Disturbance of Natural Vegetation by Camping: Experimental Applications of Low-Level Stress

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ABSTRACT / Previously undisturbed sites in four different vegetation types were camped on for one night and for four nights. Changes in vegetation cover and vegetation height were measured after camping and one year later. Results are presented separately for different campsite zones-parts of the site where campers slept, cooked meals, and stored their packs. Just one night of camping was sufficient to cause evident impact in all four vegetation types, although the amount of impact varied significantly between zones and between vegetation types. Vegetation impact on campsites used four nights was generally less than twice as severe as impact on the sites used one night. The effects of camping on vegetation were also predicted for 12 other vegetation types on the basis of vegetational responses to experimental trampling. These results suggest that impact can almost always be minimized by confining camping to a small number of campsites instead of dispersing use across many campsites.

The Congress of the United States of America established a system of wilderness areas so that some lands in the United States would be preserved and protected in their natural condition. Wilderness lands are also generally open to recreational use, however, and this use inevitably conflicts with nature preservation goals. Of the recreational activities that occur in wilderness, the impacts of camping can be particularly severe and widespread. In a survey of wilderness managers, campsite deterioration was the most commonly reported problem. Managers of about one third of all wildernesses reported that campsite deterioration was a problem "in many places" (Washbume and Cole 1983). One of the challenges confronting wilderness managers, then, is to keep the impacts of camping to levels that do not severely compromise nature preservation goals. For this purpose, managers need to understand the nature of camping impacts and how the severity of impact varies with factors that are subject to management control.

The most obvious impacts of camping are well documented (Bratton and others 1978, Cole 1981, Kuss and others 1990). Two factors that clearly influence the severity of campsite impact are frequency of use and site durability. Sites that are used infrequently and sites that are capable of resisting deterioration will usually be less impacted than those that are used frequently and those that are readily disturbed by camping. General relationships between frequency of use, site durability, and campsite impact have been assessed in a number of studies of existing campsite conditions (e.g., Cole 1986, Cole and Marion 1988, Marion and Merriam 1985). However, because it is seldom possible to control or even document the past use of existing sites, estimates of the impacts caused by different use frequencies are imprecise. Consequently, our ability to predict the effects of different intensities of campsite use is low.

Although several studies have quantified the effects of a known amount of camping on previously unused sites (Bogucki and others 1975, Leonard and others 1983), neither of these studies have been manipulative experiments (sensu Hurlbert 1984) with random assignment of different treatments to replicated experimental units. Consequently, I utilized an experimental design to assess the effects of low levels of camping on four vegetation types in different parts of the United States. These experiments were part of a larger study of the effects of both trampling and camping (Cole 1993). Specific objectives were to estimate the effects of two camping frequencies on the height and cover of vegetation and how these effects vary between different vegetation types. Another objective was to see if it is possible to predict some of the effects of camping from the results of experimental trampling studies. Experimental trampling methodologies are well established and easily applied (Cole and Bayfield 1993). Experimental camping is much more problematic. Treatments are costly, and disturbance is less spatially uniform and, therefore, more difficult to quantify. If a consistent relationship between the effects of a given amount of camping and an amount of trampling can be identified, then the

KEY WORDS: Campsites; Ecological impact; Resistance: Vegetation impact; Wilderness

effects of camping can be predicted on the basis of experimental trampling results.

Methods and Study Areas

Trampling and camping experiments were conducted in four different regions of the country-the Cascade Mountains in Washington, the Rocky Mountains in Colorado, the White Mountains in New Hampshire, and the Great Smoky Mountains in North Carolina. Each of these regions contains substantial wilderness acreage and receives heavy recreational use.

Camping Experiments

In each vegetation type, six previously undisturbed sites suitable for camping were identified. All sites were flat and as similar to each other as possible. Treatments were assigned randomly to these sites. Three of the campsites were camped on for one night and the other three were camped on for four nights. The four nights of camping were spread over several weeks; camping never occurred on consecutive nights. Campsites were divided into three zones on the basis of the activities that occurred in each zone. Camping parties consisted of two people-the field assistants collecting data. All campers were given the same instructions. They were told to arrive at the campsite in the late afternoon and to leave in the early morning. They were told to drop their backpacks in the intermediate zone, set their tent up in the tent zone, cook in the kitchen zone, and to not walk through the controls. Otherwise they were free to do as they pleased. Clearly this means of administering the treatments interjected bias from self-conscious behavior. It is hoped that the effects of this bias-necessary to standardize the amount, type, and location of use-were minimal.

In each campsite, campsite zones and controls were delineated along a 29-m-long transect as follows: (1) a 4-m-long kitchen zone, centered around what would become the fire site; (2) a 3-m-long tent zone; (3) a 3-m-long intermediate zone between the tent and kitchen zones; and (4) two 4.5-m-long controls, beyond the kitchen and the tent zones. Four 30- x 50-cm subplots were established at predetermined locations in each of the campsite zones, as well as in the control (Figure 1). In each subplot, the following parameters were measured: (1) the cover of each vascular plant species, and of lichens and mosses-estimates made by eye were recorded as the closest of the following values: 0, 1, 5, 10, 15, 20, 30, 40, 50, 60,70, 80, 90, or 100%; (2) mean vegetation height-we used

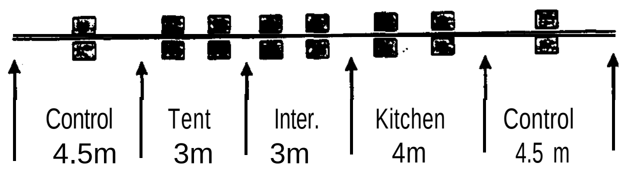

Figure **1.** Layout of experimental campsite zones and subplots.

a point quadrat frame with 5 pins located 5 cm apart. The frame was placed 10 times, systematically, along the length of the subplot. The pins were dropped to the ground. Where the pin hit bare ground, a 0 was recorded. Where it hit live vegetation, the height of the pin strike was recorded to the nearest 1 cm.

