	4.0	4.3	0.3	.37

[1] Difference is the median change between 1979 and 1984; positive values indicate an increase over this period. Seedling and vegetation loss are relative differences (control value minus campsite value, divided by control); mineral soil increase and organic horizon loss are absolute differences (control value minus campsite value). The significance of differences between use categories was tested with the Kruskall-Wallis analysis of variance. Slight deviations from 1979 median values reported in Cole (1982) reflect corrected data for two campsites and the closure of six high-use sites.

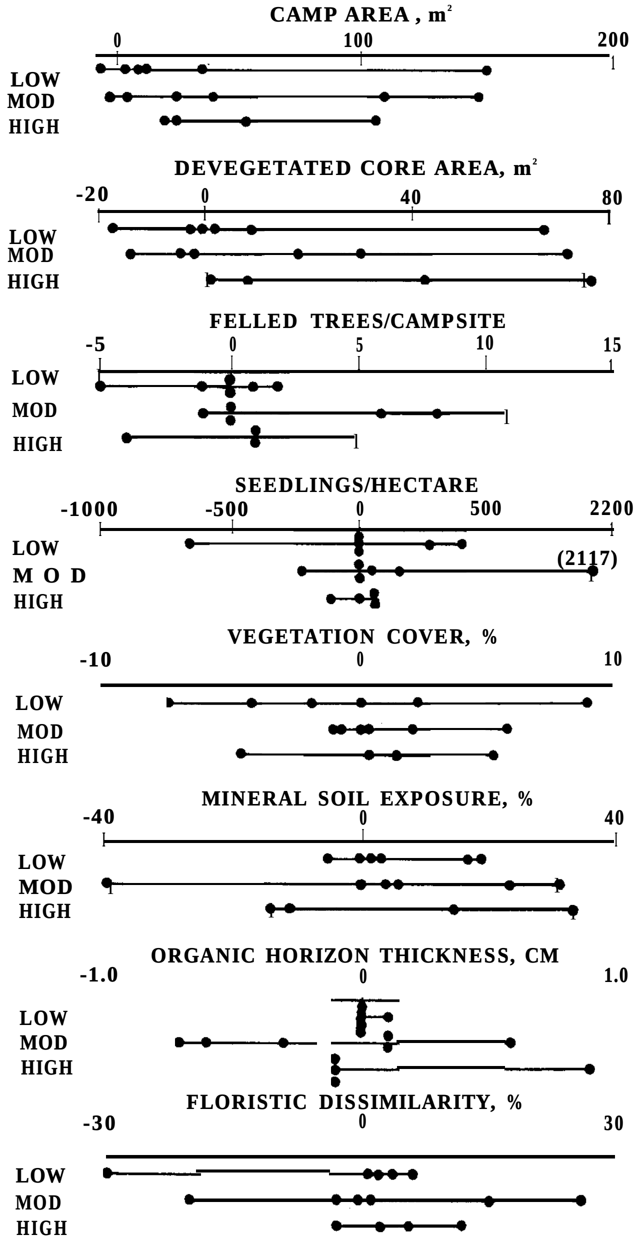

Figure 6.-Distribution of change values for low-, moderate-, and high-use sites. Each dot represents amount of change (1984 campsite value minus 1979 campsite value) on one campsite.

As with individual change parameters, there were no significant differences between use categories in the change index ($p = 0.51$). When graphed, however, a clear pattern does emerge (fig. 7). Measures of central tendency are similar across all use categories, but variability in amount of change decreases as use level increases. Compared to high-use sites, conditions on low-use sites are much more likely to either improve or deteriorate consistently over time (fig 8).

This finding should not be surprising. Studies of both existing campsites (Stohlgren 1982) and experimental trampling studies (Bayfield 1979) have found that more lightly used sites tend to recover more rapidly than more heavily used sites. Similarly, studies of existing campsites (for example, Cole and Benedict 1983) and experimental trampling studies (for example, Cole 1985) have concluded that low-use sites are more susceptible to deterioration, with small increases in use level, than are high-use sites. Conditions on low-use sites can either improve or deteriorate dramatically, depending on how they are used and managed; conditions on high-use sites are unlikely to change much over 5 years regardless of how they are used and managed. This "inertia" on high-use sites is well illustrated by comparing high-use sites that were closed to use around 1979 with high-use sites, at the same lakes, that remained open to use after 1979.

