INT 4901 PUBLICATION REPRINT #130

Aldo Leopold Wilderness Research Institute: Publication # 130
CITATION: Cole, David N. 1985. Management of ecological impacts in wilderness areas in the United States. In: Bayfield, N. G.; Barrow, G. C., eds. The ecological impacts of outdoor recreation on mountain areas in Europe and North America. R.E.R.G. Report No. 9. Wye, England: Recreation Ecology Research Group: 138-154.

MANAGEMENT OF ECOLOGICAL IMPACTS IN WILDERNESS AREAS IN THE UNITED STATES

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In: The Ecological Impacts of Outdoor Recreation on Mountain Areas of Europe and North America.
R.E.R.G. Report No. 9. Wye, England: Recreation Ecology Research Group, 1985.

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SUMMARY

1. The goals established for managing wilderness areas in the United States stress preservation of natural conditions and avoidance of conspicuous evidence of human use. Different types of recreational impact compromise these goals to varying degrees. With a few noteworthy exceptions, natural conditions of the vast majority of wilderness have been little affected by recreation because use is highly concentrated. However, site impacts are abundant and conspicuous wherever significant use occurs.

2. Research on campsite impacts has identified what changes have occurred and their severity. The major factors that influence how much occurs on an individual site are (i) the amount and frequency of use the site receives, (ii) the type and behavior of its users, and (iii) the environmental conditions of the site itself. The effectiveness of various means of manipulating these factors to control site impacts is evaluated. The appropriateness of different management strategies varies both within and between wilderness areas, with amount and type of use.

3. Practices commonly taken to mitigate trail damage and damage associated with the use of pack and saddle stock are described. Much less is known about the severity of wildlife disturbance and water pollution or how such problems should be rectified. Reasons why these impacts should be of particular concern are suggested.

4. The paper concludes by noting important barriers to improved management of ecological impacts. These include insufficient research, lack of monitoring, poor communication both between researchers and managers and among managers, and poorly defined management objectives.

INTRODUCTION

Bob Lucas' paper in this publication provides a brief overview of the goals of wilderness management and the most important problems that wilderness managers confront. While he emphasized management techniques intended to enhance recreational experiences, I will talk primarily about management technqiues designed to minimize the effects of recreation on wilderness lands. Both approaches primarily consist of managing visitors.

I will describe the types of recreational impact occurring in wilderness and discuss current management techniques. Because we've already heard about research on impacts such as trail damage and wildlife disturbance, I will focus primarily on campsite impacts. Campsite impacts are a high priority to managers. They are particularly pronounced and they can have profound effects on visitor experiences because visitors spend much of their time in camp. Moreover, many techniques for managing campsite impacts exist, and the most appropriate and effective techniques for managing particular situations are not always obvious.

TABLE 1 Managers' evaluations of ecological impact problems, U.S National Wilderness Preservation System, and likely additions

	Percent of areas with:		
	No problems	Few problems	Many problems
Campsite Impacts (Human-caused)			
Vegetation	29	44	27
Soils	34	44	22
Trail Impacts (Human-caused)			
Vegetation	56	35	9
Soils	39	43	18
Packstock Damage	58	32	10
Wildlife Disturbance	65	28	7
Water Pollution	82	16	2

Source: Washburne & Cole, 1983

First, I want to offer a few observations about the condition of the wilderness resource and about which recreational impacts seem to be the most seriously compromising wilderness goals.

THE SIGNIFICANCE OF RECREATIONAL IMPACTS

To evaluate the significance of recreational impacts in wilderness areas, it is important to examine the goals of wilderness management. The American Wilderness Act states that wilderness is an area "which is protected and managed so as to preserve its natural conditions and which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable" (emphasis added). Some recreational impact will be tolerated, but the integrity of these largely undisturbed ecosystems should not be substantially compromised and the evidence of this impact should not be conspicuous.

With a few exceptions, recreational use has not substantially compromised the natural conditions of wilderness areas in the United States. Recreational use is highly concentrated along a few major trails and at a few popular destinations, leaving the vast majority of most wildernesses essentially unvisited and largely undisturbed by recreational use. Even in the most heavily used part of the popular Eagle Cap Wilderness in Oregon, for example, I estimated that less than 2% of the area has been significantly altered by recreational use (Cole, 1981). In most areas, such activities as fire suppression and livestock grazing have had a much more widespread effect on natural conditions than has recreational use (Vale, 1977, Vankat & Major, 1978; Cole, 1981).

There are at least three important exceptions to the generalization that natural conditions are not being substantially compromised by recreational use. First, the human introduction of fish, particularly trout, into formerly barren lakes has occurred throughout much of the wilderness system. Along with angling, this has probably caused widespread changes in the distribution and population structure of fisheries, as well as the basic ecology of certain lakes and streams. Second, hunting is common in wilderness, outside of the National Parks. Along with unintentional harassment of animals, this has altered the distribution, population structure, and behavior of many animal species. Third, recreational use is sometimes concentrated on rare ecosystem types, such as lakes or meadow, or places inhabited by rare plants or animals. Where this leads to a loss of rare species or substantial disturbance of a rare ecosystem type, natural conditions have been substantially compromised.

Recreational use compromises other goals of the Wilderness Act as well. A particular concern of mine is the proliferation of human impact both in the traditionally popular portions of each wilderness and in places that until recently showed little evidence of human use. In the places where visitors spend most of their time, the mark of man is becoming increasingly conspicuous. A second problem, which pertains to the goal of leaving these areas "unimpaired for future use and enjoyment" occurs where trails and campsites deteriorate to the point where they are no longer functional or desirable.