Camping treatments occurred in early summer of 1988. Initial measurements were taken prior to camping. Follow-up measurements were taken shortly after the final night of camping and again one year after camping.

The types of vegetation impact that can be described are changes in vegetation cover and vegetation height. Change is assessed by calculating relative cover and relative height. In both cases, vegetation conditions after camping are expressed as a proportion of initial conditions, with a correction factor applied to account for spontaneous changes on the control plots. This approach was originally developed by Bayfield (1979).

Relative cover is based on the sum of the coverages of all species, rather than a single estimate of total vegetation cover. This measure accounts for loss of overlapping layers of vegetation that may occur without a decrease in total cover. It is calculated in the following manner: (1) sum the percent coverages of all individual species for each subplot; (2) derive the mean sum cover of the four subplots in each campsite zone (tent, intermediate, kitchen) and in each control; and (3) calculate relative vegetation cover as

$$\frac{\text{surviving cover on campsite subplots}}{\text{initial cover on campsite subplots}} \times cf \times 100\%.$$

where *cf* is the initial cover on control subplots divided by the surviving cover on control subplots.

Relative cover was assessed separately for the tent, intermediate, and kitchen zones. Relative vegetation cover would be 100% in the absence of any change in cover caused by camping. Therefore, the extent to which relative cover after camping deviates from 100% provides a measure of the damage response to camping. Relative cover one year after camping can be compared with that immediately after camping to provide a measure of the recovery response.

Relative vegetation height was calculated in an analogous manner. In each subplot, all height measures were summed, and this sum was divided by the number of nonzero values. These values were used to derive a mean height of the four subplots in each campsite zone and control. Finally, these mean height values were substituted for the mean cover values in the formula for relative cover given above. Both relative height after camping and after one year of recovery were calculated for each campsite zone.

Three-way ANOVAs were conducted to assess the effects of vegetation type, nights of camping, and campsite zone on relative vegetation cover and relative vegetation height, both after camping and after one year of recovery. Differences between means were assessed with Duncan's multiple range test. Alpha was 0.05 for all tests.

Trampling Experiments

In each region, experimental trampling was conducted in four different vegetation types. Trampling was conducted in the same vegetation type as the experimental camping in order to identify the amount of trampling that caused vegetation impact equivalent to that caused by experimental camping. These equivalents were used to predict the effects of camping in the other three vegetation types that experienced experimental trampling but not experimental camping.

The design of the trampling experiments followed the standard protocol suggested by Cole and Bayfield (1993). Four replicate sets of experimental trampling lanes were established in each vegetation type. Each set consisted of five lanes, each 0.5 m wide and 1.5 m long. Where there was any slope, lanes were oriented parallel to contours. Treatments were randomly assigned to lanes. One lane was a control and received no trampling. The other lanes received either 25, 75, 200, or 500 passes. A pass was a one-way walk, at a natural gait, along the lane. The weight of tramplers was about 70 kg and tramplers wore lug-soled boots. Measurements and analysis procedures were identical to those used in the camping experiments.

Study Locations

The study sites in northern Washington were along the crest and east of the Cascade Mountains, close to the Pasayten Wilderness. The camping experiments were conducted in a lush subalpine herbaceous vegetation type, referred to subsequently by the most abundant groundcover species, *Valeriana sitchensis* (valerian). It occurs both under an open canopy of *Abies lasiocarpa* (subalpine fir) and *Picea engelmannii* (Engelmann spruce), as well as out in the open, at an elevation of 1750 m. The three vegetation types that were only trampled were a *Pseudotsuga menziesii/Pachistima myrsinites* (Douglas fir/mountain boxwood) montane forest, a *Phylldoce empetriformis* (red mountain heather) subalpine heath, and a *Carex nigricans* (black alpine sedge) alpine turf. Further description of these types can be found in Cole (1993).

The study sites in northern Colorado were located on the east slope of the Rocky Mountains, mostly within the Comanche Peak Wilderness. The camping experiments were conducted in an *Abies lasiocarpal Picea engelmannii* forest, at 3350 m elevation, referred to subsequently by the most abundant groundcover species--the dwarf shrub *Vaccinium scoparium* (grouse whortleberry). The three vegetation types that were only trampled were *Populus tremuloides/Geranium richardsonii* (quaking aspen/white geranium) montane forest, *Trifolium parryi* (clover) subalpine meadow, and *Kobresia myosuroides* (kobresia) alpine turf.

The study sites in northern New Hampshire were located along the eastern flank and summit of the Presidential Range, close to the Great Gulf Wilderness. The camping experiments were located in northern hardwood forests at low elevations (450 m). This vegetation type, referred to subsequently as *Maianthemum canadensis* (Canadian mayflower), has a diverse herbaceous groundcover and a dense and diverse overstory, with *Betula lutea (yellow* birch) and *Acer rubrum* (red maple) the most common tree species. The three vegetation types that were only trampled were *Betula 1utea/Acer rubrumlLeersia oryzoides* (birch/maple/cutgrass) hardwood forest, *Abies balsamea/Picea rubens/Lycopodium lucidulum (balsam* fir/red spruce/shining clubmoss) subalpine forest, and *Carex bigelowii* (Bigelow sedge) alpine meadow.

