RESEARCH

Recreational Impacts on Backcountry Campsites in Grand Canyon National Park, Arizona, USA

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ABSTRACT / Backcountry campsites were studied in three desert vegetation types (pinyon-juniper, catclaw, and desert scrub) in Grand Canyon National Park, Arizona. Relationships between amount of use and amount of impact were examined within each vegetation type. The area disturbed was small, but impacts were generally severe. Important impacts were increased soil compaction and associated decreases in infiltration rates and soil moisture content; these were substantially more pronounced on high than low use sites. The only impact parameter that differed significantly between vegetation types was core area. The types of impact identified are similar to those found in the coniferous forests studied elsewhere, as is the logarithmic relationship between amount of use and amount of impact. However, Grand Canyon sites can support more visitor use before reaching near-maximum levels of impact for important impact parameters.

Recent research has improved our understanding of ecological changes following use of backcountry campsites and the importance of factors that influence the type and magnitude of campsite impacts. Most attention has focused on how amount of impact varies with differences in the amount of use a site receives. All studies have reached similar conclusions about the importance of amount of use (Frissell and Duncan 1965, Coombs 1976, Cole and Fichtler 1983, Marion and Merriam 1985). When comparing sites receiving light but different amounts of use, impact is substantially more severe on more heavily used sites. At higher use levels, however, differences in impact related to differences in amount of use decrease in magnitude. The relationship between use and impact is a nonlinear one that frequently approximates a logarithmic model (Cole 1985a).

All previous studies of the use/impact relationship on backcountry campsites have been conducted in coniferous forests. Little is known about campsite impacts in the desert, although there is a sizeable body of literature on other arid land impacts, particularly those caused by off-road vehicles (Rowlands 1980, Webb and Wilshire 1983). Campsites along the Colorado River in Grand Canyon have been studied (Dolan and others 1974, Carothers and Aitchison 1976), but all sites were on beaches used by large rafting parties. Therefore, they are atypical of backcountry campsites. All other studies of backcountry campsites in arid or semiarid environments were also confined to riparian strips used by river runners (Schmidly and Ditton 1976, Jerry 1977, Carothers and others 1984).

KEY WORDS: Wilderness; Backcountry management; Ecological impact; Recreation; Campsites; Grand Canyon National Park; Pinyon-juniper; Desert scrub

This article describes impacts on campsites in three vegetation types (pinyon-juniper, catclaw, and desert scrub) in Grand Canyon National Park. Relationships between amount of use and various types of campsite impact are explored, as are differences in impact between the three vegetation types. The extent to which these relationships are comparable to those reported elsewhere is evaluated.

Study Area and Methods

Twenty-four campsites were selected for study. All were below the canyon rim and away from both heavily used travel corridors in the park—the Colorado River and the Bright Angel-Kaibab trail system. Twelve of these were high use sites and 12 were low use sites. All sites were the ones in the choicest locations within local destination areas for which use data were available. Campsite use level was determined by whether the site was a popular site within either a high or a low use area; use level was not determined on the basis of evident impact. Unfortunately site-specific use data are only available for three of the high use sites. These data suggest that use frequencies range between 75 and 300 nights per year on high use sites. Observations and limited use data suggest that low use sites are used between 1 and 20 nights per year.

Campsites were stratified further by vegetation type. Within each use category, four sites were studied in each vegetation type. Pinyon-juniper sites were on platforms or mesas at elevations of 1460–1585 m. Natural vegetation is an open woodland of *Pinus edulis* and/or *Juniperus osteosperma* with an understory of evenly spaced evergreen sclerophyllous shrubs and succulents. About one-half of the ground surface,

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under undisturbed conditions, is exposed mineral soil. Soils are coarse and rocky, with a sand or loamy sand texture; they are derived primarily from the Supai Group and the Redwall Limestone.