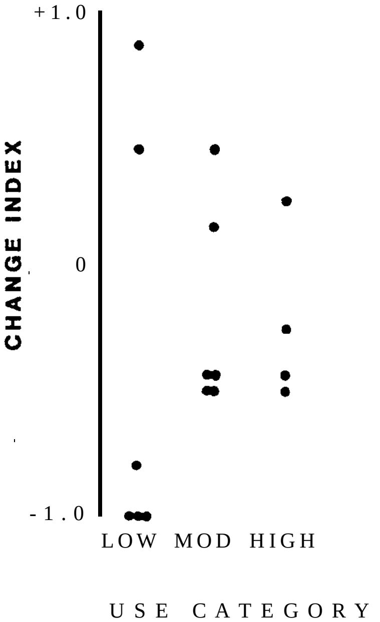

Figure 7.--Relationship between change index and amount of use. Positive index values indicate more improvement than deterioration; negative values indicate more deterioration than improvement.

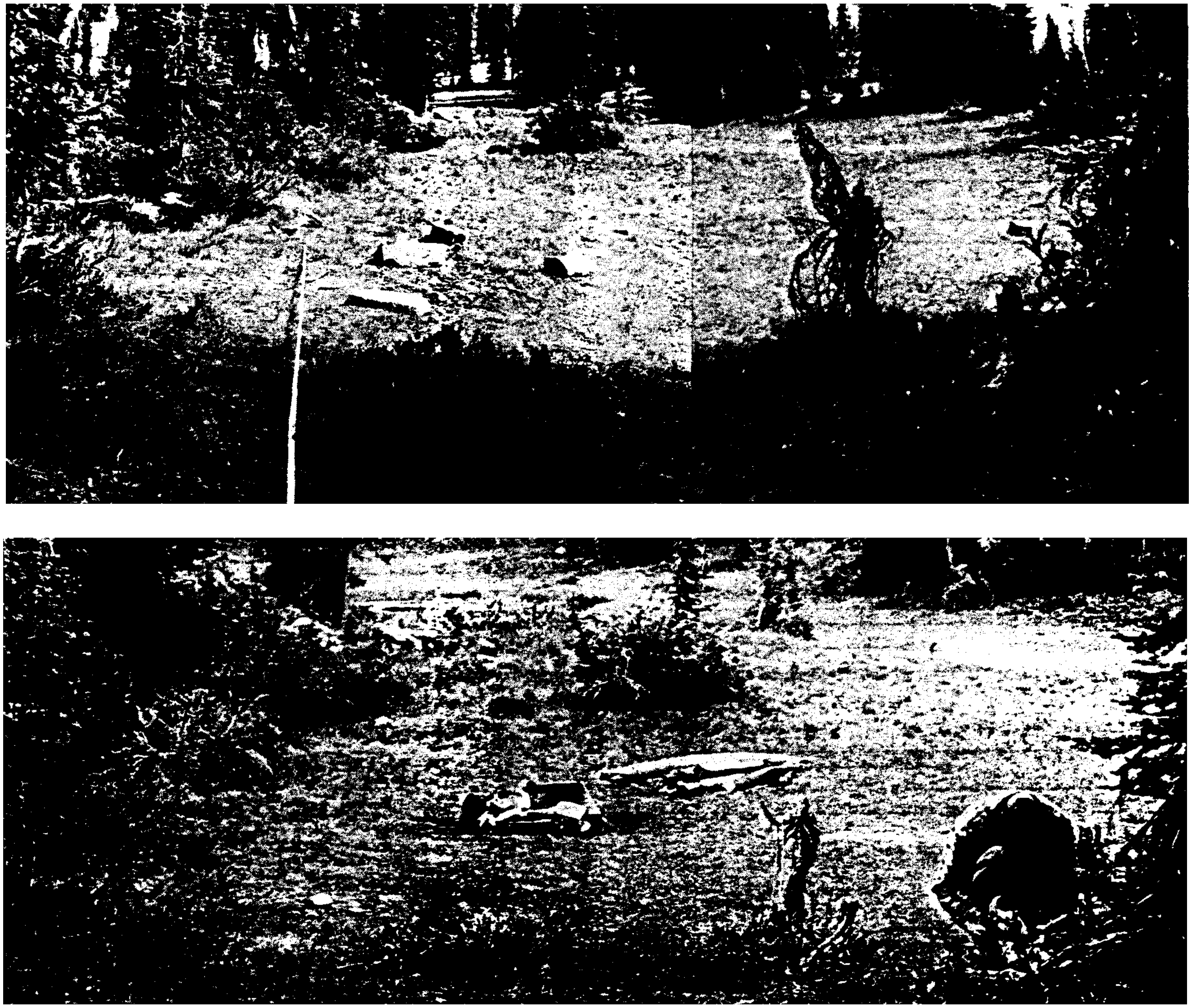

Figure &-The low-use site at Moon Lake deteriorated substantially between 1979 (top) and 1984 (bottom). Both photographs were taken from the campsite center toward a satellite fire ring on the periphery. Note the loss of vegetation, further tree damage, and expansion of the satellite area.

Ecological Changes on Open and Closed Campsites

During the late 1970's, managers instituted and began enforcing a regulation prohibiting camping within 200 ft (61 m) of lakeshores. Although this policy officially closed six of the 10 high-use sites examined in 1979, there was some noncompliance, thus use was reduced but not eliminated. A comparison of conditions on closed sites in 1979 and 1984 identifies changes following 5 years of use reduction, not true closure. This, however, is the normal closure situation in wilderness where few rangers with large areas to patrol make enforcement difficult.

Of the median differences for all impact parameters, only two showed significant difference; between open and closed sites (table 5). Camp area increased less on closed than open sites. The median closed site was only 6 percent larger than it was in 1979; the median open high-use site was 17 percent larger. The other significant difference was in condition class, a visual rating of overall impact (Frissell 1978). The median class for both open and closed sites in 1979 was 4.0-a site without much surviving vegetation and with considerable exposure of mineral soil and tree roots. Between 1979 and 1984, condition class ratings increased (impact worsened) on two open sites and stayed constant on the other open sites;

Table 5.-Comparison of amount of change on open and closed high-use sites[1]

