

# Ecological Impacts of Wilderness Recreation and Their Management

This chapter was written by David N. Cole, research biologist with the Aldo Leopold Wilderness Research Institute, Rocky Mountain Research Station, Forest Service, Missoula, MT.

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## INTRODUCTION

Four parallel trails gouged into a wildflower-dotted alpine meadow, denuded campsites with severe soil erosion, numerous trees battered and scarred by tethered livestock. Such examples of recreational impact are all too common in wilderness these days. In many places, managing such impacts presents at least as difficult a challenge as managing for quality wilderness experiences.

This chapter begins with a discussion of the significance of recreational impacts, its purpose being to bring recreation impacts into perspective with other wilderness management problems. This discussion is followed by a description of important types of recreational impact, those caused by trampling, campfires, construction and maintenance of trails, pack animals, wildlife disturbance, and water pollution and disposal of human waste. The next section describes minimum impact education, the proactive program that should be one of the primary means of preventing ecological impacts in the first place. Most of the chapter deals with impacts associated with campsites, trails, and pack and saddle stock and alternative management responses to impact problems.

The examples used in this chapter are largely drawn from large wildernesses in the West. This reflects the author's experience, as well as the fact that less research has been published on eastern wildernesses. Some examples are taken from developed recreation areas with vehicular access. The general dearth of research on the ecological effects of wilderness recreation leaves many of the interpretations offered open to debate. Study locations are noted in the text; caution should be exercised when extrapolating the results of a single study to distant areas. Recent textbooks on recreation ecology have been written by Liddle (1997) and Hammitt and Cole (1998).

## SIGNIFICANCE OF RECREATIONAL IMPACTS

To evaluate the significance of recreational impacts in wilderness areas, it is important to reexamine the goals of wilderness management. The relevant phrases in the Wilderness Act state 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). This implies that some recreational impact will be tolerated, but (1) the integrity of relatively undisturbed wilderness ecosystems should not be substantially compromised and (2) the evidence of impact should not be conspicuous. The first of these objectives is concerned with protecting wilderness ecology; the second, with protecting quality of the visitor’s experience. Both are important.

What constitutes a substantial compromise of ecosystem integrity? There is no clear answer to this question. I suggest that the most significant impacts are those that seriously disrupt ecosystem composition, structure and function and that are evident at large spatial scales. Impacts that alter a large proportion of a relatively rare ecosystem type are particularly detrimental. Irreversible changes are most undesirable, but where impact occurs repeatedly, even easily reversible changes are significant.

The ecological impacts of recreation are severe. The composition, structure and function of sites that are used for recreation are often nearly completely altered. At the site scale, then, recreation impacts are as profound as any human threat to wilderness. However, these impacts are highly localized. Recreational use is highly concentrated along a few major trails and at a few popular destinations. This leaves the vast majority of most wildernesses essentially unvisited and, therefore, virtually undisturbed by recreational use. For example, even in the most heavily used part of the Eagle Cap Wilderness, Oregon, less than 2 percent of the area has been significantly altered by

recreational use (Cole 1981). Marion and Leung (1997) estimate that only .05% of the backcountry at Great Smoky Mountains National Park has been directly disturbed by recreation use. At large scales, then—from the perspective of landscapes, watersheds and regions—recreation impacts are generally not severe. At these scales, far more potent threats to the integrity of wilderness ecosystems exist. Acid rain is altering the basic ecology of lakes throughout uncommon ecosystems in certain areas. A New York State “wilderness” in the Adirondack Mountains, provides an example of an area substantially affected by acid rain. In addition to external threats, such as acid rain, internal threats can also be potent. The impacts of fire suppression and livestock grazing, though less severe than recreation at the site scale, are expressed over vast wilderness acreages (Cole and Landres 1996).

Generally, then, recreation use, while causing locally severe impact, does not substantially compromising wilderness landscapes. There are several important exceptions to this generalization, however. The first exception is the introduction of fish, often exotic species, into formerly barren lakes and streams and the subsequent removal of fish through angling. In such cases adding a new component to the food chain has significantly affected entire aquatic ecosystems. It has reduced, displaced, or eliminated competitors or prey organisms and has stimulated the invasion or expansion of predatory populations. Fish stocking has been implicated as one of the reasons for the decline in amphibian populations in the wilderness of the Sierra Nevada, for example (Knapp and Matthews 2000). Angling, while partially negating the effect of introductions, has altered the population structure of fisheries and, in extreme cases, has nearly eliminated a major consumer and link in the food chain (fig. 16.1).

Generally, fishing is allowed throughout wilderness. In a few cases, angling pressure is attenuated by “catch-and-release” regulations. Such regulations are in effect in parts of the Frank Church-River of No Return Wilderness, Idaho, and the Golden Trout

Wilderness, California, for example. But wilderness designation seldom brings such restrictions. A more common action is discontinuing of artificial stocking of fish. This will allow some formerly barren areas, where reproduction is poor, to revert to a more natural state.

A second recreational impact that can be significant at large spatial scales is disturbance of wildlife as a result of hunting or unintentional harassment. Hunting is generally allowed in wildernesses, outside of the national parks. Although long-lasting effects are difficult to document, unintentional disturbance has undoubtedly altered the distribution, population structure, and behavior of many wildlife species.

Finally, less common, but also significant, is physical alteration or pollution of uncommon ecosystems or sites inhabited by rare plants or animals. Disturbance of such places can lead to the elimination of rare species or the alteration of most examples of certain ecosystem types. Pollution of lakes, disturbance of meadows by packstock, and camping impacts along desert riparian strips are examples of such impacts that occur in certain wildernesses.

The effect of human impact on visitors, in contrast, is most significant when it is apparent at the site scale—the scale most relevant to human life and interaction with the natural environment. Consequently, recreational use—because it severely impacts ecosystems at the site scale-- commonly compromises the goal of avoiding conspicuous evidence of human impact. The importance of such impacts depends on the visitor's sense of aesthetics and sensitivity to change, whether or not the change is recreationally desirable, and the magnitude of the change. Thus, trail impacts in meadows are more troublesome than impacts in forests because they are more obvious and aesthetically displeasing, even though the amount of change in meadows may be less than in forests. Felling of trees and cutting of brush may be desirable and appropriate on trails where it makes travel easier but undesirable and inappropriate elsewhere.

