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Twenty Years of Change on Campsites in the Backcountry of Grand Canyon National Park

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Abstract This article draws on three separate research and monitoring studies to describe 20-year trends in the number and condition of campsites in the backcountry of Grand Canyon National Park. Results are used to assess the effectiveness of a complex and innovative management program, adopted in 1983, that sought to concentrate use on designated campsites in popular places and disperse camping in more remote places. In 1984, conditions on 12 high-use campsites and 12 low-use campsites were carefully assessed. Conditions on 22 of these campsites were reassessed in 2005. In addition, campsite-monitoring surveys were conducted between 1985 and 1992 and again in 2003 and 2004. In these surveys, all campsites were located and their condition rapidly assessed. The detailed assessment of a sample of sites suggests relatively little change in condition during the 20-year period. The high-use sites were more highly disturbed than the low-use sites, but they did not change more during the study period. In contrast, changes at larger scales were dramatic. The total number of campsites more than doubled during the study period. Surprisingly, the proliferation of new campsites was greater in places where camping was only allowed on designated campsites than in places where camping was allowed anywhere. Concern that concentration of use on designated sites would cause unacceptable impact was unfounded. Management implications for other internationally significant protected areas that allow backcountry camping are explored.

Keywords Campsite impact · Designated campsites · Recreation management · Trends

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Introduction

Grand Canyon National Park is one of the great natural wonders of the world. As such, it has been a major tourist destination for more than a century. Although most tourists are content to view the canyon from the rim, many venture into the canyon down a few established trails into the backcountry by hiking or riding on mule trains. Where they walk, stop, and congregate, congestion and ecologic impacts occur. Like many other international destinations for adventure tourists, management of crowding and impacts is a challenge (Buckley 2004). Lessons learned in managing the backcountry of the Grand Canyon have application in protected areas around the world.

During the 1970s, the popularity of the Grand Canyon backcountry increased greatly, and by the 1980s, substantial numbers of people were leaving the developed trails into the canyon in favor of hiking down long-abandoned trails built by miners and pioneering routes cross-country. By the early 1980s, use levels on these trails averaged approximately 32,000 visitor nights (one person spending one night) per year, with more than one half of this use occurring between March and May. Crowding increased in the more popular areas, and impacts associated with hiking and camping appeared in many places that had never been disturbed before.

In 1974, the National Park Service responded by limiting use through setting a maximum number of groups per day that could enter at each trailhead (generally about 16 people/d at each trailhead). Despite the daily limits imposed at trailheads, hikers tended to congregate at a few locations, typically sources of water, including sensitive seeps and springs. Managers continued to be concerned about crowding and about increasing impacts associated with camping. These concerns led the park to adopt in 1983 a more complex backcountry-management plan based on zones, with each zone intended to offer a different recreation opportunity and each zone having a different campsite-management strategy.

As will be described in more detail later, the overall strategy of this program was to concentrate camping in heavily used places and disperse it in more remote places. Campsite-impact research had suggested that such a strategy might be effective (Cole 1983), but the strategy had never been tested. There were concerns that concentration of use would lead to unacceptable levels of impact on some sites, while dispersal of use elsewhere would lead to proliferation of campsite impacts. Consequently, the park began a backcountry-campsite research and monitoring program in 1984.

The strategy of concentrating use in popular places (frequently referred to as "confinement strategy") and dispersing it elsewhere has been adopted by some parks and wilderness areas (Leung and Marion 2000) and is central to Leave-No-Trace educational programs (Hampton and Cole 2003). The effectiveness of confinement of camping has been assessed, both at one point in time (Marion and Farrell 2002) and during 3- and 5-year periods (Marion 1985, Reid and Marion 2004), in three parks in the central and eastern United States. Each study concluded that confinement is highly effective in minimizing campsite impact. Marion and Farrell (2002) and Reid and Marion (2004) provide a rich discussion of ways in which confinement strategy can be implemented. However, effectiveness has never been assessed during a long period of time or in more diverse environments, nor has the combination of confinement in some places and dispersal elsewhere been assessed.

Because we are not aware of any published accounts of change in campsite conditions during such a long time period, one objective of this article is to describe such changes during a 20-year period in the desert environment at Grand Canyon. We describe change in groundcover characteristics, shrub density, and vegetation composition. Change on high-use campsites is contrasted with change on low-use sites. Our second objective is to use these data on trends in impact to evaluate the effectiveness of a confinement-and-dispersal campsite-management strategy. Specifically, we use a sample of campsites to assess the amount of change that occurred on individual campsites. We use censuses of campsites in defined-use areas to assess change in the number of campsites. Quantification of change, both in the intensity of impact on individual campsites and in the total number of campsites, allows for an assessment of trends in aggregate campsite impact, both in places where use is concentrated (confined) and where it is dispersed.

Backcountry Campsite Management at Grand Canyon

The 1983 backcountry-management plan identified three backcountry zones: threshold (the most heavily used), primitive, and wild (the least heavily used). These were in addition to a "developed corridor" zone (the zone with hardened trails, developed campgrounds, and park infrastructure below the canyon rim). The backcountry zones (land classes that varied in amount of use, impact, development, and management) were subdivided into a number of geographically distinct use areas. There were 26 threshold-use areas, 40 primitive-use areas, and 22 wild-use areas.

In most threshold use areas (which varied in size from approximately 300 to 2000 ha), camping was only allowed on designated sites at one specific location in the use area, although as many as four individual designated sites were clustered at each location (Fig. 1). Designated sites were long-established, user-built campsites, denoted by signs. Management modification of sites was minimal, although many of these sites had primitive toilets. Campfires were prohibited throughout the backcountry, so there were no fireplaces. Campers had to reserve a site before their trip, with the daily use limit for the use area set by the number of designated campsites. One threshold-use area did not require the use of designated campsites. The four groups permitted to camp in this use area each night were allowed to camp wherever they wanted.