Impact parameter	Open sites 1979	Open sites 1984	Open sites Diff.	Closed sites 1979	Closed sites 1984	Closed sites Diff.	Significance
	-------------Median						
Camp area (m^2)	212	267	37	217	234	14	0.04
Devegetated core area (m^2)	89	112	26	123	76	-11	.06
Damaged trees (number)	14.5	14.5	-3.0	12.5	13.0	0	.19
Trees with exposed roots (number)	5.5	8.5	1.0	4.5	3.5	-1.0	.16
Felled trees (number)	7.5	7.5	1.0	4.0	7.0	0.5	.50
Seedlings/hectare	206	229	23	692	673	-1	50
Seedling loss (percent)	96	95	0	82	85	0	.50
Vegetation cover (percent)	6.1	6.5	1.0	3.6	3.8	0.4	.33
Vegetation loss (percent)	91	87	-2	96	95	-1	.46
Mineral soil exposure (percent)	43	53	2	38	52	8	.26
Mineral soil increase (percent)	42	50	3	30	50	8	.33
Organic horizon thickness (cm)	0.10	0	-0.10	0.25	0.05	-0.15	.16
Organic horizon loss (cm)	0.30	0.40	0.10	0.55	0.60	0.15	.16
Floristic dissimilarity (percent)	48	56	4	66	71	4	.33
Species richness (number)	12	13	-1	10	10	0	.83
Condition class	4.0	4.3	0.3	4.0	4.0	0	.03

[1]Difference is the median change between 1979 and 1984; positive values indicate an increase over this period. Seedling and vegetation loss are relative differences (control value minus campsite value, divided by control); mineral soil increase and organic horizon loss are absolute differences (control value minus campsite value). The significance of differences in amount of change between open and closed sites was tested with the Mann-Whitney test.

on closed sites condition class ratings remained constant on all but one site, which improved.

The size of the devegetated core increased on all of the open sites, but on only half of the closed sites. The median change was an increase of 280 ft^2 (26 m^2) on open sites and a decrease of 118 ft^2 (11 m^2) on closed sites. Although not quite statistically significant using the Mann-Whitney test, this difference would be judged significant with a parametric t-test. Data for this variable are approximately normally distributed. Therefore, it would be relatively safe to consider this difference applicable beyond the few sites actually sampled.