Few studies of visitor perceptions of impact show much relationship between visitor satisfaction and amount of impact. Visitors consistently report that recreation impact—*if it occurred*—would adversely affect their wilderness experience (Roggenbuck and others 1993). However, many visitors do not notice ecological impacts that have occurred. Of those who do notice impact, many do not conceive of these impacts as “damage”--or undesirable change. Finally, most visitors do not change their behavior or have less satisfactory experiences even when confronted by impacts that they consider undesirable. For example, even those who dislike the heavy evidence of horse use in the Bob Marshall Wilderness are likely to continue to camp in the same places and travel the same trails and, on the whole, enjoy it. This suggests that while most wilderness visitors do not like the “idea” of recreation impact, few visitors are bothered much by even relatively high degrees of alteration.

In dramatic contrast, site impacts are the foremost concern of many managers (Godin and Leonard 1979, Marion and others 1993). Managers are often well aware of such impacts and are charged, as managers, to effectively deal with them. They have been charged with this management responsibility despite the common indifference of visitors to the impacts that occur around them. Most of the discussion that follows deals more with management to avoid conspicuous evidence of human use than with management to maintain ecosystem integrity.

## RECREATIONAL ACTIVITIES AND ASSOCIATED IMPACTS

Now that we have examined the significance of recreational impacts in light of wilderness management goals, we will take a more detailed look at the effects of various recreational activities on the wilderness resource.

### TRAMPLING

The old adage to “take nothing but pictures and leave nothing but footprints” is outdated. In many places, too many footprints have left an unwanted legacy. The effects of human trampling have been investigated for more than 80 years, and we now have a clear understanding of many of the general effects of trampling. These can be conveniently displayed in a conceptual model (fig. 16.2).

*Trampling* has three initial effects: abrasion of vegetation, abrasion of surface soil organic layers, and compaction of soils. Plants can be crushed, sheared off, bruised, and even uprooted by recreational trampling. Although several studies have shown that very light amounts of trampling can stimulate growth (e.g., Bayfield 1971), any consistent trampling is likely to reduce the vigor and reproductive capacity of all but the most resistant species.

Studies have revealed a variety of physiological and morphological changes that occur when vegetation is trampled. Changes include reductions in plant height, stem length, and leaf area, as well as in number of plants that flower, number of flower heads per plant, and seed production (Liddle 1997). In Glacier National Park, Montana, Hartley (1999) found reduced carbohydrate reserves in the roots of trampled glacier lilies, presumably a response to a reduction in the ability to photosynthesize after trampling. All of these changes are manifested in reduced vigor and reproduction, leading to less plant biomass and cover. Thus, most recreation sites exhibit a gradient in

which the cover of vegetation decreases from undisturbed vegetation to places where trampling stress is concentrated and no cover survives. The sharpness of this gradient depends on both the fragility of the vegetation and whether the trampling is concentrated or dispersed. For example, the gradient from no vegetation to normal cover levels is very narrow along trails, where trampling is concentrated, particularly those through fragile vegetation, and quite wide on campsites, where trampling is dispersed, particularly those in resistant vegetation.

Plants vary in their ability to tolerate trampling. Some plants are even favored by trampling--not as a direct response to abrasion, but in response to reduced competition with other plants and favorable changes in microclimate that result from trampling. For example, trampling often increases light levels and temperature ranges--changes that favor certain species. Many, if not most, of these favored species are introduced plants that are brought into the wilderness by humans and packstock.

The vegetation that grows in areas of moderate disturbance, then, is very different in composition from undisturbed vegetation. It consists of trampling-tolerant survivors as well as either native or nonnative invaders capable of growing in the local environment and dispersing to the site. Which of these types of plants dominates is highly variable. In the Eagle Cap Wilderness, dandelion, a Eurasian weed, is the most common plant on lower elevation campsites. Apparently it cannot tolerate conditions on campsites in subalpine forests, where the most common plants are native rushes and sedges that were originally on the site and that survive trampling, although at reduced densities (Cole 1982a). Non-native invasive species are more problematic on low elevation recreation sites (Marion and others 1986).

The tendency for the original site occupants to decrease in density, creating more favorable conditions for new invaders, explains the observation that *species richness*--the number of different species occupying the site--often increases with low to moderate levels of trampling before declining to zero as trampling intensifies (Liddle 1997).

Knowledge of which species and types of plants are most tolerant of trampling can be useful in locating sites with resistant vegetation types. Morphological characteristics that generally make a plant more tolerant (Cole 1987) include:

1. A procumbent or trailing, rather than erect, growth form.
2. A tufted growth form.
3. Arming with thorns or prickles.
4. Stems that are flexible rather than brittle and rigid, particularly if they are woody.
5. Leaves in a basal rosette or cluster.
6. Small, thick leaves.
7. Flexible leaves that can fold under pressure.
8. Either very large or very small structure.

Physiological characteristics that increase tolerance include:

1. Ability to initiate growth from intercalary meristems, located at the base of leaves, as well as from apical meristems at the tips of stems and branches, where they are likely to be damaged.

2. Ability for perennials to initiate seasonal regrowth from buds concealed at or preferably below the soil surface.
3. The ability to reproduce vegetatively from suckers, stolons, rhizomes, or corms, as well as through seeding.
4. A rapid rate of growth.
5. Ability to reproduce during a time when recreational use is low.

Generally, broad-leaved herbs, lichens, low shrubs and tree seedlings have little tolerance and are quickly eliminated on recreation sites. Elimination of tree seedlings on forested recreation sites portends major, undesirable changes on these sites once the overstory dies. Established trees, because of their size, are little affected by trampling except in the few cases where studies have found reduced growth rates (Brown and others 1977), increased water stress (Settergren and Cole 1970), and damage to root systems and increased windthrow as a result of erosion (Frissell and Duncan 1965).

Cole (1995a) has shown, for groundcover plants, that the ability to resist trampling (*resistance*) decreases with erectness and that broad-leaved herbs are less resistant than grasslike plants and shrubs. Herbs growing in shade are particularly intolerant of trampling because *adaptations to shading*--possession of large, thin leaves and tall stems--make these plants vulnerable when trampled. This explains the common finding that trampling of forested sites generally results in more rapid loss of vegetation than trampling of open woodlands or meadows (Cole 1993a). Low shrubs, such as heather, are relatively resistant to trampling stress but once damaged they recover slowly. Their *resilience* is low. Grasslike plants are most tolerant of trampling.