Catclaw sites were on alluvial terraces above drainageways with permanent or seasonal water, at elevations of 850–1100 m. Undisturbed vegetation consists of relatively closely spaced *Acacia greggii* trees and a highly variable understory of sclerophyllous shrubs and perennial and annual grasses. Vegetation and litter cover are high, so exposed mineral soil is uncommon. Soils are primarily alluvial and derived from a variety of rock types; loamy sand and sandy loam textures are common.

Desert scrub sites are located on drier colluvial and bedrock sites at the same elevation as the catclaw sites. Natural vegetation is more diverse than in the other types, consisting of various evergreen and deciduous xeromorphic shrubs, succulents, grasses, and occasional trees. Vegetation, litter, and mineral soil cover is intermediate between the two other types. Soils are usually moderately deep sandy loams derived from Tapeats Sandstone or Bright Angel Shale.

Field and Laboratory Techniques

Each sample site consisted of both a campsite and an undisturbed control site in the vicinity. A point was established near the center of the devegetated core of the campsite. The distances from this center point to the first significant amount of vegetation were measured along 16 directions. This defined the campsite core area. Four 1-m^2 quadrats were located along the N, S, E, and W transects, one-half way to the edge of the core. Percentage of 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%. Means were calculated using the midpoint of each class. Ten penetration resistance readings were taken in each quadrat with a pocket soil penetrometer. Next to each quadrat bulk density, moisture content, and infiltration rates were sampled. The irregular hole method of determining bulk density was used (Howard and Singer 1981); stone and gravel particles >2 mm in diameter were discarded before calculating density. Gravimetric moisture was calculated by weighing sealed soil samples before and after drying and dividing this difference by the dry weight. Infiltration rates were measured with a double-ring infiltrometer. Initial infiltration was the rate the first cm of water entered the ground; final infiltration was based on the fifth cm. Both were expressed in cm/min.

About 25 1-m^2 quadrats were randomly located along transects immediately beyond the core, in the campsite perimeter. Within each quadrat, cover of live vascular vegetation, cryptogams, organic litter, mineral soil, and rock was estimated. The cover of each 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. Bulk density, gravimetric moisture, and infiltration rate measurements were taken in four quadrats, as on cores.

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. In one case it was not possible to find an undisturbed control; only limited data were collected on this site. 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. Four regularly distributed sets of bulk density, gravimetric moisture, and infiltration rate measurements were taken. Finally, 40 penetration resistance readings were taken systematically throughout the control plot.

Data Analysis

The amount of change that has occurred on campsites is inferred by comparing core and perimeter measures on campsites with control measures. Two different methods were used. Absolute change is the difference between the measure on the campsite, either core or perimeter, and the measure on the control site. This was the preferred measure where conditions on different control sites were not highly variable. Where they were variable, relative change —absolute change as a percentage of control measures—was used.

Change in species composition on the perimeter was estimated by comparing the species composition of the perimeter and the control. To quantify differences, the following coefficient of floristic dissimilarity was calculated:

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

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

Bulk density, moisture content, and infiltration rate values are based on only four measures each on core, perimeter, and control locations; penetration resistance is based on 40 measures in each location. Given the inherent variability in the results these procedures provide, it would be prudent to treat these values as

Table 1. Median changes on campsite cores in Grand Canyon National Park.[a]

Impact parameter	Camp site	Control site	Absolute change	Relative change (%)	p
Area (m²)	32				
Litter cover (%)	<1	60	−60	−99	<0.001
Bulk density (g/cm³)	1.60	1.27	0.24	20	<0.001
Penetration resistance (kg/cm²)	2.8	0.7	2.0	337	<0.001
Soil moisture (%)	3.8	5.5	−1.2	−21	0.002
Initial infiltration rate (cm/min)	0.5	1.9	−1.3	−73	<0.001
Final infiltration rate (cm/min)	0.15	0.56	−0.46	−79	<0.001

[a]Probabilities (p) are based on one-tailed Wilcoxon matched-pairs signed-ranks tests; values <0.05 are significant. A two-tailed test was used for soil moisture.

estimates of change, rather than absolute measures of change.

