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Trends in Campsite Condition: Eagle Cap Wilderness, Bob Marshall Wilderness, and Grand Canyon National Park

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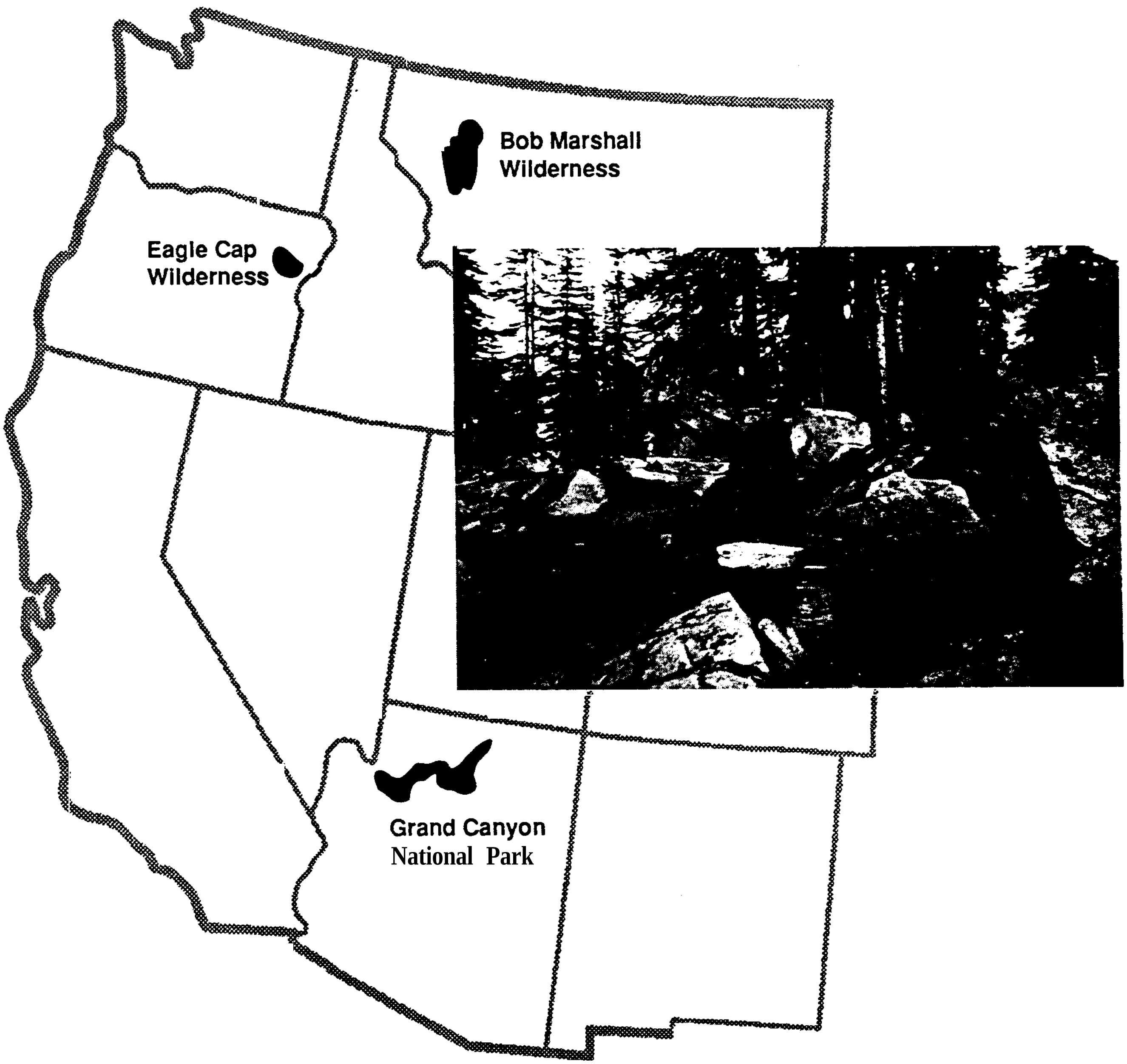

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RESEARCH SUMMARY

Changes in the condition of well-established campsites were followed in three backcountry areas: Eagle Cap Wilderness in Oregon, Bob Marshall Wilderness in Montana, and Grand Canyon National Park in Arizona. The period over which change was followed varied from 5 years at Grand Canyon to 11 years at Eagle Cap.

In all three areas, there was tremendous variation in response, both between and within campsites. Certain campsites improved, while others deteriorated, and others were relatively unchanged. Moreover, on individual sites, certain types of impact became more pronounced while other types diminished. The mean response of all campsites, at Grand Canyon and Eagle Cap and of recently used Bob Marshall sites, was one of slight deterioration. This suggests that there is little reason to be either optimistic or pessimistic about the future condition of established campsites. Continued use of these sites may cause further deterioration but at rates that are low when compared with the amount of impact that has already occurred._ On the other hand, apparent decreases in visitor use in recent years and attempts to mitigate campsite impact have not led to improved campsite conditions.

The types of impact that most frequently increased over time were campsite expansion, exposure of mineral soil, and damage to trees. In contrast, impacts to ground cover vegetation tended to decline or were stable in all three areas.

Changes on high-use and low-use sites were compared in Eagle Cap and Grand Canyon. In both cases high-use sites were more highly impacted than low-use sites, and the difference between low-use and high-use sites increased over the study period. With few exceptions, high-use sites either deteriorated or were stable. The response of low-use sites was more variable. Certain low-use sites deteriorated as much as the high-use sites, while others improved substantially.

In all three areas, change was followed on sites that were no longer being camped on. The response of these sites was highly variable, apparently depending on previous impact levels and on environmental characteristics. Generally, more highly impacted sites recovered more slowly than lightly impacted sites. In addition, sites with fertile and well-watered soils and sites with long growing seasons recovered well.

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INTRODUCTION

More than 25 years ago the Wilderness Act created the National Wilderness Preservation System. Since then many changes have occurred, and there are diverse opinions about whether conditions in wilderness have improved or deteriorated. But lack of longitudinal research data has made it difficult to draw conclusions about trends in wilderness conditions (U.S. GAO 1989). Trend data are needed for both visitor use characteristics (Roggenbuck and Lucas 1987) and resource conditions (Cole 1987b). Toward these ends, trend studies have been conducted on both wilderness visitors and campsite conditions in wilderness. This report describes changes over time in the condition of selected long-established campsites in three wilderness/backcountry areas. Additional reports will describe trends in the number and distribution of campsites, trail conditions, and visitor characteristics and preferences.

Of two studies of change on established wilderness campsites, one described changes in conditions over 9 years on seven open campsites in the Boundary Waters Canoe Area Wilderness, MN (Merriam and Peterson 1983). Some sites improved, some deteriorated, and some were relatively stable. On individual sites, certain types of impact increased while others decreased. The overall trend suggested was one of slight deterioration over this period. The second study described changes in condition over 5 years on campsites in the Eagle Cap Wilderness, OR (Cole 1986a). One of the case studies reported here is a continuation of this study for an additional 6 years.

The case studies reported here were conducted in the Eagle Cap Wilderness, the Bob Marshall Wilderness, MT, and Grand Canyon National Park, AZ. These areas represent a spectrum of environments, use levels, and types of use. The Eagle Cap study was conducted on forested sites in subalpine lake basins. This wilderness receives moderate levels of use, primarily by backpackers. The Bob Marshall study was conducted on lower elevation mountainous sites. Use levels are relatively low, but use by outfitted parties and parties with packstock is unusually high. The Grand Canyon study was conducted on desert sites. Use levels are relatively high, and all use is by backpackers.

The field methods and periods of study also varied between areas. The periods between measurements were 11 years in the Eagle Cap, 9 years in the Bob Marshall, and 5 years in the Grand Canyon. Consequently, each area is treated as a separate case study.

As will become apparent, the patterns of change that occurred on these campsites are complex. Consequently, the results are presented in considerable detail for the interested reader. Others might find it easier to skip over much of the detail, concentrating on the conclusions presented at the end of each case study (pages 12, 20, and 30) and the discussion and management implications section.

EAGLE CAP CASE STUDY

Study Area and Methods

In 1979, 26 campsites in the Eagle Cap Wilderness were selected for study (Cole 1982); 22 of these sites were in similar environmental situations-subalpine forests around lakes (fig. 1). They were all located between 2,150 and 2,400 m elevation in an *Abies lasiocarpa / Vaccinium scoparium (ABLA/VASC)* forest type on soils derived from granitic bedrock. These sites were stratified on the basis of estimated use levels as follows: six light-use sites (less than 5 nights per year), six moderate-use sites (10 to 20 nights per year), and 10 heavy-use sites (more than 25 nights per year). Six of the heavy-use sites were within 60 m of lakes. Around the time the study commenced, these lakeshore sites were officially closed to camping; the other four heavy-use sites were farther from lakeshores and remained open for camping. Four additional sites were in different environments-two in timberline meadows (2,500 m elevation) and two in midelevation forests (2,000 m elevation) along riverbanks.

Figure l-Most of the study sites in the Eagle Cap Wilderness were in subalpine forests close to lakes (figure deleted due to poor reproduction.).

In 1984 all 26 of these campsites were revisited. Changes in the 5 years between 1979 and 1984 are reported in Cole (1986a). In 1990, 20 of these campsites were reexamined, including all four of the sites in other environments, but only 16 of the ABLA/VASC sites. Of these 16, three were light-use sites, three were moderate-use sites, four were open high-use sites, and six were closed high-use sites. Although officially closed, some camping continued on the lakeshore sites. Results will be presented (1) for all 20 sites combined, (2) for low-use ABLA/VASC sites in comparison to similar open high-use sites, and (3) for open high-use ABLA/VASC sites in comparison to similar closed high-use sites.

Methods are described briefly as follows, and more detail can be found in Cole (1982). 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" 15 to 140 cm tall were counted within the camp area, excluding any untrampled "islands"; larger trees were counted in 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 1990, the center point-a buried nail-was relocated. Distances to the edge of the disturbed campsite and to the first significant 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 in this area, as in 1979.

On each campsite, approximately 15 quadrats, 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 percentage if under 10 percent or, if over 10 percent, in 10 percent coverage classes. The midpoints of each coverage class were used to calculate mean coverages for the campsite. The thickness of organic horizons was measured at four points between 1 and 2 m from the center point, along each transect. In 1990, 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 91 to 201 m^2, coverage of total ground vegetation, exposed mineral soil, and each plant species was estimated for the entire plot. Seedlings were counted on a 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 1990.

The magnitude of change over the 11 years between 1979 and 1990 is expressed in three ways: (1) mean conditions in 1979 and in 1990; (2) the mean absolute amount of change, which is calculated by subtracting conditions in 1979 from conditions in 1990; and (3) to provide a different perspective on the magnitude of this change, absolute change, is divided by conditions in 1979 to obtain relative change. Although means are reported in the tables, median values are often used in the text to describe the response of a "typical site."

For some types of impact, campsite conditions changed, but so did comparable conditions on the control sites. In these situations changes caused by camping are confounded by other causes of environmental change such as recent precipitation patterns. The "noise" resulting from these extraneous causes was reduced by calculating two indexes that compare campsite and control conditions. The first index --absolute difference-- is the measure on the control site minus the measure on the campsite. The second index --relative difference-- is absolute difference expressed as a percentage of the measure on the control site. These indexes provide estimates of how much impact has occurred on campsites. Change over time, in these indexes, can be attributed to camping because broad environmental changes are factored out. Where both campsite and control conditions change, these indexes are used for comparative purposes.

The direction of response often varied between sites; some sites would improve while others would deteriorate. Consequently, the number of sites that responded in each possible way is reported.

We evaluated the significance of the difference between conditions in 1979 and 1990 with the Wilcoxon matched-pairs, signed-ranks test in the cases where data were not normally distributed. Where data were normally distributed, we used a paired *t-test*. Null hypotheses were rejected if probability values were 0.05 or less. A significant difference indicates a pronounced and consistent change, either toward improvement or deterioration. A nonsignificant difference suggests either that conditions were generally unchanged or that conditions changed but not in a consistent, direction. The magnitude of changes and the proportion of sites that improved, deteriorated, and stayed the same can be used to decide between these two latter options.

To test the hypotheses that (1) heavy-use sites deteriorated more than low-use sites and (2) open sites deteriorated more than closed sites, we used one-tailed nonparametric Mann-Whitney and parametric *t* -tests. Given the small sample sizes, the likelihood of incorrectly accepting the null hypotheses (that there are no differences) is relatively high.

Changes on All Sites

Trends for Individual Types of Impact- Campsite area, the area visibly disturbed by camping activities, increased significantly from a mean of 193 m^2 in 1979 to 206 m^2 in 1990 (table 1). The median site increased 10 m^2, or about 4 percent. Thirteen of the 20 sites increased in size, while only three decreased in size. Decreases tended to be larger than increases, however. The median decrease on sites that decreased in area was 59 m^2, while the median increase on sites that increased was 17 m^2. Most of the increases in area had occurred by 1984; mean area was actually higher in 1984 (227 m^2) than in 1990. Surprisingly, all but one of the closed sites increased in area. Conversely, all of the sites that were unchanged or that decreased in size were sites that remained open to use.

In contrast to campsite area, the size of the devegetated central core of the campsite decreased from a mean of 92 m^2 in 1979 to 69 m^2 in 1990. This decrease was not pronounced and consistent enough to be statistically significant; 11 of the 20 sites experienced decreases. Although devegetated area decreased on five of the open sites, most of the sizable decreases in devegetated area occurred on closed campsites. When only open sites are considered, the mean devegetated area was virtually unchanged between 1979 and 1996. Devegetated area was substantially higher in 1984 than in either 1979 or 1990, suggesting that this variable is subject to sizable year-to-year fluctuations. For example, a few sparse plants growing close to the center of the site can drastically reduce devegetated area, even though the total amount of vegetation cover on the campsite has not increased substantially. Several of the sizable reductions in devegetated area resulted from transplanting of plugs in the center of largely barren sites (fig. 2).

Results for tree damage were mixed (table 1). The number of damaged trees (those with nails, scars, or broken branches) declined slightly, but so did the total number of trees on each site. The number of

Table 1 -Mean change in size and tree damage on all 20 campsites,[1] Eagle Cap Wilderness

Statistic	Camp area	Devegetated core area	Damaged trees	Trees with exposed roots	Felled trees
	------- m^2 -------		----------- *Number* ----------		
Conditions					
1979	193	92	11	5	5
1990	206	69	10	7	5
Change					
Absolute	13	-23	-1	1	**0**
Relative (percent)	7	-25	-9	20	0
Number of sites					
Increase	13	5	6	10	4
Decrease	3	11	10	3	8
Unchanged	4	4	4	. 7	8
Significance	0.04	0.08	0.19*	0.02*	0.64

[1]Absolute change is the condition in 1990 minus the condition in 1979. Relative change is absolute change as a percentage of the condition in 1979. The significance of differences between 1979 and 1990 was tested with the Wilcoxon matied-pairs, signed-ranks test, or with the paired t-test where denoted with an l .

Figure 2-The devegetated area on this Eagle Cap Wilderness campsite has been reduced substantially by transplanted plugs, but total vegetation cover remains low.

felled trees was virtually unchanged. A decrease in number of trees could have resulted either from the elimination of all traces of trees that had been felled or from measurement error (individual counts in tree clumps involves some subjectivity). Both probably occurred. The likelihood that the former occurred suggests that tree damage may be greater than the data suggest because trees that are completely eliminated are not counted.

The most dramatic change involved the incidence of tree root exposure, which increased from a mean of five trees in 1979 to seven trees in 1990. This increase is statistically significant and occurred on 10 of the 18 sites that had trees on them. In 1979 the median site had exposed roots on 30 percent of its trees; median tree root exposure increased to 38 percent in 1984 and 48 percent in 1990. Tree damage is cumulative-new damage is not offset by recovery from damage as it is for such impacts as vegetation loss. These data suggest a trend of continued slow increases in tree damage.