In a survey of wilderness managers, we found that a majority of areas have impact problems on campsites and trails, with campsite problems more prevalent (Washburne & Cole, 1983). Damage to soil and vegetation associated with packstock use is the third most commonly perceived problem, occurring in 42% of the areas. Wildlife disturbance and water pollution are perceived to be problems in 35% and 18% of the areas, respectively (Table 1). Although these perceptions may not correspond with the actual severity of impact, they probably are reflected in the intensity of management activities designed to mitigage these problems.

CAMP SITES

Because impacts on campsites are the most common problem managers recognize and because we feel that proliferation of campsite impacts and excessive deterioration of campsites seriously compromise wilderness goals, the Forest Service's Wilderness Management research program has devoted much of its effort to improving campsite management.

Our first question was: What and how severe are the effects of wilderness camping? To get some idea, we took detailed measurements on 22 campsites in subalpine forests in the Eagle Cap Wilderness, Oregon (Cole, 1982a). We examined a range of sites from those used less than once per year to those used several times a week during the 10-week summer season. Median conditions on these 22 sites were as follows:

1. Trampling had eliminated almost 90% of the undergrowth vegetation from the 200 m^2 camp area, and the sparse vegetation that did survive was quite dissimilar in composition to that found on undisturbed sites.
2. Trampling had worn away much of the soil organic horizon, exposing mineral soil on 31% of the campsites, in comparison to a median mineral soil exposure of 1% on undisturbed sites.
3. This trampling damage was most pronounced toward the center of the sites where essentially no vegetation persisted and 50% of the organic horizon had been removed.
4. Essentially all of the overstory trees onsite had been damaged, through firewood collection, having stock tied to them, or malicious or thoughtless acts such as hacking with axes and hammering nails into trees. Over one-fourth of the trees had been felled and one-third had exposed roots.
5. Over 90% of the tree seedlings had been eliminated. After the current overstory dies, these sites apparently will no longer be forested.
6. Trampling had compacted the soil, resulting in bulk density increases of 15% and infiltration rate decreases of 30%
7. The organic content of the surface soil (A horizon) was 20% higher than on undisturbed sites. There were also increases in pH and the concentration of Mg, Ca and Na ions.

The most severely disturbed sites were even more highly altered. The only parameters we examined that were not affected by camping were soil texture and the concentrations of NO_3, K, PO_4, and total N.

Campsite impact is highly concentrated. In most places only occasional campsites are encountered; but in a few popular destination areas, campsites are frequent. In a 132 ha area around two popular lakes in the Eagle Cap Wilderness I found 221 campsites (Cole, 1982b). Still this represents only 1.3% of this most highly disturbed area, suggesting little threat to the ecological integrity of the area. The most serious problem is one of visual impact; conspicuous evidence of human impact is almost everywhere. Not only is there little opportuntiy to camp on an undisturbed site, but pronounced impacts are found around almost every corner and behind every tree clump. In terms of the Wilderness Act's wording, man's imprint is definitely <u>not</u> "substantially unnoticeable".

Our second set of questions about campsites were: What causes certain campsites to be much more seriously damaged than others? What actions can managers take to minimize campsite impacts? How effective are these actions?

The major factors that influence how much change occurs on an individual site are (1) the amount and frequency of use the site receives, (2) the type and behavior of its users, and (3) the environmental conditions of the site itself. Season of use is a less important determinant of campsite impact than of trail impact or packstock damage to meadows. Use of trails and meadows when soils are saturated and particularly fragile is common, but campsites in this condition are generally avoided.

TABLE 2. Management actions that affect campsite impact, US National Wilderness Preservation System, and likely additions.

Management actions	FS	NPS	F&WS	BLM	All agencies
	Percent of areas that have taken this action:				
Manage Amount or Frequency of Use					
- No camping allowed	1	8	59	0	9
- Use is limited	6	38	8	9	13
- Use dispersal is encouraged	58	52	7	36	50
- Encourage camping on previously unused sies	16	2	0	0	11
- Camping allowed on designated sites only	5	44	7	0	14
- Encourage camping on previously used sites	15	16	0	9	13
- Some campsites temporarily closed	15	24	7	9	16
Manage Type of Use					
- Minimum impact education program	60	65	5	36	56
- Maximum limit on party size	58	49	10	18	48
- Fires prohibited	1	43	59	0	15
- Fires discouraged	20	16	0	36	18
- No stock allowed in camp	11	40	0	11	15
Manage Site Conditions					
- Camping allowed on designated sites only	5	44	7	0	14
- No camping allowed in certain ecosystems	4	22	3	9	8
- No camping allowed close to water bodies	37	22	7	18	30
- Some campsites permanently closed	20	41	3	0	21

Source: Washburne & Cole, 1983
FS = Forest Service
NPS = National Park Service
F&WS = Fish and Wildlife Service
BLM = Bureau of Land Management

TABLE 3. Relationship between selected campsite impact parameters and the amount of use a site receives.