Two different analyses were used to determine the statistical significance of results. The first analysis involved testing whether conditions on the campsite core and perimeter were different from each other and from controls. Most parameters did not meet the assumptions required to use parametric tests; consequently, medians are reported as measures of central tendency, and the Wilcoxon matched-pairs signed-ranks test was used to test the null hypothesis that campsites were identical to controls. The second set of tests determined whether amount of impact was related to amount of use or vegetation type. To test the null hypothesis that amount of use had no effect on amount of impact, Mann-Whitney U tests were used. To test the null hypothesis that vegetation type had no effect on amount of impact, Kruskall-Wallis one-way analysis of variance was used. Interactions between the two independent variables were generally not significant. More complete statistics and descriptions of techniques can be found in Cole (1985b).

Results

What Impacts Have Occurred?

Median values are used to typify campsites, without differentiating between use levels and vegetation types. Campsite cores, by definition, are essentially devoid of vascular and cryptogam vegetation. In comparison, undisturbed controls have vascular and cryptogam vegetation cover of 60% and 3%, respectively. Over 99% of the organic litter has also been removed from campsite cores (Table 1). The mineral soil that is exposed, when vegetation and litter are lost, has been highly compacted (Figure 1). Median bulk density on the core is 1.60 g/cm³, compared to only 1.27 g/cm³ on

Figure 1. The high use desert scrub campsite at Cedar Spring illustrates the small but barren and compacted core surrounded by the little-disturbed perimeter.

controls. Penetration resistance is more than three times higher than on controls, with a median value of 2.8 kg/cm².

Soil compaction of this magnitude can inhibit revegetation of campsites. Although no quantitative data exist for desert vegetation, compaction levels in this range have inhibited root elongation, even in coarse-textured soils (see, for example, Zisa and others 1980). Reductions in root volume should be particularly detrimental in deserts, where moisture is limiting. Seed germination is likely to suffer because seeds lying on the compacted surface are more subject to desiccation and less likely to receive proper incubation and moisture; "safe" sites for germinating are eliminated (Harper and others 1965). Emergence of seedlings is also likely to be restricted by the strength of a highly compacted crust.

Soil compaction also alters soil moisture relations. Median initial and final infiltration rates on the core

Table 2. Median changes on campsite perimeters in Grand Canyon National Park.[a]

Impact parameter	Camp site	Control site	Absolute change	Relative change (%)	p
Floristic dissimilarity (%)	31				
Vegetation cover (%)	55	60	−8	−12	0.026
Cryptogam cover (%)	2	3	0	−22	0.068
Litter cover (%)	51	60	−8	−14	0.019
Mineral soil cover (%)	15	10	2	36	0.464
Rock cover (%)	7	3	3	30	0.060
Shrub density (no./m^2)	0.98	0.79	0.14	22	0.060
Bulk density (g/cm^3)	1.21	1.27	0.01	1	0.429
Penetration resistance (kg/cm^2)	0.9	0.7	0.1	33	0.003
Soil moisture (%)	4.9	5.5	0.1	2	0.761
Initial infiltration rate (cm/min)	1.9	1.9	−0.1	−5	0.455
Final infiltration rate (cm/min)	0.54	0.56	−0.07	−24	0.057

[a]Probabilities (p) are based on one-tailed Wilcoxon matched-pairs signed-ranks tests; values <0.05 are significant. A two-tailed test was used for soil moisture.

are reduced to 0.5 cm/min and 0.15 cm/min, respectively. This represents a reduction, in each case, of over 70%. The reduction in water infiltration limits recharge of water supplies in the soil. Median soil moisture levels on the core are only three-quarters of what they are on controls (Table 1).

While these results indicate that impacts on campsite cores are severe, they are confined to a relatively small area. The median area of the core was only 32 m^2. Beyond this core, impact severity decreases dramatically. For all parameters examined, core impact was significantly higher than perimeter impact. In contrast, perimeters differed significantly from controls only in their vegetation and litter cover and their soil penetration resistance (Table 2).