Most primitive use areas were larger (typically 1000 to 8000 ha) than threshold-use areas, and hikers were allowed to camp wherever they wanted on dispersed campsites (a strategy referred to as "at-large camping"). In term of appearance and impact, some of these dispersed sites were similar to the designated campsites in threshold areas, but most were less highly impacted. No facilities were provided. In one primitive use area, camping was only allowed on designated campsites. Hikers were required to reserve a permit for the use area for the night they planned to camp there. Nightly quotas for primitive-use areas were typically approximately three groups per use area. In the very lightly used wild-use areas, hikers were allowed to camp wherever they wanted and were encouraged to camp where they would leave no trace. Little use occurs in these areas, and

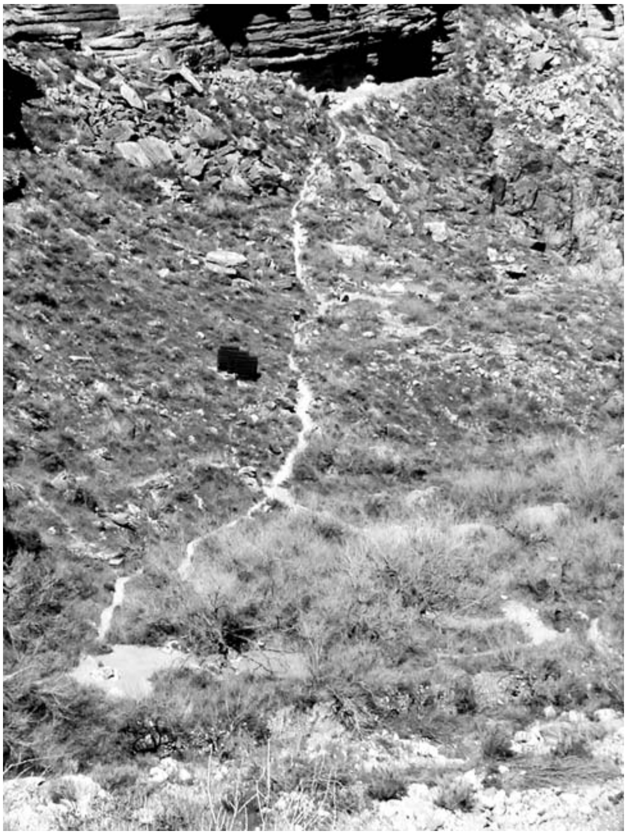

Fig. 1 The location in the Monument Creek use area (threshold zone) with allowable camping has four individual designated campsites (high use; catclaw vegetation type)

campsite impacts were minimal. We did not study any of these particular areas.

Use levels differ substantially between threshold- and primitive-use areas. Using data collected during the past 5 years from 24 use areas, the median annual number of user nights was 1.46/ha in threshold-use areas and 0.40/ha in primitive-use areas. Differences between use areas with designated sites and at-large camping were more substantial. The median annual number of user nights was 1.75/ha in areas with designated sites and 0.27/ha in areas with at-large camping.

Although visitors are not required to obtain permits in person, user surveys indicate that 70% obtain permits from the backcountry office in the park, which has numerous educational displays there about, among other things, low-impact camping methods and regulations. Rangers go through both Leave-No-Trace education principles and camping regulations with each group, and the group leader is required to sign a statement that they understand all regulations. Those who obtain their permits through the mail are sent a package of educational material, including a video as well as a bulletin about policies for the specific area they are visiting, and they must sign the statement that they understand the regulations. Surveys of backcountry visitors suggest that virtually all overnight visitors understand park camping policies.

Methods

We draw on data from three separate studies. The first study involved a detailed examination of 24 campsites, widely distributed along primitive trails in the Park's backcountry but along neither the Colorado River nor the developed trail corridors (e.g., Bright Angel Trail). Sample size was a balance between the number of sites that could be studied in one field season and the number required to have a reasonable degree of statistical power (four campsites in each of six combinations of use level and vegetation type). All campsites were within 40 km of each other; several were clustered, with two to four sites situated within 50 to 200 m of each other.

We selected 12 high-use and 12 low-use sites. The high-use sites include many of the most heavily used campsites in the backcountry, most of which are designated as campsites. Limited data suggest that most of these sites are used approximately 100 nights/y, with some being used as much as $\geq$200 nights/y. The low-use sites ranged from several that are virtually unused to others that are regularly used but at low levels, probably $\leq$20 nights/y. None of these sites has been modified substantially by management. There were no fireplaces (campfires were prohibited) and for those with toilets, the facilities were located at least 50 m away.

Within each use stratum, four sites each were located in pinyon–juniper, catclaw, and desert scrub vegetation types. The pinyon–juniper sites were at higher elevations (1400 to 1600 m). Natural vegetation is characteristically open woodland of *Pinus edulis* (Colorado pinyon) and *Juniperus osteosperma* (Utah juniper), with an understory dominated by evenly spaced evergreen sclerophyllous shrubs and succulents. Approximately one half of the ground surface under undisturbed conditions is mineral soil (Fig. 2). The catclaw sites were on alluvial terraces above drainages with permanent or seasonal water at elevations of 850 to 1100 m. Undisturbed vegetation consists of closely spaced *Acacia greggii* (catclaw acacia) trees (Fig. 1) and a highly variable understory of shrubs and grasses. Vegetation cover is high (typically <80%); organic litter horizons are thick; and exposed mineral soil is minimal. The desert scrub sites are located on drier sites than catclaw but at similar elevations (900 to 1100 m), located mostly on colluvial deposits or bedrock. Undisturbed vegetation consists of diverse regularly spaced shrubs and a groundcover of grasses (Fig. 3). In terms of vegetation, organic litter, and mineral soil cover, these sites are intermediate between pinyon–juniper and catclaw sites.