Impact parameter		Light-use sites (n = 6)	Moderate-use sites (n = 6)	Heavy-use sites (n = 10)	Kendall's tau (= 0·05)
			Median		
Camp area	(m^2)	48	224	205	NS
Devegetated area	(m^2)	19	122	93	0·30
Tree with exposed roots	(%)	3	33	39	0·41
Damaged trees	(%)	74	85	97	NS
Seedling loss	(%)	73	92	89	NS
Surviving vegetation cover	(%)	9	6	4	-0·41
Decrease in depth of organic horizons	(%)	3	21	68	0·36
Floristic dissimilarity	(%)	31	60	64	0·33
pH increase	(%)	3	5	11	NS
Decrease in infiltration rates	(%)	8	57	12	NS
Increase in soil organic matter	(%)	19	26	20	NS
Increase in bulk density	(%)	16	11	16	NS

Source: Cole 1982*a*

Amount and frequency of use can be manipulated in several ways to control site impacts. Recreational use can be reduced or limited, either in the entire area or on the individual campsite. Without reducing total use, the severity of impact on individual sites can be reduced by dispersing use among a large number of sites. Alternatively, the number of impacted sites can be reduced by increasing the use of a small number of sites. Length of stay can also be limited. Another option is rest-rotation, in which damaged sites are temporarily closed until they have recovered sufficiently to be used again.

The type of use a site receives (e.g., size of groups and whether or not visitors have packstock) influences both how much and what types of impact occur. Both amount and type of impact are also dependent upon user behavior - whether or not campers build fires, cut trees, or pollute the site. Managers can use education or regulations to limit behavior or types of use that are particularly destructive.

The influences of environmental conditions on site impact can be manipulated in either of two ways. First, use can be confined to resistant sites, or, at least, use of sensitive sites can be discouraged. Second, sites can be shielded or hardened from impact. For example, firewood can be provided so that it need not be scavenged, or hitchrails can be erected so packstock will not be tied to trees.

As Table 2 illustrates, all of these strategies are being tried somewhere within the wilderness system. However, none have been widely accepted. The only ones tried in close to one-half of the areas are encouraging use dispersal, educating visitors in how to minimize their impact, and limiting the size of parties. The least common strategy is shielding or hardening the site (not included in the table) because this is generally considered to be inconsistent with wilderness management goals.

EFFECTIVENESS OF CAMPSITE MANAGEMENT STRATEGIES

Amount and frequency of use

Of the factors that influence impact, the usual assumption has been that the amount and frequency of use at a site is most important. To evaluate this, the campsites we examined in the Eagle Cap Wilderness were selected from three distinct use categories: (1) light-use sites, mostly at trailless lakes, where use frequency was judged to be less than 5 nights per year; (2) moderate-use sites at lakes reached by trails, where estimated use frequencies were 10 to 20 nights per year; and (3) heavy-use sites, probably used 25 to 50 nights per year. All sites were located in the same plant community type, on *Abies lasiocarpa/Vaccinium scoparium* subalpine forest, to reduce confounding environmental variability.

Even campsites used no more than a few nights per year have been severely altered (Table 3): most overstory trees have been damaged, most seedlings have been eliminated, most of the vegetation cover has been lost, soil has been compacted, and soil chemical changes have occurred. Sites used 5 to 10 times more frequently, about one night per week during the main use season, differed: the affected and devegetated areas were usually much larger, exposure of tree roots was pronounced, organic horizons were thinner, and changes in the species composition of the undergrowth were more extreme. Compared with these sites, the only major difference on the most heavily used sites - those used several nights per week - was that organic horizons were even thinner.

Similar results have been found in subalpine forests elsewhere (Cole & Fichtler, 1983). In ecosystems as fragile as these, site degradation is inevitable even at low use intensities. If use frequencies could be kept very low (probably less than one night per year in subalpine forests in the Northern Rocky Mountains), site deterioration could be minimal. Where this is not possible, manipulating use distribution will have more effect on the number of impacted sites than on the severity of impacts. Concentrating use on a small number of sites will minimise the number of impacted sites, without much increase in site deterioration; dispersing use among a large number of sites will increase the number of impacted sites, with little improvement of conditions on existing sites. The 221 campsites we found in the 132 ha area in the Eagle Cap (Cole, 1982b) illustrates the likely result of a dispersal program in a heavily used area. So many highly altered sites - more than half had lost at least 25% of their vegetation cover - are unnecessary in an area where the average number of parties probably does not exceed 10 per night.

The dispersal strategy seems only appropriate where use levels are very low and where ecosystems are particularly resistant. Where use levels are too high to avoid visibly altering sites, concentration seems more appropriate. The option of a moderate number of lightly impacted sites is not a realistic one because such sites are vulnerable to extremely rapid deterioration with only minor increases in use.

Another management alternative that seems unlikely to succeed is rest-rotation, in which sites are used for several years and then allowed to recover before being used again. Several studies have found that near-maximum levels of deterioraton occur within the first few years after a site is opened (LaPage, 1967; Merriam & Smith, 1974). However, particularly in mountain environments, recovery takes decades or even centuries (Willard & Marr 1971; Parsons, 1979).

To test such a program, we documented what happened when 7 out of 15 campsites at Big Creek Lake in the Selway-Bitterroot Wilderness in Montana were temporarily closed to allow recovery. Eight years after closure, vegetation cover on closed sites was still only one-third of that on controls, and mineral soil exposure was 25% compared with 0.1% on controls (Cole & Ranz, 1983). The most pronounced change since initiation of the closures has been the creation of seven new campsites, close to the closed sites, on which conditions have rapidly deteriorated. Within 5 years of their creation, vegetation loss was as high on the new sites as on long-established sites. Loss of organic horizons and resulting exposure of mineral soil took longer to occur, but after 8 years was as pronounced as on long-established sites.