Tree seedling density on campsites increased significantly from a mean of 457 seedlings per hectare in 1979 to 548 seedlings per hectare in 1990 (table 2). Seedling density increased on 12 of the 18 forested sites, with the median site experiencing a 14 percent increase. Simultaneously, seedling densities decreased on control sites. Calculations of the relative difference between campsites and controls indicate that, in 1979, the median campsite had lost 92 percent of its seedlings. This loss had decreased to 89 percent in 1984 and 80 percent in 1990. Although it is clear that seedling loss remains a significant impact on campsites, the increase in the number of surviving tree seedlings is unexpected, unexplained, and encouraging.

Ground cover conditions changed somewhat between 1979 and 1990 (fig. 3). Vegetation cover increased, although not enough to be statistically significant (table 2). The most substantial change was an increase in mineral soil exposure from a mean of 33 percent in 1979 to 44 percent in 1990. Mineral soil exposure increased on 16 of the 20 sites. In a few cases, changes were dramatic. On one site, soil exposure increased from 7 percent in 1979 to 74 percent in 1990. The primary cause of soil exposure, then, was loss of litter cover from parts of the site that were not vegetated. (The litter category in figure 3 refers only to "exposed" litter-litter that was not underneath ground cover vegetation.)

In contrast to the campsites, ground cover conditions on control sites were relatively stable. Based on the relative difference between campsites and controls, the median campsite, in 1979, had lost 87 percent of its vegetation cover. The magnitude of vegetation loss decreased over time-to 85 percent in 1984 and 81 percent in 1990. In 1979, the median campsite had 24 percent more exposed mineral soil than controls. This difference increased to 42 percent in 1984 and 51 percent in 1990.

Despite this increase in the areal extent of soil exposure, the thickness of organic horizons in the central part of the campsite (where duff depth was measured) was unchanged between 1979 and 1990 (table 2). Organic horizons, which were measured at points 1 to 2 m from the center point, decreased on seven sites, increased on five, and stayed the same on eight. In 1979, organic horizons were already

Table 2 -Mean change in seedling density and ground cover conditions on all 20 campsites,[1] Eagle Cap Wilderness

Statistic	Seedling density		Vegetation cover		Mineral soil cover		Organic horizon thickness	
	Camp	Control	Camp	Control	Camp	Control	Camp	Control
	---*No./ha*----		------------percent------------				-----cm-----	
Conditions								
1979	457	5,060	15	60	33	1	0.2	0.9
1990	548	3,335	19	60	44	3	0.2	0.9
Change								
Absolute	91	-1,991	4	0	11	0	0	0
Relative (percent)	20	-39	27	0	33	0	0	0
Number of sites								
Increase	12	2	12	4	16	7	5	8
Decrease	4	15	7	4	3	3	7	9
Unchanged	4	2	1	11	1	9	8	2
Significance	0.09	0.001	0.13*	0.96*	0.02	0.05*	0.90	0.67

[1]Absolute change is the condition in 1990 minus the condition in 1979. Relative change is absolute change as a percentage of the condition in 1979. The significance of differences between 1979 and 1990 was tested with the Wilcoxon matched-pairs, signed-ranks test, or with the paired r-test where denoted with an * .

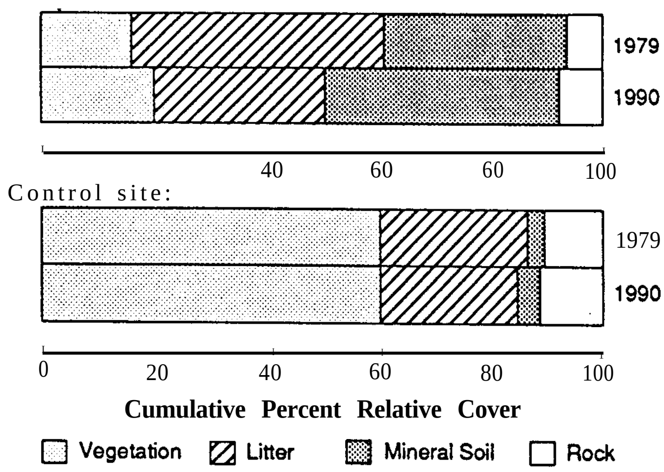


Figure 3- Mean coverage of ground cover categories on campsites and control sites in 1979 and in 1990, Eagle Cap Wilderness.

Table 3 -Mean change in indexes of species composition and diversity on all 20 campsites,[1] Eagle Cap Wilderness

Statistic	Floristic dissimilarity	Species richness	Simpson's index
	Percent	*Number*	
Conditions			
1979	55	12	0.25
1990	57	13	0.26
Change			
Absolute	1	1	0.01
Relative (percent)	2	8	4
Number of sites			
Increase	12	9	7
Decrease	7	8	13
Unchanged	0	3	0
Significance	0.40	0.49*	0.69*

[1]Absolute change is the condition in 1990 minus the condition in 1979. Relative change is absolute change as a percentage of the condition in 1979. The significance of differences between 1979 and 1990 was tested with the Wilcoxon matched-pairs, signed-ranks test, or with the paired *t-test* where denoted with an * .

largely depleted close to the center of the site; thickness had been reduced a median of 75 percent in comparison to controls. By 1990, the median reduction in thickness was 78 percent. This suggests that, currently, most ground cover disturbance is occurring away from the central part of the site.

Changes in vegetative characteristics were relatively minor. For vegetation cover, the trend was one of slight improvement. Vegetation cover increased on 12 of the 20 campsites, although the median change was an increase in cover of just 2 percent. The most dramatic improvement on a site that was being used was an increase in cover from 8 percent in 1979 to 22 percent in 1990 (on a site with a control cover of 60 percent). The most pronounced deterioration was a decrease in cover from 8 percent in 1979 to 2 percent in 1990 (on a site with a control cover of 30 percent).

Changes in species composition were even less pronounced. Floristic dissimilarity-an index of the difference in composition between campsites and controls (Cole 1978)-was virtually unchanged (table 3). In 1979 the mean floristic dissimilarity between campsites and controls, which theoretically can vary from 0 percent (no difference) to 100 percent (completely different), was 55 percent; in 1990 it was 57 percent. Although the difference between campsites and controls increased on 12 of 19 sites, the median change was an increase of just 3 percent. To investigate further, we calculated the floristic dissimilarity, between years, for campsites and for controls. The mean dissimilarity for campsites was 28 percent; the mean dissimilarity for controls was 17 percent. This indicates that species composition on campsites is more variable, over time, than on controls. But the trajectory of change on campsites is not away from the composition one would expect on undisturbed sites.

For both individual species and for growth forms, differences in relative cover, between campsites and undisturbed controls, were pronounced, but changes over time were not. For example, figure 4 shows the mean relative cover of the four most common vascular plant species. *Juncus parryi* and *Carex rossii* increase in relative cover on campsites; they are among the species most resistant to camping disturb ante. *Vaccinium scoparium* and *Phyllodoce empetriformis* decrease in relative cover on campsites; they are relatively fragile species. However, changes over time are minimal for all four species. For the two resistant species, the difference between campsites and controls decreased slightly. For the two fragile species, the difference between campsites and controls was unchanged. Changes in the frequency and cover of other species can be found in appendix 1.

Changes in the relative cover of different growth forms were also minor (fig. 5). In 1979, the relative cover of graminoids was significantly higher on campsites than controls; graminoids were more resistant to campsite impacts than other growth forms. Shrubs and bryophytes had lower relative cover on campsites than on controls, suggesting that these growth forms were relatively fragile. By 1990, differences between campsites and controls had declined for both graminoids and bryophytes; differences increased for shrubs and forbs.

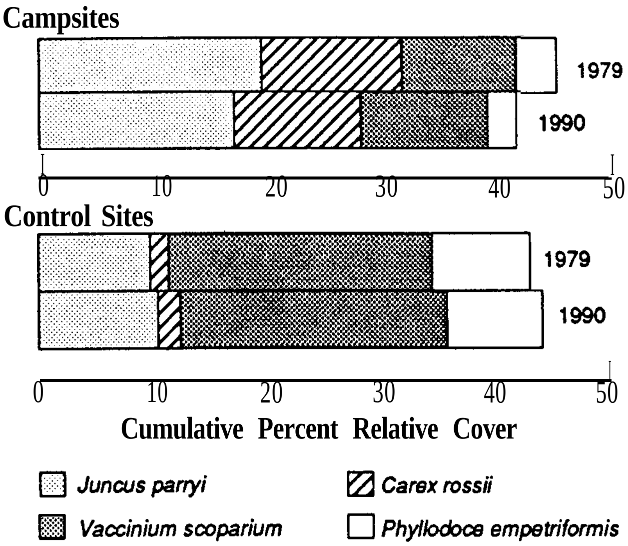


Figure 4- Mean relative cover of four common species on campsites and control sites in 1979 and in 1990, Eagle Cap Wilderness.

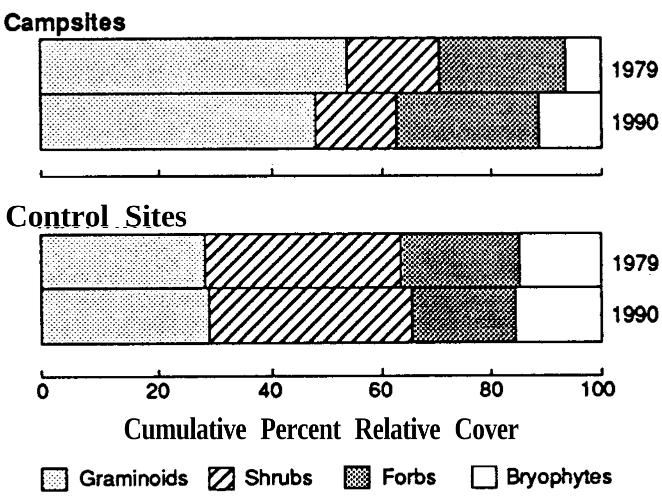


Figure 4- Mean relative cover of growth forms on campsites and control sites in 1979 and in 1990, Eagle Cap Wilderness.

Changes in species diversity were also minor. Species richness (the number of species in the 15-m^2 quadrats) increased on nine sites and decreased on eight (table 3). The low-elevation site that was no longer in use experienced an increase in richness from 12 to 35 species. But aside from this site, the maximum increase was seven species and the maximum decrease was also seven. Simpson's index, which indicates the extent to which the vegetation is dominated by a small number of species, was also virtually unchanged. Because larger numbers indicate increased dominance (lower diversity), more sites increased in diversity than decreased, but the mean change was only about 4 percent and not statistically significant.

Overall Trends- These results suggest that certain types of impact had already reached peak levels by 1979, while others have continued to increase since that time. The impacts that had already stabilized are generally those that occur to ground cover vegetation: devegetated core area, seedling density, vegetation cover, and species composition. Ground cover vegetation is so fragile that damage occurs quickly (Cole 1987a). Levels of vegetation damage stabilize quickly. Thereafter, conditions are unlikely to change greatly unless there is a dramatic change in the amount or type of use.

The two types of impact that continue to intensify strongly are exposure of tree roots (fig. 6) and increase in mineral soil exposure. These impacts result from erosion of organic horizons and mineral soil, impacts that are caused only by frequent use or a high-impact style of use (for example, tying horses to trees) or that occur only after long periods of use. These two impacts were among the few found to be more pronounced on frequently used campsites (Cole 1982). Such impacts could conceivably be limited through management of recreational use.

Campsite area is intermediate in response. Between 1979 and 1984, campsite area increased substantially on 10 of the 20 sites. However, between 1984 and 1990, only three of these sites continued to increase in size. The mean camp area increased 13 percent between 1979 and 1984; between 1984 and 1990 the mean camp area decreased 6 percent. This suggests that site area has stabilized on most of these sites.

To assess overall impact, a summary impact rating was calculated for each site. Impact indicators used in this summary rating were camp area, relative difference in vegetation cover, absolute difference in mineral soil cover, floristic dissimilarity, relative difference in seedling density, percentage of trees with exposed roots, and relative difference in duff depth. For each of these indicators, campsites were assigned a rating of 1,2, or 3 (low to high amount of impact). The impact rating is the mean of all types of impact that apply.

The mean impact rating increased from 2.0 in 1979 to 2.1 in 1990. This change was not statistically significant. Ten of the sites were relatively stable (impact ratings changed no more than 0.2). Impact ratings increased by more than 0.2 on seven sites and deteriorated by more than 0.2 on three sites. If substantial change were defined as a change in impact rating of more than 0.4, one site deteriorated substantially and two sites improved substantially. More subjective evaluations of the change data led to the same overall conclusions:

Table 4- Mean change in campsite conditions on three low- use and four high-use campsites,[1] Eagle Cap Wilderness

Statistic	Amount of use Low	High
Camp area (m^2)		
1979	161	218
1990	193	263
Change	33	45
Devegetated core area (m^2)		
1979	67	109
1990	55	135
Change	-11	26
Trees with exposed roots (No.)		
1979	3	8
1990	5	11
Change	2	3
Vegetation cover (percent)		
1979	13	7
1990	16	8
Change	3	2
Mineral soil exposure (percent)		
1979	25	43
1990	35	66
Change	10	23
Organic horizon thickness (cm)		
1979	0.3	0.1
1990	0.2	0.1
Change	-0.1	0
Floristic dissimilarity (percent)		
1979	48	52
1990	47	62
Change	-1	9
Impact rating		
1979	1.6	2.2
1990	1.7	2.6
Change	0.1	0.4

[1]Change is the condition in 1990 minus the condition in 1979.

1979 to 135 m^2 in 1990; the mean area on low-use sites decreased 11 m^2, from 67 m^2 in 1979 to 55 m^2 in 1990. Vegetation cover increased between 1979 and 1990 on both categories of site, but the increase was much greater on low-use sites. Mineral soil exposure increased on most sites, but again, the increase was much greater on high-use sites. Only for loss of organic horizons did the difference between low-use and high-use sites decline between 1979 and 1990. This can be explained by the fact that, by 1979, organic horizons were already virtually gone in the central portion of high-use sites.

In 1979, mean camp area was substantially lower on low-use sites than on more frequently used sites. The difference was not statistically significant with 95 percent confidence; however, it would have been significant with a lower confidence level of 90 percent. Between 1979 and 1990, mean camp area on high-use sites increased 45 m^2; on low-use sites the mean increase in area was 33 m^2. As with devegetated core area, high-use sites are more impacted than low-use sites, and the difference between high-use and low-use sites increased between 1979 and 1990.

The impact ratings suggest that overall conditions deteriorated slightly on both categories of campsite (fig. 7). Deterioration was greater on the high-use sites, although the difference between use levels was not statistically significant. Again, given the small sample to work with, statistical significance would not be expected.

For certain types of impact, such as loss of vegetation cover, conditions on the high-use sites were generally stable, while they improved substantially on the low-use sites. For other impacts, such as exposure of mineral soil, continued use exacted a toll on all sites, but the deterioration was most pronounced where the use was heaviest. For most impacts, high-use sites are two or three times as highly impacted as low-use sites. Estimates of use levels suggest, however, that the high-use sites are used about 10 times as frequently as the low-use sites.