All sites were first assessed in 1984 (Cole 1986) and measured again in 1989. In 2005, all but 2 of these sites were assessed for a third time. Therefore, the results presented in this article apply to only 22 campsites. By providing precise measures of change on a small sample of campsites, this study provides an assessment of trends in the condition of campsites that existed in 1984.

To assess trends in overall campsite impact, data on changes in the condition of campsites must be complemented with data on change in the number of campsites. For this purpose, we used some of the data collected in two efforts to census all of the campsites in different use areas in the Grand Canyon backcountry. The first of these censuses, the Rapid Campsite Assessment (RCA), was initiated in 1985 and continued until 1992. Each year, approximately 5 of the 66 threshold and primitive use areas were surveyed, with emphasis placed on the 30 use areas that contained established trails or routes. In total, approximately 40 use areas were surveyed between 1985 and 1992, and >300 campsites were assessed. For each campsite, the RCA recorded the number and size of barren areas. Each campsite typically contains one to several barren areas, places used for cooking or sleeping, where all the vegetation has been eliminated, and the soil is highly compacted. In addition, data on soil compaction, access trails, perimeter vegetation, tree damage, and permanent impacts from fires were also collected, although these are not reported here.

The second survey, the Rapid Site Inventory (RSI), was conducted mostly in 2003 and 2004, with some additional data collection in 2005. This survey covered the 32 most frequently visited backcountry use areas in Grand Canyon National Park. As in the earlier survey, the goal was to locate and assess the condition of most campsites. Although the effort expended locating sites was roughly equivalent for each of the surveys, the RSI collected information on a wider array of variables than the RCA but with less quantification. Site descriptors included variables such as soil, dominant vegetation, water presence, site visibility, global information system coordinates, and digital imagery. Recreation-impact assessment variables included capacity, barren core presence, social trails, campfire impacts, litter, human waste, and vegetative damage. Of particular note, concern about subjectivity in defining campsite perimeters led to the decision not to attempt to quantify the size of individual barren areas or entire campsites. A total of 757 backcountry sites were located and assessed in the 2003 to 2004 RSI survey.

Detailed Study of Selected Campsites

Each sample site consisted of both a campsite and an undisturbed control site in the vicinity. Because the understory vegetation typically was sparse (Fig. 2), it was difficult to establish a nonarbitrary boundary to the entire campsite. Consequently, we could not use some standard campsite impact parameters, such as campsite area, area of vegetation loss (Cole 1989), or aggregate area of impact (Reid and Marion 2004). Instead, we took separate measurements in the campsite core (the central portion of the campsite that was largely devoid of vegetation and therefore easy to define) and along the campsite perimeter, i.e., the area several meters beyond the core. If campsite disturbance had expanded, this would be evident in changes in the perimeter zone.

Fig. 2 This low-use campsite with pinyon–juniper (on the Esplanade above Hermit Creek) illustrates the difficulty of defining the edge of the area disturbed by camping

Fig. 3 This high-use campsite in desert scrub (at Cedar Springs) illustrates the high degree of groundcover disturbance in the central core of the campsite

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 (a clump of vegetation at least 1 m^2 in area) were measured along 16 cardinal directions. This defined the central core area. Within this core, four 1-m2 quadrats were located along north, south, east, and west transects, halfway to the edge of the core. Percentage cover of vegetation (usually absent) and organic litter were recorded in the following coverage classes: $<$1%, 1% to 5%, 6% to 25%, 26% to 50%, 51% to 75%, 76% to 95%, and 96% to 100%. Mean coverage was calculated using the midpoint of each coverage class. Various soil parameters were also measured (bulk density, penetration resistance, infiltration rate, and moisture) (Cole 1986), but the measures used were not considered precise enough to be repeatable; hence, these measures were discontinued.

Approximately 25 1-m^2 quadrats were randomly located along transects in the campsite perimeter. Within each quadrat, cover of live vascular vegetation, 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.

Control sites were circular, with an area of 50 m^2. They were located 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. Instead of using quadrats, we made ocular estimates of live vascular vegetation cover, organic litter cover, mineral soil cover, and rock cover for the entire 50-m^2 control. The cover of each vascular plant species was estimated, and the number of rooted shrubs was counted by species. Suitable control sites could not be found for two campsites. The campsite and control center points were marked with buried nails, as were the end points of the perimeter transects. This permitted the precise relocation of all measurement units.

In 1989 and 2005, measurements were repeated. In each year, all measurements were taken during spring, at the height of the growing season for herbaceous plants. Core and perimeter measurements were taken in the same places as in 1984, regardless of whether the core had enlarged or decreased during this time.

The magnitude of change that occurred during 20 years is expressed in two ways: (1) median conditions in 1984, 1989, and 2005 and (2) median amount of change, which is calculated by subtracting conditions in 1984 from conditions in 2005 for each site and then reporting this difference for the median site. Readers should note that this estimate of change on the median campsite is not the same as the difference between median 1984 conditions and median 2005 conditions for all campsites. In addition, for each parameter, we report the number of sites on which that parameter increased, decreased, or stayed the same between 1984 and 2005. Finally, we evaluate the statistical significance of differences between conditions in 1984 and 2005 with the Wilcoxon matched-pairs signed-rank test. In the few situations where data are normally distributed, we present means and evaluate the statistical significance of differences with paired Student *t* tests. Null hypotheses were rejected if probability values were $\leq$0.05. Changes on both campsites and control sites are shown.