For all other parameters, differences between open and closed sites are minor. Recovery from tree damage will be a very slow process, if it occurs at ail. Vegetational recovery and tree regeneration are also likely to require decades, even if all use is eliminated. Colonization of the campsite core is occurring on some sites. This decreases the devegetated area, but the few plants involved are not sufficient to increase percentage of vegetational cover substantially. Moreover, loss of organic matter continues unabated; on closed sites, mineral soil cover continues to increase and organic horizon thickness continues to decrease.

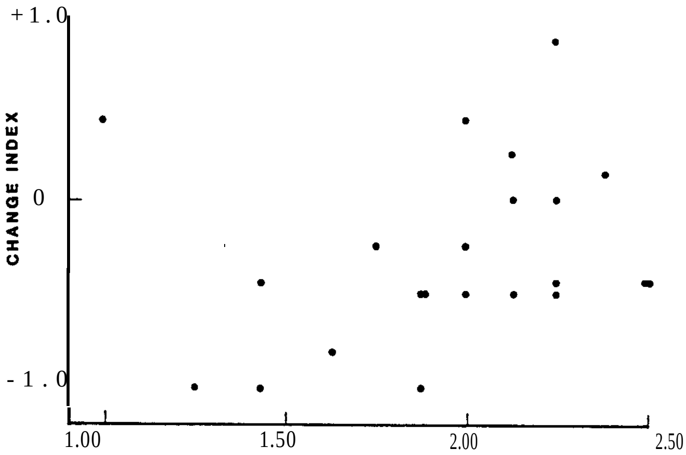

Figure 9.--Relationship between change index and an index of overall impact in 1979. Larger impact index values indicate more overall impact. Positive change values indicate more improvement than deterioration; negative values indicate more deterioration than improvement.

Predicting Change Over Time

By correlating the synthetic change index with various measures of campsite conditions taken in 1979, it was possible to assess the utility of existing site conditions as predictors of future change. Using Kendall's tau as a correlation coefficient, the only significant correlation was between change index and a synthetic index of overall impact (impact index) in 1979 (Cole 1982). The correlation was positive (0.28; $p = 0.04$). The sites that were most highly impacted in 1979 were the sites most likely to improve over the 5-year period; the less impacted sites were the sites most likely to deteriorate (fig. 9).

Although this finding is somewhat surprising at first, it reinforces what was discovered about the relationship between amount of use and amount of change. Low-use sites are more likely to be lightly impacted than high-use sites. So, in much the same way that low-use sites have more potential to deteriorate over tune, the more undisturbed campsites also have more potential for deterioration. With the exception of the Olive Lake site (impact index = 1.00; change index = 0.43)-a site that appeared to have been unused between 1979 and 1984-the sites that were relatively undisturbed in 1979 were the sites that changed most between 1979 and 1984.

This finding has important management implications that will be discussed in the next section; however, it does not identify a useful predictor of future change. Lightly impacted sites, if used, are the sites most likely to deteriorate; but, if unused, they are the sites most likely to improve.

Correlations are also useful for identifying key indicators-single parameters that reflect the amount of change that has occurred in a complex of impact parameters. The best indicators are those most closely correlated with overall change and for which data are easily gathered. The campsite condition parameters most highly correlated with overall amount of impact in 1979 were condition class and floristic dissimilarity (Cole 1982). In other words, those sites with the highest condition class and floristic dissimilarity values were generally the campsites- that had been most disturbed by camping.

In a similar analysis, changes between 1979 and 1984 in single impact parameters were correlated with the change index (table 6). These correlations suggest that the most useful single indicators of ongoing change on established campsites are changes in the number of seedlings and percentage of vegetational cover. Overall deterioration was greatest on those sites that lost the most seedlings and vegetational cover between 1979 and 1984; conversely, those sites with the largest increase in vegetational cover and seedlings were those that improved the most. Several other individual measures of change are also significantly, but less highly, correlated with the change index.

Such results may be highly site-specific; from this one study it is not possible to evaluate general applicability. Nevertheless, the objective of identifying simple indicators of complex changes is a worthwhile one. Similar attempts to correlate changes in single parameters with changes in a number of parameters might help identify consistently useful indicators.