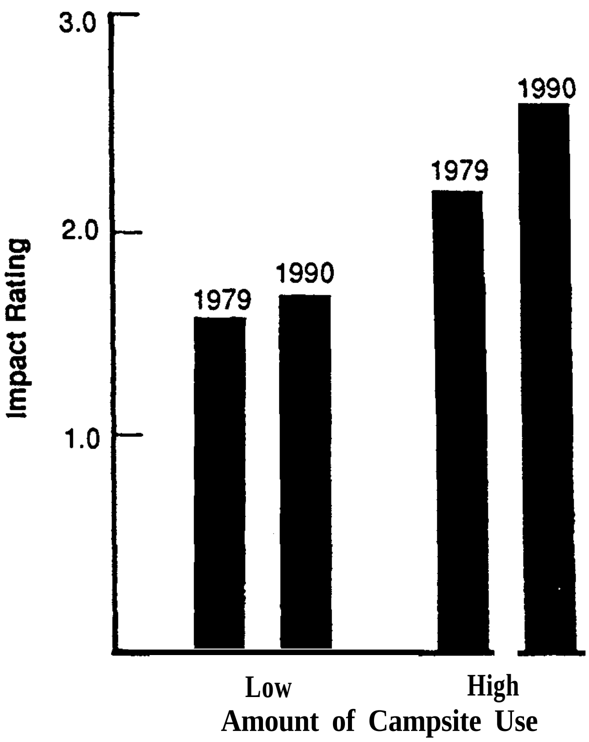


Figure 7- Change in overall impact rating between 1979 and 1990 on low-use and high-use Eagle Cap campsites.

In addition to examining mean response, it is also worth assessing the variability of response across use levels. One of the most significant findings in the analysis of change on campsites between 1979 and 1984 was that variability in amount of change declined as use level increased (Cole 1986a). Compared to high-use sites, low-use sites were much more likely to either improve or deteriorate substantially. The 1990 results confirm this tendency for low-use sites to be more variable in response. For example, the low-use site at Bear Lake improved substantially. Vegetation cover increased from 8 to 22 percent, and the devegetated core area decreased from 55 m^2 to less than 1 m^2. In contrast, the low-use site at Hidden Lake deteriorated more than many of the high-use sites. Camp area increased by 82 m^2 (the largest increase on any campsite), devegetated core area increased by 21 m^2, the number of trees with exposed roots increased from six to 12, and mineral soil exposure increased from 7 to 19 percent. All four of the high-use sites deteriorated substantially. To quantify this variability, the coefficient of variation for the change in impact index was calculated. Variation was an order of magnitude higher on low-use sites (2.83) than on high-use sites (0.26).

The small sample size makes it risky to draw definitive conclusions about how amount of change varies between sites that receive different amounts of use. On these few sites, however, differences in amount of impact, related to amount of use, are increasing over time. All of the high-use sites continue to deteriorate slowly. Certain low-use sites are improving, while others are deteriorating. Presumably, variation in response on low-use sites reflects differences in the amount or type of use the sites received over the period. On low-use sites, decreases in amount of use or adoption of low-impact techniques by users may be reflected in reduced impact. Changes in the amount or type of use either have not occurred on the high-use sites or are not manifested in improving conditions.

Open and Closed Sites- Of the 10 original high-use sites in the ABLA/VASC vegetation type, only four are still open to camping. The other six are less than 60 m from lakes. Camping was prohibited on these sites in the late 1970's, and violators were cited or asked to move or both. Most of these sites are still used occasionally, although use levels have been reduced dramatically. Day use of these sites is still legal and commonly occurs. On two of the sites, active rehabilitation (soil scarification and transplanting) was attempted.

In 1979 there were no significant differences between these two sets of sites (table 5). Closures had just been instituted and were not being enforced. Between 1979 and 1984, camp area was the one variable that increased significantly more on open than on closed sites (Cole 1986a). But the open sites appeared to be experiencing larger increases in devegetated core area and in the number of trees with exposed roots. These tendencies had intensified further by 1990. In 1990, the open sites had a significantly larger devegetated core and more trees with exposed roots than the closed sites. Between 1979 and 1990, such deterioration was also significantly more pronounced on the open sites. Finally, open sites also experienced a significantly greater increase in camp area between 1979 and 1990 (although open sites were not significantly larger than closed sites in 1990).

The impact ratings suggest similar conclusions. In 1979 the closed sites had a higher mean impact rating, although the difference was not significant. Between 1979 and 1990 the change in impact rating on open sites was significantly greater than on closed sites. By 1990 the impact rating on open sites was significantly higher than on closed sites.

Variation in response was also much greater on closed sites than on open sites. The coefficient of variation of the change in the impact rating was much higher on closed sites (13.15) than on open sites (0.26). Two of the closed sites deteriorated over the 11 years, two generally improved, and two were relatively unchanged. In contrast, all of the open sites deteriorated.

Earlier Conditions- Another factor that might explain response over the 11 years is the condition of the campsite in 1979. One of the findings for the period between 1979 and 1984 was a relationship between amount of change and impact rating in 1979 (Cole 1986a). The sites that were more impacted in 1979 were more likely to have improved in condition, while the sites that were less impacted in 1979 were more likely to have deteriorated.

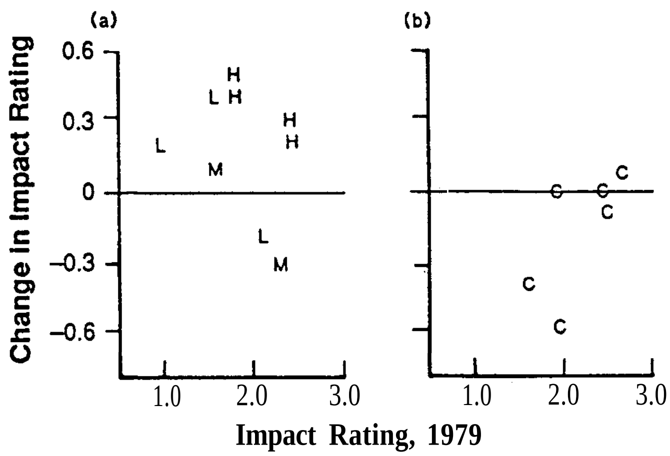
This relationship was reexamined for the period between 1979 and 1990, and there was no correlation between amount of change and conditions in 1979. Within each use category, sites that were more highly impacted in 1979 tended to have either improved more or deteriorated less than those that were less impacted in 1979 (fig. 8a). On the closed sites, however, the sites that were more highly impacted in 1979 improved less than the sites that were less impacted (fig. 8b). None of these correlations are significant.

Although not conclusive, this pattern of response suggests (1) that when comparing sites that receive similar amounts of use, more lightly impacted campsites have more potential to deteriorate than more highly impacted sites (highly impacted sites are already close to maximum possible impact levels) and (2) that less-impacted sites can recover more rapidly than more highly impacted sites. Both of these conclusions confirm suggestions of previous research (Cole 1986a; Willard and Marr 1971).

Table 5- Mean change in conditions on four open high-use and six closed high-use sites,’ Eagle Cap Wilderness

Statistic	**Open**	**Closed**	Significance
Camp area (m^2)			
1979	218	195	0.59
1990	263	204	.12
Change	45	9	.04*
Devegetated core area (m^2)			
1979	109	125	.69
1990	135	63	.04
Change	26	-63	.03
Trees with exposed roots (No.)			
1979	8	4	.52
1990	11	4	.03
Change	3	0	.05*
Vegetation cover (percent)			
1979	6	4	.22*
1990	8	7	.38*
Change	2	3	.45*
Mineral soil exposure (percent)			
1979	43	41	.92
1990	66	58	.37
Change	23	16	.46
Organic horizon thickness (cm)			
1979	0.1	0.2	.37
1990	0.1	0.1	.47
Change	0	-0.1	.50
Floristic dissimilarity (percent)			
1979	52	67	.17
1990	62	68	.25
Change	9	1	.15
Impact rating			
1979	2.2	2.3	.75
1990	2.6	2.3	.08
Change	0.4	0	.Ol l

[1]The significance of differences between open and closed sites was tested with the Mann-Whitney U test, or with the *t-test* where denoted with an * .



Conclusions

The principal conclusions to be drawn from this study of 11 years of change on Eagle Cap campsites are:

1. The general trend on established campsites that continue to be used is one of slight deterioration.
2. Trend varies between types of impact. Few of these sites were experiencing any further loss of seedlings or vegetation cover or any enlargement of the devegetated central core. On the other hand, most sites were experiencing substantial increases in mineral soil exposure and in tree root exposure. Most sites experienced modest increases in camp area.
3. Differences in amount of impact between low-use and high-use sites are increasing with time. All high-use sites are deteriorating. Certain low-use sites are deteriorating, while others are improving. Consequently, median conditions on low-use sites are relatively stable, while they are deteriorating on high-use sites.
4. Although high-use sites are more highly impacted than low-use sites, differences in amount of impact are not as great as differences in the amount of use these sites receive. In this case, a site used 10 times as frequently as another site would typically be only several times more highly impacted.
5. Differences in amount of impact between open and closed high-use sites are also increasing with time. All open high-use sites are deteriorating. Certain closed high-use sites are improving, while others are still deteriorating. Consequently, median conditions on closed high-use sites are relatively stable, while they are deteriorating on open sites.

BOB MARSHALL CASE STUDY

Study Area and Methods

In 1981,35 campsites in the Bob Marshall Wilderness were selected for study (Cole 1983a). Sites in both grasslands and forests were selected, but all sites were at relatively low elevations for a mountainous wilderness in the Western United States (1,250 to 1,675 m). Only well-established sites were examined, although use levels ranged from the most frequently used sites in the area to sites used no more than a few times per year. Six of the camps were used exclusively by backpackers. Twenty-four were used predominantly by private parties with stock (hereafter called horse camps), although they were also used by backpackers and outfitters (fig. 9). Finally, five of the base camps assigned to outfitters were studied.

In 1990, 29 of these sites were reexamined. These sites included five of the six backpacker sites, 19 of the 24 horse camps, and all five outfitter camps. Between 1981 and 1990, however, one of the outfitter camps was dismantled and was no longer in use. It is also worth noting that the effective season at which this study was conducted differed between years. In 1981 the survey was conducted between early July and mid-August, and all the sites that were surveyed had been used that year. In 1990 the survey was started a week earlier and was completed by late July. More significantly, spring was unusually wet that year and much of the backcountry was difficult to access early. Consequently, only nine of the 29 sites had been used before the survey was conducted in 1990.

Results will be presented (1) for all 29 sites combined, (2) for the nine recently used sites in comparison to the 20 sites that had not been used, and (3) for the five backpacker sites in comparison with the 19 horse sites and the four remaining outfitter sites.

With only a few exceptions, field methods were identical to those employed in the Eagle Cap study. Campsites and undisturbed control sites were measured and compared. The primary differences on Bob Marshall sites were: (1) the thickness of organic horizons was not measured; (2) soil penetration resistance was measured with a pocket soil penetrometer in the uppermost portion of the mineral soil within each quadrat; and (3) coverages were not estimated for individual species, although total cover of nonnative (exotic) species was estimated.

Data analysis and presentation are similar to that in the Eagle Cap study. To test the null hypothesis that the type of use a campsite receives has no effect on either campsite conditions or amount of change, nonparametric Kruskall-Wallis and parametric one-way analysis of variance tests were used.

Changes on All Sites

Trends for Individual Types of Impact- Campsite area-the area visually disturbed by camping activities-increased significantly from a mean of 263 m^2 in 1981 to 315 m^2 in 1990 (table 6). The median site increased 29 m^2, or about 12 percent. Sixteen of the 29 sites increased in size and 10 decreased. Increases were typically larger than decreases. The median increase on sites that increased in size was 72 m^2; this is a 34 percent increase in camp area in just 9 years. Two sites increased by more than 300 m^2 over these 9 years. No attempt was made to assess the increase in size of offsite areas disturbed by pack and saddle stock. These “stock-holding areas” are typically at least as large as the campsites and sometimes much larger (Cole 1983a).

In contrast, the size of the devegetated central core of the campsites decreased significantly from a mean of 41 m^2 in 1981 to 34 m^2 in 1990. This devegetated core area decreased on 19 of the 29 campsites. On the median site, the barren core decreased by more than 50 percent.

Results for tree damage were mixed (table 6). The mean number of both damaged trees and trees with exposed roots decreased between 1981 and 1990; however, so did the total number of trees. On the median site, 100 percent of trees were damaged, both in 1981 and 1990. This demonstrates the extremely high levels of tree damage that characterize campsites in the Bob Marshall. The fact that the total number of trees (which includes felled and other dead trees) declined from a mean of 25 in 1981 to 23 in 1990 suggests an increase in tree damage. Moreover, the mean number of felled trees increased significantly from three in 1981 to four in 1990. On one site, the number of felled trees increased from 13 in 1981 to 22 in 1990. There were no significant changes in the number of trees with large scars (>1,000 cm^2).

These data suggest that tree damage has increased but not substantially. It was impossible, however, to document precisely the changes in tree damage in the places where stock are kept. These "stock-holding areas" are where the majority of tree damage occurs (Cole 1983a). Notes and photographs taken in 1981 clearly show that damage had increased around many of the campsites by 1990. Some of the 1981 control sites had even been damaged when stock were confined on them. Therefore, the onsite tree data presented here substantially underestimates actual increases in tree damage.

In 1990, as in 1981, most sites had no tree reproduction. Nineteen of the 29 sites experienced no change in seedling density (table 7). However, increases in density were more common than decreases. Density increased on seven sites and decreased on three sites. Three sites that had no seedlings onsite in 1981 had seedlings onsite in 1990, while only one site that had seedlings onsite in 1981 had lost all reproduction by 1990. In general, loss of reproduction is a severe and relatively unchanging impact on these sites.

Table 7 -Mean change in seedling density, ground cover conditions, and soil penetration resistance on all 29 campsites,[1] Bob Marshall Wilderness

Statistic	Seedling density		Vegetation cover		Exotic spp. cover	
	Camp	Control	Camp	Control	Camp	Control
Conditions						
1981	56	1,247	33	85	16	10
1990	79	1,171	42	89	22	9
Change						
Absolute	23	-75	9	4	5	-2
Relative (percent)	41	-6	27	5	31	-20
Number of sites						
Increase	7	9	22	12	21	12
Decrease	3	12	6	1	8	9
Unchanged	19	8	1	16	0	8
Significance	0.58	0.42	0.001*	0.001	0.02	0.60

Statistic	Mineral soil cover		Penetration resistance	
	Camp	Control	Camp	Control
Conditions				
1981	14	1	3.3	2.3
1990	11	1	2.4	1.7
Change				
Absolute	-3	0	-0.8	-0.6
Relative (percent)	-21	0	-24	-26
Number of sites				
Increase	9	5	4	6
Decrease	18	6	23	21
Unchanged	2	18	1	1
Significance	0.58	0.89	0.001*	0.001

[1]Absolute change is the condition in 1990 minus the condition in 1981. Relative change is absolute change as a percentage of the condition in 1981. The significance of differences between 1981 and 1990 was tested with the Wilcoxon matched-pairs, signed-ranks test, or with the paired t-test where denoted with an * .

Ground cover conditions on these sites improved slightly between 1981 and 1990 (fig. 10). Vegetation cover increased significantly on campsites from a mean of 33 percent in 1981 to 42 percent in 1990. Vegetation also increased significantly on control sites, but changes on controls were less pronounced. The difference between campsite and control conditions decreased significantly over the 9 years. Based on the relative difference between campsites and controls, the median site had lost 68 percent of its vegetation cover in 1981. In 1990 the median loss was 56 percent.

Many of the plants that increased on campsites were nonnative species. Cover of these exotics increased from a mean of 16 percent in 1981 to 22 percent in 1990. Exotic species cover increased on 21 of the 29 campsites. The proportion of the vegetation cover that is nonnative increased from a mean of 39 percent in 1981 to 45 percent in 1990. In the most extreme case, one site that had 5 percent exotic vegetation cover in 1981 had 55 percent in 1990. There were significant increases between 1981 and 1990 in the number of exotic species on campsites, as well as in the number of quadrats in which exotic species were recorded. By 1990 the median campsite had four exotic species, and exotics were found in 12 of the 15 quadrats. So, although the increased vegetation on these sites is encouraging, the fact that the prevalence of nonnative species is increasing onsite is not encouraging. Data for individual nonnative species coverages can be found in appendix 2.