The study sites in North Carolina were located along the crest and southeast flank of the Great Smoky Mountains, within Great Smoky Mountains National Park. The camping experiments were conducted at relatively low elevations (about 700 m) on a site that was recovering from previous agricultural usage. Tree species, the most abundant of which was *Liriodendron tulipifera* (yellow poplar), were slowly filling in the old field. The groundcover of the vegeta-. tion type, referred to subsequently as *Potentilla simplex* (old-field cinquefoil), is a diverse mix of forbs and grasses. The three vegetation types that were only trampled *were Liriodendron tulipifera/Amphicarpa bra*teata (yellow poplar/hog peanut) cove hardwood forest, *Fagus grandifolia/Carex pensylvanica* (beech/sedge)

Table 1. Results of three-way ANOVAs (F values) of effects of vegetation type, nights of camping, and campsite zone on relative vegetation cover and relative vegetation height

Source of variation	Relative vegetation cover: After camping	Relative vegetation cover: One year later	Relative vegetation height: After camping	Relative vegetation height: One year later
Vegetation type	21.3[a]	18.9[a]	36.3[a]	1.2
Nights of camping	22.8[b]	0.9	4.1[b]	7.0[b]
Campsite zone	13.9[a]	3.5[b]	8.1[a]	2.4
Vegetation x nights	6.8[a]	7.9[a]	1.0	4.6[a]
Vegetation x zone	1.0	2.6[b]	1.3	1.1
Nights x zone	1.3	0.9	0.1	2.9
Veg x nights x zone	0.7	0.2	1.2	1.5

[a]0.01 < *P*.
[b]0.05 > *P* > 0.01.

forest, and *Abies fraseri/Picea rubenslDryopteris campyloptera* (spruce/fir/mountain wood fern) subalpine forest.

Results

Vegetation Cover

Relative vegetation cover after camping varied significantly with vegetation type, nights of camping, and campsite zone (Table 1). The interaction between vegetation type and nights of camping was also statistically significant. Relative cover after camping was significantly greater in the tent (67%) and intermediate (61%) zones than in the kitchen (46%) zone. Relative cover was greater on the sites camped on for one night (66%) than on the sites used four nights (50%), but differences were statistically significant only in the *Maianthemum canadensis* vegetation type. After one night of camping, relative cover was significantly greater in the dwarf-shrub-dominated *Vaccinium scoparium* type (85%) than in the three types with a predominantly herbaceous groundcover, *Maianthemum canadensis* (65%), *Potentilla simplex* (59%), and *Valeriana sitchensis* (54%). After four nights of camping, relative cover was significantly greater in the *Vaccinium scoparium* (73%) and *Potentilla simplex* (60%) types than in the *Valeriana sitchensis* (42%) and *Maianthemum canadensis* (26%) types.

All four vegetation types lost a substantial amount of cover after just one night of camping (Figure 2). One night of camping was sufficient to eliminate 30%-50% of the vegetation from the kitchen zone. In the relatively resistant *Vaccinium scoparium* type, one night of camping had little effect in the tent and intermediate zones. In the other three types, however, one night of camping eliminated at least 25% of the cover from the tent and intermediate zones.

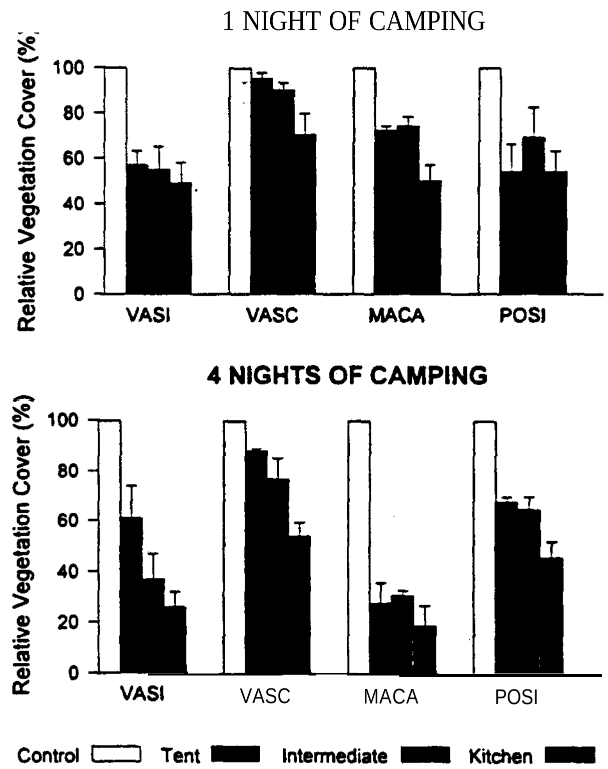

Figure 2. Relative vegetation cover on campsites used one night and four nights in four vegetation types- *Valeriana sitchensis* (VASI), *Vaccinium scoparium* (VAX), *Maianthemum canadensis* (MACA), and *Potentilla simplex* (POSI). Vertical bars indicate 1 standard error.

Although four nights of camping resulted in a greater loss of vegetation cover than one night of camping, the increase in cover loss was not proportional to the increase in use. A fourfold increase in use frequency resulted in increases in cover loss that varied, with vegetation type and campsite zone, from no further cover loss to an increased loss of between twofold and threefold. The campsite zones and vegetation types that were least affected by one night of camping were the zones and types on which the difference in cover loss between the one-night and four-night campsites was greatest. Mean cover loss after four nights of camping, as a proportion of loss after one night of camping, was 165% in the tent zone, 187% in the intermediate zone, and 144% in the kitchen zone. Mean cover loss after four nights of camping, as a proportion of loss after one night of camping, was 228% in *Maianthemum canadensis,* 208% in *Vaccinium scoparium,* 125% in *Valeriana sitchensis,* and 100% in *Potentilla simplex.*

After one year of recovery, relative cover varied significantly with vegetation type and campsite zone, but not with nights of camping (Table 1). However, interactions between vegetation type and zone and between vegetation type and nights of camping were both significant. Mean relative cover one year after camping was lower in the kitchen zone (77%) than in the intermediate zone (80%), which had less cover than the tent zone (88%), but these differences were statistically significant only in *the Vaccinium scoparium* type. Where there were significant differences between vegetation types, cover was always lower in the *Maianthemum canadensis* type than in the *Valeriana* sitchens and *Potentilla simplex* types. Cover values in *the Vaccinium scoparium* type were similar to those in the *Valeriana sitchensis* and *potentilla simplex types* in the tent zone and similar to those in *the Maianthemum canadensis* type in the other zones and on sites camped on for four nights. There were no significant differences between vegetation types one year after one night of camping.