The effect of camping on the species composition of the campsite perimeter is estimated by comparing the species composition of the perimeter and the control. To quantify differences, the following coefficient of floristic dissimilarity was calculated:

$$FD = 0.5 \sum | p_1 - p_2 | ,$$

where p_1 is the mean relative cover of a given species on the campsite perimeter, and p_2 is the relative cover of the same species on the control. Relative cover is the percent of total cover accounted for by a given species (i.e., one species' cover divided by the total cover of all species). Both native and nonnative species were included.

Site Inventories Using Rapid-Survey Techniques

Results of the two campsite inventory studies (RCA and RSI) were compared to estimate general park-wide trends in backcountry conditions and to further assess the effectiveness of the park's zone-based campsite-management strategy. Although the two studies used somewhat different methods, the effort expended in locating sites was equivalent in both studies as were some of the indicators of campsite condition. Both studies attempted to find most (but not all) campsites; in each case a 95% site detection rate was estimated.

In this article, we simply report change in the number of campsites and in the number of barren areas in the 23 most heavily used use areas in the park. These indicators were consistent across the two studies, except in how tightly packed clusters of campsites were handled. At some popular destinations, individual campsites merge into clusters of sites where it is impossible to determine where one site ends and the next begins. Estimates of the number of campsites in such a cluster are imprecise. In the early inventory, evaluators used their best judgment to decide how many individual campsites were in a cluster. For the later inventory, all the campsites in a single cluster were simply reported as one cluster. Consequently, the later inventory underestimates the total number of campsites. The number of barren areas is directly comparable between the two inventories.

Results

Changes on the 22 Sample Campsites

Generally, conditions on campsite cores changed very little from 1984 to 2005. Median core area decreased slightly between 1984 and 1989 and increased between 1989 and 2005 (Table 1). Approximately equal numbers of campsite cores increased in size as decreased. Mean change in core area was an increase of 3 m^2 and median change was a decrease of 2 m^2. The test of significance suggests no consistent change in core area during the 20-year period. Although stability was the norm, three campsites decreased in size by at least 25 m^2, and four campsites increased by at least 25 m^2.

By definition, campsite cores have been highly impacted by camping. Most of the vegetation cover and organic litter cover have been eliminated, exposing mineral soil and/or rock. During the 20-year period of the study, however, average conditions improved slightly. Both vegetation and litter cover increased slightly on campsite cores. Even with this increase, cores typically are mostly bare soil and/or rock. Vegetation cover did increase >10% on six campsites, and litter cover increased >10% on five campsites. These campsites experienced a decrease in core area during the same period. Most of these were low-use sites.

On the campsite perimeter, vegetation and litter cover decreased between 1984 and 1989 and increased between 1989 and 2005 (Table 2). Conversely, mineral soil cover increased between 1984 and 1989 and decreased between 1989 and 2005. During the entire 20-year period, vegetation, litter, mineral soil, and rock cover all increased significantly on campsite perimeters, whereas they remained stable on controls. Clearly, there is no evidence of a dramatic loss of vegetation that might suggest that campsites had expanded substantially. Only four campsites experienced a decrease in vegetation around the perimeter, and maximum vegetation loss was only 9% (i.e., vegetation cover on the perimeter in 2005 was 9% less than it was in 1984). Our finding that vegetation cover generally increased is likely the short-term result of the near-record amount of rain that fell during the winter of 2005. The increased vegetation was provided by annual species, which were uncharacteristically luxuriant in 2005 but may have been largely absent in subsequent years.

Table 1 Core changes on 22 campsites

Core characteristics	Core area (m^2)	Vegetation cover (%)	Litter cover (%)
Median			
1984	44	0	0
1989	38	1	2
2005	46	5	4
Change[a]	–2	5	2
No. of sites			
Decreased	12	0	1
Increased	10	19	16
Unchanged	0	3	5
Significance[b]	0.66	<0.01	<0.01

[a] Median difference between conditions in 1984 and 2005 (1984 value subtracted from 2005 value)

[b] Wilcoxon matched-pairs signed ranks test ($\alpha = 0.05$), difference between 1984 and 2005

Shrub density decreased significantly, both on campsite perimeters and controls, from 1984 to 1989 and from 1989 to 2005 (Table 3). Reasons for this decrease are unclear. Apparently, shrub seedlings are not establishing or surviving at rates sufficient to offset shrub mortality. The fact that decreases were recorded on controls as well as campsite perimeters suggests that recreational use is not the reason for the decrease. Competition with abundant annual exotic grasses could be a factor, but addressing this possibility is beyond the scope of this article.

Figures 4 through 6 summarize differences in mean groundcover conditions, as well as changes with time, between campsite cores, perimeters, and controls. It is clear that campsite cores are dominated by mineral soil and/or rock, whereas perimeters and controls have substantial vegetation cover as well as mineral soil and rock. A much smaller proportion of the ground has litter cover without an overlying layer of vegetation. This litter groundcover category was more prevalent on campsite perimeters than on undisturbed controls sites in 1984 and 1989. In fact, this is the primary difference between perimeters and controls. In 2005, however, there was little difference in litter cover between perimeters and controls.

These figures also show the increase in vegetation cover that occurred on campsite cores. This change occurred on some but not all of the campsites. The other apparent trend is the increase in vegetation cover on campsite perimeters in 2005 at the expense of ground covered with organic litter but without an overlying vegetation layer. A majority of the perimeter vegetation cover (57%) was contributed by annual herbs and grasses that grew luxuriantly after abundant winter rainfall. A large proportion of these annuals (63% of annual cover) were nonnative species.