The likely effect of a rest-rotation system, as this example illustrates, is an increase in the number and area of impacted sites without any significant improvement in the condition of sites in use.

Type of use

Many types of campsite damage could be most effectively controlled by modifying user behavior. For example, damage to trees could be eliminated if users could be taught not to hack them, break off branches for firewood, or tie packstock to them. Problems with litter appear to have been greatly reduced by a program asking visitors to pack out whatever they pack in. The major problem is how to effectively convince visitors to change their behavior.

Although the widespread adoption of minimum impact procedures could greatly reduce damage to overstory trees and the ecological and aesthetic pollution of campsites, those impacts associated with trampling - loss of ground vegetation and disturbance of the soil - cannot be reduced substantially by changing user behavior. Trampling damage is affected more by where visitors camp, the size of their party, and their mode of travel.

Although the effect of party size on campsite impact has never been formally studied, large groups will certainly increase the disturbed area of individual campsites due to a need to spread out more. Further, what we have learned about the use-impact relationship suggests that this larger area will be disturbed to a significant degree, but the greater number of people in the party is unlikely to contribute to unusually severe disturbance of any part of the campsite. Thus, establishing lower party size limits is likely to have little effect on the intensity of vegetation loss or soil compaction, but it could reduce the size of areas affected. However, current party size limits are as high as 60 people; even the most common limit, 25, probably has no effect on campsite condition. To be effective, party size limits probably have to be 10 or less and this action has to be supported by educating parties not to spread out on campsites, revegetating sites, and keeping people off the peripheries of existing large sites. As an example, in Mt. Rainier National Park in Washington, party size is limited, minimum impact education is stressed, all campsites are closely monitored, and where site expansion is occurring, rocks or logs are 'planted' to keep people off the area.

Parties that travel with packstock also have much more potential for causing damage than do backpackers. In addition to increased trail damage and disturbance of grazing areas, packstock also contribute to greater campsite damage. In the Bob Marshall Wilderness in Montana, where about 65% of visitors travel with packstock (Lucas, 1980), we compared campsites used almost entirely by backpackers with sites used primarily by parties with packstock (Cole, 1983). Compared with backpacker sites, packstock sites:

1. were generally about 6 times larger

2. had 10 to 20 times as many damaged trees

3. had lost twice as much of their surface organic horizons

4. had much more highly compacted soils with slower infiltration rates

5. had been more completely invaded by nonnative plant species

Aside from prohibiting or severely limiting use of packstock (actions that have been taken in only a few wilderness areas) little can be done to mitigate this disturbance. However, it is possible to confine this damage by building hitchrails and corrals, keeping stock out of camp areas, and requiring the use of specially designated stock camps. Where use of such facilities is deemed inappropriate, some tree damage could be avoided if users could be convinced not to tie horses to trees for extended periods.

Campsite location

Influencing where people camp can be achieved directly by allowing camping only in designated areas on resistant sites, or indirectly by teaching visitors to choose resistant sites. Choosing resistant sites is particularly important in lightly used areas where dispersal is being encouraged. In popular places, any site will be highly altered so it is only important to avoid use of particularly fragile areas and to try to choose locations where impacts will not be highly visible.

Beyond a few obvious generalizations, such as choosing sites with no vegetation at all, we still have a lot to learn about which sites are resistant and which are fragile. In about one-third of all wilderness areas, camping is not allowed within a certain distance, usually 100 to 200 feet, of water bodies (Washburne & Cole, 1983), often because such sites are considered to be unusually fragile. We tested this assumption in our Eagle Cap study (Cole, 1982a) and found sites set back from lakes to be as severely disturbed as lakeside sites.