Table 6.-Correlation between overall amount of change and change in individual parameters'

Impact parameter	Statistic: Kendall's tau	Statistic: Significance
Increase in:		
Camp area		0.19
Devegetated core area		.48
Damaged trees		.10
Trees with exposed roots	0.27	.05
Felled trees	.29	.04
Seedlings	- .35	.10
Vegetation cover	- .33	.02
Mineral soil exposure		.10
Organic horizon thickness		.21
Floristic dissimilarity	.28	.04
Condition class		.39

'A positive tau indicates that overall deterioration increases along with increases for individual parameters. Nonsignificant correlations are left blank.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The major findings of this study were:

1. Campsites receiving consistent use generally continue to deteriorate over time, even on former high-use sites that are currently closed to camping.

2. The most consistent and pronounced changes involve outward expansion of three zones of disturbance: a zone of exposed mineral soil, a zone in which vegetation is gone but organic horizons remain at least partially intact, and a zone of disturbed vegetation. These zones, particularly the zone of mineral soil, vary in pattern from well-defined and centralized zones to a poorly defined and diffuse pattern. Figure 10 provides an example of typical change, based on those that occurred on the moderate-use campsite at Blue Lake.

3. Most likely to deteriorate are lightly impacted sites that receive continued ***or*** increasing use. Unfortunately, lack of campsite-specific use figures made it impossible to determine whether use levels on lightly impacted sites were increasing, decreasing, or remaining constant. Observations suggest that use is increasing in the more undisturbed parts of the wilderness. This may partially explain the finding that it was the more lightly impacted sites that deteriorated most consistently between 1979 and 1984.

4. Low-use sites are more likely to experience pronounced changes-either improvement or deterioration-than high-use sites. The direction of change is presumably dictated by the level and type of use the site receives. Deterioration is more likely on low-use sites with increasing use levels or use by high-impact users.

5. High-use sites did not recover significantly after closure; however, the types of deterioration most pronounced ***on*** open sites ***were*** less pronounced on closed sites.

Generally, these conclusions support those of earlier studies. The most pronounced change following initial use of campsites in the Boundary Waters Canoe Area was campsite expansion (Merriam and others 1973). Long-term increases in devegetated area and mjneral soil exposure were also recorded on campsites (Merriam and Peterson 1983). On car campgrounds in California, changes over 5 years in such parameters as vegetation cover, species composition, and exposed mineral soil were minor (Magill 1970). No measures of area of impact were taken.

After 15 years of effective closure, campsites in subalpine forests in Rings Canyon National Park were covered with organic matter but little vegetational recovery had occurred (Parsons and DeBenedetti 1979). On campsites in subalpine forests in the Selway-Bitterroot Wilderness, after 8 years of less effective closure, little recovery of either organic litter or vegetation had occurred (Cole and Ranz 1983). Once campsites in such harsh environments are substantially impacted,