The vegetation types that lost the most cover after one and four nights of camping, *Valeriana sitchensis* and *potentilla simplex,* recovered substantially during the year following camping (Figure 3). For example, in the kitchen zone in *Valeriana sitchensis,* relative cover was 26% after four nights of camping; one year later, relative cover was 106%. Recovery was less pronounced in the *Maianthemum Canadensis* type, and vegetation cover actually declined in the dwarf-shrub-dominated *Vaccinium scoparium* type during the year of recovery. Delayed damage of dwarf shrubs after trampling has been reported elsewhere (Bayfield 1979, Cole 1993).

After one year of recovery, differences between the tent, intermediate, and kitchen zones had disappeared in the three herbaceous vegetation types. In

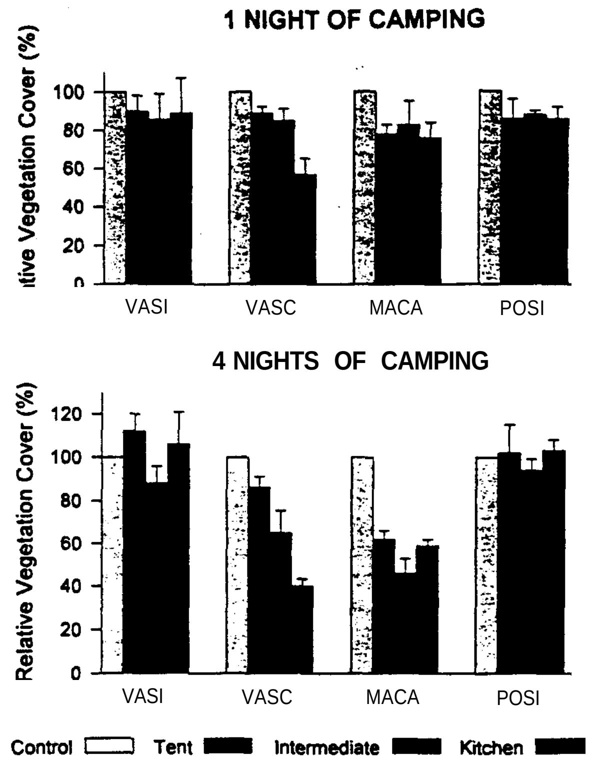

Figure 3. Relative vegetation cover, after one year of recovery, on campsites used one night and four nights in four vegetation types- *Valeriana sitchensis* (VASI), *Vaccinium scoparium* (VASC), *Maianthemum canadensis* (MACA), and *Potentilla simplex* (POSI). Vertical bars indicate 1 standard error.

the Vaccinium scoparium type, however, the kitchen zone remained significantly more impacted than the other zones on both the one-night and four-night camps.

During the course of the study, some shortcomings of the sampling design surfaced. Camping activities and impacts were seldom distributed uniformly across the campsite. Some of this variation was controlled by stratifying the site into the three different zones. However, there was still substantial variation within zones. When the places that received the most concentrated activity were outside of the subplots that were sampled, mean measures of change underestimated how much impact was occurring in some parts of the campsite. To assess maximum levels of impact that occurred in each zone, the changes that occurred on the most intensely disturbed of the four subplots are reported (Table 2).

Relative cover values for the most disturbed subplots were much lower than mean values. For example, mean relative cover for all subplots in the kitchen zone of the one-night *Valeriana sitchensis* campsites was 49%. However, mean relative cover for the most dis-

Table 2. Relative vegetation cover in **the** most intensely disturbed of four subplots in tent, intermediate, and kitchen zones[a]

	Relative vegetation cover (%)					
	After camping			After one year		
	Tent	Intermediate	Kitchen	Tent	Intermediate	Kitchen
Valeriana sitchensis (WA)						
1 night/year	43 ± 7	41 ± 14	21 ± 6	81 ± 10	70 ± 12	85 ± 19
4 nights/year	51 ± 11	26 ± 3	12 ± 4	83 ± 7	76 ± 5	95 ± 18
Vaccinium scoparium (CO)						
1 night/year	86 ± 7	76 ± 6	59 ± 11	75 ± 3	74 ± 10	46 ± 5
4 nights/year	75 ± 2	59 ± 4	3 ± 4	70 ± 6	39 ± 6	23 ± 5
Maianthemum canadensis (NH)						
1 night/year	57 ± 1	34 ± 5	23 ± 11	62 ± 7	60 ± 7	65 ± 10
4 nights/year	20 ± 3	12 ± 5	3 ± 3	52 ± 20	40 ± 4	39 ± 8
Potentilla simplex (NC)						
1 night/year	44 ± 4	58 ± 12	34 ± 2	83 ± 22	84 ± 11	73 ± 10
4 nights/year	44 ± 4	45 ± 7	25 ± 4	97 ± 23	7 ± 26	73 ± 3

[a]The effects of one and four nights of camping, immediately after camping and after one year of recovery, are shown for each of four study sites. Values are ± 1 standard error.

turbed subplots in the kitchen zone on these campsites was 21%. This illustrates the substantial variation in impact that occurred within zones. Variation was least pronounced in the tent zone, where the primary activity-sleeping-is relatively uniformly distributed. Variation was most pronounced in the kitchen zone. Relative cover was 35% or less in the most disturbed parts of the kitchen *zone* on all sites other than the *Vaccinium scoparium* sites that were used just one night. In the *Maianthemum canadensis* type, four nights of camping reduced relative cover to just 3% in the most disturbed parts of the kitchen zone.

Relative Height

Relative vegetation height after camping varied significantly with vegetation type, nights of camping, and campsite zone (Table 1). No interactions were significant. After camping, relative height was greatest in the dwarf-shrub-dominated *Vaccinium scoparium* type (75%). Among the three herbaceous types, relative height was significantly greater in the *Maianthemum canadensis* (38%) and *Valeriana sitchensis* (37%) types than in the *Potentilla simplex* (20%) type. Relative height was significantly greater on the sites camped on for one night (46%) than on the sites camped on for four nights (39%). Relative height was also significantly greater in the intermediate zone (51%) than in either the kitchen (43%) or tent (35%) zones. This contrasts with the response of relative cover values, which were greatest in the tent zone. Apparently sleeping has a more pronounced effect on vegetation height than on vegetation cover. Plants are flattened but not killed outright.