Although their size spares them from most trampling damage, large shrubs and trees are affected by a number of associated recreational activities. Vegetation removal during trail construction and for firewood will be discussed below. Trees may be felled for

tentpoles, hitch rails, or other structures, and shrubs and trees may be removed to create additional tent space. They are also subjected to *deliberate mutilation*--carved initials and ax scars. In contrast to most species, aspen usually dies from these surface injuries, suggesting that aspen groves make poor recreation sites (Hinds 1976).

Normally, less than half of a given volume of soil is solid matter; the rest is pore space that contains air and water. Trampling *compacts the soil*--presses together the solid soil particles, filling or compressing many of the pores. Larger pores--those that permit rapid percolation of water after precipitation and are normally occupied by air--are severely reduced by trampling (Monti and Mackintosh 1979). This can indirectly affect vegetation and soil microbiota (fig. 16.3). It can cause oxygen shortages and reduce water availability. Along with the greater difficulty plant roots have in moving through compacted soils, these changes generally reduce plant vigor and retard reproduction and establishment of seedlings.

Increases in *bulk density*--the weight of soil packed into a given volume--as high as 170 percent have been recorded on backcountry campsites in Sequoia National Park, California (Stohlgren and Parson 1986). But increases are more commonly 30 percent or less. A loss of 60 percent of the larger soil pores was recorded on developed campsites in Ontario (Monti and Mackintosh 1979). Compaction is generally most pronounced in the upper 6 inches of soil. Generally, susceptibility to compaction is least where soils are sandy or have a narrow range of particle sizes, and where trampling occurs when soils are dry (Lull 1959).

In addition to effects on aboveground vegetation, compaction will also affect soil biota. Larger organisms, such as earthworms, that help rejuvenate the soil find it more difficult to penetrate dense soils. Microbiota are likely to be adversely affected by lower oxygen concentrations. Of particular concern are adverse effects on mycorrhizal fungi, which improve nutrient uptake and water absorption in

plants and may be a limiting factor in revegetating disturbed areas (Reeves and others 1979). Perhaps of even more importance, compaction drastically reduces the rate at which water filters into the soil. Several studies have reported infiltration rates cut by more than 95 percent on developed campsites (Brown and others 1977). Water that does not filter into the soil runs off across the surface. Greater runoff increases erosion potential and decreases the supply of soil water. Although this reduced water supply is unlikely to be a problem in areas with plentiful rainfall, it is likely to increase water stress in arid environments or during dry periods of the year (Settergren and Cole 1970).

Erosion is likely to be a more common and significant problem. Deeply eroded trails are unsightly and difficult to use. Erosion on campsites and other sites of concentrated use, by removing the most productive soils on the site, diminishes the potential for vegetational growth on the site. Moreover, the formation of soil is such a slow process that erosion can be considered an irreversible process.

Abrasion and loss of organic matter exacerbates many of these same problems. Normally, thick organic horizons protect the mineral soil from much of the direct impact of trampling and decrease surface water runoff. Loss of these layers facilitates increased compaction and runoff. This leads to further loss of organic litter carried off by running water, completing what Manning (1979) has called the “*vicious circle*” of soil impact. On canoe-accessible campsites along the Delaware River, in Pennsylvania and New Jersey, organic soil horizons were only one-third as thick as on undisturbed sites (Marion and Cole 1996).

Loss of litter directly affects plant and animal populations, both above and below the soil surface. For example, vegetation composition is likely to shift as plants that germinate best on organic media give way to those that are more successful on bare mineral

soil. Seeds of most species are unlikely to germinate on a smooth, compacted soil surface devoid of litter without a variety of microenvironments.

Soil biota are a little-studied but important component of ecosystems. Microbial communities develop in response to plant exudates and organic matter. In turn, they contribute to ecosystem functioning by metabolizing nutrients, transforming soil organic matter, producing phytohormones and contributing to soil food webs. Soil biota are affected by many of the types of impact just described. As soils are compacted, biota requiring larger pores to live in will be eliminated. Populations will decline and shift in composition as primary energy sources—aboveground plants and soil organic matter—are eliminated. Zabinski and Gannon (1997) report substantial reductions in the functional diversity of microbial populations on a backcountry campsite in Montana.

## CAMPFIRES

Collecting and burning wood in campfires results in its own special impacts (fig. 16.4). As with trampling, these impacts are both aesthetic (firerings, blackened rocks, and charcoal) and ecologic (felled trees and sterilized soils). Ecological impacts result from both the removal of wood, either live or dead, standing or on the ground, from large areas around the campsite, and the burning of this wood in campfires (Cole and Dalle-Molle 1982).

The removal of firewood and associated trampling greatly enlarge the area affected by camping activities. In Great Smoky Mountains National Park in Tennessee and North Carolina, the area disturbed by firewood collection was typically more than nine times the size of the devegetated area around campsites. In this much larger area, number of live and dead trees, usually the smaller size classes,

were reduced, as were woody fuels. Pieces of wood 1 to 3 inches in diameter were barely one-third as abundant as on neighboring undisturbed sites (Bratton and others 1982). Around backcountry campsites in Yellowstone National Park, Taylor (1997) reports that the density of tree saplings is typically reduced until a distance of 45 m from the center of the campsite is reached. Because leaves, needles, and twigs--the tree components most critical to nutrient cycling--are little affected by firewood collection, removing downed wood need not adversely affect long-term site productivity. The major source of damage is likely to be the elimination of large (more than three-inch diameter) woody debris. Decaying wood of this size plays an important role in the ecosystem that has only recently been appreciated (Maser and others 1988). It has an unusually high water-holding capacity, accumulates nitrogen, phosphorus, and sometimes calcium and magnesium, and is a significant site for nitrogen-fixing microorganisms. It is the preferred substrate for seedling establishment and subsequent growth of certain species. Of particular importance, *ectomycorrhizal fungi*--organisms that develop a symbiotic association with the roots of most higher plants, improving the plants' ability to extract water, nitrogen, and phosphate from less fertile soils--are also concentrated in decayed wood. Consequently, although collection of smaller pieces of wood is unlikely to cause adverse impacts, elimination of large woody debris is likely to reduce site productivity, particularly on droughty and infertile soils.