This low level of impact beyond the core is surprising. Even species composition was not substantially different from controls. Median floristic dissimilarity between perimeters and controls was only 31%, less than the median dissimilarity between two undisturbed stands in the same vegetation type. No growth form—trees, shrubs, cacti, annual grasses, perennial grasses, annual forbs, perennial forbs, or cryptogams—provides relative cover more than a few percent higher or lower on campsite perimeters than on unused controls. The same is true of nonnative species, which contribute about one-quarter of the cover on both disturbed and undisturbed sites.

In contrast to the findings of all other campsite studies, trampling pressure does not appear to favor one vascular groundcover species over another. All common species must be about equally tolerant of trampling. None can survive the level of trampling on the core, but they all can survive perimeter levels. The only exceptions are *Erodium cicutarium* and *Bromus rubens*, two nonnatives, and *Gutierrezia sarothrae*, a native shrub—species that are found sporadically on the core of some of the more lightly used sites.

Do Impacts Vary with Use Level?

Of the types of impact studied, the ones that were significantly greater on high use sites are core area and the following core changes: litter loss, increase in bulk density and penetration resistance, and decrease in soil moisture and final infiltration rate (Table 3). Change in soil moisture on perimeters was also significantly different. For the other types of impact, median measures of change were usually greater on the high use sites, but variability was high and differences were not significant.

Although statistically significant, differences between high and low use sites, in litter loss and decrease in infiltration rates, are small in comparison to differences between low use sites and controls. The magnitude of differences in impact related to use are graphically presented in Figure 2. Although differences in use cannot be quantified, use pressure should generally increase from controls to low use perimeters, high use perimeters, low use cores, and high use cores. These graphs portray differences in the susceptibility of Grand Canyon campsites to various types of impact. The most fragile elements of the site are cryptogams and infiltration rates, particularly final rates; changes in these are apparent even on low use perimeters. Vegetation loss, litter loss, and increase in rock and mineral soil are not pronounced on perimeters and they are equally severe on high and low use cores. Grand Canyon sites are most resistant to increases in

Table 3. Median amount of change in relation to amount of use.[a]

Impact parameter	Amount of use: High	Amount of use: Low	p
Core area (m^2)	50	22	0.002
Vegetation cover—relative change			
Perimeter (%)	−14	−5	0.230
Cryptogam cover—absolute change			
Perimeter (%)	0	−3	0.103
Floristic dissimilarity			
Perimeter (%)	36	29	0.204
Shrub density—absolute change			
Perimeter (no./m^2)	0.31	0.05	0.396
Litter cover—relative change			
Core (%)	−99	−95	0.001
Perimeter (%)	−23	−5	0.194
Mineral soil cover—absolute change			
Perimeter (%)	6	5	0.088
Rock cover—absolute change			
Perimeter (%)	4	1	0.109
Bulk density—absolute change			
Core (g/cm^3)	0.54	0.20	0.009
Perimeter (g/cm^3)	0.01	0.03	0.300
Penetration resistance—absolute change			
Core (kg/cm^2)	3.5	1.0	0.001
Perimeter (kg/cm^2)	0.4	0.1	0.064
Soil moisture—relative change			
Core (%)	−39	−14	0.006
Perimeter (%)	−6	29	0.024
Initial infiltration rate—relative change			
Core (%)	−77	−57	0.136
Perimeter (%)	−20	5	0.146
Final infiltration rate—relative change			
Core (%)	−82	−67	0.047
Perimeter (%)	−32	−24	0.178

[a]Probabilities (p) are based on one-tailed Mann-Whitney U tests; values <0.05 are significant.

core area, bulk density, and penetration resistance, and to decreases in soil moisture. These impacts are much greater on high use cores than on low use cores.