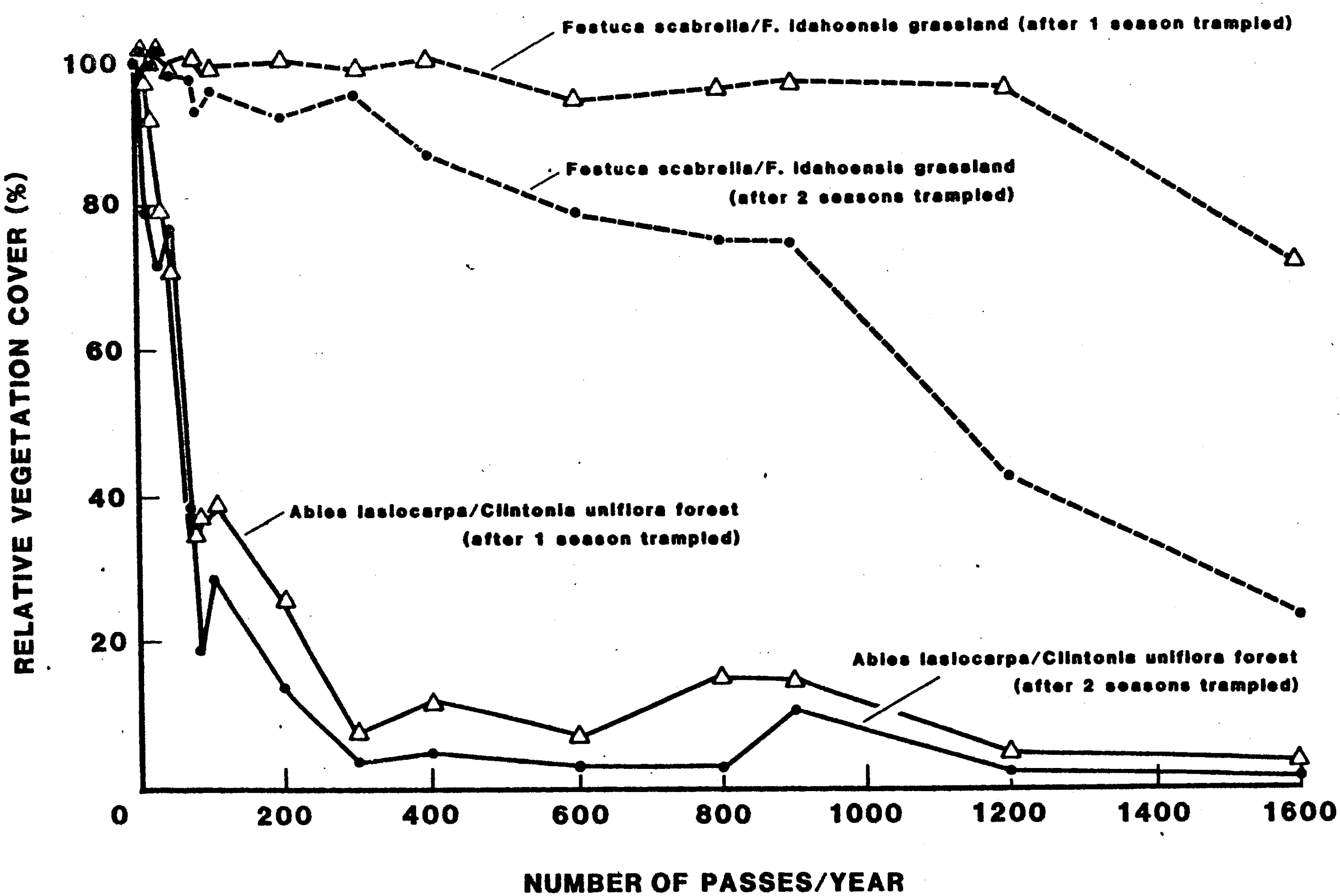

Figure 1. Relationship between number of passes year^{-1} and relative vegetation cover (percentage of original cover left, adjusted for changes on the control).

We have consistently found sites in nonforested vegetation to be less altered than those in forests. In the Bob Marshall Wilderness, for example, the median vegetation loss on sites in grasslands or open forests with a grassy understory was 20%, compared with median losses of 62, 66 and 84% in the three common forest types in the area. Similar results have been reported elsewhere (Weaver & Dale, 1978; Cole 1981).

Our most recent research is examining resistance under the controlled conditions of experimental trampling. We are trampling five forest types and one grassland at use levels from 0 to 1,600 passes by a walker per year and frequencies from once per season to twice per week for 8 weeks. The study is in its third season now and will continue until year-to-year change equilibrates.

This is generating a wealth of intriguing information that we are just starting to analyse. Figure 1 relates relative vegetation cover (Bayfield, 1979) after each of the first 2 years of trampling to number of passes per year for the grassland and one forest type. All five forested types have curves like that of the *Abies lasiocarpa/Clintonia uniflora* type. For each there is a straight-line relationship between relative cover and log of the number of passes (r^2 = 0.86 for *Abies lasiocarpa/Clintonia uniflora*), corroborating our earlier conclusion that most impact is caused by a relatively small amount of use. The slope of regression lines for each forest type is significantly different, indicating that some of these types are more fragile than others.

The slope of the grassland curve is very different from that of the forested types. The grassland is much more resistant; it tolerated 1,200 passes with essentially no loss of cover.

In the forested types, most damage occurred the first year. This rapid loss of cover is the reason why use dispersal and rest-rotation systems are likely to be ineffective in many forested types. The grassland resisted damage the first year, but lost considerable vegetation the second year. Here rotating use among a large number of sites may prove effective. It will be interestng to determine how many years of trampling it will take before year-to-year change stabilizes. It is already clear, however, that conclusions drawn from one year of trampling would be misleading if extrapolated to sites that have been used for many years.

The differences in resistance between forest and grassland vegetation is most pronounced at low to moderate use levels - 100 to 800 passes. This illustrates the value of camping on resistant sites in settings where use levels are relatively low. Where use is heavy and concentrated, camping on particularly resistant sites is much less important.

Summary

What we have learned so far suggests that the appropriateness of these different management strategies varies both within and between wilderness areas, particularly with amount and type of use. In popular places, camping impacts can be minimized by (1) confining use to a small number of sites, (2) locating these sites where disturbance is not visually obtrusive (e.g., in forests), (3) educating users to keep these areas clean and pleasant, and (4) confining packstock damage through facilities and/or education.

In more remote areas where campsite occupancy rates could be very low, impacts can be minimized by dispersing use among a large number of sites - if campers can be taught to choose apparently unimpacted, resistant sites and to leave little trace of use. It may also be necessary in some situations to limit party size, use of packstock, and campfires.

TRAIL IMPACTS

The nature of damage to trails has been dealt with extensively at this conference, so I will not elaborate. Instead, I will briefly describe some of the most common techniques for preventing and repairing trail damage. Trail damage is a problem in most wilderness areas and more money is invested in mitigating this impact - primarily in the form of maintaining and relocating trails - than any other.