Loss of large woody debris is likely to adversely affect the populations of invertebrates, small mammals, and birds that use the wood as a food source or living place (Bull and others 1997). It eliminates sites protected from trampling where seedlings can regenerate and removes natural dams that decrease the potential for soil erosion. Clearly, loss of large woody debris due to firewood collection is a serious impact where a sizable area is affected; recovery rates, moreover, are likely to be lengthy. Collection of wood that can be broken by hand is likely to have little effect.

A wood campfire severely affects the area burned. Fenn and others (1976) found that a single intense campfire burned 90 percent of the organic matter in the upper inch of soil. Fires cause pronounced changes in soil chemistry. Reported fire effects include the loss of nitrogen, sulfur, and phosphorus, increases in pH and many cations, and reductions in the moisture-holding capacity, infiltration rates, and microbotic populations of soil. Overall, these changes constitute a sterilization of the soil, likely to render the site less hospitable for the growth of vegetation and likely to require at least 10 to 15 years to recover, particularly if the site has been used for some time (Cole and Dalle-Molle 1982). Such impacts are particularly pronounced where fires have been built in several places on a single campsite.

Other problems result from carelessness with campfires. Escaped campfires have burned thousands of acres. More common is the destruction of small vegetational coppices by creeping root fires. This has been a serious problem in subalpine tree clumps in the mountains of the Southwest. Here, such clumps are very beautiful, are valued highly as campsites, and regenerate very slowly, if at all.

Although more research will be necessary before we understand the significance of firewood collection and burning, the preceding review suggests some important means of minimizing impact. *With firewood collection, the key is not disturbing woody debris larger than about 3 inches in diameter.* The firewood collection problem can be minimized by teaching visitors to collect only wood they can break by hand. In fact, if campers would leave their axes and saws at home many impacts--loss of large woody debris, scarring, and felling of trees--would be eliminated. It may also be necessary to prohibit or discourage campfires, or to promote the use of small stoves in areas where wood production is low. If use in such areas is high, firewood will quickly disappear, tempting visitors to use the larger pieces. In fact, campfires should probably be discouraged or prohibited wherever use is very high--regardless of site productivity--to avoid adverse impacts. As of 1991, about one-half of National Park Service backcountry areas prohibited campfires, at least in some

places (Marion and others 1993). This prohibition was most common in areas with little firewood--arid, arctic, and alpine regions. Many areas prohibit fires in zones of low productivity, such as the whitebark pine forest, at high elevations in the Sierra Nevada. Such a prohibition at high elevations would also reduce the destruction of tree coppices by escaped campfires.

*Minimizing campfire impacts* is more complex, involving *a choice between either confining impacts to a small total area of concentrated use or dispersing and covering up evidence of use*. Generally, in heavily used areas, campers should be encouraged to use established firerings so that only a small amount of ground is severely altered. This requires leaving a firering at well-used sites, encouraging campers to use these sites, and keeping them clean and attractive. In areas that are not used frequently, it might be better to persuade visitors to use undamaged sites, to build small, less-damaging fires, and to camouflage the site when they leave to discourage repeated use of the site and, through the addition of organic matter, initiate recovery of the site. In this case campers must be willing to select undisturbed sites and be able to leave the site looking undisturbed. The worst situation is allowing firerings to move around a site, continually being rebuilt after being removed by rangers or earlier campers, and allowing many fire sites to proliferate at popular destinations. Unfortunately, this situation is all too common. Further discussion of the pros and cons of dispersal and concentration can be found in the section on campsite management in this chapter and in Cole and Dalle-Molle (1982).

## TRAIL CONSTRUCTION AND MAINTENANCE

The construction and maintenance of trails have pronounced effects on vegetation and soil. Although these impacts are usually deliberate and considered necessary to provide recreational opportunities and to manage visitor traffic, their impacts, as with all others, should be kept to a minimum.

*The major impacts of trail construction and maintenance stem from the opening up of tree and brush canopies, the building of a barren, compacted trail tread that may alter drainage patterns, and the creation of a variety of new habitats in the process.* Forest Service (FS) standards for maximum clearing widths and heights range from 4 by 8 feet on hiker trails to 8 by 10 feet on trails for stock. This clearance increases light intensity considerably and reduces competition for species that can survive along the trail. These changes can alter the composition of vegetation substantially (Hall and Kuss 1989). Composition along trails also shifts in response to increased trampling and grazing, increased nitrogen from manure and urine, and increased moisture, the result of having fewer trees to intercept precipitation, fewer plants to transpire, and more watershed along the sides of the compacted trail tread. Trail corridors can contribute to the rate of spread of exotic plant species, as has been reported for Glacier National Park, Montana (Tyser and Worley 1992) and Rocky Mountain National Park, Colorado (Benninger-Truax and others 1992).

The creation of a bare compacted trail tread and a narrow zone of disturbed vegetation on either side is a dramatic change, but is usually accepted by visitors. The dramatic changes are confined to a zone usually no more than 8 feet wide, although in meadows compositional changes have been noted more than 20 feet from the center of the trail (Cole 1979; Foin and others 1977). Probably more disturbing are sites, usually boggy areas, where the disturbed, barren tread widens, greatly exceeding the FS maximum tread width

standard of 24 inches. This change is caused by use--not construction--although poor location and design during construction may have initiated the problem.

Trail construction can also create new habitat by other means. Examples include creation or elimination of rock faces where trails traverse rock outcrops; creation of debris slopes where boulders are pushed downslope to build the trail; creation of flat, soil-covered surfaces where trails traverse steep talus slopes; and creation of boggy areas where trails impede normal drainages. Again, these changes do not affect large areas and are generally considered to be acceptable; however, they should be recognized as undesirable and kept to a minimum.