Studies in other ecosystem types have found a somewhat different order to how rapidly these types of impact increase as use increases. All previous studies have found that infiltration rates decline to near-minimum levels with quite low use (James and others 1979, Cole 1982). In the coniferous forests studied previously, however, vegetation loss occurs much more rapidly than mineral soil exposure. Consequently the magnitude of difference between high and low use sites is greater for mineral soil exposure than for vegetation loss, except when comparing very lightly used sites (see, for example, Cole and Fichtler 1983, Marion and Merriam 1985). This reflects the presence of thick organic horizons that must be removed before soil is exposed. In the Grand Canyon, vegetation is more resistant and the thin and patchy organic matter is more readily eliminated. As a result, mineral soil is exposed as rapidly as vegetation is lost and soil exposure is not much greater on high than on low use sites. Other studies have also found larger campsite areas (Cole 1982), and more pronounced increases in bulk density and penetration resistance on high use sites (Marion and Merriam 1985), but differences were not as pronounced as on Grand Canyon sites.

The nonlinear use/impact model reported elsewhere applies to campsites in the Grand Canyon desert. Impact rises sharply with initial increases in use, with further increases in impact tapering off at higher use levels. This would be more evident in the graphs in Figure 2 if the x-axis could be quantified. Since high use sites receive an order of magnitude more use than low use sites and cores receive at least an order of magnitude more use than perimeters, the x-axis approximates a logarithmic scale.

The most serious impacts on Grand Canyon sites appear to be those associated with soil compaction, in-

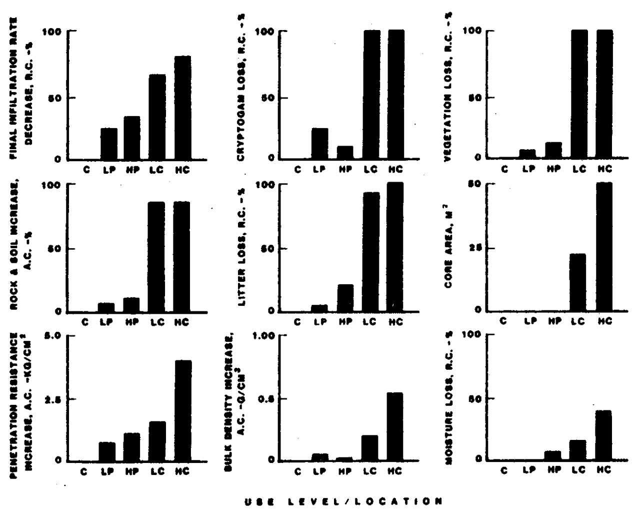

Figure 2. Median amount of impact in relation to use level and location on campsites in Grand Canyon National Park. Use level/locations are: controls (*C*), low-use perimeters (*LP*), high-use perimeters (*HP*), low-use cores (*LC*), and high-use cores (*HC*). *R.C.* is relative change; and *A.C.* is absolute change.

creases in bulk density and penetration resistance, and decreases in soil moisture. Compaction is particularly pronounced on Grand Canyon sites and is likely to aggravate problems with inherently low moisture. Fortunately, these most serious impacts are the types to which these sites are least vulnerable; they only become pronounced at relatively high use levels. This suggests that management aimed at keeping use levels on individual campsites low is likely to be more beneficial here than in most areas studied previously. Such a management strategy must involve either reducing use or increasing the number of campsites. These costs must be weighed against the benefit of maintaining low levels of impact on individual sites.

Do Impacts Vary between Vegetation Types?

For most of the impact parameters examined there are sizeable differences in median values between vegetation types. However, there is so much variability, even within the same vegetation type, that only differences in core area are statistically significant (Table 4). Campsites located in pinyon-juniper are generally more than twice the size of sites in catclaw or desert scrub. Site expansion is easier in the pinyon-juniper type because the vegetation is more open and the surrounding terrain is less rugged.

There is little value, in terms of minimizing impact, to trying to concentrate camping on one of these vegetation types; differences in durability are not sufficiently pronounced. Across the range of use and vegetation examined in this study, difference in amount of use is a more important determinant of amount of impact than difference in vegetation type. Each type is somewhat more prone to certain types of problems, however. By recognizing this, management can be tailored to the unique problems each vegetation type presents.