The major problems with trails are (1) erosion, (2) muddy stretches in areas of water-saturated soil, and (3) the development of impromptu trails. Problems with erosion and muddiness are most effectively dealt with through careful location, design, and maintenance of trails. Erosion potential is reduced by locating trails on sidehills and avoiding long, steep grades through the use of switchbacks or zig-zags. To divert water off the tread, trails are usually outsloped and incorporate natural grades. Water bars, culverts, parallel ditches, and cross ditches are common drainage control devices, while the use of soil cement, paving, or steps is rare. It is very common to have older steep trails replaced with better designed, longer trails with gentler grades. However, in many cases this is taken to the extreme. I know of one case where a 6 km trail was replaced with an 18 km zig-zag trail that takes all day to climb.

Muddiness problems are usually dealt with through relocation, if possible, or through some type of bridging. By far the most common type of bridging is log decking, commonly known as corduroy. More elaborate designs involve elevated trails, with earth or gravel fill supported either by logs or flat rocks. These may or may not be ditched on either side or utilize culverts to facilitate drainage.

Three types of impromptu trails are common: (1) multiple, parallel trails, (2) shortcuts on switchbacks, and (3) informal trail systems to popular attractions or in popular destination areas.

Multiple trails are common in poorly drained areas; on soils with homogeneous fine-grained textures (such as in meadows), where the formation of deep, narrow trails causes hikers and horses to walk beside the trail; and in open areas, where users can spread out. The only common response to this problem has been trail relocation. In particular there has been a strong push to get trails out of meadows into the adjacent forested areas.

Shortcutting switchbacks is dealt with by discouraging or, in a few cases, prohibiting shortcutting. Brochures are often provided that describe appropriate behavior, and in some places signs have been erected. The potential for shortcutting can be reduced during trail construction by trying to screen one switchback from another, building barriers of rock or vegetation, avoiding the use of numerous short switchbacks, and by utilizing wide turns.

Managers seldom attempt to do anything about informal trail systems. Often encouraging visitors to use lightly used areas instead of more popular places even aggravates the problem. Where trail proliferaton occurs, developing an 'official' trail system based on existing use patterns and encouraging its use is probably the most straightforward solution. However, managers should be concerned with the cumulative effect of repeatedly adding to the official trail system.

Trail proliferation also occurs where indiscriminant trail relocation has resulted in numerous closed trails that are not recovering. Trails should not be relocated unless (1) the new section is in a more resistant environment or is better designed, and (2) it is feasible to keep hikers off the old section of trail (Proudman, 1977).

PACKSTOCK DAMAGE

Although only 11% of the parties entering wilderness have packstock and there is no packstock use at all in 25% of the wilderness areas, packstock damage is considered to be a problem in almost half the wilderness areas in the USA (Washburne & Cole, 1983). Packstock use causes added damage to campsites and trails already affected by human use, and also causes unique damage. Of particular concern is damage to meadows where stock graze overnight. In the Eagle Cap Wilderness, such grazing disturbed two to three times the area of all campsites and trails (Cole, 1981). Moreover, the meadows disturbed in this way are scarce ecosystems, suggesting that these impacts are particularly significant as well as widespread.

The wilderness and National Park areas in the Sierra Nevada of California have been greatly affected by packstock use. Here packstock impact has been well documented and restrictively managed for at least 20 years. Here, as in most areas with significant amounts of packstock use, problems resulting from use of recreational packstock are superimposed upon the even more drastic effects of past grazing by sheep or cattle. Although most domestic livestock grazing has been curtailed in the Sierra Nevada National Parks, 42% of all wilderness areas in the United States currently have domestic livestock grazing (Washburne & Cole, 1983).

Alteration resulting from the use of packstock is caused by both trampling and grazing. Trampling of meadows leads to soil compaction, loss of vegetation cover, and shifts in species composition similar to those caused by humans. However, change in species composition and loss of cover are accentuated by the selective grazing of stock. In addition to being an undesirable change in natural conditions, this also results in a lack of palatable forage for recreational stock users and for native wildlife.

A particularly severe problem in Sierra Nevada meadows has been accelerated rill, channel, and gully erosion in response to trampling disturbance of channel banks and the meadow sod itself. This has lowered water tables, drying out the meadows and promoting meadow invasion by trees and weedy herbaceous species (Summer & Leonard, 1947; DeBenedetti & Parsons, 1979).

Most of the meadows in the Sierra Nevada have recovered significantly over the last 20 years as a result of restrictions on stock use, voluntary decreases in stock use, and meadow restoration programs. Bare areas have diminished and weedy, unpalatable species have become less prevalent. Management actions judged effective in reducing stock damage include prohibiting stock use in certain areas, limiting parties to 20 – 25 head of stock and the duration of stay at certain locations to as short as 24 hours, only allowing use after a flexible opening date when soils have started to dry out, and manipulating where the animals graze with drift fences. Off-trail travel with stock is prohibited except where such use is well established. Further, in Sequoia and Kings Canyon National Parks, selected meadows have been closed to grazing to preserve representative examples of all meadow types in as pristine a condition as possible. Common actions in other areas include prohibiting stock confinement near water bodies and requiring stock parties to carry their own feed.

Channel entrenchment and lowering of the water table have been halted by building check dams and planting willow cuttings on collapsing streambanks. Over a dozen Sierra Nevada meadows, with gullies up to as deep as 4·5 meters, have been stabilized in this manner. In the 1960s, crews removed invading trees from meadows by hand, but this practice has been suspended in recent years because it was only temporarily successful (DeBenedetti & Parsons, 1979).