Perhaps the two most serious changes are disruptions of drainage systems and aesthetic problems resulting from obtrusive engineering of trails. Unfortunately, the solution to one of these problems is likely to aggravate the other. That is, designs to solve drainage problems may be perceived as overengineering, while lack of engineering may lead to drainage problems. This trade-off will be discussed in more detail in the trail management section of this chapter. The solution demands a careful balance--enough engineering to avoid disturbing drainage while remaining sensitive to building trails that blend into the natural environment (fig. 16.5). In each situation, those who construct trails will have to evaluate which is more “natural” and appropriate--a high-standard trail that avoids off-trail disturbance or a low-standard trail that risks the possibility of more resource damage and a less comfortable walking surface.

## GRAZING OF RECREATIONAL PACKSTOCK

Pack and saddle stock trample vegetation and soil along trails and on campsites, as hikers do, leading to the changes noted in the section on trampling impact. Differences between stock and hiker impact will be summarized in the section of this chapter on packstock management. Here we will outline changes occurring on areas grazed by recreational packstock--meadows and grasslands that are generally unaffected by hikers.

Grazing areas are affected primarily by trampling and grazing, although defecation may also cause minor changes (fig. 16-6). Grazing, by removing leaves, disrupts the ability of plants to manufacture food. Excessive and repetitive defoliation depletes food reserves, reducing plant vigor and reproductive capacity. Numerous studies have illustrated that grazing can reduce current growth; stem, leaf, and seed stalk heights; reproductive activity; basal and foliar cover; and root growth (see McClaran and Cole 1993). Loss of vigor, in turn, makes vegetation more susceptible to trampling damage, particularly penetration of the vegetative mat by stock hooves, and results in a reduction in cover.

Trampling causes changes in vegetation and soil conditions, as described earlier. Of particular concern in grazing areas is disturbance of wet meadows. Wet soils, thick organic deposits, and vegetation mats are all susceptible to deformation and disintegration when trampled. Heavy trampling of such sites can lead to a surface of broken sod and hummocks, increased erosion, and even lowering of water tables. In Kings Canyon National Park, California, disturbance by recreational stock, superimposed on the earlier effects of sheep and cattle grazing, led to accelerated rill, channel, and gully erosion of meadows. Gullies up to 14 feet deep lowered water tables and

dried out meadows, promoting invasion of lodgepole pine, before being stabilized through improved meadow management and grazing programs (DeBenedetti and Parsons 1979).

Plants differ in their susceptibility to grazing, much as they differ in susceptibility to trampling. Those capable of growing from buds close to or under the ground are more likely to survive close grazing than those with buds located where they can be removed by grazing. Of even more importance, plants are preferentially grazed so that the least palatable species are most likely to survive grazing. Olson-Rutz and others (1996a,b) report short-term effects of a packstock grazing experiment, including preferential grazing of grasses, decreasing vegetal cover and reduced subsequent year production of grass and forb stems. All of these selective forces, along with the introduction of exotic species in manure, coats, hooves, and supplemental feed, contribute to pronounced changes in species composition and reductions in forage. In the Eagle Cap Wilderness, montane valley-bottom meadows grazed by stock had only about two-thirds the vegetational cover of nearby ungrazed meadows. The grazed meadows were dominated by forbs and had a sizable component of annual and exotic species, while the ungrazed meadows were dominated by native grasses and sedges (Cole 1981).

Because it reduces available forage, stock grazing may adversely affect wildlife populations that use the same forage resource. For such competition to occur, there must be overlap in the diets of the stock and wildlife species and they must be using the same meadows. Of the important ungulates in wilderness areas, competition with elk is most likely. Elk and horses have similar diets (Hansen and Clark 1977), and elk commonly use popular grazing areas as winter range. Unpublished range studies in the Bob Marshall Wilderness, found that recreational stock grazing has caused deterioration of forage areas that are used by elk in winter. Competition with bighorn sheep and mountain goats is also possible, but winter range of these species is probably less accessible to livestock.

## WILDLIFE DISTURBANCE

Recreational activities can impact animals in four different ways (Knight and Cole 1995a). Animals can be indirectly affected through habitat modification or through pollution (particularly through leaving trash). They can be directly affected through exploitation--hunting, fishing, trapping or collecting. Finally, they can be directly disturbed--either intentionally or unintentionally. We know most about the short-term responses of individuals to disturbance--nest abandonment, elevated heart rates or flight. We know little about how entire populations or communities of animals are affected or about long-lasting effects.

Firewood collection can affect small mammal and bird populations by altering food sources and living places and eliminating protected sites (Cole and Landres 1995). Similar modifications of habitat are also likely to affect reptile and amphibian populations. Organic trash around campsites also attracts animals, ranging from invertebrates to small rodents, certain birds, and large mammals, such as bears. Blakesley and Reese (1988), for example, found seven bird species to be positively associated with campgrounds and seven species to be negatively associated.

Although habitat modification and improper disposal of trash are the major source of impact for smaller wildlife species, most of these changes are highly localized and, with the exception of the attraction of "pest" species to campsites, not evident to most users. Change becomes highly significant only where a species' entire habitat is disturbed or where the "pest" is a bear. Improper food storage and disposal has frequently been implicated as a causal factor in a chain of events that ultimately ends in the death of bears. Consequently, appropriate food storage procedures and/or devices have been implemented in many backcountry areas.

Perhaps of more widespread significance to the achievement of wilderness management goals are the changes resulting from stocking fish, angling, hunting, and unintentionally harassing wildlife. As noted earlier, hunting outside of national parks and angling are accepted practices that are likely to continue in wilderness, despite their considerable alteration of natural conditions (Anderson 1995). Fish stocking, which has been shown to adversely affect amphibian populations (Knapp and Matthews 2000), occurred in more than 40 percent of all wildernesses according to a survey conducted in 1980 (Washburne and Cole 1983). This practice has been discontinued in some wildernesses, however.

Although poorly understood, unintentional harassment, particularly of birds and large mammals, has undoubtedly altered the distribution, structure, and behavior of animal populations (Knight and Cole 1995a). Where harassment affects an entire population (as is likely to be the case with grizzly bear or hunted, localized populations of bighorn sheep and mountain goat) or affects most of a species' habitat, this disturbance is probably much more disruptive to wilderness ecosystems than many of the impacts we have been discussing, such as effects of trampling on trails and campsites. Harassment of wildlife by recreationists produces excitement or stress in animals. This may lead to panic, exertion, disruption of essential functions such as breeding or nesting, displacement to other areas, and sometimes death. Animals that are healthy and have ample food and places to escape to are more capable of withstanding harassment than animals that are underfed, highly parasitized, experiencing severe weather, giving birth or nesting, or lacking secure areas for escape. Damage to animals--in terms of increased energy expenditures or radical changes in behavior or distribution--also increases as disturbance becomes more frequent and more unpredictable (Knight and Cole 1995b).