Camping generally reduced vegetation height more than vegetation cover. In the three herbaceous vegetation types, one night of camping reduced relative vegetation height to 60% or less in each of the three campsite zones-tent, intermediate, and kitchen (Figure 4). Height reduction was less pronounced in the dwarf-shrub-dominated *Vaccinium scoparium* type. However, even in this type, one night of camping caused substantial reductions in vegetation height in all campsite zones.

Sometimes four nights of camping caused greater reductions in height than one night of camping, but in many cases it did not (Figure 4). In the tent zone, four-night sites had lower relative height values than one-night sites only in the *Maianthemum canadensis* type. In the kitchen zone, four-night sites had lower relative height values than one-night sites in all types except for *Maianthemum canadensis.* In the intermediate zone, four-night sites had lower relative height values in two of the four vegetation types. As was the case with cover loss, the relationship between frequency of use and height reduction was not linear. Substantial increases in use frequently were associated with much smaller reductions in vegetation height.

After one year of recovery, relative vegetation height varied significantly with nights of camping, but not with vegetation type or campsite zone (Table 1). Moreover, the interaction between nights of camping and vegetation type was statistically significant. One

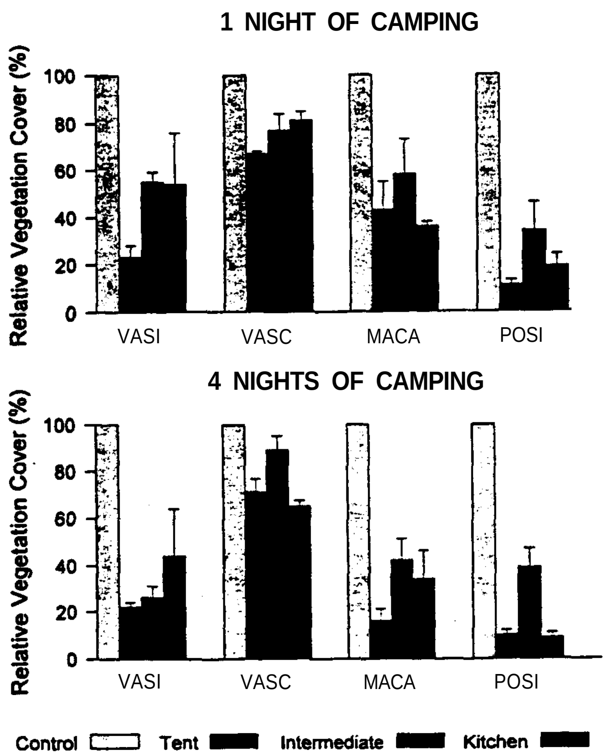

Figure 4. Relative vegetation height on campsites used one night and four nights in four vegetation types- *Valeriana sitchensis* (VASI). *Vaccinium scoparium* (VASC), *Maianthemum canadensis* (MACA), and *Potentilla simplex* (POSI). Vertical bars indicate 1 standard error.

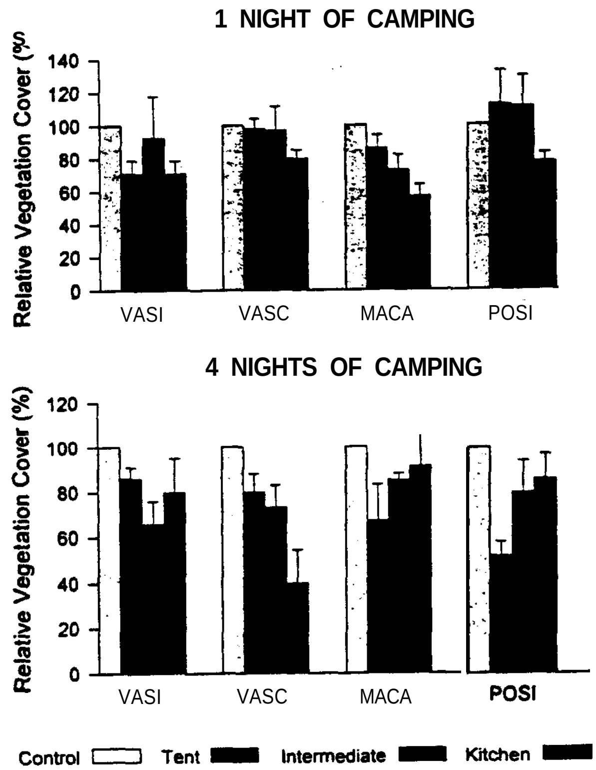

Figure 5. Relative vegetation height, after one year of recovery, on campsites used one night and four nights in four vegetation types- *Valeriana sitchensis* (VASI), *Vaccinium scoparium* (VASC), *Maianthemum canadensis* (MACA), and *Potentilla simplex* (POSI). Vertical bars indicate 1 standard error.

year after the camping occurred, relative height was greater on the sites used one night (86%) than on the sites used four nights (74%). but differences were significant only in *the Vaccinium scoparium* and *Potentilla simplex* types. The *Vaccinium scoparium* type, the type least disturbed initially by camping, recovered less than the other types during the year following the camping treatments. Consequently, relative height differences between vegetation types were minimal one year after camping (Figure 5).

As with cover loss, the magnitude of height reduction varied within campsite zones, as well as between campsite zones. The mean relative height of the most intensely disturbed subplots was often much less than the mean relative height of all subplots (Table 3). Relative height was 5% or less in places after four nights of camping in both the *Maianthemum canadensis* and *Potentilla simplex* types.

Comparison to Trampling Experiments

Trampling experiments were conducted close to the camping experiments in the four vegetation types. In all four types, relative vegetation cover declined as trampling intensity increased (Figure 6). As was the case with camping impact, the *Vaccinium scoparium* type was substantially more resistant to trampling impact than the other three vegetation types. For example, in the three herbaceous vegetation types, relative cover after 75 trampling passes was 35% or less; in *Vaccinium scoparium,* relative cover was 75% after 75 passes.