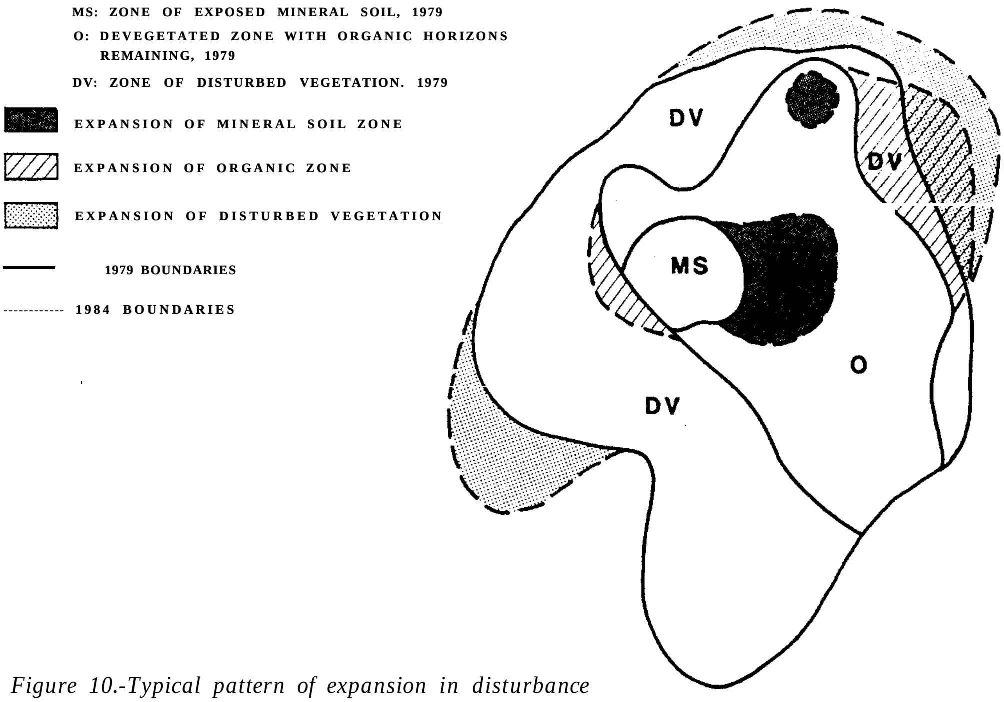

Figure 10.-Typical pattern of expansion in disturbance zones based on actual changes, between 1979 and 1984, on the campsite at Blue Lake.

Figure 11.-The transplants on this closed campsite at Mirror Lake survived but had not spread. Total vegetational cover remains low. Note the fire ring on this closed campsite.

recovery will require many decades-even if all use is curtailed. With a continuation of illegal camping and day use, recovery may never occur. Even attempts to increase recovery rates by transplanting vegetation have met with limited success. Transplanting was tried on two Eagle Cap campsites that had mean vegetational covers of 6.3 and 10.8 percent in 1979. By 1984, mean cover on these sites was 7.3 and 12.3 percent, respectively. Most transplants had survived, but they had not spread (fig. 11).

This is the first study to document both greater deterioration and greater recovery on the more lightly used and impacted campsites. In theory, these results were expected because the general relationship between use and impact is curvilinear. At low-use levels, even minor differences in amount of use tend to be associated with pronounced differences in amount of impact. At high-use levels, in contrast, even pronounced differences in amount of use usually have little effect on amount of impact (Cole in press). It was on the basis of this relationship that Cole and Benedict (1983) suggested visitors should avoid camping on lightly impacted sites. With continued use such sites are likely to deteriorate rapidly, but if left unused they retain the ability to recover rapidly.

Perhaps the most important management implication of this study is that campsite management is most important in areas where use levels and impacts are currently low. Here, poor management can bring rapid deterioration and good management can bring rapid recovery. High-use and high-impact sites are not likely to deteriorate or improve substantially in as short a time as given in this study, regardless of what managers do.

The keys to managing low-use areas are: (1) maintain low levels of use, (2) avoid consistent use of the same campsites, and (3) discourage high-impact types of use. Use levels need to be low enough to avoid consistent use of the same campsites. This requirement limits the ability of low-use zones to absorb excess use from other, more highly used areas. To avoid substantial deterioration of zones that are currently lightly impacted, it may be necessary to limit use of lightly used zones before limiting use of heavily used zones.

Avoiding consistent use of the same campsites will permit recovery to occur and avoid the creation of highly impacted sites incapable of rapid recovery. This can be accomplished by convincing people to either choose apparently undisturbed sites or visit more heavily used places, where well-impacted sites already exist. Any sites in low-use areas that are consistently used and highly impacted should be closed and rehabilitated.

Even one-time use can cause significant deterioration if campers are not-careful about minimizing impact. Large parties that do not practice low-impact techniques can quickly damage a site. Such problems are compounded when the party travels with stock (Cole in press). High-impact types of users should be encouraged to visit places where well-impacted sites already exist.

The keys to managing high-use areas are: (1) concentrate use on resistant, well-impacted sites, (2) discourage user behavior that contributes to long-term site deterioration, and (3) effectively close and rehabilitate poorly located or unneeded sites. In high-use areas. it is impossible to avoid consistent use of the same campsites. Therefore, it is best to concentrate use on a relatively small number of sites. This minimizes the area disturbed by camping. Concentration can be implemented by either requiring that visitors camp on designated sites or by asking that they camp on sites that are already well impacted. It is particularly important to discourage camping on the lightly impacted sites that are often dispersed among the highly impacted sites in a high-use area. These are the sites most likely to suffer pronounced deterioration.