Generalizing about harassment is made more difficult by the considerable variability between and within species. Effects on wolves, which are relatively intolerant of disturbance, are much more serious than effects on coyotes. Similarly, effects on eagles, which may not return to feeding sites for several hours after disturbance (Stalmaster and Newman 1978), are more serious than effects on jays. Within species, prior experience with humans strongly tempers responses. Some individuals can learn to tolerate at least predictable disturbances (Knight and Temple 1995). Differences between hunted and nonhunted populations can also be profound, because hunted animals have experienced a need to escape. Individuals giving birth or with young are more readily disturbed than others.

Disturbance of several subspecies of bighorn sheep has been widely studied, primarily in California and Canada. Although a number of these studies have implicated harassment as a cause of declining sheep populations, most recent work suggests that sheep can habituate to human intrusion. One Canadian study monitored heart rates and behavioral responses to disturbance. While largely unaffected by foot traffic approaching from a road below, sheep responded dramatically to the presence of dogs and foot traffic approaching from upslope (an unexpected action that blocks their preferred escape route). The authors conclude that recreational disturbance can be minimized by confining use to established trail systems and discouraging people from taking dogs (MacArthur and others 1982).

Several trends may greatly increase wildlife disturbance. First is the popularity of attempting to disperse visitors from popular parts of the wilderness to less visited places. Such dispersal occurs when use levels are limited in popular places, forcing visitors to seek out less popular places. It can also result from educational messages asking visitors to avoid popular places or to seek out places where opportunities for solitude are greater. Where increased dispersal occurs, the frequency of wildlife harassment may increase and the size of

secure areas where harassed animals can escape may decrease. Any attempt to alter visitor use distributions should consider the consequences to wildlife.

The second trend is toward increased off-season use. Cross-country skiing, in particular, can stress populations at a time of year when they are least able to tolerate it (fig. 16.7). Cassirer and others (1992) documented disturbance of elk by cross-country skiers in Yellowstone National Park. Ferguson and Keith (1982) have documented a tendency for elk and moose to move away from trails being used by skiers. Significantly they found that a single skier usually caused the animals to flee; the passage of additional skiers was irrelevant. Therefore, a few large parties are likely to cause less disturbance than many widely dispersed small parties. Although little is known about the consequences of such disturbance to reproduction or survival, we do know that flight increases the necessary caloric intake of these animals. Some ungulates adapt to winter conditions by decreasing activity to conserve energy (Moen 1976). Disturbance interferes with this adaptation and may increase food demand beyond the supply provided by winter range. Clearly the severity of such an effect would vary from year to year and from place to place; only through increased monitoring of wildlife populations in relation to disturbance will we be able to ascertain how serious problems are. Nevertheless, many managers are currently educating winter users about the threats posed by harassment and the need to avoid animals.

Other significant problems occur when use is concentrated on limited critical habitat. Use does not need to coincide with the presence of animals. For example, summer grazing by packstock reduces available food sources on critical elk winter range. Recreational use around desert waterholes and salt licks can also cause more substantial problems than one would expect from total use. Managers should identify habitat critical to wildlife at various seasons and develop plans for minimizing disturbance.

Three general approaches to *minimizing problems with wildlife disturbance* can be identified. Of foremost importance in wilderness is *management of people*. Access can be limited, as where overnight use is prohibited or where sensitive places are closed to all visitation--actions that currently are almost entirely confined to Fish and Wildlife Service (FWS) and National Park Service (NPS) wildernesses. Alternatively access can be restricted at certain critical times of the year, such as feeding times, nesting times for birds and postnatal periods for mammals. There is also considerable potential to educating users about avoiding wildlife conflict. One of the primary principles of the Leave-No-Trace educational program is "Respect Wildlife".

The other potential strategies involve modification of wildlife behavior and habitats. *Behavioral modification*--habituation to predictable, harmless human activity--is useful where hunting is not allowed. For example, aversive training of "problem" bears has been tried. This can be used to attenuate reactions to human disturbance, although the appropriateness of such an approach must be questioned (Whittaker and Knight 1998). Finally, *habitats can be modified* to change population distributions or to mitigate disturbance, although the appropriateness of such actions in wilderness must be questioned.

## WATER POLLUTION AND DISPOSAL OF HUMAN WASTE

Most management concern with water pollution has centered on the potential for transmission of disease by organisms present in water. Many different organisms are capable of causing illness in humans (Cilimburg and others 2000). *Three prominent sources of water contamination are: (1) the recreational user, his dogs, and packstock; (2) domestic livestock; and (3) wildlife*. Even where animal contamination is absent, bacteria and other pathogens can be found in the soil, forest floor, and stream sediment (Silsbee and Larson

1982). Therefore, even so-called pristine areas receiving almost no recreational use at all can harbor organisms that are harmful to humans.

Water quality studies in mountainous wilderness in the West have generally found very low levels of bacterial contamination, even in areas of concentrated use. For example, at Rae Lakes, one of the most popular alpine lake basins in Kings Canyon National Park, coliform bacteria counts were usually low enough to allow drinking (Silverman and Erman 1979). Along the Colorado River, in Grand Canyon National Park, Arizona, water was unfit for drinking but coliform levels were generally low except when major tributary streams were in flood (Brickler and others 1983). Here the primary source of contamination appeared to be domestic livestock or wildlife. Springs and streams in Great Smoky Mountains National Park also exceeded maximum permissible levels of coliform bacteria. Again, contamination did not appear related to recreational use (Silsbee and Larson 1982).

Even where contamination is not evident, transmission of disease does occur. Most common is giardiasis, an intestinal disease caused by the protozoan, *Giardia* sp. Although it is not clear whether contamination is spreading or whether the disease is being more frequently and accurately diagnosed, it is clear that surface waters in many, if not most, wildernesses are contaminated with *Giardia* (Cilimburg and others 2000). As with bacterial contamination, most (but not all) experts believe that humans, domestic animals, and wildlife all act as hosts capable of spreading the organism. Beaver have most frequently been implicated as the major source of *Giardia* contamination.