WILDLIFE DISTURBANCE

Disturbance of wildlife is commonly a perceived problem in wilderness areas, particularly those administered by the Fish and Wildlife Service and the National Park Service. Very little monitoring of recreational disturbance of wildlife has been done, however, so the extent of disturbance must be largely conjectural.

Certainly in terms of the potential for significant impact, wildlife disturbance should be a major concern. Hunting is allowed in wilderness areas, outside of the National Parks, and wildlife populations are undoubtedly more sensitive, particularly at low levels of recreational use, than vegetation, soil, or water. Certain management actions such as dispersing visitors from areas of concentrated use to currently unused areas and promoting off-season use may greatly increase wildlife disturbance and lead to widespread changes. The potential for such changes needs to be considered before such actions are taken, and, if initiated, the effects of such actions should be monitored as closely as possible.

Of the wildlife affected by recreation, problems with birds and large nonpredatory mammals are perceived to be most common (Washburne & Cole, 1983). At least from the human point of view, problems with bears are the most serious. The most common management actions for avoiding disturbance are prohibiting overnight use and closing certain sensitive parts of the wilderness to visitation. Such actions are almost entirely confined to areas administered by the Fish and Wildlife Service and the National Park Service. Hunting is generally prohibited in National Parks, and in a few Fish and Wildlife Service areas all recreational use is prohibited.

Less regulatory approaches include educating visitors about problems resulting from wildlife disturbance and discouraging use of sensitive areas. Many areas now warn cross-country skiers against adding to the normal winter stresses on large ungulates, such as deer and elk, by approaching them too closely.

One interesting example of management stems from concern over recreational disturbance of the rare California bighorn sheep in the Sierra Nevada of California. An apparent correlation between increasing numbers of recreational users and a decline in bighorn numbers led to regulations in the early 1970s. Use of one of the major trails entering the bighorn range was limited to 25 hikers per day and off-trail hiking and grazing of packstock were prohibited. In addition, the main trail through the area was no longer identified with a sign or maintained. More recent research indicates that bighorn-human encounters are rare and do not necessarily adversely affect the bighorn population (Hick & Elder, 1979). The main condition under which problems occur is when hikers get above the sheep. Consequently, most of the current management emphasis is on keeping hikers on the trail.

WATER POLLUTION

Managers have been concerned primarily with the health hazard associated with water pollution. Fecal contamination of water certainly occurs, but all studies to date show generally very low levels of bacterial contamination in wilderness, even in areas of concentrated use. For example, at Rae Lakes, one of the most popular alpine lake basins in the Sierra Nevada of California, coliform levels in the water are low enough so the water is usually safe for drinking (Silverman & Erman, 1979). In recent years,however, increasing numbers of wilderness users are being treated for infections caused by *Giardia lamblia*, an intestinal protozoan pathogen. While it is not clear whether contamination is spreading or whether the disease is merely being more frequently diagnosed, it is clear that surface waters in many, if not most, wilderness areas are contaminated with *Giardia*.

However, where level of bacterial contamination has been related to amount of recreational use, there is no evidence that areas receiving more recreational use present higher health hazards than lightly used areas do (Stuart *et al.*, 1971: McDowell, 1979). This suggests that management of recreational use will do little to reduce health hazard. The major management option available is to suggest that visitors purify their water. In addition, visitors to most areas are told how to properly dispose of human waste; toilets of some kind are provided in about one-third of all areas, at least in heavily used locations (Washburne & Cole, 1983).

An unexpected finding of the Rae Lakes study (Silverman & Erman, 1979) was that despite no effect on health hazard, recreational use was associated with changes in the basic ecology of these lakes. Heavily used lakes had more rooted aquatic plants, more benthic macroinvertebrates, more dissolved iron, and less dissolved nitrate than lightly used lakes (Taylor & Erman, 1979, 1980). The authors suggest that recreational use leads to an increase in trace elements, such as iron, that formerly limited plant growth. Growth of plants and macroinvertebrates is stimulated and this increased growth depletes available nitrates. At a lake in a semiwilderness area in Canada, researchers (Dickman & Dorais, 1977) found unusually high phosphorus loadings and increases in phytoplankton that they attributed to increased erosion triggered by human trampling within the lake basin.

Changes of this type have seldom been documented and receive much less management concern than does fecal contamination. However, such changes in lake ecology may be much more pronounced and are more directly related to recreational use. Along with fish stocking and angling, they may represent a particularly significant, largely neglected, impact on aquatic systems, particularly where such ecosystems are rare.

CONCLUSIONS

As with the people problems in the paper by Bob Lucas, we are still in a searching stage in dealing with ecological impact problems. The fact that we have much more to learn is not bothersome; it is exciting. What is bothersome are certain barriers to improved management:

1. There is an inadequate amount of research into the factors that determine degree of impact and how managers can manipulate these factors to minimize impact. As far as I know, I am the only person in the United States working full-time on recreational impacts, despite the fact that 32 million ha have been designated as wilderness. Only a handful of people in the United States are working on the subject at all.

2. More important, managers are doing very little monitoring of wilderness conditions or the effects of their management actions. Consequently, we are missing opportunities to learn about what does and does not work. Further, undesired consequences of management actions often go undetected, time and money are wasted in ineffective actions, and visitors are unnecessarily burdened with regulations.