The capacity of these sites for vegetative growth is remarkable when compared with the slow revegetation occurring on closed sites in the Eagle Cap. The outfitter site at Murphy Flats was dismantled in 1983. Since that time vegetation cover has increased from 30 to 66 percent, and the devegetated core has disappeared; in 1981 it had been 22 m^2. In 1990 it was difficult to even find the campsite. A corral without any vegetation in 1981 could not even be found in 1990 (fig. 11). Of the vegetation growing onsite, however, 84 percent consists of nonnative species.

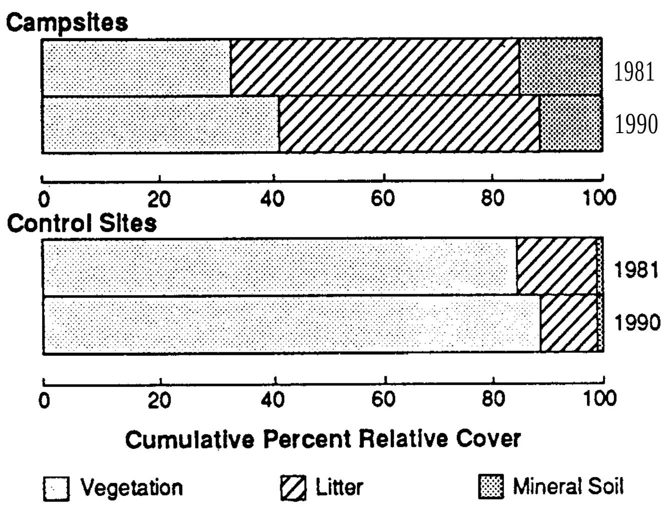


Figure 10 --Mean coverage of ground cover categories on campsites and control sites in 1981 and in 1990, Bob Marshall Wilderness.

Mineral soil exposure decreased from a mean of 14 percent in 1981 to 11 percent in 1990. Despite the fact that exposure decreased on 18 of the 29 sites, this change was not statistically significant. Changes were generally relatively small; two sites experienced increases in exposure that exceeded 10 percent, and five sites experienced decreases of more than 10 percent. This result contrasts with the pronounced increases in mineral soil exposure found on Eagle Cap campsites.

When exposed, mineral soils are readily compacted by trampling. Soil penetration resistance in 1981 was much higher on campsites than on controls (table 7). Penetration resistance declined significantly between 1981 and 1990 on both campsites and controls. This particular measure of soil compaction varies greatly with soil moisture levels, and the wet spring in 1990 resulted in substantially lower values everywhere. Differences between campsites and controls did not change significantly between 1981 and 1990. The median absolute difference between campsites and controls in 1981 was 0.9 kg/cm^2; this difference was 0.7 kg/cm^2 in 1990. Differences between campsites and controls increased on 16 sites and decreased on 12 sites, suggesting no overall trend toward either deterioration or improvement.

Overall Trends -These results suggest that most types of impact had already reached peak levels by 1981. Only increases in campsite area and tree damage appear to be continuing. Ground cover conditions appear to have improved substantially, although it is not clear whether to consider increased cover by nonnative species to be improvement or deterioration. Certainly a more complete vegetative cover, even if it is composed of exotics, will help to inhibit loss of organic matter, soil compaction, and increased runoff and erosion.

To assess overall impact, each campsite was assigned an impact index rating in 1981 and in 1990. This index is based on seven indicators of impact: vegetation loss, mineral soil increase, tree damage, tree root exposure, social trails, camp area, and barren core camp area (Cole 1983b). Each variable is rated as 1,2, or 3. The mean of these ratings is the impact index, with 1.0 suggesting minimal impact and 3.0 maximum impact.

Table 8 -Mean changes on the nine sites that had already been used in 1990 and the 20 sites that had not,[1] Bob Marshall Wilderness

Statisic	Used	Unused	Significance
Camp area (m^2)			
1981	355	219	0.04
1990	499	228	.002
Change	144	9	**.00l**
Devegetated core area (m^2)			
1981	78	24	.02
1990	65	20	.00l
Change	-13	-4	.83
Vegetation aver (percent)			
1981	**23**	**38**	.1l*
1990	24	50	.001
Change	1	12	.83
Exotic species cover (percent)			
1981	15	17	.96
1990	15	**25**	**.37**
Change	0	**8**	**.04**
Mineral soil exposure (percent)			
1981	18	**12**	**.31**
1990	18	**8**	**.03**
Change	0	-4	**.02**
Impact index rating			
1981	2.7	2.4	.04
1990	2.6	2.0	.00l
Change	-0.1	-0.4	.02

[1]The significance of differences between used and unused sites was tested with the Mann-Whitney U test, or with the t-test where denoted with an *.

Clearly, sites that had not been used in 1990 improved more (or deteriorated less) than sites that had been used in 1990. It is tempting to conclude that this greater improvement is **a** result of their not having been used that year-that seasonal recovery is pronounced and that if we had taken measurements later in the season improvements would have been less pronounced. An alternative hypothesis, however, is that the unused sites are less frequently used than the used sites and, therefore, that differences are not seasonal but instead reflect differences in amount of use.

This alternative hypothesis can be evaluated by testing whether the amount of impact on these two categories of site differed significantly in 1981. If so, differences may reflect long-term recreational use pressures rather than seasonal pressures. In 1981 the used sites were significantly larger, had a significantly larger devegetated core, and significantly higher impact index ratings. However, vegetation cover, exotic species cover, and mineral soil cover were not significantly different.

There appears to be support for each of the two hypotheses. Clearly, some of the apparent improvement in conditions represents seasonal improvement since the previous use season. In particular, a surprisingly high degree of vegetation recovery occurs during each off-season. Much of this regrowth will probably be eliminated once use of these sites commences. This would suggest that the estimates of change on used sites (table 8) might be more accurate estimates of long-term change than those for all 29 sites. It is also clear, however, that the "used sites were already more highly impacted in 1981. They are probably more frequently used than the other sites.

In sum, we believe that our estimates of change would have been different if we had taken measurements later in the summer-at a time more seasonally equivalent to the 1981 measurements. We believe that change values between those for all sites and those for just the used sites would be most representative of the amount of change that has occurred on campsites. Quantitatively, this would result in larger increases in camp area and smaller increases in vegetation cover (fig. 12). Perhaps mineral soil exposure would have increased slightly over the 9 years instead of decreasing slightly. The most significant change would be in the number of sites that deteriorated or improved. Of the nine "used' sites, two deteriorated and five were stable; none improved. As in the Eagle Cap, more "used" sites were generally stable than changed, and more “used” sites deteriorated than improved.

Type of Use -Another factor that might influence amount of change on these sites is the type of visitor that typically uses the site. Five of the Bob Marshall campsites were used primarily by backpackers, four were outfitter base camps, and 19 were used primarily by private horse parties. Mean conditions in 1981 and in 1990, as well as the amount of change between 1981 and 1990, are shown in table 9 for each of these user categories. Unfortunately, the small sample of backpacker and outfitter sites makes the tests of statistical significance difficult to rely on. Many nonsignificant differences may have been significant if a larger sample of sites had been available. Moreover, many of the most substantial impacts on the horse and outfitter camps occur outside of the main camping area, in the places where stock are confined. Because we have no data for these places for 1990, total impact is greatly underestimated on the horse and outfitter camps, making them appear more similar in condition to backpacker sites than they really are. For example, in 1981 the median camp area on outfitter sites was 233 m^2; however, the median disturbed area (camp plus stock-holding area) was 3,143 m^2 (Cole 1983a). The median number of trees with exposed roots on the campsite was eight, but the median on the larger disturbed site was 37.

There was abundant visual evidence of additional impact in the stock-holding areas-impact that, by definition, does not occur on the backpacker sites. We must conclude that, as in 1981, horse and outfitter camps remain many times larger than backpacker camps and they have many times the number of damaged trees. We suspect that differences between these types of camps (particularly in regard to the number of damaged trees in stock-holding areas) increased between 1981 and 1990.

On the campsites proper, differences between these three types of camp are less pronounced. In 1981, backpacker camps were significantly smaller than the other types (table 9). Between 1981 and 1990 the mean size of all three site categories

Table 9 -Mean changes on five backpacker, 19 horse, and four outfitter campsites, [1]Bob Marshall Wilderness

Statistic	Type of use: Backpacker	Horse	Outfitter	Significance
Camp area (m^2)				
1981	104	311	277	0.02
1990	111	374	364	.03
Change	7	63	87	.62
Devegetated core area (m^2)				
1981	12	52	28	.40
1990	11	46	11	.42
Change	-1	-6	-17	.85
Vegetation cover (percent)				
1981	25	34	.44	.66*
1990	38	40	51	.75*
Change	13	6	8	.41*
Exotic species cover (percent)				
1981	3	16	**39**	.07
1990	7	19	44	.10
Change	4	3	5	.50
Mineral soil exposure (percent)				
1981	6	11	32	.04
1990	6	10	23	.08
Change	0	-1	-9	.71
Impact index rating				

increased, but the mean increase was greatest on outfitter camps (87 m^2) and least on backpacker camps (7 m^2). So, in 1990, differences in camp area between backpacker sites and the other types were even greater than in 1981.

The other types of impact that were significantly less pronounced on backpacker sites in 1981 were mineral soil exposure and the prevalence of exotic plant species. In contrast to camp area, these differences did not increase over the 9 years. The amount of change in exotic species cover between 1981 and 1990 was virtually identical on all three types of site. Mineral soil exposure declined on horse and outfitter sites and was stable on backpacker sites. Consequently, differences declined. In 1981 the mean mineral soil exposure on outfitter sites was more than five times that on backpacker sites; in 1990, soil exposure on outfitter sites was less than four times that on backpacker sites.

The impact index ratings suggest that all three categories of site have changed comparably-they all have improved slightly. As mentioned earlier, however, this ignores changes in the stock-holding areas. We frequently observed recent damage in these places-recently exposed roots, felled trees, and churned-up ground (fig.. 13). Newly disturbed ground cover may be offset by recovery elsewhere, suggesting that long-term deterioration may not be occurring. However, the tree damage is cumulative; new damage is added to old damage. If new trees are being damaged, overall conditions must be deteriorating. Consequently, the primary difference between these three types of sites in the amount of change that occurred over this period is probably more dramatic increases in tree damage in the stock-holding areas associated with horse and outfitter sites.

Earlier Conditions -We examined the relationship between amount of change between 1981 and 1990 and the condition of the campsite in 1981. We found no correlation. This contrasts with the results of the Eagle Cap study, and it may reflect the large number of uncontrolled variables in the Bob Marshall study (vegetation type, type of use, and amount of use).

Conclusions

The principal conclusions to be drawn from this study of 9 years of change on Bob Marshall campsites are:

1. The general trend on established campsites was one of slight improvement. However, most improvement occurred on sites that had not yet been used during the 1990 season. When only "used" sites are considered, the general trend is one of slight deterioration.

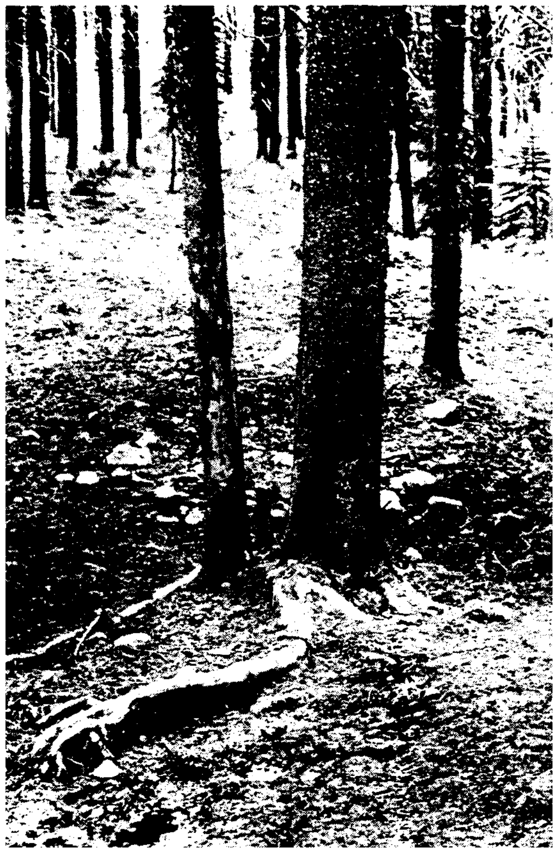


Figure **13 -** Stock have recently been confined in this area adjacent to a campsite, Bob Marshall Wilderness. Note the exposed tree roots and churned-up soils.

2. Regardless of whether all sites or only "used" sites are considered, most sites were relatively stable.

3. The types of impact that are continuing to increase are enlargement of campsite area and, perhaps, an increase in tree damage, particularly in places where stock are held.

4. Considerable seasonal recovery of vegetation occurs on many of these sites. Moreover, once camping is removed, as it was on one outfitter site, a dense vegetation cover can reestablish rapidly on many of these sites. Unfortunately, much of the cover consists of nonnative species.

5. Backpacker sites remain much less severely impacted than horse and outfitter camps. No substantial differences in amount of change between these three types of camp were documented. It was apparent, however, that tree damage in offsite stock-holding areas is continuing to increase around horse and outfitter camps. Tree damage and the areal extent of disturbance are the types of impact that are particularly pronounced on horse and outfitter camps (Cole 1983a).

GRAND CANYON CASE STUDY

Study Area and Methods

In 1984, 24 campsites in Grand Canyon National Park were selected for study (Cole 1986b). All sites were located along "primitive" trails in the Park's backcountry but along neither the Colorado River nor the "developed" trail corridors (fig. 14). We selected 12 high-use and 12 low-use sites. The high-use sites were among the most heavily used backcountry sites in the Park. They receive substantially heavier use than any of the Eagle Cap or Bob Marshall sites. The low-use sites ranged from several that are virtually unused to others that are regularly used but at low levels. Within each use stratum, four sites each were located in pinyon-juniper; catclaw, and desert scrub vegetation types.

Twenty of these campsites were resurveyed in 1989; the other four were resurveyed in 1990. Sites were surveyed in April and May of each year. Conditions in 1984 were considered to be unusually dry; however, conditions in 1989 and 1990 were even more droughty. Results will be presented (1) for all 24 sites combined, (2) for the 12 high-use and 12 low-use campsites, and (3) for the eight sites located in the pinyon-juniper, catclaw, and desert scrub vegetation types.

As in the other case studies, each sample site consisted of both a campsite and an undisturbed control site in the vicinity; however, the other aspects of the methodology differed. A point was established near the center of the disturbed core of the campsite. The distances from this point to the first significant amount of vegetation were measured along 16 cardinal directions. This defined the campsite core area. Within this core, four 1-m^2 quadrats were located along the north, south, east, and west transects, halfway to the edge of the core. Percentage cover of organic litter was visually estimated in each quadrat using the following coverage classes: <1, 1-5, 6-25, 26-50, 51-75, 76-95, and 96-100 percent. Vegetation cover, by definition, was negligible in the core; however, cover was estimated where it was present. Mean coverage was calculated using the midpoint of each class. Ten penetration resistance readings were taken in each quadrat with a pocket soil penetrometer.

A second set of measurements was taken on the campsite perimeter-the area immediately beyond the core. About 25 quadrats of 1 m^2 each were randomly located along transects in the campsite perimeter. Within each quadrat, cover of live vascular vegetation, cryptogams, organic litter, mineral soil, and rock were estimated. The cover of each vascular plant species was estimated, and the number of shrubs rooted in each quadrat was counted by species. Two penetration resistance readings were taken in each quadrat.

Control sites were circular, with an area of 50 m^2. They were close to the campsite in an area undisturbed by camping but similar to the campsite in terms of vegetation, substrate, slope, rockiness, and distance from water. Within this area all rooted shrubs were counted, and the cover of live vascular vegetation, cryptogams, organic litter, mineral soil, rock, and each individual species was estimated, Forty penetration resistance readings were taken systematically throughout the control plot.