These data were used to compare cover loss caused by different trampling intensities to cover loss caused by the two camping frequencies, For example, mean relative cover after one night of camping in the tent zone was 57% in *Valeriana sitchensis* 95% in *Vaccinium scoparium,* 72% in *Maianthemum canadensis,* and 54% in *Potentilla simplex* (Figure 2). In *Valeriana sitchensis,* the same amount of vegetation change (a reduction of relative cover to 57%) was caused by about 20 trampling passes (Figure 6). In *Vaccinium scoparium,* relative cover was reduced to 95% after about 15 passes. In *Maianthemum canadensis,* relative cover was reduced to 72% after about 15 passes, and in *Potentilla simplex,* relative cover was reduced to 54% after about 40

Table 3. Relative vegetation height in the most intensely disturbed of four subplots in tent, intermediate, and kitchen zones[a]

	Relative vegetation height (%)					
	After camping			After one year		
	Tent	Intermediate	Kitchen	Tent	Intermediate	Kitchen
Valeriana sitchensis (WA)						
1 night/year	21 ± 6	29 ± 4	15 ± 7	55 ± 7	64 ± 24	46 ± 5
4 nights/year	15 ± 2	15 ± 2	11 ± 6	73 ± 4	54 ± 11	62 ± 14
Vaccinium scoparium (CO)						
1 nightlyear	58 ± 5	55 ± 14	64 ± 3	85 ± 5	58 ± 14	59 ± 4
4 nights/year	61 ± 1	79 ± 6	54 ± 2	63 ± 10	52 ± 9	23 ± 7
Maianthemum canadensis (NH)						
1 night/year	28 ± 7	20 ± 6	14 ± 6	64 ± 4	59 ± 8	32 ± 9
4 nights/year	7 ± 3	26 ± 13	0 ± 0	50 ± 6	60 ± 5	50 ± 12
Potentilla simplex (NC)						
1 night/year	8 ± 2	19 ± 8	10 ± 4	87 ± 27	98 ± 23	60 ± 30
4 nights/year	7 ± 1	13 ± 2	5 ± 2	44 ± 3	49 ± 4	64 ± 11

‘The effects of one and four nights of camping, immediately after camping and after one year of recovery, arc shown for each of four study sites. Values are ± 1 standard error.

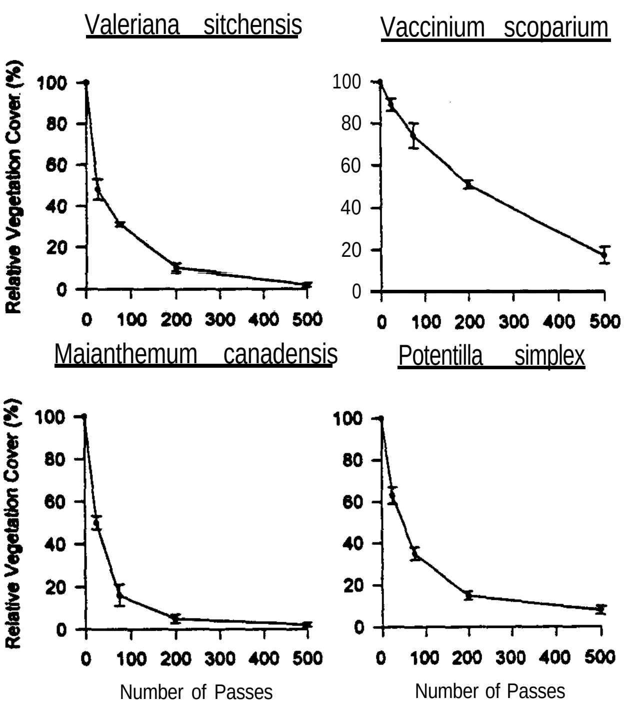

Figure 6. Relative vegetation cover after different trampling intensities in four vegetation types. Vertical bars indicate 1 standard error.

passes. For these four vegetation types, then, the trampling intensity that caused a loss of cover equivalent to one night of camping in the tent zone varied between 15 and 40 passes. A similar process was used to identify ranges of trampling passes that are equivalent to camping impacts for the other zones and use frequencies (Table 4).

Interestingly, trampling intensity equivalents for four-night sites were generally less than twice those for one-night sites. A fourfold increase in campsite use caused less additional impact than a fourfold increase in trampling intensity. The curvilinear relationship between amount of use and amount of impact demonstrated in trampling experiments (Cole 1987) is even more strongly curvilinear when the recreational activity is camping. This probably reflects a higher level of activity concentration while camping (Cole 1991).

The ranges of equivalents presented in Table 4 can be used to predict the impacts of camping in vegetation types for which there are data on responses to experimental trampling, even if there are no data on responses to experimental camping. For the kitchen zone, for example, Table 4 suggests that estimates of relative cover after four nights of camping should lie between the estimates of relative cover after 60 trampling passes and after 180 trampling passes. Estimates of relative cover after 60 and 180 passes can be derived through interpolation of experimental trampling results similar to those presented in Figure 6. Predictions of the effects of camping on the 16 vegetation types for which trampling data are available (Cole 1993) are shown in Table 5. Although these predictions have not been validated, their likely validity was increased by incorporating variability into the predictions in the form of a range of estimates. The predic-

Table 4. Number of trampling passes causing vegetation change equivalent to that caused by one and four nights of camping in tent, intermediate, and kitchen zones[a]

	One night/year			Four nights/year		
	Tent	Intermediate	Kitchen	Tent	Intermediate	Kitchen
Relative vegetation cover						
Mean subplot	15-40	15-25	25-90	20-60	25-70	60-180
Most disturbed subplot	20-60	30-70	75-175	25-90	60-175	150-400

[a]Ranges in number of passes reflect differences between the four vegetation types.