3. Communication between researchers and managers and among managers is poor. There is very little sharing of common experience, so again there is little opportunity to learn from past experience.

4. Management objectives are seldom clearly defined. In particularly, it is seldom clear when an ecological impact becomes a 'problem' that deserves management attention. Each manager has a different idea of what is and is not a problem. When a wilderness area's management staff changes often, this contributes to inconsistent management.

For management to improve, more explicit problem definition, in the form of specific management objectives, will be an important prerequisite. Such objectives should form the basis for determining where and what management is needed. With an investment in monitoring, research, and improved communication of what does and does not work, management should be more cost-effective, less of a burden on wilderness visitors, and more successful in minimizing ecological impact.

REFERENCES

BAYFIELD, N.G. (1979). Recovery of four montane heath communities on Cairngorm, Scotland, from disturbance by trampling. Biol. Conserv., 15, 165-179.

COLE, D.N. (1981). Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness: some management implications. Biol. Conserv., 20, 247-270.

COLE, D.N. (1982a). Wilderness campsite impacts: effect of amount of use. Ogden, Utah. USDA For. Serv. Res. Pap. INT-284. Intermountain Forest and Range Experiment Station.

COLE, D.N. (1982b). Controlling the spread of campsites at popular wilderness destinations. J. Soil & Water Conserv., 37, 291-295.

COLE, D.N. (1983). Campsite conditions in the Bob Marshall Wilderness, Montana. Ogden, Utah. USDA For. Serv. Res. Pap. INT-312. Intermountain Forest and Range Experiment Station.

COLE, D.N. & FICHTLER, R.K. (1983). Campsite impact and frequency of use in three western wilderness areas. Environ. Manage., 7, 275-288.

COLE, D.N. & B. RANZ, (1983). Temporary campsite closures in the Selway-Bitterroot Wilderness. J. For., 81, 729-732.

DeBENEDETTI, S.H. & PARSONS, D.J. (1979). Mountain meadow management and research in Sequoia and Kings Canyon National Parks: a review and update. In Proc. Conf. on Scientific Research in the National Parks, 1st, USDI National Park Service Trans. & Proc., No. 5 ed. by R.M. Linn, 1305-1311. Washington, DC., Government Printing Office.

DICKMAN, M. & DORAIS, M. (1977). The impact of human trampling on phosphorus loading to a small lake in Gatineau Park, Quebec, Canada. J. Environ. Manage., 5, 335-344.

HICKS, L.L. & ELDER, J.M. (1979). Human disturbance of Sierra Nevada bighorn sheep. J. Wildl. Manage., 43, 909-915.

LaPAGE, W.F. (1967). Some observations on campground trampling and ground cover response. Broomall, Pa. USDA For. Serv. Res. Pap. NE-68. Northeast Forest Experiment Station.

LUCAS, R.C. (1980). Use patterns and visitor characteristics, attitudes and preferences in nine wilderness and other roadless areas. Ogden, Utah. USDA For. Serv. Res. Pap. INT-253. Intermountain Forest and Range Experiment Station.

McDOWELL, T.R. (1979). Geographic variations in water quality and recreational use along the upper Wallowa River and selected tributaries. PhD thesis, Oregon State Univ., Corvallis.

MERRIAM, L.C., Jr. & SMITH, C.K. (1974). Visitor impact on newly developed campsites in the Boundary Waters Canoe Area. J. For., 72, 627-630.

PARSONS, D.J. (1979). The recovery of Bullfrog Lake. Fremontia, 7 (2), 9--13

PROUDMAN, R.D. (1977). AMC field guide to trail building and maintenance. Appalachian Mt. Club.

SILVERMAN, G. & ERMAN, D.C. (1979). Alpine lakes in Kings Canyon National Park, California: baseline conditions and possible effects of visitor use. J. Environ. Manage., 8, 73-87.

STUART, D.G., BISSONNETTE, G.K., GOODRICH, T.D. & WALTER, W.G. (1971). Effects of multiple use on water quality of high-mountain watersheds: biological investigations of mountain streams. Appl. Microb., 22, 1048-1054.

SUMNER, L. & LEONARD, R.M. (1947). Protecting mountain meadows. Sierra Club Bull., 32 (5), 53-69.

TAYLOR, T.P. & ERMAN, D.C. (1979). The response of benthic plants to past levels of human use in high mountain lakes in Kings Canyon National Park, California, USA. J. Environ. Manage., 9, 271-278.

TAYLOR, T.P. & ERMAN, D.C. (1980). The littoral bottom flora of high elevation lakes in Kings Canyon National Park. California Fish & Game, 66, 112-119.

VALE, T.R. (1977). Forest changes in the Warner Mountains, California. Annals Assoc. of Amer. Geogr., 67, 28-45.

VANKAT, J.L. & MAJOR, J. (1978). Vegetation changes in Sequoia National Park, California. J. Biogeogr., 5, 377-402.

WASHBURNE, R.F. & COLE, D.N. (1983). Problems and practices in wilderness management: a survey of managers. Ogden, Utah. USDA For. Serv. Res. Pap. INT-304. Intermountain Forest and Range Experiment Station.

WEAVER, T. & DALE, D. (1978). Trampling effects of hikers, motorcycles, and horses in meadows and forest. J. Appl. Ecol., 15, 451-457.

WILLARD, B.E. & MARR, J.W. (1971). Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biol. Conserv., 3, 181-190.