The data we collected on cover of individual species on campsite perimeters and control sites provide the

Table 3 Changes in shrub density on campsite perimeters and controls

Density changes	Shrub density (shrubs/m^2)	
	Perimeter	Control
Median		
1984	1.08	0.71
1989	0.77	0.60
2005	0.52	0.57
Change[a]	−0.28	−0.22
No. of sites		
Decreased	15	14
Increased	5	5
Unchanged	2	3
Significance[b]	0.01	0.01

[a] Median difference between conditions in 1984 and 2005 (1984 value subtracted from 2005 value)

[b] Wilcoxon matched-pairs signed ranks test ($\alpha = 0.05$), difference between 1984 and 2005

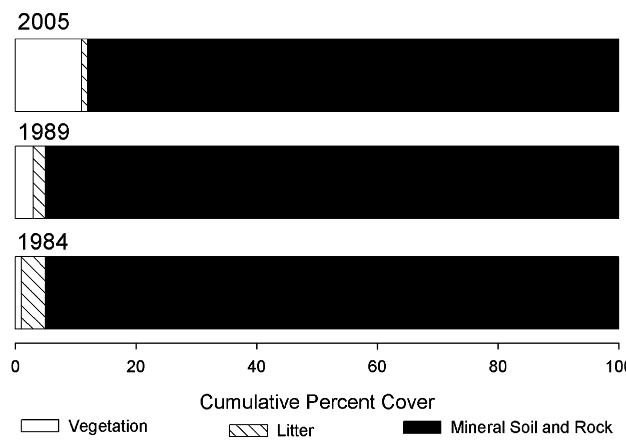

Fig. 4 Groundcover on campsite cores in 1984, 1989, and 2005

Table 2 Groundcover changes on campsite perimeters and controls

Groundcover characteristics	Vegetation		Litter cover		Mineral Soil cover		Rock cover	
	Perimeter	Control	Perimeter	Control	Perimeter	Control	Perimeter	Control
Median								
1984	54	63	51	63	16	27	7	3
1989	46	63	46	63	30	27	5	3
2005	62	63	62	63	16	27	8	3
Change[a]	7	0	5	0	4	0	1	0
No. of sites								
Decreased	4	5	4	7	7	5	5	1
Increased	15	4	16	3	14	5	13	5
Unchanged	3	13	2	12	1	12	4	16
Significance[b]	<0.01	0.90	<0.01	0.47	0.05	0.38	0.03	0.20

[a] Median difference between conditions in 1984 and 2005 (1984 value subtracted from 2005 value)

[b] Wilcoxon matched-pairs signed ranks test ($\alpha = 0.05$), difference between 1984 and 2005

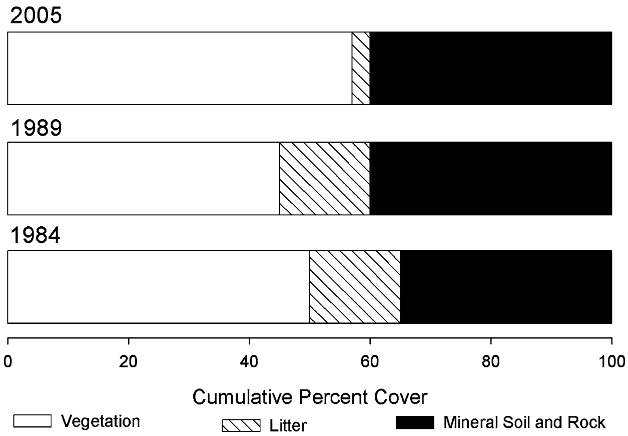

Fig. 5 Groundcover on campsite perimeters in 1984, 1989, and 2005

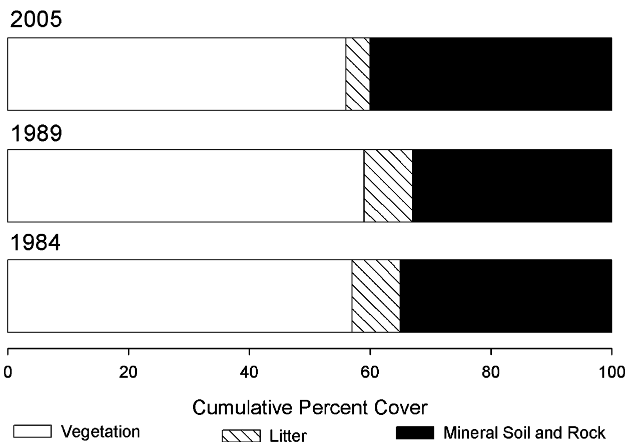

Fig. 6 Groundcover on control sites in 1984, 1989, and 2005

opportunity to gain more insight into impacts on the species composition of vegetation. In 1984, mean floristic dissimilarity (the index of difference in species composition between campsite perimeters and controls) was 33%. Dissimilarity increased between 1984 and 1989 to 42% and decreased between 1989 and 2005 to 36%. These index values suggest only slight differences in composition between perimeters and controls and little change with time. Differences between 1984 and 2005 did not quite meet the 0.05 criterion for statistical significance ($p = 0.06$).

In 2005, campsite perimeters differed from control sites primarily in having less grass cover, including both annual and perennial grass cover (Table 4). Perimeters also had less cover of nonnative species than did controls sites. The most abundant species on both campsites and control sites was the nonnative annual grass, *Bromus rubens* (red brome). Surprisingly, mean *B. rubens* cover was higher on control sites (37%) than on campsite perimeters (25%), suggesting that although this species is weedy it is still sensitive to trampling. Differences in this one species account for most of the difference between campsite perimeters and control sites.