In particular, pinyon-juniper is more prone to core expansion. Such increases in area are a concern because core impacts are so severe. Expansion can be discouraged by educating people about the need to keep sites small, strictly limiting party size, and planting cactus in places where expansion is occurring. Catclaw sites tend to have more informal trails that do sites in other types. This may merely reflect the fact that catclaw sites tend to be clustered around water sources; such clustering encourages the development of braided trail networks. Perhaps more serious is the tendency for these trails to be badly eroded where they descend to water sources. This tendency reflects the location of these sites on alluvial terraces. Trails descend terrace banks at steep grades and the alluvial material is particularly erodible. This suggests that catclaw sites, particularly in high use areas, should be designed so that traffic flow is confined to a small number of trails, in places that are not likely to erode severely. Desert scrub sites are usually more similar to catclaw sites, although trailing and erosion are less pronounced and troublesome.

Discussion and Conclusions

Management Implications for Grand Canyon National Park

Impacts on Grand Canyon sites are unusual in being confined to such small areas. Median areas of disturbance on campsites in the Eagle Cap Wilderness, Oregon, and the Bob Marshall Wilderness, Montana, for example, were about 200 m^2 and 400 m^2, respectively (Cole 1982 and 1983). Small campsites are the fortuitous result of a hostile environment with relatively few small comfortable places to camp. They also reflect prohibitions on packstock (outside of the developed Bright Angel-Kaibab trail system) and campfires, strict party size limits of 8 for most parties (with some accommodation for groups as large as 16), and no history of "frontier-style" camping. Use of these areas was negligible prior to the development of lightweight equipment and the spread of a low-impact ethic.

Although deserts are often characterized as being fragile, they are relatively resistant to camping impact. Thorny vegetation and rough terrain keep impacted sites small. The vegetation is also quite resistant to im-

Table 4. Median amount of change on campsites in different vegetation types.[a]

Impact parameter	Vegetation type: Pinyon-juniper	Catclaw	Desert scrub	p
Core area (m^2)	56	24	24	0.044
Vegetation cover—relative change				
Perimeter (%)	−3	−18	8	0.470
Cryptogam cover—absolute change				
Perimeter (%)	0	−1	−1	0.443
Floristic dissimilarity				
Perimeter (%)	36	20	66	0.144
Shrub density—absolute change				
Perimeter (no./m^2)	0.13	0.31	0.19	0.421
Litter cover—relative change				
Core (%)	−99	−99	−96	0.214
Perimeter (%)	−29	−9	−9	0.653
Mineral soil cover—absolute change				
Perimeter (%)	−5	5	−6	0.320
Rock cover—absolute change				
Perimeter (%)	3	2	4	0.837
Bulk density–absolute change				
Core (g/cm^3)	0.18	0.44	0.39	0.221
Perimeter (g/cm^3)	0.04	−0.16	0.06	0.284
Penetration resistance—absolute change				
Core (kg/cm^2)	1.9	2.0	2.6	0.681
Perimeter (kg/cm^2)	0.1	0.0	0.4	0.073
Soil moisture—relative change				
Core (%)	−9	−37	−28	0.138
Perimeter (%)	−3	20	−4	0.899
Initial infiltration rate—relative change				
Core (%)	−60	−82	−70	0.652
Perimeter (%)	68	−22	−12	0.096
Final infiltration rate—relative change				
Core (%)	−82	−67	−80	0.497
Perimeter (%)	−30	22	−63	0.155

[a]Probabilities (p) are based on Kruskall-Wallis one-way analysis of variance tests; values <0.05 are significant.

pact. This is evident in the low levels of vegetation cover loss and change in species composition on perimeters. Adaptations to survival in desert environments appear to promote resistance to trampling. Ephemeral annuals can complete their life cycle in a time period sufficiently short to avoid most recreational trampling. Succulents and drought-enduring species have small firm leaves with very thick cuticles. They often are armed with thorns or spines that keep most users away. Other adaptations to drought that also increase resistance to trampling include leaves with a large proportion of tough sclerenchyma tissue and a tendency for aerial plant parts to be small in proportion to the root system.