The campsite and control center points were marked with buried nails, as were the endpoints of the perimeter transects. This permitted the precise relocation of all measurement units. On two sites only a few measurements could be taken, both in 1984 and 1989.

The sites reexamined in 1990 after 6 years-were not different from those reexamined in 1989; so for ease of discussion, the text will be written as if all sites were reexamined in 1989, after 5 years. Data analysis and presentation is similar to that for the other case studies, except that changes on campsite cores and perimeters are reported separately.

Changes on All Sites

Trends on Campsite Cores -Conditions on campsite cores were relatively unchanged over the 5 years. The only statistically significant change was a mean increase in vegetation cover of 5 percent (table 10). Although statistically significant, vegetation cover did not increase substantially on many sites. Vegetation cover on the median site did not change; even on the 10 sites that did increase in cover, the median increase was only 4 percent. However, three sites did experience substantial increases in cover; all of these were low-use sites with no evidence of recent use. Cover on one of these sites increased from 10 percent in 1984 to 62 percent in 1989. Substantial decreases in cover on campsite cores were impossible, by definition.

Although there were no significant trends for the other types of impact, this does not mean that conditions were unchanged on individual sites. Mean core area was virtually unchanged over the 5 years, but 16 sites changed in size by more than 10 percent. Nine of these changes were decreases and seven were increases. The largest change was a 38-m^2 increase in size. These results suggest that there have been substantial changes on individual sites, but no clear overall tendency for cores to either increase or decrease in size.

Changes in the cover of organic litter on cores parallel changes in vegetation (fig. 15). Litter cover generally increased; on all but a few sites, changes were subtle. Litter increased on more sites than it decreased. Mean litter cover increased from 5 percent in 1984 to 9 percent in 1989; however, cover on

Table 10 -Mean changes on the awe of all 24 campsites, [1]Grand Canyon National Park

Statistic	Core area	Vegetation cover	Organic litter cover	Penetration resistance
	m^2	-------percent------		*kg/cm^2*
Conditions				
1984	51	1	5	2.7
1989	50	7	9	2.1
Change				
Absolute	-1	5	4	-0.6
Relative (percent)	-2	500	80	-22
Number of sites				
Increase	9	10	10	10
Decrease	14	3	5	13
Unchanged	1	11	9	1
Significance	0.46	0.04	0.08	0.09*

the median site was unchanged. Increases were typically larger than decreases. The median increase on sites that increased was 4 percent, while the median decrease was 2 percent. On one site, however, litter cover increased from 5 percent in 1984 to 44 percent in 1989.

Penetration resistance values tended to decline, although the decline was not statistically significant. This indicator of soil compaction decreased on 13 sites and increased on 10 sites. Declines in penetration resistance were also more common than increases on controls (table 11). This suggests that penetration resistance values, which vary with soil moisture, generally tended to be lower in 1989 than in 1984. On the median site, the absolute difference between campsite and control values was the same in 1989 as it was in 1984. This strongly suggests that there has been no overall change in the level of soil compaction over this period.

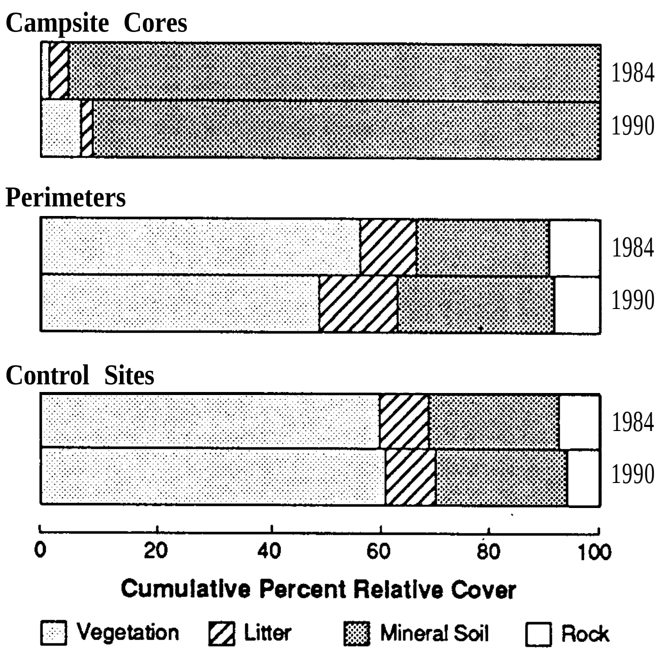


Figure 15- Mean coverage of ground cover categories on campsites and control sites in 1984 and in 1989, Grand Canyon National Park.

Overall, conditions on the core of most campsites were relatively stable. Where change did occur, deterioration was more common than improvement, but the magnitude of improvement was greater than the magnitude of deterioration. Because cores were defined as areas without vegetation, substantial deterioration was unlikely to occur on cores. The major type of deterioration that could occur was enlargement of the core over time. Five sites experienced substantial increases in core area (increases of at least 10 m^2, or 20 percent). These sites were varied, including both high-use and low-use sites and all three vegetation types. The most dramatic changes, however, were substantial improvements on three sites-increases in vegetation and organic litter and decreases in core area. All three of these sites are low-use catclaw sites that appear to have been unused over the study period.

Trends on Campsite Perimeters-Overall trends are not pronounced on campsite perimeters (tables 11 and 12), and deteriorating conditions are more common than improving conditions. Three types of impact deteriorated consistently enough to be statistically significant, although in one case similar changes on the control suggest that the change is not a result of camping.

Table 11 -Mean changes in penetration resistance and shrub density on the perimeter and control of all 24 campsites, [1]Grand Canyon National Park

Statistic	Penetration resistance		Shrub density	
	Perimeter	Control	Perimeter	Control
	------ *kg/cm²* ------		----- *Shrubs/m²* -----	
Conditions				
1984	1.0	0.7	.41	1.00
1989	1.0	0.5	.10	0.86
Change				
Absolute	0.1	–0.1	–0.32	–0.14
Relative (percent)	10	–14	–23	–14
Number of sites				
Increase	11	9	7	7
Decrease	10	11	15	15

Table 12 -Mean changes in ground cover conditions on the perimeter and control of all 24 campsites,[1] Grand Canyon National Park

Statistic	Vegetation cover		Cryptogam cover		Litter cover		Mineral soil cover		Rock cover	
	Perimeter	Control	Perimeter	Control	Perimeter	Control	Perimeter	Control	Perimeter	Control
	Percent									
Conditions										
1984	52	61	5	9	53	61	25	24	8	7
1989	47	62	3	6	52	62	30	24	7	6
Change										
Absolute	-5	1	-1	-4	-1	2	4	-1	-1	0
Relative (percent)	-10	1	-20	-44	-2	3	16	-4	-13	0
Number of sites										
Increase	6	4	5	5	9	4	13	2	3	0
Decrease	15	3	11	8	12	3	9	3	13	4
Unchanged	2	16	7	10	2	16	1	18	7	19
Significance	0.01*	0.30	0.20	0.08	0.72	0.87	0.04*	0.89	0.09*	0.09

[1]Absolute change is the condition in 1989 minus the condition in 1984. Relative change is absolute change as a percentage of the condition in 1984. Significance was tested with the Wilcoxon matched-pairs, signed-ranks test, or with the paired t-test where denoted with an *.

Shrub density decreased on 15 of 22 campsite perimeters and on 15 of 22 controls (table .11). The mean change was a 23 percent decrease in density on perimeters and a 14 percent decrease on controls. In 1984, shrub density, surprisingly, was greater on campsite perimeters than on controls. This appeared to result from a large number of small individuals, particularly of *Gutierrezia sarothrae* (broom snakeweed), on perimeters. During the 5 years between 1984 and 1989, a number of individuals disappeared, both on perimeters and controls. In 1989, perimeters and controls were more similar than they were in 1984-perhaps as a result of smaller individuals not surviving the generally droughty conditions.

In contrast to the increase in vegetation on cores, vegetation cover decreased significantly on perimeters (table 12). Mean vegetation cover decreased from 52 percent in 1984 to 47 percent in 1989 (fig. 15). Vegetation cover decreased on the perimeter of 15 sites and increased on six sites. The median decrease on the sites that decreased was 8 percent; on one site vegetation cover decreased from 58 percent in 1984 to only 33 percent in 1989. Increases were smaller; the largest increase was only 8 percent. Vegetation cover was relatively stable on controls, suggesting that these decreases on perimeters result from camping impacts.

This loss of vegetation corresponds with less pronounced and nonsignificant decreases in the cover of cryptogams and litter, as well as a significant increase in mineral soil exposure (table 12). Mineral soil cover increased on 13 of 23 sites. The median on nine sites, but decreases were generally small (median decrease of 1 percent).

As on campsite cores, penetration resistance values increased and decreased-in approximately equal numbers. There is no evidence of any significant overall trend in the level of soil compaction.

Overall, the perimeters of most sites are relatively stable; changes on most sites were small. More sites are deteriorating than improving. Eight sites show evidence of substantial deterioration along their perimeter-loss of vegetation and organic litter and an increase in soil exposure. Six of these eight sites are high-use sites. The two low-use sites that are deteriorating are in an area that appears to have increased in popularity.

Vegetation Changes - The most common species growing on cores in 1984 were two nonnative annuals, *Bromus rubens* (red brome) and *Erodium cicutarium* (filaree), and the native shrub *Gutierrezia sarothrae.* These were still the most common species on cores in 1989, although the number of species found on cores had increased by 1989. Species found on several cores in 1989 include *Sporobolus cryptandrus* (sand dropseed), *Ephedra nevadensis* (Nevada joint-fir), *Calochortus flexuosus* (straggling mariposa), and *Cryptantha* sp. (hiddenflower).

In 1984 the species composition of campsite perimeters was not greatly different from the composition of controls. The mean floristic dissimilarity between perimeters and controls was only 31 percent. This was less than the difference typical of two undisturbed stands in the same vegetation type.

and was statistically significant. Increasing dissimilarity can result from either changes on campsites, changes on controls, or both. To investigate further, we calculated the floristic dissimilarity between years for perimeters and for controls. The mean dissimilarity on perimeters between 1984 and 1989 was 25 percent, while the mean difference on controls was 31 percent. The change in species composition on controls was greater than that on perimeters on 14 of the 18 sites that experienced increases in difference between campsite and control. These data suggest that both campsites and controls changed between 1984 and 1989, with the greater changes tending to occur on the controls.

Species richness declined on both campsite perimeters and controls. On perimeters the mean number of vascular plant species decreased from 19 in 1984 to 17 in 1989. Fifteen of 22 sites experienced a decrease in species richness; the median loss was three species. The seven species that were most frequently absent from sites where they were found in 1984 were annuals. Two were grasses, ***Vulpia octoflora*** (six-weeks fescue) and ***Poa bigelovii*** (Bigelow's bluegrass); five were forbs, ***Plantago purshii*** (Indian wheat), ***Descurainia pinnata*** (yellow tansy mustard), ***Astragalus nuttallianus*** (Nuttall locoweed), Gilia ***flavocincta*** (thread-stemmed gilia), and ***Lepidium lasiocarpum*** (sand peppergrass). The only species found much more frequently in 1989 was ***Calochortus flexuosus.***

Species richness also declined on 18 of the 22 controls. This, along with the fact that species composition changed as much on controls as on campsites, suggests that these changes result from changes in the natural environment, rather than from camping. As on campsites, the most common species to be absent from controls were annuals. This suggests that the major factor accounting for change in species composition was the severe drought condition in 1989.

Changes in species composition were further explored by calculating the mean relative cover of each growth form and of nonnative species. These relative covers are displayed for both years and for campsite perimeters and controls (table 13). The most pronounced shifts between 1984 and 1989 were an increase in the relative cover of shrubs and a decrease in the relative cover of annual grasses. ***Bromus rubens,*** a nonnative annual grass, contributed 26 percent of the total cover on campsite perimeters in 1984; in 1989 it contributed only 14 percent. Consequently, the cover of nonnative species was substantially lower in 1989. Similar changes occurred on controls, reinforcing the notion that changes in vegetation composition are a response to natural environmental changes, such as the amount and distribution of precipitation, rather than camping.

In 1984 the only growth forms that differed significantly, in relative cover, between perimeters and controls were shrubs and total forbs. Shrubs were relatively more abundant on campsites, and forbs were relatively less abundant on campsites. In 1989 there were no significant differences in the relative cover of different growth forms. Changes in the frequency and cover of individual species are listed in appendix 3.

Overall Trends -To assess overall impact, a summary impact rating was calculated for each site. Impact indicators used in this summary rating were: core area, vegetation cover on the core, organic litter cover on the core, relative difference in vegetation cover on perimeters, and absolute difference in mineral soil exposure on perimeters. For each of these

Table 13 -Mean relative cover of growth forms and of nonnative species on the perimeter and control of all 24 campsites, Grand Canyon National Park

Statistic	Perimeters		Controls	
	1984	1989	1964	1989
Shrubs-trees'	55	68	53	68
Cacti	‹1	‹1	1	1
Shrubs'	40	49	35	48
Trees*	15	19	17	19
Grasses-total'	32	23	34	24
Annuals'	28	16	28	18
Perennials*	4	7	6	6
Forbs-total	4	4	6	4
Annuals	2	1	3	1
Perennials*	2	3	3	3

indicators, campsites were assigned a rating of 1,2, or 3 (low to high amount of impact). The impact rating is the mean of the five indicators.

The mean impact rating was 2.0 in 1984 and 2.1 in 1989. This change was not statistically significant. Sixteen of the sites were relatively stable (impact ratings changed no more than 0.2). Impact ratings increased by more than 0.2 on five sites and decreased by more than 0.2 on three sites. The five sites that deteriorated include both high-use and low-use sites and were located in all vegetation types but pinyon-juniper. The three sites that improved were all low-use catclaw sites that appear to have been unused over the 5 years. Only two sites changed substantially (changes of more than 0.4); one improved and one deteriorated

Factors That Influence Amount of Change

Amount of Use- In 1984, high-use sites differed significantly from low-use sites in several ways. High-use sites had larger core areas, less vegetation and organic litter on the core, and higher penetration resistance readings on the core (table 14). None of the impacts on the campsite perimeter that were remeasured in 1989 differed between high-use and low-use sites in 1984. Bulk density and soil moisture were higher on the perimeter of high-use sites in 1984 but were not remeasured in 1989.

All four of the differences between high-use and low-use sites that were significant in 1984 were also significant in 1989 (table 14). Moreover, the magnitude of difference between high-use and low-use sites increased. Mean vegetation cover increased by 2 percent on high-use cores, from 0 percent in 1984 to 2 percent in 1989. Mean vegetation cover increased by 8 percent on low-use cores, from 3 to 11 percent. Mean litter cover increased by 1 percent on high-use cores and by 6 percent on low-use cores. Mean penetration resistance on high-use cores declined from 3.8 kg/cm^2 in 1984 to 3.4 kg/cm^2 in 1989; means on low-use cores declined from 1.6 kg/cm^2 to 0.9 kg/cm^2. Core areas were virtually unchanged on both sets of sites, but the area of low-use cores did decrease slightly. All of these changes in the magnitude of difference between high-use and low-use sites are relatively small. For none of these is there a statistically significant difference between high-use and low-use sites in the amount of change between 1984 and 1989.