On control sites, the only statistically significant changes between 1984 and 2005 were increases in the cover of annual forbs (Table 4). Mean annual forb cover increased from 3% in 1984 to 15% in 2005. Mean annual grass cover increased from 34% in 1984 to 46% in 2005, although this difference did not quite meet the 0.05 criterion for statistical significance. Campsite perimeters also experienced increases in the cover of annual forbs and grasses. Increases in the cover of nonnative species and decreases in the cover of shrubs were statistically significant on campsite perimeters. Changes of similar magnitude on control sites were not significant. These data suggest that composition changed on campsites but that changes were more reflective of general environmental change than human impact.

In Figures 7 and 8, covers are standardized such that the graphs depict the percentage of the total vegetation made up by the different growth forms. These graphs show the general similarity between the vegetation of campsite perimeters and control sites. There is substantially more variation between years than between campsite perimeter and control, but the pattern of variation with time is similar between perimeters and controls, suggesting that they do not reflect camping impacts. Herbaceous vegetation, particularly of annual species, is much more abundant in wet years than in dry years. Annual forbs respond even more than annual grasses to wet years.

Table 4 Change in mean cover of different growth forms on campsite perimeters and controls sites

Growth form	Perimeters				Controls			
	1984	1989	2005	p[a]	1984	1989	2005	p[a]
Shrubs and trees	40	37	32	<0.01	44	43	39	0.19
Cacti	<1	<1	<1	0.92	<1	<1	<1	0.17
Shrubs	27	25	21	<0.01	27	30	23	0.23
Trees	13	12	11	0.18	17	14	16	0.47
Total grasses[b]	29	13	35	<0.01	37	17	52	0.10
Annuals[b]	26	10	33	<0.01	34	15	46	0.07
Perennials[b]	3	3	1	0.08	3	2	6	0.94
Total forbs	4	4	17	<0.01	5	2	17	<0.01
Annuals	3	2	15	<0.01	3	1	15	<0.01
Perennials	1	2	2	0.14	2	1	2	0.93
Nonnatives[b]	26	10	33	0.04	33	15	44	0.18

[a] Paired Student t tests ($\alpha = 0.05$), difference between 1984 and 2005

[b] Growth forms for which 2005 cover differed significantly between perimeters and controls

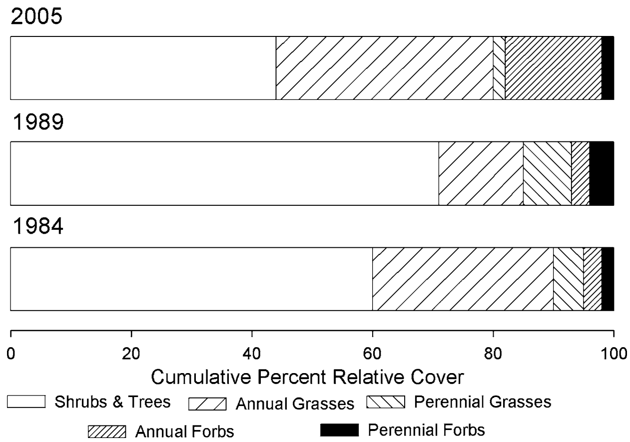

Fig. 7 Relative cover of growth forms on campsite perimeters in 1984, 1989, and 2005

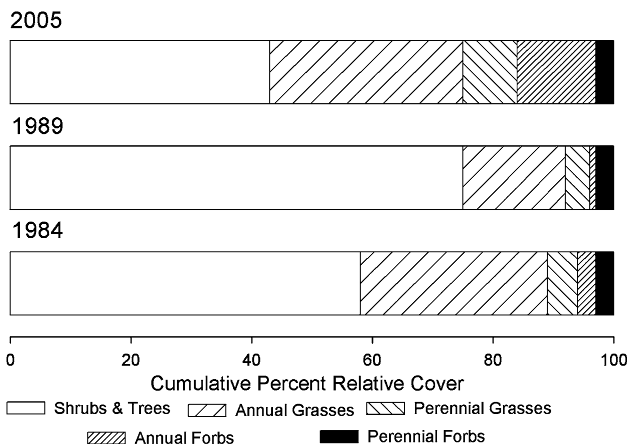

Fig. 8 Relative cover of growth forms on control sites in 1984, 1989, and 2005

Effect of Amount of Use

The median core area of high-use sites was approximately 2.5 times as large as the median core area of low-use sites (Table 5). Although high-use sites were larger, they did not change more than low-use sites during the 20-year period. The median high-use site got slightly smaller during this period, whereas the median low-use site got slightly larger; however, differences were not statistically significant. High-use sites also had less vegetation and organic litter on their cores, although differences were not always statistically significant and were never sizable. Rates of change between 1984 and 2005 were not significantly different.

Perimeter conditions on high-use sites were not significantly different from perimeter conditions on low-use sites (Table 6). In 1984, this was expected because on both high and low use sites perimeter conditions were measured beyond the highly disturbed core. We were interested in monitoring conditions on the perimeter because we were concerned that campsite impacts might expand out into the perimeter with time and that this trend might be more pronounced on high-use sites. As suggested by the data in Table 6, however, there is no evidence that impact increased on perimeters. Vegetation cover on perimeters increased more often than it decreased. Shrub density decreased but no more so than on control sites. This parallels the finding that core area did not generally increase with time, nor is there any evidence that high-use perimeters were impacted more than low-use perimeters during the 20-year period. Differences between high- and low-use sites were not statistically significant in 2005, and the amount of change did not differ significantly.