Table 5. Predicted relative vegetation cover after one and four nights of camping in the kitchen zone in 16 different vegetation types[a]

	Predicted cover (%)			
	One night/year		Four nights/year	
	Mean	Maximum	Mean	Maximum
Washington				
Pachistima myrsinites	80-95	70-80	70-85	60-70
Carex nigricans	100	90-100	90-100	70-95
Phyllodoce empetriformis	60-80	45-65	40-70	20-50
Valeria Sitchensis	25-50	l0-30	l0-35	5-15
Colorado				
Trifolium parryi	90-95	60-90	60-90	35-65
Kobresia myosuroides	85-95	70-90	70-90	45-75
Vaccinium scoparium	70-90	55-75	55-80	3O-60
Geranium richardsonni	55-65	20-60	20-60	l0-30
New Hampshire				
Carex bigelowii	70-80	60-75	60-75	35-65
Leersia oryzoides	30-70	20-30	20-45	l0-20
Lycopodium lucidulum	35-60	25-40	25-45	15-30
Maianthemum canadensis	15-50	5-20	5-30	5-10
North Carolina				
Carex pennsylvanica	55-90	45-60	45-70	30-50
Potentilla simplex	30-60	20-35	20-45	l0-25
Amphicarpa bracteata	25-45	15-30	15-35	1O-15
Dryopteris campyloptera	l0-35	5-15	5-20	5

[a]Both mean effects and maximum effects are shown. Mean effects are based on all four subplots in each campsite zone; maximum effects are based on the most intensely disturbed of those subplots.

tions are based on a range of equivalents derived from four different vegetation types, rather than the results from a single vegetation type or a mean derived from several different vegetation types. They will be invalid only for vegetation types with equivalents that lie substantially outside of the range defined by the four vegetation types included in this study. Ultimately, validity can only be assessed by measuring the effects of camping on vegetation types for which predictions have been made.

Differences in impact among all 16 vegetation types are much more pronounced than differences among the four types in the experimental camping study. For example, in the *Carex nigricans* type, one night of camping would be expected to cause no cover loss in any of the campsite zones. In contrast, in the *Dryopteris campyloptera* type, the predicted result of one night of camping in the kitchen zone is a reduction in relative cover to l0%-35%. Predicted levels of impact in the most disturbed parts of the site are also shown in the table. Similar predictions could also be developed for relative height and for conditions after one year of recovery. However, equivalents for the postrecovery data vary much more between vegetation types. Therefore, predictions about postrecovery campsite conditions, based on these equivalents, would be even less precise than those for conditions following camping.

Discussion

Attempts to manage the impacts of camping in wilderness areas are hampered by an inability to estimate or predict, with any precision, the effects of different use frequencies on different vegetation types. The study reported here is a first attempt to quantify the effects of documented and controlled levels of camp ing, utilizing an experimental design. As with most experiments, there are limitations to the results. In the study reported here, only short-term responses to one season of camping are reported. The effects of camping for many successive years may be quite different. In addition, while it was possible to quantify the magnitude of impact at certain locations on the campsite, it was not possible to quantify the areal extent of impact. Nevertheless, several important conclusions can be drawn from the study.

Campsite use frequencies as low as one night of use were sufficient to cause evident vegetation impact in all four vegetation types. In the three herbaceous vegetation types, evident impact was widespread on campsites used jut one night. In the dwarf-shrub Vaccinium scopium type, only parts of the site that received concentrated use experienced evident impact. Earlier studies of established campsites have reported that lightly used campsites often had experienced substantial impact (Cole and Fichtler 1983, Cole and Marion 1988, Frissell and Duncan 1965, Marion and Merriam 1985). The results of the study reported here corroborate this general conclusion and provide more precise quantification of the low levels of use that are capable of causing widespread campsite impact.

Height reduction was more pronounced following low levels of campsite use than cover loss. This suggests that the first evidence of vegetation impact on a developing campsite is likely to be a reduction in vegetation height. Since height reduction is likely to be particularly evident in tall vegetation, evidence of previous camping use is likely to appear more rapidly in tall vegetation than in short vegetation.

The impacts of camping vary substantially between vegetation types. In the most resistant of the four types that were studied, the dwarf-shrub-dominated *Vaccinium scoparium* type, relative cover after four nights of camping was about three times greater than in the least resistant type, *Maianthemum candensis* Vegetational response to camping is simliar to the response of vegetation to trampling disturbance. Results from trampling experiments also indicate that ‘shrub-dominated vegetation types are usually more resistant than types dominated by erect forbs (Cole 1987, 1993).

The ability of vegetation to resist being disturbed by camping (resistance) and the ability of vegetation to recover from camping disturbance (resilience) varied independently. The two vegetation types that were disturbed most by just one night of camping, *Valeriana sitchensis* and *Potentilla simplex*, recovered rapidly. One year after camping there was little evident impact on any of the campsites in these two vegetation types. The sites in the *Vaccinium scoparium* type were not highly disturbed by camping initially, but they continued to deteriorate after camping had ceased. Finally, sites in the *Maianthemum canadensis* type were only moderately disturbed by one night of camping; however, they were highly disturbed by four nights of camping, and these sites experienced only a moderate amount of recovery during the year after the camping treatments.

Experimental trampling studies also indicate that shrub-dominated vegetation types usually recover more slowly than forb-dominated vegetation types (Cole 1988, 1993). For long-established campsites, the magnitude of vegetation impact is determined as much by the ability of vegetation to recover from disturbance as by the ability to resist disturbance. In studies of established campsites, vegetation impact has been equally pronounced on sites located in dwarf-shrub vegetation as on sites located in erect-forb vegetation (Cole 1981).

The magnitude of differences in vegetation impact between vegetation types varied with use frequency. Differences in vegetation cover loss between the most and least resistant types were more pronounced after four nights of use than after one night of use. This parallels the finding in experimental trampling studies that differences in impact between vegetation types were greatest at moderate trampling intensities of 100-200 passes per year (Cole 1987).