The only site characteristics for which amount of change differed significantly between high-use and low-use sites were the mineral soil and litter cover on campsite perimeters (table 151. The mean change in mineral soil exposure on high-use sites was an increase of 9 percent; on low-use sites there was no change. In 1989, high-use perimeters had 10 percent more soil exposure than controls; low-use perimeters had just 2 percent more soil exposure than

Table 14 -Mean change in conditions on the core of 12 high-use and 12 low-use campsites,[1] Grand Canyon National Park

Statistic	Amount of use		Significance
	High	Low	
Core area (m^2)			
1984	67	34	0.001
1989	67	34	.001
Change	0	-1	.75
Vegetation cover (percent)			
1984	0	3	.02
1989	2	11	.02
Change	2	9	.74
Litter cover (percent)			
1984	1	9	.01
1989	2	15	.001
Change	1	6	.77
Penetration resistance (kg/cm*)			
1984	3.8	1.6	.001*
1989	3.4	0.9	.001
Change	–0.4	–0.7	.59*

Table 15 -Mean change in conditions on the perimeter of 12 high-use and 12 low-use campsites, [1]Grand Canyon National Park

Statistic	Amount of use High	Low	Significance
Vegetation cover (percent)			
1984	54	49	0.27*
1989	51	44	.21*
Change	-4	-5	.64*
Cryptogam cover (percent)			
1984	3	6	.12
1989	2	5	.46
Change	-1	-2	.66
Litter cover (percent)			
1984	56	51	.28*
1989	49	55	.27*
Change	-6	5	.001*'
Mineral soil cover (percent)			
1984	22	28	.41
1989	31	28	.3*'
Change	9	0	.001*'
Shrub density (No./m^2)			
1984	1.34	1.47	**.39**
1989	.85	1.31	.10
Change	-0.49	-0.17	.32
Penetration resistance (kg/cm*)			
1994	1.1	**0.9**	.17*
1989	1.5	0.6	.001
Change	0.4	-0.3	.08*

[1]Change is the condition in 1989 minus the condition in 1984. Significance was tested with the Mann-Whitney U, or with *t*-test where denoted with an * . Tests for 1984 **and** 1989 are one-tailed; tests for change are two-tailed.

controls. This greater amount of impact on high-use sites is statistically significant. It suggests that increased mineral soil exposure on perimeters is an impact that is already more pronounced on high-use sites and becoming more pronounced on those sites as time passes.

The mean change in litter cover on high-use sites was a decrease of 6 percent; the mean change on low-use sites was an increase of 5 percent. The decrease on high-use sites is significant, as is the increase on low-use sites. Nevertheless, differences in the amount of litter cover on high-use and low-use sites in 1989 are not significant. However, if the trend of greater deterioration on high-use sites continues differences will become substantial in the future.

Penetration resistance on high-use and low-use campsite perimeters in 1984 were not significantly different. Resistance tended to increase on high-use sites and decrease on low-use sites, although this difference in response was not significant. Nevertheless, in 1989, soil compaction on campsite perimeters was significantly greater on high-use sites.

Vegetative conditions and vegetation impact on campsite perimeters did not differ significantly between high-use and low-use sites. Cover declined on both types of sites, as is reflected in the significant overall decline in vegetation cover on the perimeter (table 12). Floristic dissimilarity increased and species richness decreased on both high-use and low-use sites. The only significant difference in species composition in 1989 was a greater relative cover of shrubs on low-use sites than on high-use sites. Shrub cover on high-use and low-use sites had not been significantly different in 1984; in 1989, mean shrub cover was 29 percent on low-use sites and 22 percent on high-use sites. Although vegetative cover is being lost on the perimeter of both high-use and low-use sites, the high-use sites are experiencing a more pronounced loss of shrubs. This may have serious long-term implications because recovery of shrub clumps takes such a long time (Wallace and others 1980).

Mean impact ratings in 1984 were 1.73 on low-use sites and 2.38 on high use sites. The difference was statistically significant. Between 184 and 1989, ratings on low-use sites declined slightly to 1.68, while they increased slightly on high-use sites-to 2.47. Although the amount of change did not differ significantly between high-use and low-use sites, the magnitude of difference increased over the 5 years.

Overall, several conclusions can be drawn about high-use and low-use sites. High-use sites continue to be more highly impacted than low-use sites. For virtually all types of impact, the magnitude of difference between high-use and low-use sites increased between 1984 and 1989. Typically, this results from (1) greater improvement on the core of low-use sites and (2) greater deterioration on the perimeter of high-use sites. Core conditions differ more between high-use and low-use sites than perimeter conditions do. However, the significant differences in amount of change between 1984 and 1989 result from higher levels of deterioration around the perimeter of high-use sites.

Differences Among Vegetation Types -In 1984 there was only one significant difference among vegetation types in impact on cores. Pinyon-juniper cores were several times as large as sites in the other types. Core area did not change substantially between 1984 and 1989 on sites in any of the three vegetation types (table 16).

By 1989, campsites had changed to the point where conditions other than core area differed between vegetation types. In 1989, catclaw cores had significantly more vegetation than sites in the other types (table 16). Catclaw and desert scrub cores had significantly more litter cover than pinyon-juniper sites. For both vegetation and litter, the core of catclaw sites improved substantially while sites in the other two vegetation types changed little over the 5 years. The three sites with the largest increases in vegetation cover on cores were low-use catclaw sites with no evidence of recent use. Cover on these sites increased from 2,5, and 10 percent in 1984 to 26,29, and 62 percent, respectively, in 1989. This shows that, in the absence of use, lightly impacted catclaw sites are capable of substantial recovery in just 5 years. In contrast, on two unused pinyon-juniper sites, vegetation cover increased 1 percent in one case and was unchanged in the other.

Vegetation, litter, and mineral soil cover on perimeters differed among vegetation types in 1984. Pinyon-juniper sites have relatively low vegetation and litter cover and relatively high mineral soil cover. However, these differences, which were also significant in 1989, merely reflect conditions on controls. There were no significant differences among vegetation types in either the absolute or relative difference between campsite perimeters and controls.

For these three ground cover characteristics there are also no significant differences in amount of change between 1984 and 1989 (table 17). The increase in mineral soil cover that characterizes the overall trend on campsite perimeters occurs on sites in all three vegetation types. The loss of vegetation cover on perimeters is substantially more pronounced on desert scrub sites, although this difference is not

Table 16 -Mean change in conditions on the core of eight campsites in each of three vegetation types, [1]Grand Canyon National Park

Statistic	Vegetation type: Pinyon-juniper	Catclaw	Desert scrub	Significance
Core area (m^2)				
1984	82	34	36	0.04
1989	82	31	37	.04
Change	0	-3	1	.48
Vegetation cover (percent)				
1984	0	2	2	52
1989	0	16	3	.02
Change	0	14	1	.06
Litter cover (percent)				
1984	1	2	12	.22
1989	1	14	11	.04
Change	0	12	-1	.06
Penetration resistance (kg/cm^2)				
1984	2.6	2.5	3.0	.81*
1989	2.6	2.0	1.9	.74
Change	0	-0.5	-1.2	.37*

‘Change is the condition in 1989 minus the condition in 1984. Significance was tested with Kruskal-Wallis, or with parametric one-way analysis of variance tests where denoted with an * .

Table 17- Mean change in conditions on the perimeter of eight campsites in each of three vegetation types,[1] Grand Canyon National Park

Statistic	Pinyon-juniper	Catclaw	Desert scrub	Significance
	Vegetation type			
Vegetation cover (percent)				
1984	33	68	55	0.001*
1989	32	64	45	.001*
Change	-1	-4	-10	.07*
Cryptogam cover (percent)				
1984	5	2	9	.06
1989	5	3	2	.06
Change	1	1	-7	.01
Litter cover (percent)				
1984	30	74	55	.001*
1989	29	72	57	.001*
Change	-1	-2	2	.75*
Mineral soil cover (percent)				
1984	52	7	16	.001
1989	54	11	23	.001*
Change	2	4	7	.57
Shrub density (No./m^2)				
1984	1.02	1.72	1.53	.79
1989	0.96	1.33	0.98	.65
Change	-0.06	-0.39	-0.55	.34
Penetration resistance (kg/cm^2)				
1984	0.6	1.0	1.4	.04*
1989	0.9	1.0	1.1	.83
Change	0.3	0.1	-0.2	.51*

[1]Change is the condition in 1989 minus the condition in 1984. Significance was tested with Kruskal-Wallis, or with parametric one-way analysis of variance tests where denoted with an * .

quite significant. However, the increase in both absolute and relative difference between perimeters and controls is significantly greater on desert scrub sites. Changes in several other vegetation characteristics also suggest that more deterioration occurred on the perimeter of desert scrub sites. The decrease in cryptogam cover between 1984 and 1989 was significantly greater on desert scrub sites. The increase in floristic dissimilarity between perimeters and controls is also significantly greater on desert scrub sites.

Neither shrub density nor penetration resistance differed significantly between vegetation types in 1989. Amount of change did not differ either. Penetration resistance differed between vegetation types in 1984, but this difference disappeared by 1989.

Overall, pinyon-juniper sites continue to be substantially larger than sites in the other types. They naturally have less vegetation and organic matter and more exposed mineral soil. For the most part they are relatively stable. Core conditions do not change dramatically on pinyon-juniper sites, even when camping use is discontinued. One of the high-use designated sites on Horseshoe Mesa was closed shortly after our 1984 measurements were taken. It appears that this site has not been used since, but change has been negligible. Perimeters of pinyon-juniper sites are not highly subject to impact in part because the large core area provides sufficient room for campers to spread out.

The core of sites in the other vegetation types is also relatively stable when subjected to continued regular camping use. But the catclaw sites-at least the ones that were never severely impacted-appear capable of relatively rapid revegetation when camping use stops. The response of desert scrub sites, once camping is eliminated, is unclear because use continued on all sites.

There is also some evidence to suggest that the slight deterioration that characterizes the overall trend on campsite perimeters was most pronounced on the desert scrub sites. Four of the five sites with the largest declines in vegetation cover on the perimeter were desert scrub sites. The largest changes were on lightly used sites in areas that have recently increased in popularity.

Mean impact ratings in 1984 were 2.33 on pinyon-juniper sites, 2.06 on catclaw sites, and 1.84 on desert scrub sites. These differences were not statistically significant. Between 1984 and 1989, ratings declined 0.03 on pinyon-juniper sites and 0.15 on catclaw sites; they increased 0.26 on the desert scrub sites. The increase in impact between 1984 and 1989 on desert scrub sites was significantly different from the decrease in impact on catclaw sites.

The minimal change in mean impact on pinyon-juniper sites accurately reflects the general stability of those sites. None of these sites changed substantially. Similarly, most desert scrub sites deteriorated and the mean change in rating is positive. The mean value for catclaw sites is more deceptive. Several of the catclaw sites improved greatly; hence, the mean decline in impact ratings. But a number of the catclaw sites deteriorated as greatly as the desert scrub sites. The greater tendency for catclaw or desert scrub sites to deteriorate probably results from their small size. The natural tendency for campers to spread out is constrained on these sites by the rough terrain and the tough and spiny vegetation. It appears that, over time, these sites will expand slowly to provide more space for campers. The pinyon-juniper sites are already large enough for campers, so little further change is occurring.

Earlier Conditions- We examined the relationship between amount of change between 1984 and 1989 and the condition of the campsite in 1984. No correlation was found. When we considered only high-use sites, however, we found a significant correlation between amount of change and the prior condition of the site (Kendall's tau = 0.45; $p = 0.03$). The high-use sites that were less impacted in 1984 were more likely to have deteriorated substantially by 1989 than those that were more highly impacted. This corroborates the similar result on Eagle Cap campsites. There was no similar correlation on low-use sites.

Conclusions

The principal conclusions to be drawn from this study of 5 years of change on Grand Canyon campsites are:

1. The general trend on established campsites, particularly those that continue to be used, is one of slight deterioration. Most sites are relatively stable, however.

2. Trend varied with type of impact and between campsite cores and campsite perimeters. The cores, which were already severely impacted in 1984, generally did not change much. Vegetation and organic litter cover increased slightly on many campsite cores, suggesting some improvement in conditions. In contrast, conditions deteriorated on the perimeters of most sites. Vegetation cover and organic litter cover declined, and mineral soil exposure increased.

3. Differences in amount of impact between low-use and high-use sites are increasing with time (fig. 16). This results primarily from more pronounced improvements on the cores of low-use sites and more pronounced deterioration on the perimeters of high-use sites. But responses of individual sites vary from this typical response. Low-use cores are more likely to have deteriorated or improved substantially than high-use cores.

4. Although high-use sites are more highly impacted than low-use sites, differences in amount of impact are not as great as differences in the amount of use these sites receive. Sites that receive an order of magnitude more use typically are no more than several times as highly impacted.

5. Change in campsite condition varied between sites in different vegetation types. Virtually all of the pinyon-juniper sites were relatively stable, even those that appeared to have been unused over the 5 years. This can be accounted for by the unusual size of these sites in 1984, the high level of impact that already existed in 1984, and the harsh, xeric conditions on these sites. In contrast, the catclaw sites-located in the most mesic places-are capable of surprisingly rapid recovery, once camping ceases. Where high-use continues, however, the catclaw sites, along with the desert scrub sites, often deteriorated over the period.

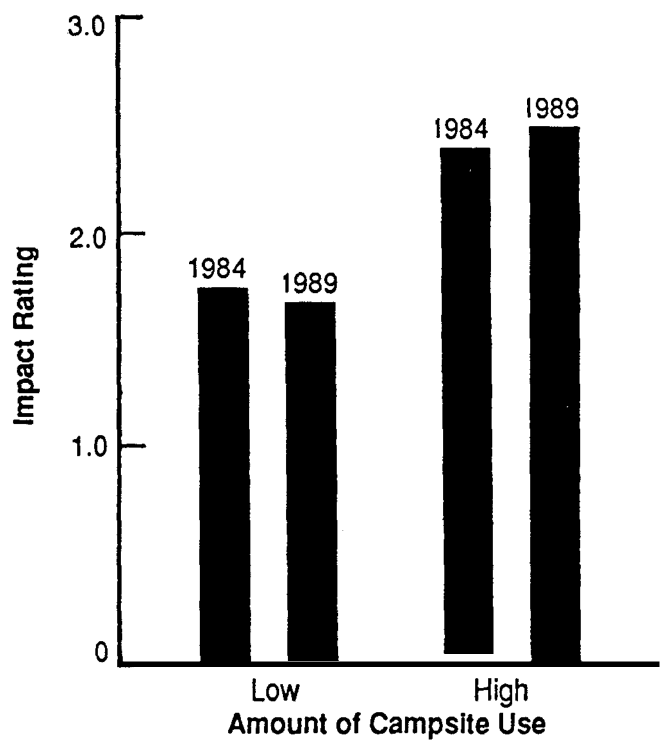


Figure 16- Change in overall impact rating between 1984 and 1989 on low-use and high-use Grand Canyon campsites.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Not surprisingly, there is no simple answer to the question, “How are wilderness campsites changing over time?” As these case studies show, certain campsites are getting better, while others are getting worse, and many are relatively stable. Moreover, on a single campsite, certain types of impact may be getting worse, while other types are improving. On the Grand Canyon sites, we even had situations where vegetation cover was increasing on the campsite core and decreasing on the campsite perimeter.

In all three areas, most sites were relatively stable overall. In the Eagle Cap and Grand Canyon, the number of sites that deteriorated exceeded the number that improved. In the Bob Marshall, the opposite was the case; however, as noted in the previous discussion, if only recently used sites are considered, deteriorated sites outnumbered improved sites here as well. This suggests, to the extent that these case studies are representative, that the overall trend on established sites is one of slight deterioration over time.

Trends vary between types of impact, however. The most consistent increase in impact is continued enlargement of sites over time. Camp area tended to increase on Eagle Cap and Bob Marshall campsites. Although not measured on Grand Canyon campsites, the deterioration of campsite perimeters there suggests a slow expansion of sites. Merriam and others (1973), in their study of changes on Boundary Waters Canoe Area campsites, found that campsite expansion was the most prominent change that followed initial use of campsites.

Other types of impact that often deteriorated were mineral soil exposure and tree damage, particularly exposure of tree roots. Mineral soil exposure tended to increase on sites in the Eagle Cap and Grand Canyon, although it was unchanged on Bob Marshall sites. Potential reasons for the lack of increased soil exposure on Bob Marshall sites include relatively thick organic horizons and low use levels. Sites with thick organic horizons are less vulnerable to mineral soil exposure than sites with thin organic horizons. Particularly where organic horizons are thick, exposure may occur only where trampling disturbance is pronounced (Cole 1987a).