Changes at Larger Spatial Scales

Compared with our finding that individual campsites did not change much during 20 years, changes at larger scales were dramatic. In the 23 most popular use areas in the park, 332 campsites were found in the late 1980s. From 2003 to 2004, in these same use areas, we found 514 individual campsites as well as 70 clusters of campsites. Although the number of campsites in a cluster varied from two to perhaps five or six, we estimated that the average was approximately three. This suggests a total of more than 700 individual campsites in 2003 and 2004, more than double the number in the late 1980s. The number of barren areas

Table 5 Median change on campsite cores on high- (n = 12) and low-use (n = 10) campsites

Core characteristics	Amount of use		
	High	Low	p^a
Core area (m^2)			
1984	59	23	<0.01
1989	56	23	<0.01
2005	54	21	0.01
Change[b]	−3.5	0.3	0.60
Vegetation cover (%)			
1984	0	0	0.01
1989	0	1	0.04
2005	4	12	0.11
Change[b]	4	11	0.32
Litter cover (%)			
1984	0	3	<0.01
1989	1	4	0.09
2005	2	12	0.11
Change[b]	1	10	0.37

[a] Mann Whitney U-test

[b] Median difference between conditions in 1984 and 2005 (1984 value subtracted from 2005 value)

Table 6 Median change on campsite perimeters on high- (n = 12) and low-use (n = 10) campsites

Perimeter characteristics	Amount of use		
	High	Low	p[a]
Vegetation cover (%)			
1984	55	41	0.28
1989	52	32	0.07
2005	67	60	0.62
Change[b]	7	5	0.74
Litter cover (%)			
1984	54	50	0.48
1989	46	52	0.78
2005	62	68	0.94
Change[b]	4	6	0.37
Mineral soil cover (%)			
1984	15	24	0.40
1989	29	31	0.99
2005	17	13	0.57
Change[b]	5	1	0.09
Shrub density (no. of shrubs/m^2)			
1984	1.28	1.00	0.46
1989	0.72	0.88	0.50
2005	0.48	0.62	0.44
Change[b]	−0.32	−0.24	0.36
Floristic dissimilarity (%)			
1984	36	31	0.36
1989	42	44	0.82
2005	33	37	0.35
Change[b]	2	10	0.11

[a] Mann Whitney U-test

[b] Median difference between conditions in 1984 and 2005 (1984 value subtracted from 2005 value)

almost tripled, from 523 in the 1980s to 1466 just 20 years later.

Clearly, Grand Canyon hikers have pioneered new sites and created new barren areas since the 1980s. Proliferation of camping-related impacts was one of the concerns of park managers and one of the reasons they implemented the designated-campsite program in the more popular threshold zone. Because there has been little change, on average, in the area or intensity of disturbance on individual campsites, we can conclude that aggregate campsite impact has more than doubled in the past 20 years.

Change in the number of campsites and the number of barren areas were slightly greater in the more heavily used threshold zone than in the primitive zone. We calculated an index of change by dividing the number of campsites in 2003 and 2004 by the number of campsites in the late 1980s. This ratio (larger numbers mean more campsite proliferation) had a mean of 2.4 in threshold-use areas and 2.1 in primitive-use areas. The mean ratio of barren areas in 2003 and 2004 compared with the late 1980s was 3.1 in threshold-use areas and 2.7 in primitive-use areas.

The proliferation of campsites is not surprising where at-large camping is allowed; however, it should not occur where a designated-camping policy is in place. Our data show that proliferation was as great in use areas with designated-site camping as it was in use areas with at-large camping (Fig. 9). The mean ratio of campsites in 2003 and 2004 compared with the late 1980s was 2.2 both in areas with designated sites and in areas with at-large camping. The mean ratio of barren areas in 2003 and 2004 compared with the late 1980s was 2.9 in areas with designated sites and 2.8 in areas with at-large camping.

Discussion and Conclusion

From these studies, we can conclude that most of the sites that were well established in 1984 were not that different 20 years later. Stability was as characteristic of high-use sites as it was of low-use sites. There was relatively little change in the size of most campsites in our sample between 1984 and 2005. Core area size was unchanged, and there was little evidence of increased impact on campsite perimeters. Vegetation cover (mostly annual species) increased and decreased, apparently in response to annual variation in amount of winter rainfall. Vegetation composition also fluctuated greatly between years, both on campsites and on controls. Although there may have been changes in ecologic parameters that we did not measure (e.g., soil microbial populations or soil chemistry), the primary directional change we observed was a consistent decrease during the period in the density and cover of shrubs.

Despite the relative stability of individual sites, the number of campsites increased >2-fold during the 20-year period. Because the area and intensity of impact on individual sites has remained stable, this suggests that aggregate campsite impact has more than doubled in the past 20 years. This increase in impact greatly exceeded the more modest 25% increase in backcountry use during this period from approximately 32,000 visitor nights in the early 1980s to approximately 40,000 visitor nights in the early 2000s.

We conclude that the campsite-management strategies adopted at Grand Canyon National Park have only been partially successful. In 1984, a primary concern was that designation of campsites and concentration of use on those sites might lead to severe degradation of heavily used sites. Our data suggest that these concerns were largely unwarranted. Although high-use sites are highly impacted (devoid of vegetation and highly compacted), they remain