Where level of contamination has been related to amount of recreational use, it is not clear whether areas receiving more recreational use present higher health hazards than lightly used areas do (Cilimburg and others 2000). In fact, one study of used and

unused watersheds in Montana found less contamination in the watershed open to recreational use and a decrease in contamination after the closed watershed was opened to use (Stuart and others 1971). The authors concluded that the primary source of contamination was wildlife and wildlife populations and, therefore, contamination was reduced by recreational use. In an unpublished study in the Anaconda-Pintler Wilderness, Montana, elevated bacterial counts were most often found just downstream from trail crossings used by horses and pack animals. In the Eagle Cap Wilderness, contamination levels were higher in streams, particularly at midelevations in meadows, than in lakes; and coliform counts generally peaked along with runoff after a storm (McDowell 1979).

All of this suggests that management of recreational use is likely to do little to reduce health hazards. The most important management action is informing visitors about the prevalence of contamination and the need to treat water. In Great Smoky Mountains National Park, the NPS removed more than 100 spigot pipes at backcountry springs, to erase the impression that such water was safe to drink. Instead, through trail signs, brochures, and direct visitor contact (Silsbee and Larson 1982) visitors are advised to treat water. Treatment is particularly important when using turbid water after a storm; water should be taken above rather than below trail crossings.

Proper control of waste, both from humans and recreational stock, is also important, although this will not eliminate health hazards. Toilets may be appropriate at sites that receive heavy, consistent use throughout the season. However, knowledge is insufficient to provide specific guidance about when toilets are or are not necessary. Where provided, toilets must be sensitively located by managers, because their presence--especially when accompanied by a direction sign saying toilet--is a reminder of civilization and may not be consistent with the spirit of wilderness.

Where soil is available and use levels are not too high, disposal of human waste in individual “cat-holes” is recommended. Even this practice poses problems, however. Research in Montana’s Bridger Range has shown that significant numbers of intestinal pathogens in feces survived an entire year of burial (Temple and others 1982). Statements that nature will take care of wastes “in a few days” are misleading and may promote careless disposal. This research shows that the possibility of disease transmission persists for a considerable time. Moreover, depth of burial (2 to 8 inches) made no difference in survival of pathogens; neither did it matter whether disposal occurred at high or low elevations, in forest or in meadow. This emphasizes the need to promote burial at sufficient depth and far enough away from campsites and water bodies to minimize the chance of direct contact by other users. Although education campaigns in proper human waste disposal are common, greater emphasis on the potential hazard and the need for careful disposal seems in order. Horses and mules should be kept away from surface water as much as possible and they should never be confined where manure is likely to contaminate water sources.

Other types of water pollution appear to be more prevalent and also more subject to management control. In the Kings Canyon National Park study, where the health hazard was minimal (Silverman and Erman 1979), recreational use was associated with a number of changes in the basic ecology of lakes. The most heavily used lakes had less nitrate and more iron, and more aquatic plants than other lakes (Taylor and Erman 1979). The authors suggest that recreational use--through erosion of trails and campsites, improper waste disposal, destruction of vegetation, and campfires--may cause an increase in trace elements, such as iron, the absence of which formerly limited plant growth. Stimulated plant growth results in increased nitrogen uptake and, therefore, decreased nitrate levels. Insects, aquatic worms, and small clams were also more abundant on the bottom of more heavily used lakes (Taylor and Erman 1980). At a lake in a

semiwilderness area in Canada, Dickman and Dorais (1977) found unusually high phosphorus levels and increases in phytoplankton that they attributed to increased erosion of phosphorus-rich substrate, triggered by human trampling.

Although we do not know how common lake eutrophication has become, its effects are felt throughout the food chain. Moreover, such changes are long-lasting. In the Kings Canyon National Park study, changes were still prevalent at Bullfrog Lake, a formerly heavily used lake, 16 years after it had been closed to camping and grazing. Such changes are highly significant because they are likely to affect the entire lake ecosystem. This can be a serious problem in wilderness areas with a small number of heavily used lakes. In this situation, recreational use can dramatically alter the structure and functioning of all representatives of that type of ecosystem. This would clearly constitute a serious failure to achieve the goal of preserving natural conditions. This suggests that aquatic ecosystems may be the wilderness ecosystems most prone to significant disruption by recreation use (fig. 16.8).

#### MINIMUM IMPACT EDUCATION—LEAVE NO TRACE

Education is one of the keys to reducing recreation impacts in wilderness. Most wildernesses have an educational program and many have elaborate programs that utilize a variety of media (Douchette and Cole 1993). The success of the “pack-it-in, pack-it-out” litter control program shows what can be done through education. Without education, impact management will always be primarily reactive. Through education, management can become more proactive and preventive in nature. But there are limits to what education can accomplish. Education is not a panacea; instead, it is a foundation on which to build a comprehensive management program.

Impacts vary from those that can be entirely avoided through education to those that are unavoidable, regardless of how educated and careful visitors are. Impacts such as tree damage and site pollution from ashes, food remains and other waste products, can be virtually eliminated through education. These impacts result entirely from unnecessary behaviors. Impacts such as those from building campfires and grazing stock can be dramatically reduced, but not eliminated, unless the activities of building campfires and traveling with stock are eliminated. Finally, impacts such as those resulting from trampling are largely unavoidable. They will be left wherever use occurs. Even here, however, it is possible for education to reduce impacts somewhat—if visitors show concern for where they walk and set up camp.

The main purpose of low-impact educational programs is to teach appropriate behavior. Appropriate behavior varies both between and within wildernesses--particularly between heavily and lightly used areas. In most heavily used areas, site impacts are most effectively minimized by containment of impacts--encouraging repetitive use of a small number of sites. Consequently, educational programs should stress not damaging new sites and keeping existing sites pleasant, to encourage repeat use. Lightly used areas usually call for dispersal and the discouragement of repetitive use of sites--the exact opposite of the educational message in heavily used places. Site selection and minimum-impact camping are particularly important in lightly used areas. Appropriate behavior also varies, to some extent, between western and eastern wildernesses, with life zone and even between managing agencies.