Increased tree root exposure was documented only on the Eagle Cap sites. On Bob Marshall sites, increased root exposure was observed in places where stock was kept, but the extent of increase was not quantified. Tree damage of all types is cumulative. Damage to new trees is not offset by recovery of other trees. Therefore, as long as any new damage occurs, the overall trend in tree damage is toward deterioration.

In contrast to soil exposure and tree damage, impacts to ground cover vegetation declined or were relatively stable in all three areas. The size of devegetated core areas decreased, and the amount of vegetation cover and number of tree seedlings increased. There was also little evidence of change in species composition except for the increase in nonnative vegetation on Bob Marshall sites. Apparently, these types of impact equilibrate quickly to a given level of camping intensity.

In another study in the Boundary Waters Canoe Area on campsites of widely differing ages, older campsites (those more than 13 years old) had substantially higher levels of tree damage and mineral soil exposure but comparable levels of vegetation impact (Cole and Marion 1986). This tends to support the findings of the current study. Campsite area was not significantly greater on the older Boundary Waters sites. However, this may reflect the imposition of a party size limit of 10 and a campsite maintenance program that actively attempts to limit expansion.

In some way or another, each of these areas was unique in terms of the types of impact that occurred. Exotic species were a problem on Bob Marshall and Grand Canyon sites but not on the subalpine sites in the Eagle Cap. Bob Marshall sites are characterized by extremely severe tree damage-an impact that rarely occurs in the Grand Canyon. On Eagle Cap sites, increases in mineral soil exposure are particularly pronounced. These differences suggest that it is important to tailor indicators and monitoring procedures to each area.

In the two studies that compared changes on low-use and high-use sites, high-use sites were generally more highly impacted, and the magnitude of difference increased over the study period. With few exceptions, high-use sites either deteriorated or were relatively stable. In contrast, certain low-use sites deteriorated as much as the high-use sites, while others improved substantially. This variability in response is at least as much a distinguishing characteristic of low-use sites as their lower impact levels.

As reported in earlier studies, the relationship between amount of use and amount of impact is curvilinear (Cole 1982). High-use sites may be more highly impacted than low-use sites, but differences in amount of use are much greater than differences in amount of impact.

The earlier finding that lightly impacted sites are more likely to deteriorate over time than heavily impacted sites (Cole 1986a) was only partially supported by these results. When comparing sites that receive similar amounts and types of use, this relationship may apply. However, more definitive research is needed. If this relationship is generally found, it would suggest that campsite conditions are becoming more homogeneous over time.

In all three studies, we were able to examine change on sites that were no longer being used. Changes on these sites were highly variable. In some cases they deteriorated further despite being virtually unused. In other cases, sites recovered so much that it was difficult to find them. This variability in response appears to be influenced by both previous use/impact levels and environmental characteristics. Generally, high-impact/high-use sites recover slowly. For example, a decade of closure on the high-use Eagle Cap sites has resulted in minimal improvement. In contrast, sites that have not been highly impacted are likely to recover more rapidly when use ceases. For example, in Grand Canyon, three low-use catclaw sites that were no longer in use experienced pronounced increases in vegetation cover.

Environmental conditions are also important. The most dramatic recovery occurred in the Bob Marshall on a high-use outfitter site that was closed to use. This site was difficult to find less than 10 years after it was closed. Rapid recovery probably resulted from a combination of a long growing season, fertile and well-watered soils, and an abundance of nonnative species adapted to recolonizing disturbed sites. In the Grand Canyon, relatively mesic catclaw sites recovered relatively rapidly, while unused xeric pinyon-juniper sites changed slowly.

The two conclusions of this study-that established sites tend to deteriorate slowly and that closed sites recover at variable rates-can be added to previous work on changes following the initial establishment of sites to suggest a typical campsite "life history" (fig. 17). As a campsite first develops, deterioration is rapid, often reaching near-maximum levels after a few years of use (Merriam and others 1973). This "development" phase is followed by a more stable phase during which deterioration continues but at a much slower rate. Campsite expansion, tree damage, and mineral soil exposure appear to be the impacts that tend to become accentuated during this phase. If the site is effectively closed to use, recovery will occur. The rate of recovery is variable but always slower than the rate of deterioration. Recovery will occur more rapidly where growing conditions are more favorable and on sites that were not severely impacted. Management can speed recovery by ameliorating growing conditions and helping with the recolonization process.

The results of these studies give little reason to be either optimistic or pessimistic about the future condition of established campsites. There is little

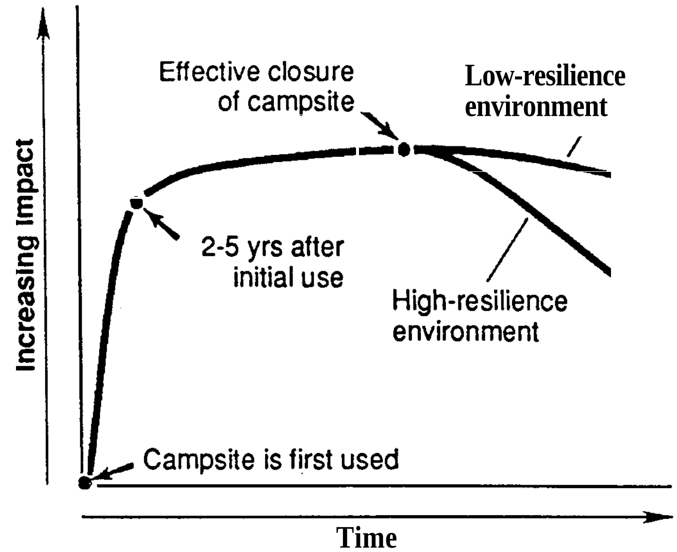


Figure 17- The "life history" of a typical campsite.

evidence to suggest that established campsites are much worse than they were a decade ago. Many wilderness campsites have been severely impacted for decades. Continued use of these sites may cause further deterioration, but at rates that are low when compared with the impact that has already occurred.

On the other hand, some have suggested that apparent declines in wilderness use, shifts toward wilderness activities that have lower impact, and increasing visitor knowledge about low-impact camping techniques might be reflected in a reduction in problems (Lucas 1989). These results suggest that there is little evidence that campsite deterioration problems are declining.

The reader should remember that this study only describes change on established campsites. Campsite impact, in any area, is a function of both the number of sites and the condition of those sites. If the number of campsites increases greatly, campsite impact problems will increase greatly, even if the original sites are relatively unchanged. Change in number of campsites is the subject of another report in preparation.

Changes in condition-either improvement or deterioration-are most likely to occur on low-use sites and in lightly used places. This suggests that these sites and places should be given higher priority by management because this is where "good" management can be most beneficial. On frequently used established campsites, management should focus on avoiding increases in site area and tree damage. Actions that can be effective include user education, party size limits, and active rehabilitation and maintenance of campsite perimeters (Cole 1986a).

METHODOLOGICAL PROBLEMS AND IMPLICATIONS

Several methodological problems became apparent when sites were reinventoried. The most significant problem was the inability to precisely document offsite impacts. This shortcoming was most serious on the Bob Marshall sites where impacts in stock-holding areas were often more substantial than those occurring on the campsite proper. Offsite tree damage also had to be ignored on Eagle Cap campsites. Unfortunately, we do not have any practical suggestions for how to monitor these impacts. They have a tendency to shift around over time. Monitoring plots can be established where offsite impacts are most pronounced. However, when the site is re-examined, use might have shifted to a place outside of this monitoring plot.

Even on the campsite proper, use can shift enough to cause problems. On several Bob Marshall sites, the devegetated central core in 1981 had recovered substantially, while a newly devegetated area had developed a short distance away. But this is rare.

A final limitation was the effect of the small sample size on the power of statistical tests. Sample sizes were small because of the time required to obtain detailed, careful measurements. Over the intervening years, sample sizes tended to decline due to changes on sites such as managers closing sites or visitors no longer choosing to use a site. More definitive conclusions could be drawn if sample sizes were larger.

On the positive side, the methods used were sufficient to deal with the problems of year-to-year and seasonal changes in environmental conditions. Substantial temporal variation was apparent on sites in both the Bob Marshall and the Grand Canyon. By following changes on control plots, it was possible to separate changes in environmental conditions from changes caused by camping.

Finally, these results suggest that lightly impacted sites are more likely to change than heavily impacted sites and that most established sites change relatively slowly. This argues against the wisdom of monitoring heavily impacted sites frequently. It also suggests that there is little value in monitoring established sites more frequently than, perhaps, once every 5 years. Frequent monitoring is needed most where conditions are relatively undisturbed and there is reason to think that amount of use has increased or the type of use is shifting toward a type with more potential to cause impact.

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APPENDIX 1: FREQUENCY AND MEAN COVER OF SPECIES ON CAMPSITES AND CONTROL SITES IN THE EAGLE CAP WILDERNESS

	Frequency'						Mean cover'					
	Camps			Controls			Camps			Controls		
Species	1979	1964	1990	1979	1984	1990	1979	1964	1990	1979	l984	1990
Acer glabrum	0	1	1	1	1	1	0	+	.1	.5	.3	.3
Achillea millefolium	1	0	1	4	5	4		0		.4	.5	.6
Agrostis thurberiana	1	1	1	0	0	0	.1		.1	0	0	0
Agrostis variabilis	4	1	0	3	1	1	.1	.1	0	.7	.5	.1
Allium validum	0	0	0	1	1	1	0	0	0	.5	1.0	.5
Amelanchier alnifolia	0	0	0	1	1	1	0	0	0	.5	.5	.5
Anaphalis margaritacea	0	0	0	0	0	2	0	0		0	0	.5
Anemone oregana			1	1	1	1		.5	.7	.5	.5	.5
Antennaria alpina	7	7	6	13	13	12	.7	.7	.8	1.3	1.2	
Antennaria lanata	9	9	a	11	13	11	1.0	1.0	1.2	3.0	2.0	2.3
Antennaria microphylla	0	0	0	1	1	1	0	0	0	.5	.5	.5
Aquilegia flavescens	0	0	0	1	1	1	0	0	0	.5	.5	.5
Arabis lyallii	1	1	2	0	0	0	+	+	+	0	0	0
Arenaria aculeata	0	0	0	4	4	4	0	0	0	.5	.5	.5
Arenaria macrophylla	1	1	1	1	1	1	.5	1.0	6.3	6.0	1.0	3.5
Arnica cordifolia	2	2	1	2	3	3	+	.3	1.1	3.5	4.0	4.7
Arnica mollis	0	0	0	2	2	2	0	0	0	1.7	1.2	.8
Arnica parryi	0	0	0	1	0	2	0	0	0	.5	0	.5
Aster alpigenus	6	5	4	5	3	6	.3	.4	.3	1.5	1.4	1.6
Aster conspicuus	0	0	0	1	1	1	0	0		1.0	.5	.8
Bromus vulgaris	1	1	1	1	1	1	.1	.1	3.3	4.0	1.0	2.5
Calamagrostis canadensis	0	0	1	0	0	0	0		3.4	0	0	0
Calamagrostis rubescens	1	1	0	0	1	0	.2	..2	0	0	.5	0
Calochortus eurycarpus	0	0		0	1	1	0	0			.5	1.0
Carex geyeri	1	2	3	4	4	2	.2	.4	.3	.8	.8	.5
Carex luzulina	1	0	0	0	0	0	.5	0	0	0	0	0
Carex microptera	4	5	7	3	3	6	.4	1.0	.9	4.5	6.2	3.5
Carex nigricans	2	2	2	3	3	3	30.7	25.3	19.7	47.6	42.7	37.0
Carex rossii	16	16	17	17	17	16	.7	.6	.6	1.1	1.1	1.3
Carex *scopulorum*	0		0	3	3	2	0	0	0	3.8	3.6	3.5
Carex spectabilis	6	7	6	6	5	7	2.6	3.4	3.0	3.6	3.8	3.1
Cassiope mertensiana	3		1	2	2	1			.1	.9	.6	.6
Castilleja *chrysantha*	1	2	2	5	5	5	.1	.1	.1	.4	.4	.4
Cerastium arvense	0	0	1	0	0	0	0	0	.1	0	0	0
Chimaphila umbellata	0	0	0	1	1	1	0	0	0	.5	.5	.5
Claytonia lanceolata	0		1	0	0	0	0	0	6.1			0
Danthonia intermedia	5	2	3	5	4	5	.5	.5	.5	2.4	3.8	4.6
Deschampsia cespitosa	0	0	0	2	2	1	0	0	0	5.5	3.0	5.0
Disporum trachycarpum	0	1	1	1	0	0	0		.2	.5	0	0
Dodecatheon alpinum	1	1	1	1		0	.2	.1	.1	.5	0	0
Epilobium alpinum	4	6	1	3	2	4	.3	.2		.2	.l	.2
Epilobium angustifolium	1	2	1	5	5	2	+	.1	.1	.5	.4	.2
Epilobium sp.	0	1	1	1	0	0	0	.1	.2	.2	0	0
Erigeron peregrinus	9	8	8	14	15	16	1.3	.7	.7	2.2	2.1	2.4
Eriogonum flavum piperi	0	0	0	1	1	1	0	0	0	2.0	.5	.5
Eriogonum ovalifolium	2	1	1	1	1	2	.l	.1	.2	.2	.2	.3
Festuca occidentalis	1	1	1	1	1	1		.1	.3	.5	.5	.5
Festuca viridula	4	6	7	10	10	12	.4	.5	.4	2.4	3.5	2.7
Fragaria vesca	0	1	2	1	1	1	0	+	.2	.5	.5	.4
Galium triflorum	0	0	1	1	1	1	0	0	1.6	3.0	3.0	3.0
Gaultheria humifusa	2	1	2	4	4	4	.5	.9	.7	2.8	3.0	1.8
Gayophytum humile	1	2	0	1	0	0	.2	.l	0	.5	0	0
Gentiana calycosa	1	1	3	3	3	5	1.0	1.0	1.3	.3	.5	3.1
Goodyera oblongifolia			0	1	1	1	0	0	0	.5	.5	.5
Hieracium albertinum	1		1	2	2	4		0	.2	.3	.a	.7
hieracium albiflorum	1		0	1	1	0	.1	+	0	.5	.5	**0**
Hieracium gracile	4		8	10	12	11	+	+	.1	.4	.5	.5

(con.)

APPENDIX 1 (Con.)