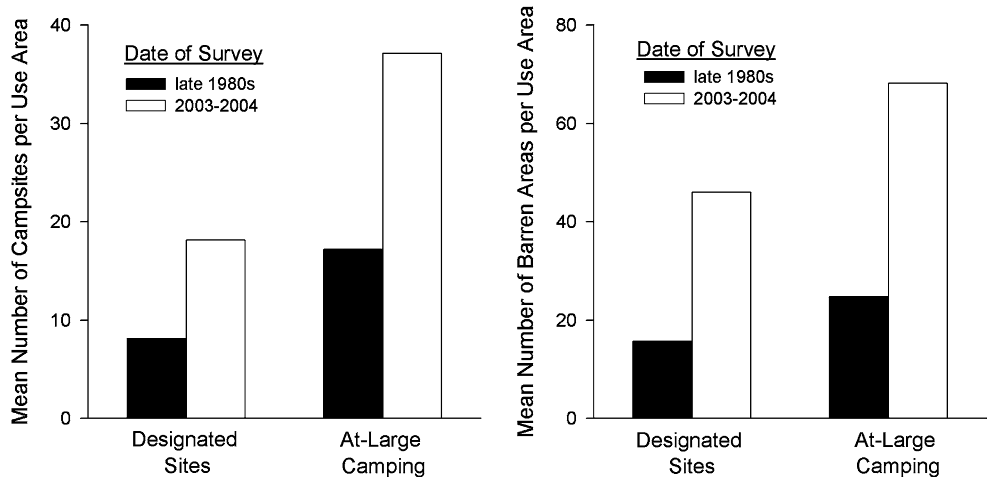

Fig. 9 Change in the mean number of campsites and barren areas on campsites in use areas with designated sites and use areas with at-large camping

small and have not deteriorated substantially. The primary problem on designated sites is the increase in number of barren areas, caused primarily by people setting tents up in new places beyond the perimeter of the main designated site. Where this is occurring, managers must either accept larger sites or lower the group size limits, although some site expansion might be avoided by incorporating campsite design and maintenance techniques that limit this behavior (Marion and Sober 1987, Marion and Farrell 2002).

Concern about the proliferation of campsites in zones with at-large camping proved more warranted. At-large camping is a means of giving visitors the freedom to choose their own campsites and find the levels of solitude they are seeking. None of the at-large campsites we studied deteriorated dramatically during the 20 years of the study. This does not mean, given the many hundreds of at-large campsites in the backcountry, that some have not deteriorated greatly. Some undoubtedly have. However, our study suggests that substantial deterioration of established at-large campsites is more the exception than the rule.

What the park should be concerned about in zones that allow at-large camping is the ongoing creation of new campsites. During the past 20 years, pioneering of new sites has continued, and even abandoned campsites recover extremely slowly on these arid sites. Consequently, the area disturbed by camping has approximately doubled in zones where at-large camping is allowed, despite the fact that use has not increased much and that these places are not the most popular destinations in the backcountry.

Surprisingly, campsite proliferation was equally pronounced in zones with designated sites, places where pioneering a new campsite is illegal. Although a designated-site policy should preclude the development of new campsites, illegal camping outside of designated campsites means that implementation of a designated-site policy can reduce but not eliminate campsite proliferation. From observations, discussions with visitors, and social surveys (Stewart 1989), we know that a substantial number of visitors camp off the designated sites for various reasons, including (1) mistaking "illegal" sites for designated sites, (2) assigned sites being too small for their group, and (3) itinerary constraints caused by underestimating time, effort, and distance. Visitors should be well informed of regulations, given the rigors of obtaining a permit, but enforcement is limited by the large size of the backcountry and the small number of rangers that patrol it.

Our studies have implications for large backcountry parks and protected areas around the world that allow primitive camping. They suggest that a strategy of concentrating use on designated campsites in popular places and dispersing it elsewhere can be an effective way to limit impact while also maintaining visitor freedom. In popular places, designated sites do not deteriorate substantially, and proliferation of sites, in places with designated sites, is less than it would be without site designation. The challenge to management is getting as many people as possible to use designated sites and dealing with some of the problems of concentrated use (most notably human waste). Keys to success include (1) having a larger number of designated sites than available permits, because some people will always be off itinerary, (2) adjusting group size to camp area so that campers do not expand campsites, (3) maintaining sites so that they are attractive, and (4) both locating and maintaining sites so that expansion is difficult or unnecessary (Marion and Farrell 2002). Toilets are a common solution to the problem of human waste, but they are costly to maintain, and they detract from the undeveloped nature of the backcountry setting. Another option is to attempt to convince campers to pack out their human waste, using commercial products developed for this purpose.

The challenge to management of more remote places with at-large, dispersed camping is to avoid the creation of entirely new campsites. Keys to effective at-large camping programs include (1) inventory and monitoring, (2) education, and (3) maintenance and restoration. Inventory and monitoring is important to determine whether or not campsites are proliferating. If they are, it may suggest the need for designated sites or at least increased efforts to keep visitors from pioneering new campsites. Lack of long-term monitoring is one of the reasons why there are so few rigorous assessments of management effectiveness. The usual reason given for lack of monitoring is insufficient funds, reflecting the low priority attached to it. Reasons for this low priority may include a belief that the application of science to recreation is unimportant and that management based on common sense, intuition, and personal experience is adequate (Cole 2006). Regardless of the reason, inadequate investment in monitoring is costly because there is little ability for adaptive management, i.e., learning from past successes and failures.

Leave-No-Trace education is important in many ways. Key points are convincing visitors to either camp on well-established sites or to pick durable unimpacted sites for camping and to leave little evidence of their overnight stay. Visitors also must be taught ways to avoid causing further impact. Finally, maintenance and restoration are needed to eliminate campsites that are unnecessary (e.g., if there are many more campsites than are needed in any area), excessively impacted, or located where campsites are undesirable.

Neither the cross-sectional study of a sample of sites nor the inventory of all sites alone would have provided the insights obtained by employing both research designs. As has been found elsewhere (Cole 1993), campsite impacts are increasing, and the magnitude of change is more a function of change in the number of campsites than change in the condition of long-established campsites. Earlier studies have suggested that problems with proliferation can be solved by implementing a designated-site policy. Our results suggest that such policies may reduce problems and may be the most practical management option, but we should not assume they will solve the problem entirely.

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