This inherent resistance makes differences in impact between high and low use sites more pronounced in Grand Canyon than in other places reported in the literature. In coniferous forests, vegetation is frequently disturbed over large areas, even on sites receiving quite low use. Once sites are used 10–20 nights per year, continued loss of organic matter and exposure of mineral soil are likely to be the only pronounced consequences of further increases in use (Cole and Fichtler 1983, Marion and Merriam 1985). In such places, use levels have to be as low as a few nights per year before impact levels are substantially less than those on high use sites.

On Grand Canyon campsites, the most important impacts—increases in bulk density and penetration resistance and reductions in soil moisture—only reach serious levels after use exceeds 20 nights per year. Thus it is more feasible to limit impact through controlling use levels, because benefits can be gained without severely limiting use. Nevertheless, in most of the more popular destination areas use levels are still too high to feasibly reduce impact by dispersing use among a number of sites. Even if use of sites in popular areas could be reduced to less than 20 nights per year, recovery is unlikely because the resilience of desert vegetation and soil is low.

This suggests that the current policy of either designating campsites or encouraging use of existing sites is appropriate in popular areas. This policy will minimize the area subject to camping impacts. In less popular areas, however, impacts could be minimized by encouraging use of sites with little evidence of previous impact. If such sites are used infrequently, by parties practicing low-impact camping techniques, and any obviously impacted sites are permanently closed and rehabilitated, camping impacts should be negligible outside of popular destination areas.

General Conclusions

The nonlinear use/impact model that applies to Grand Canyon campsites is similar to that reported elsewhere (Frissell and Duncan 1965, Cole and Fichtler 1983, Marion and Merriam 1985). The major difference is that the point above which increases in impact taper off with increasing use is associated with an unusually high use level. The location of this point is critical because it identifies the use threshold above which differences in amount of use have little effect on impact and use concentration is the most appropriate management strategy. Below this point use differences do have a pronounced effect, and therefore dispersal of use among many sites may be more appropriate.

The impacts associated with backcountry camping and the general shape of the curve that describes the relationship between use and impact appear to be consistent across all environmental settings. Beyond this rather crude level of generalization, results and management implications become increasingly site-specific. The types of impact that should be of most concern to management vary between environments, as does the susceptibility of campsites to these critical types of impact. Use thresholds, above which concentration is appropriate and below which dispersal is appropriate, vary between environments and with type of impact. Finally, the magnitude of differences in the durability of sites will vary between general environments, as will the environmental factors that determine durability.

More precise site-specific knowledge is needed for professional management of backcountry campsites. Management should emphasize minimizing the most critical types of impact. Use thresholds need to be identified for these critical impacts. This information will guide decisions about where concentration or dispersal is appropriate. Critical impacts should also be emphasized in monitoring programs. Monitoring programs will also be improved by understanding the relative susceptibility of campsites to various types of impact. More fragile elements, such as cryptogams in Grand Canyon, are good indicators of incipient deterioration; they are particularly useful for monitoring areas where use dispersal is encouraged. More resistant elements—those that are only impacted substantially on high use sites—are more useful indicators in more popular areas. Finally, understanding how durability differs between sites is important in deciding where to concentrate camping and in tailoring management to each local environment's unique problems.

Further Research

The fact that campsite impacts are readily apparent and similar in many different environmental settings had led some to assume that we know all we need to about campsite impacts. This study suggests that this is not the case; the information of most use to managers is quite site-specific. Although the results and management implications of a study should be generally applicable to other environmentally similar areas, they cannot be readily applied in dissimilar environments. Separate studies are needed.

Use/impact relationships of the type described here are useful in predicting the use levels required to create certain types and levels of impact. Very different curves are needed to describe the relationship between use levels and site recovery, in situations where use levels of existing sites might be reduced in an attempt to improve site conditions. Very limited research suggests that campsite recovery is negligible unless all use is curtailed (Cole and Ranz 1983) and that recovery rates are much faster on lightly used than on heavily used parts of campsites—provided all use is eliminated (Stohlgren 1982). More research on recovery rates, for which results are likely to be particularly site-specific, is needed to complement further research on use/impact relationships.

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