Species	Frequency[1]						Meancover'					
	Camps			Controls			Camps			Controls		
	1979	1984	1990	1979	1984	1990	1979	1984	1990	1979	1984	1990
Holodiscus discolor	0	0	0	1	1	1	0	0	0	.5	..5	.5
Hypericum anagalloides	0	0	0	1	1	0	0	0	0	.5	.5	0
Hypericum formosum	0	0	1	5	5	6	0	0		.7	.6	.5
Juncus drummondii	2	3	2	2	2	2	3.7	2.1	+	5.2	3.0	5.2
Juncus parryi	17	17	16	18	17	17	2.7	2.6	2.9	5.5	4.8	5.9
Ledum glandulosum	1	1	1	4	4	4	.3	.2	.3	3.8	3.8	4.0
Lewisia pygmaea	3	3	2	0	1	1	1.2	2.9	3.1	0	1.7	1.3
Ligusticum tenuifolium	5	5	6	8	6	5	2.3	1.1	1.5	3.0	2.2	2.0
Linanthastrum nuttallii	0	0	0	1	1	1	0	0	0	.5	.5	.5
Lonicera utahensis	0	0	0	2	2	2	0	0		.5	1.5	.9
Luzula hitchcockii	7	6	5	9	9	8	.8	.6	.7	4.1	5.1	4.3
Luzula piperi	0	2	2	0	1	1	0	+	1.2	0	.2	.2
Mitella pentandra	0	0	1	1	1	1	0		.8	.5	1.0	.8
Muhlenbergia filiformis	10	11	11	10	12	10	.9	.7	.5	.8	1.2	.8
Oryzopsis exigua	1	1	1	5	5	4	.2	.2	.2	.4	.5	.5
Osmorhiza chilensis	0	0	1	1	1	1	0	0	.3	1.0	.5	.4
Pedicularis contorta	0	0	0	1	1	1	0	0	0	.5	.5	1.0
Penstemon fruticosus	0	0	0	1	1	2	0	0		.3	.5	.5
Penstemon rydbergii	1	2	i	-3	3	4	.l	.2	.7	1.6	1.3	1.5
Phleum alpinum	3	3	3	3	4	2		.l	.l	.4	.4	.3
Phyllodoce empetriformis	10	10	9	14	14	16	.6	.5	.6	9.4	8.7	10.6
Physocarpus malvaceus	0	0	0	1	1	1	0	0	0	2.0	5.0	3.5
Poa gracillima	0	0	0	1	1	1	0	0	0	1.0	.5	.5
Poa leibergii	0	0	0	1	1	1	0	0	0	.5	.5	.5
Poa sandbergii		0	0		1		0		0	.5		
Polemonium pulcherrimum	2	1	1	1	2	2	.6	.2	.5	.8	2.7	.8
Polygonurn phytolaccaefolium	0	1	1	4	4	4	0	.4	.5	1.1	.8	1.1
Potentilla diversifolia	0	0	0	1		1	0	0	0	1.0	1.0	1.0
Potentilla flabellifolia	6	6	6	6	7	7	1.5	1.7	1.8	7.3	4.9	6.5
Potentilla glandulosa	0	0	0	1	1	1	0	0	0	.5	.5	.5
Potentilla gracilis glabrata	0	0		1	1	1	0	0	0	.5	.5	.5
Pyrola secunda	1	0	2	1	1	1	+	0	.l	4.0	3.0	2.8
Ranunculus eschscholtzii	0	0	0	3	2	1	0	0	0	.5	.6	1.6
Ranunculus populago	1	1	0	2	2	1	.l	.l	0	3.0	4.5	.5
Ranunculus uncinatus	0	0	1	0	0	0	0	0	.4	0	0	0
Ribes lacustre	0	0	1	1	1	1	0	0	.l	2.0	2.0	2.0
Sagina saginoides	1	3	4		0	0	+	.4	.l	0		
Senecio cymbalarioides	1	0	0	2	2	1	+	0	0	2.2	2.5	.3
Senecio triangularis	0	0	1	0	0	0	0	0	.l	0	0	0
Sibbaldia procumbens	11	11	10	10	10	10	1.0	1.6	2.0	1.1	1.2	1.1
Taraxacum officinale	1	1	2	0	0	0		.l	.8	0	0	0
Thalictrum occidentale	1	1	1	1	1	1	.l	.4	.8	20.0	15.0	17.5
Trisetum spicatum	0	1	3	5	4	5	0	+	+	1.1	.4	.8
Trisetum wolfii	0	0	0	1	0	0	0	0	0	.5	0	0
Trifolium repens	0	1	1	0	0	0	0			0	0	0
Vaccinium caespitosum	1	1	1	4	4	4	.6	..3	.7	3.8	3.6	3.6
Vaccinium membranaceum	1	1	1	1	0	1	.9	.8	2.6	1.0	0	.5
Vaccinium scoparium	16	15	14	16	16	16	.4	.5	.6	20.0	23.2	19.9
Veratrum viride	1	1	1	1	1	1	.8	.3	.3	1.0	.5	.3
Veronica cusickii	10	9	8	12	14	13	1.2	1.2	1.5	3.1	2.9	2.3
Veronica serpyllifolia	1	1	0	0	1	0			0	0	.5	0
Veronica wormskjoldii	1	2	0	0	1	0	.1	.1	0	0	..3	0
Viola adunca				5	5	4	.l	.l	.1	.7	1.2	
Viola orbiculata	0	0	0	1	1	1	0	0	0	2.0	.5	1.3
Moss	13	17	16	19	19	20	1.4	2.5	2.4	11.3	16.2	13.8

[1]Frequency is the number of sites, out of a maximum of 20, on which the species was found each year. Mean cover is the mean for all sites, either campsite or control, on which the species was found at least once; it is not a mean for all 20 sites. A + indicates cover less than 0.05 percent

APPENDIX 2: FREQUENCY AND MEAN COVER OF NONNATIVE SPECIES ON CAMPSITES IN THE BOB MARSHALL WILDERNESS

Species	Frequency[1]		Mean cover[1]	
	1981	1990	1981	1990
Agropyron repens	3	6	0.6	0.2
Arabis glabra	2	1		
Capsella bursa-pastoris	9	3	.3	.2
Chenopodium album	2	1	+	+
Dactylis glomerata	2	3		+
Lychnis alba	2	0	.1	0
Medicago lupulina	0	2	0	
Phleum pratense	8	8	.8	.7
Plantago major	8	6	.2	.9
Poa annua	2	5		.2
Poa pratensis	20	21	7.4	12.1
Polygonum aviculare	3	3	.8	.1
Rumex acetosella	1	3	.1	.2
Rumex crispus	3	2		
Taraxacum officinale	21	22	2.7	3.6
Thlaspi arvense	4	5	.1	.1
Tragopogon dubius	0	1	0	+
Trifolium pratense.	3	1	+	+
Trifolium repens	15	17	2.3	3.8

[1]Frequency is the number of campsites, out of a maximum of 29, on which the species was found each year. Mean cover is the mean for all sites. A + indicates cover less than 0.05 percent.

APPENDIX 3: FREQUENCY AND MEAN COVER OF SPECIES ON CAMPSITE PERIMETERS AND CONTROL SITES IN GRAND CANYON NATIONAL PARK

	Frequency'				Mean cover[1]			
	Camps		Controls		Camps		Controls	
Species	1994	1989	1984	1989	1984	1989	1984	1989
Acacia greggii	11	11	10	11	17.0	15.4	26.4	17.9
Acourtia wrightii	1	1	1	2	1.4	4.0	.1	.3
Agave utahensis	2	3	4	4	1.0	.8	1.8	1.1
Allionia incarnata	1	1	1	1	.1	.4	3.0	.5
Amelanchier utahensis	1	1	0	0	4.9	6.4	0	0
Amsinckia intermedia	3	3	3	0	.1	1.0	.4	0
Androsace occidentalis	1	2	0	0	+	.1	0	0
Anemone tuberosa	2	2	1	2	.2	.4	.3	.5
Arabis perennans	3	2	6	4	+	+	.3	.2
Aristida arizonica	3	3	3	1	.1	.1	.3	.1
Artemisia arbuscula	1	2	3	4	.3	.4	1.6	1.1
Artemisia ludoviciana	1	1	4	3	.4	.3	6.0	1.6
Aster spp.	0	0	1	0	0	0	.5	0
Astragalus newberryi	4	3	0	1	.1	.1	0	.1
Astragalus nuttallianus	11	5	8	4	.3	.1	.8	.2
Astragalus spp.	1	1	1	0	.3	.3	.5	0
Atriplex canescens	3	3	0	0	2.4	2.0	0	0
Baccharis salicifolia	2	1	1	1	.5	.2	1.5	1.5
Berberis fremontii	0	0	1	0	0	0	.5	0
Bernardia incana	2	2	3	3	4.8	5.3	4.6	4.6
Bouteloua aristidoides	1	1	1	1	1.6	3.6	15.0	3.0
Bouteloua curtipendula	7	9	5	5	1.4	1.7	2.1	1.4
Bouteloua eriopoda	4	2	2	2	1.2	.4	4.5	9.6
Bouteloua gracilis	4	2	1	1	.9	.3	.3	.8
Bromus rubens	22	20	21	19	23.9	11.0	30.0	18.1
Bromus tectorom	2	1	2	2	.2		3.0	3.0
Calochortus flexuosus	3	8	2	8	+	.1	.1	.3
Castilleja chromosa	3	2	1	0	+	.1	.1	0
Castilleja linariaefolia	0	0	0	.0	0	0	0	0
Ceanothus greggii	1	1	0	0	.6	.6	0	0
Ceanothus spp.	0	0	0	2	0	0	0	.5
Cercocarpus intricatus	1	1	0	0	.6	.6	0	0
Cercocarpus montanus	0	0	1	1	0	0	3.0	3.0
Cheilanthes parryi	1	1	0	0		.2	0	0
Chrysothamnus nauseosus	2	2	5	3	1.8	1.5	1.7	.3
Cirsium rothrockii	1	0	0	0		0	0	0
Claytonia perfoliata	3	1	2	1	.2		1.2	.5
Coleogyne ramosissima	6	6	7	6	13.0	12.1	13.3	11.1
Cowania mexicana	5	5	3	3	3.0	2.9	.7	.6
Cryptantha spp.	6	6	4	3	.1	.1	.2	.2
Cymopterus purpurascens	1	2	3	3	+	+	.4	.4
Delphinium parishii	0	0	1	0	0	0	.5	0
Descurainia pinnata	10	4	6	2	.1	.8	.3	.5
Dichelostemma pulchellum	2	4	3	3	.1	.1	.4	.4
Draba cuneifolia	7	3	5	0	.1	+	.3	0
Dyssoides acerosa	1	0	1	0	.1	0	.5	0
Echinocereus engelmannii	2	5	2	2	.1	.1	.2	.2
Echinocereus triglochidiatus	0	0	2	3	0	0	.3	.5
Elymus salinus	0	0	1	0	0	0	.5	0
Encelia frutescens					1.3	1.4	4.2	2.2
Ephedra nevadensis	25	21	20	20	8.4	8.9	10.6	8.7
Erigeron concinnus	.3	2	2	0	.2	+	.3	0
Erigeron lobatus	1	0	1	0	7.2	0	3.0	0
Erigeron spp.	0	1	1	0	0	+	.3	0

(con.)

APPENDIX 3 (Con.)

	Frequency				Meancover			
	Camps		Controls		Camps		Controls	
Species	1984	1989	1984	1989	1984	1989	1984	1989
Eriogonum inflatum	1	2	0	0	.2	.3	0	0
Eriogonum spp.	1	1	0	0	.3	.4	0	0
Erioneuron pilosom	0	1	0	0	0	+	0	0
Erioneuron pulchellum	5	2	4	0	.1		.3	0
Erodium cicutarium	14	11	7	6	.3	.3	.3	.2
Fallugia paradoxa	3	3	3	3	9.7	8.5	11.3	11.3
Fendlera rupicola	0	0	1	1	0	0	3.0	3.0
Fraxinus anomala	0	0	1	1	0	0	3.0	3.0
Galium aparine	2	3	1	0	.5	.6	.1	0
Galium stellatum	1	1	0	0	.1	.6	0	0
Gilia flavocincta	5	0	3	0	.5	0	.8	0
Giossopetalon nevadense	7	7	6	7	4.4	3.9	8.3	8.3
Gutierrezia sarothrae	21	20	19	17	2.8	2.1	5.7	3.1
Haplopappus acradenius	4	4	3	3	14.4	11.9	17.0	17.0
Haplopappus spinulosus	2	2	0	0	.4	.9	0	0
Hilaria jamesii	3	0	2	0	.1	0	1.2	0
Hordeum leporinum	4	3	2	2	6.8	6.4	.2	1.2
Hymenoxys acaulis	1	1	1	1	.1		.5	.5
Juniperus osteosperma	5	5	6	5	12.8	16.3	10.6	10.1
Lepidium lasiocarpum	11	6	9	5	.3	.3	.3	.2
Lepidium montanum	2	0	1	1		0	.3	.3
Leucelene ericoides	1	2	4	2	.3	.1	1.8	.6
Lupinus brevicaulis	1	1	1	1			.5	.5
Lycium andersonii	2	3	1	1	.2	.5	.8	.8
Mammillaria tetrancistra	0	0	0	2	0	0	0	.5
Mentzelia pumila	1	0	0	0	+	0	0	0
Mirabilis multiflora	0	3	0	1	0	2.2	0	.2
Muhlenbergia porteri	3	2	3	2	.6	.8	1.8.	.2
Oenothera hookeri	0	1	0	0	0	.1	0	0
Opuntia basilaris	1	1	2	0	.1	.1	1.8	0
Opuntia chlorotica	0	1	0	0	0	.1	0	0
Opuntia erinacea	5	4	2	2	.7	.4		.2
Opuntia phaeacantha	1	1	1	1	.1	.1	3.0	.5
Oryzopsis hymenoides	1	1	0	0	.8	2.2	0	0
Parietaria hespera	5	2	4	2	.6	.1	1.2	.2
Penstemon eatonii	0	0	1	1	0	0	.5	.5
Pectocarya recurvata	1	0	0	0	.1	0	0	0
Phacelia cryptantha	3	0	3	0	1.7	0	1.3	0
Phacelia glechomaefolia	2	0	2	0	.1	0	.3	0
Pinus edulis	1	3	3	3	2.3	2.8	4.6	4.6
Pfagiothrys arizonicus	2	0	0	0		0	0	0
Plantago purshii	13	6	13	1	.6	+	.8	+
Poa bigelovii	10	4	4	0	.2		1.0	0
Poa fendleriana	8	6	8	1	.4	.3	1.0	.1
Porophyllum gracile	2	2	1	1	1.7	1.0	1.5	.3
Ptelea trifoliata	1	1	1	1	23.2	14.1	15.0	15.0
Quercus undulata	1	1	1	1	5.6	7.2	.5	1.5
Rhus trilobata	4	4	2	1	2.9	4.7	2.6	2.5
Senecio multilobatus	1	2	2	1	+	+	.5	.3
Sitanion hystrix	5	2	5	3	.1	+	.3	2
Sphaeralcea parvifolia	15	13	14	13	.5	.4	.8	.6
Sphaeralces parvifolia	1	2	1	2		.1	.2	.3
Sporobolus cryptandrus	7	5	9	7	.8	1.3	.9	.5
Stipa arida	8	9	8	7	1.1	1.8	1.7	1.2
Stipa comata	1	1	2	2	.5	5	6.0	.3

(con.)

APPENDIX 3 (Con.)

Species	Frequency				Mean cover			
	Camps		Controls		Camps		Controls	
	1984	1989	1984	1989	1984	1989	1984	1989
Stipa speciosa	2	2	0	0	.1	.1	0	0
Stipa sp.	0	1	0	0	0	.7	0	0
Streptanthus cordatus	1	4	0	0	+	+	0	0
Swertia albomarginata	0	0	1	0	0	0	.5	0
Thamnosa montana	1	1	3	2	.3	.2	1.6	.3
Thelypodiopsis linearifolia	1	0	1	0	+	0	.5	0
Thysanocarpus Iaciniatus	3	2	2	2	+	+	.3	.3
Tragopogon dubius	2	0	0	0	+	0	0	0
Vulpia octoflora	11	2	8	0	.5	.1	.8	0
Yucca angustissima	1	1	2	1	.2	.7	1.8	.3
Yucca baccata	3	4	6	6	1.6	1.9	1.8	1.8
Moss	18	8	15	5	6.8	3.7	10.0	4.4

[1]Frequency is the number of sites, out of a maximum of 22, on which the species was found each year. Mean cover is the mean for all sites, either campsites or control, on which the species was found at least once; it is not a mean for all 22 sites. A + indicates cover less than 0.05 percent.

Cole, David N.; Hall, Troy E. 1992. Trends in campsite condition: Eagle Cap Wilderness, Bob Marshall Wilderness, and Grand Canyon National Park. Res. Pap. INT-453. Ogden, UT: U.S. Department of Agriculture, Forest Service, lntermountain Research Station. 40 p.

The overall trend in condition on established campsites was one of slight deterioration, with the most deterioration occurring in campsite area, mineral soil exposure, and tree damage. Impacts to ground cover vegetation were relatively stable. Differences in amount of impact between high-use and low-use sites generally increased over time.

KEYWORDS: ecological impact, campsites, wilderness, backcountry, trends