Actions can be taken to minimize long-term deterioration of well-established campsites. Educating visitors about long-term impacts is essential and is the only means for avoiding tree damage. Education can also reduce the likelihood of unnecessary campsite expansion. Expansion can also be controlled through limitations on party size, careful selection of campsite locations, and proper design and layout of campsites. Of these, limiting party size is the obvious first choice and the only viable option where use is widely dispersed and visitors are allowed to camp wherever they please. To be effective, maximum party size limits will have to be less than 15 or 25, the most common limits in wilderness areas (Washburne and Cole 1983). If designated campsites are to be used, such sites can be located in thick vegetation and rough topography, where visitors will be unlikely to use offsite areas. Sites with poor drainage or any other condition likely to encourage offsite use should be avoided. Improvement of onsite tent pads will also encourage onsite use. Finally, large rocks, logs, and plantings of tree seedlings can be used to close off places where site enlargement is occurring. Locating campsites in forests with thick organic horizons may be the best solution to exposure of mineral soil over the long term.

Where use has been effectively limited to already well impacted sites, it is often possible to reduce the number of sites by closing and rehabilitating unneeded or poorly located sites. Success depends on eliminating all use-even day use-on the site. Efforts both to eliminate use and rehabilitate sites have generally met with limited success, except where considerable time has been invested in enforcement of closures and horticultural treatment of sites. The general ineffectiveness of current methods of closing and rehabilitating campsites is perhaps the most prominent barrier to improved management of campsites in high-use areas.

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APPENDIX: FREQUENCY AND COVER OF SPECIES ON CAMPSITES AND CONTROL SITES[1]

	Frequency of occurrence				Mean cover			
	Camps		Controls		Camps		Controls	
Species	1979	1984	1979	1984	1979	1984	1979	1984
Achillea millefolium	0	0	3	4	0	0	0.5	0.5
Agrostis thurberiana	1	1	0	0	+	+	0	0
Agrostis variabilis	4	1	4	1			2.1	1.0
Allium validum	0	0	2	3	0	0	.5	1.0
Antennaria alpina	4	3	16	14	0.3	0.4	1.3	1.1
Antennaria lanata	9	7	14	16	.4	.4	2.9	2.7
Antennaria microphylla	0	0	1	1	0	0	.5	.5
Arabis lyallii	1	1	0	0	+	+	0	0
Arabis sp.	0	0	1	1	0	0	.5	.5
Arenaria aculeata	0	0	5	5	0	0	.5	.5
Arnica cordifolia	1	1	3	2	+	+	.5	.3
Arnica mollis	1	1	5	4	.2	.1	2.1	2.6
Arnica parryi	0	0	1	0	0	0	.5	0
Aster alpigenus	5	4	4	3	.4	.5	1.1	.7
Calochortus eurycarpus	0	0	0	1	0	0	0	.5
Carex *geyeri*	1	1	2	2	.6	.7	.6	.5
Carex luzulina	0	0	1	0	0	0	.5	0
Carex microptera	4	5	5	4	.6	.8	5.4	4.4
Carex nigricans	1	1	2	2	.3	.2	5.5	2.0
Carex rossii	19	20	20	20	.6	.8	1.2	1.2
Carex scopulorum	0	0	2	2	0	0	5.5	5.3
Carex spectabilis	5	5	6	6	.9	1.0	1.0	1.8
Cassiope mertensiana	2	1	3	3	.1	.1	1.5	1.2
Castilleja chrysantha	1	2	6	6	+	+	.6	.4
Danthonia intermedia	3	2	6	3	.2	.5	1.4	1.5
-*Deschampsia cespitosa*	0	0	2	1	0	0	7.0	5.0
Dodecatheon alpinum	1	1	1	1	.1	.1	.3	.3
Epilobium alpinum	2	2	2	2	+	.1	.3	.4
Epilobium angustifolium	1	2	6	6	+	+	.4	.4
Erigeron peregrinus	9	8	16	16	.2	.1	1.6	1.5
Eriogonum flavum piperi	0	0	1	1	0	0	.5	.5
Eriogonum ovalifolium	3	2	1	1	.1	.2	.3	.3
Festuca viridula	4	6	14	15	.4	.4	2.5	3.0
Gaultheria humifusa	1	1	5	5	.1	.7	2.8	3.0
Gayophytum humile	2	2	1	0				0
Gentiana calycosa	0	0	2	2	0'	0	2	1.3
Hieracium albertinum	1	0	2	2	+	0	.8	.8
Hieracium gracile	4	5	14	14			.5	.6
Holodiscus discolor	0	0	1	1	0'	0	.5	.5
Hypericum anagalloides	1	0	0	0		0	0	0
Hypericum formosum	0	0	6	6	0	0	1.5	1.5
Juncus drummondii	1	2	3	2	.3	.2	.5	1.0
Juncus mertensianus	0	0	1	1	0	0	.5	.5
Juncus parryi	20	20	21	21	1.7	2.0	6.2	6.2
Ledum glandulosum	1	1	4	4	.1	.2	3.7	3.7
Lewisia pygmaea	1	1	0	0	+	.1	0	0
Ligusticum tenuifolium	4	3	5	5			.4	.5
Linanthastrum nuttallii	0	0	1	1	0	0	.5	.5
Lonicera utahensis	0	0	1	1	0	0	.5	2.0
Luzula campestris	0	0	1	1	0	0	1.0	2.0
Luzula hitchcockii	7	6	9	10	.4	.3	1.8	2.1
Mitella pentandra	0	0	0	1	0	0	0	.5
Muhlenbergia filiformis	9	11	10	12	.4	.4	1.6	1.8
Oryzopsis exigua	1	1	6	5	.2	.2	.5	.5
Osmorhiza chilensis	0	0	1	1	0	0	.5	.5