Although the amount of impact generally increases as use frequency increases, the increase in impact was not proportional to the increase in use. Fourfold increases in use frequency were associated with less pronounced increases in cover loss and height reduction. This result corroborates the general finding from studies of established campsites that impact increases at a decreasing rate as use frequency increases (Cole and Fichtler 1983, Cole and Marion 1988, Frissell and Duncan 1965, Marion and Merriam 1985). These earlier efforts, conducted on sites used more frequently than the experimental sites studied here, demonstrated that differences in impact between frequently and infrequently used campsites were not proportional to differences in amount of use. For the vegetation types in the study reported here, differences in impact were not proportional to differences in use, even when comparing campsite use levels as low as one and four nights per year. In these vegetation types, at least, we can conclude that impact increases at a declining rate for use frequencies of one night per year or more.

Although the effects of camping were quantified for only four vegetation types, there is some potential for cautious extrapolation to other vegetation types. Trampling experiments are relatively easy to conduct utilizing the protocols used here and described in more detail in Cole and Bayfield (1993). Based on the equivalents in Table 4, the effects of controlled levels of trampling can be used to predict the likely effects of one and four nights of camping. The 16 vegetation types that comprised the larger group of sites in this study included types that were both more resistant and less resistant than the types included in the experimental camping study. Among these were several types, such as the *Carex nigricans* and *Kobresia myosurodes* alpine turfs, which appear likely to be minimally disturbed by even four nights of camping. In contrast, just one night of camping appears likely to eliminate two thirds of the vegetation from the kitchen zone of types as fragile as the fern-dominated *Dryopteris campyloptera* type.

The results of this study demonstrate the difficulty of avoiding camping impacts, even in places where use levels are very low and visitors practice low-impact camping. Use frequencies as low as one night per year are sufficient to cause evident impact on campsites in many vegetation types. This result, along with the finding that amount of impact does not increase in proportion to increases in use frequency, suggests that impact can almost always be minimized by confining camping to a small number of campsites instead of dispersing use across a large number of campsites. Use dispersal would only minimize campsite impacts where use frequencies could be so low that evident vegetation impact never occurs. In vegetation types similar to most of those included in the study reported here, vegetation impact is likely to occur wherever use frequencies are higher than about one night of camping every five years.

There is substantial variation in the resistance of different vegetation types, however. The most resistant vegetation types, usually those dominated by short graminoids such as *Carex nigricans* are likely to be minimally affected by even several nights of use. Use dispersal is more likely to be effective in places with substantial amounts of such highly resistant vegetation (or with numerous sites without any vegetation), although even in these places dispersal will work only if total use levels are relatively low. This suggests that it may be possible to keep the impacts of camping to negligible levels in some of the places where camp ing occurs, This is possible only where use can be directed to highly resistant sites, use frequencies can be kept to one night of camping per year or less, and visitors are diligent about practicing low-impact camping. Such a management program would be a challenge to implement successfully, but the results of studies such as the one reported here should help managers tailor campsite management programs to their specific situations.

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Literature Cited

Bayfield, N. G. 1979. Recovery of four montane heath communities on Cairngorm, Scotland, from disturbance by trampling. *Biological Conservation* 15: 165-179.

Bogucki, D. J., J. L. Malanchuk, and T. E. Schenck. 1975. Impact of short-term camping on ground-level vegetation. *Journal of Soil and Water Conservation* 30:231-232.

Bratton, S. P., M. G. Hickler, and J. H. Graves. 1978. Visitor impact on backcountry campsites in the Great Smoky Mountains. *Environmental Management* 2:431-442.

Cole, D. N. 1981. Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness, Oregon: Some management implications. *Biological Conservation* 20:247-270.

Cole, D. N. 1986. Recreational impacts on backcountry campsites in Grand Canyon National Park, Arizona, USA. *Environmental Management* l0:65l-659.

Cole, D. N. 1987. Effects of three seasons of experimental trampling on five montane forest communities and a grassland in western Montana, USA. *Biological Conservation* 40:219-244.

Cole, D. N. 1988. Disturbance and recovery of trampled montane grassland and forests in Montana. USDA Forest Service Research Paper INT-389, lntermountain Research Station, Ogden, Utah, 37 pp.

Cole, D. N. 1991. Modeling wilderness campsites: Factors that influence amount of impact. *Environmental Management* 16:255-264.

Cole, D. N. 1993. Trampling effects on mountain vegetation in Washington, Colorado, New Hampshire, and North Carolina. USDA Forest Service Research Paper INT-464, Intermountain Research Station, Ogden, Utah 56 pp.

Cole, D. N., and N. G. Bayfield. 1993. Recreational trampling of vegetation: Standard experimental procedures. *Biological Conservation* 63:209-2 15.

Cole, D. N., and R. K. Fichtler. 1983. Campsite impact on three western wilderness areas. *Environmental Management* 7:275-288.

Cole, D. N.. and J. L. Marion. 1988. Recreation impacts in some riparian forests of the eastern United States. *Environmental Management* 12:99-107.

Frissell, S. S., and D. P. Duncan. 1965. Campsite preference and deterioration in the Quetico-Superior canoe country. *Journal of Forestry* 65:256-260.

Hurlbert, S. N. 1984. Pseudoreplication and the design of ecological field experiments. *Ecological Monographs* 54: 187-211.

Kuss. F. R., A. R, Graefe, and J. J. Vaske. 1990. Visitor impact management: A review of research. National Parks and Conservation Association, Washington, DC, 256 pp.

Leonard, R. E., J. M. McBride, P. W. Conkling, and J. L. McMahon. 1983. Ground cover changes resulting from low-level camping stress on a remote site. USDA Forest Service Research Paper NE-530, Northeastern Forest Experiment Station, Broomall, Pennsylvania, 4 pp.

Marion, J. L., and L. C. Merriam. 1985. Recreational impacts on well-established campsites in the Boundary Waters Canoe Area Wilderness. University of Minnesota Agricultural Station Bulletin AD-SB-2502, St. Paul. Minnesota, 16 pp.

Washburne, R. F., and D. N. Cole. 1983. Problems and practices in wilderness management: A survey of managers. USDA Forest Service Research Paper INT-304, Intermountain Forest and Range Experiment Station, Ogden, Utah, 56 pp.