(con.)

APPENDIX (Con.)

Species	Frequency of occurrence				Mean cover			
	Camps		Controls		Camps		Controls	
	1979	1984	1979	1984	1979	1984	1979	1984
Parnassia fimbriata	0	0	1	1	0	0	.5	.5
Pedicularis contorta	0	0	1	1	0	0	.5	.5
Penstemon fruticosus	0	0	2	1	0	0	.5	.3
Penstemon rydbergii	1	2	4	3	.2	.1	1.8	1.8
Phleum alpinum	4	4	4	4	.1	.1	1.5	.5
Phyllodoce empetriformis	12	12	18	17	.4	.6	10.8	9.9
*Poa annua**	1	1	0	0	.2	.2	0	0
Poa gracillima	0	0	1	1	0	0	1.0	1.0
Poa leibergii	0	0	1	1	0	0	.5	.5
Poa sandbergii	0	0	1	1	0	0	.5	.5
Poa sp.	0	0	2	2	0	0	.5	.5
Polemonium pulcherrimum	1	1	4	4	+	+	.8	.8
Polygonum phytolaccaefolium	1	1	4	4	.3	.4	1.1	.8
Potentilla diversifolia	0	0	1	1	0	0	1.0	1.0
Potentilla flabellifolia	5	4	6	7	.3	.4	5.8	4.3
Potentilla glandulosa	0	0	1	0	0	0	.5	0
Potentilla gracilis glabrata	0	0	1	1	0	0	.5	.5
Ranunculus eschscholtzii	0	0	2	1	0	0	.6	.5
Ranunculus populago	1	2	1	3	.1	.1	.7	1.8
*Sagina saginoides**	2	3	0	0	.6	.4	0	0
Senecio cymbalarioides	0	0	2	2	0	0	5.3	4.5
Sibbaldia procumbens	10	10	11	11	1.4	1.6	1.9	2.5
*Spergularia rubra**	1	1	0	0	.3	.1	0	0
*Trifolium repens**	0	1	0	0	0	+	0	0
Trisetum spicatum	0	0	6	5	0	0	1.4	.4
Trisetum wolfii	0	0	1	1	0	0	5.0	.5
Vaccinium caespitosum	1	1	4	4	.6	.3	3.9	3.6
Vaccinium scoparium	19	18	21	21	.7	.8	20.0	19.6
Veratrum viride	1	1	2	2	.4	.2	.8	.5
Veronica cusickii	9	8	14	18	.2	.6	2.3	2.1
Veronica serpyllifolia	1	1	0	0	.1	.1	0	0
Veronica wormskjoldii	1	2	0	1	.1	.1	0	.3
Viola adunca	3	4	5	5	.1	.6	1.1	2.6

‘Frequency is the number of sites, out of a maximum of 22, on which the species was found. Mean cover is the mean for all sites, either camp or control, on which the species was found; it is not a mean for all 22 sites. A plus indicates cover less than 0.1 percent. The more susceptible species are those with low ratios between campsite and control values, for either frequency or mean cover.
* denotes an exotic species.