Development of an effective low impact educational program requires considerable thought. It requires attention to both the *content* of educational messages and the *communication media* that will be used to disseminate messages.

## MESSAGE CONTENT

Knowledge about appropriate low impact techniques has developed slowly over the past few decades, with the accumulation of personal experience and recreation ecology research. Initially, most of this information was kept in the heads of dedicated wilderness rangers and dispensed during field contacts with visitors. Information was widely dispersed and often inconsistent. Starting in the mid-1980s, largely as a result of cooperation between federal land managing agencies and the National Outdoor Leadership School (NOLS), this situation began to change. Initially, experiential knowledge (from the heads of wilderness rangers and NOLS staff) and research about low impact techniques was compiled (Cole 1989a). This material formed the basis for the publication of *Soft Paths*--the first popular book devoted entirely to low impact techniques, now in its second edition (Hampton and Cole 1995). That book has been followed by a number of similar books. About the same time, work began on establishment of the national Leave No Trace (LNT) low impact education program. LNT is a partnership between federal land-managing agencies, nonprofit educational organizations (including NOLS), and the recreation industry. Its mission is “to develop a nationally recognized minimum-impact education system to educate federal land managers and the general public through training, publications, video and electronic webs” (Swain 1996).

With the LNT program, consistency in low impact education has emerged, even among the different land managing agencies. This consistency is most apparent in the following seven principles that are the crux of the LNT program:

1. *Plan Ahead and Prepare.* Take time to learn about the area you plan to visit so you know what to expect. Choose the area you visit based on an evaluation of your group’s ability and interest in minimizing impact. Travel in small groups and take appropriate

equipment. Tents with lightweight poles eliminate the need to cut trees for poles or to build lean-tos. Foam pads replace bough beds and waterproof tent floors make drainage ditches unnecessary. Stoves either eliminate or reduce firewood gathering and campfire impact. On backcountry trips, particularly, repack food so that potential trash is reduced. Finally, if traveling in bear country, be prepared and knowledgeable.

2. *Travel and Camp on Durable Surfaces.* This is a complex principle derived to a great extent from research about the relationship between amount of use and amount of impact. As discussed further below, numerous studies show that a little use causes lots of impact. Consequently, in popular areas it is best to concentrate use and impact. Stay on established trails and select a campsite that is already well-impacted. Select a site that is large enough to accommodate your group. Set up tents and the “kitchen” in places that have already been disturbed. Leave your site clean and attractive so the next group will want to camp there.

In remote, relatively pristine places, disperse use and impact. Spread out while hiking (fig. 16-9) and select a campsite with no evidence of previous use. Try to select travel routes and campsites that are durable. Disperse tents, activities and traffic routes when camped in a pristine area and naturalize the site when you leave--so the next group that happens by will not recognize it as a campsite. Keep stays short in pristine areas. Finally, stay off lightly impacted trails and campsites. Lightly impacted places are in a state of flux. If they continue to be used, they are likely to deteriorate rapidly and substantially. However, if left alone, they usually can restore themselves.

3. *Dispose of Waste Properly.* Pack out litter and waste food. Be particularly careful in bear country. Dispose of human waste appropriately, in toilet facilities if they are provided or in catholes at least 200 feet away from water, trails, and campsites. Pack out toilet paper or, at least, bury it. Do all washing away from camp and never directly in streams, lakes, or springs.

4. *Leave What You Find.* Never blaze trees, leave flagging or build rock cairns along trails. Never make trenches around tent sites or build campsite “improvements”. Avoid damaging live trees and plants and leave natural objects and cultural artifacts.

5. *Minimize Campfire Impacts.* Cook on stoves and minimize the use of campfires. If having a fire in a high-use area, use an existing firering. Keep fires small. Use only dead and downed wood that can be broken by hand. Burn the fire until only ash or small coals are left. Be sure the fire is out and scatter ashes widely--leaving a clean and attractive firering. In remote areas, select a durable fire site. Use a fire pan; build the fire on a mound of mineral soil; or build it in a shallow pit in mineral soil. Do not line the fire with rocks. Naturalize the fire site when you leave.

6. *Respect Wildlife.* Travel quietly and give animals the space they need to feel secure. Avoid approaching animals too closely, feeding them or touching them. Learn about locations and times of the year when disturbance of animals is particularly problematic. Leave pets at home or keep them under control.

7. *Be Considerate of Other Visitors.* Travel and camp quietly. Minimize undesired contact between groups, by taking breaks and camping away from the trail, from public attractions (such as lakeshores) and from other groups. Hikers, step off the trail when approached by a group on horseback.

The LNT program recognizes that educational programs need to be tailored to individual places and user groups. Behavior that may be appropriate in one place may be disastrous in another place. This is most obvious in principle 2, “Travel and camp on durable surfaces”. Recommended behaviors in popular areas (where use concentration is appropriate) are precisely the opposite of recommended behaviors in remote areas (where use dispersal is appropriate). More subtle differences also exist. For this reason, the LNT program has developed different outdoor skill booklets for different ecoregions in the United States, as well as for specialized recreational activities (such as river floating, horse use, rock climbing, snow camping, caving, and sea kayaking. LNT principles are being translated into different languages and integrated into international programs, where further modification of techniques will undoubtedly be required. “Rules are for fools” was a favorite declaration of Paul Petzoldt, one of the earliest advocates of Leave-No-Trace. Visitors must accumulate knowledge and the wisdom to consider the many variables that determine the most appropriate behavior for any given situation. Then they must use their own judgment.

## EFFECTIVE COMMUNICATION

There are many different ways to try to persuade recreation visitors to adopt recommended low impact practices. Douchette and Cole (1993) found that six different educational media were being used in more than one-half of the wilderness areas in the country: brochures, personnel at agency offices, maps, signs, personnel in the backcountry, and displays at trailheads (fig. 16-10). Some of the less commonly used media were computers and commercial periodicals, radio, and television.

Little research has been conducted that specifically evaluates the success of attempts to educate recreation users. However, social psychologists have been studying persuasive communication for years. Roggenbuck and Manfredo (1990) drew on this work to describe three conceptual approaches managers can use to persuade recreation visitors.

The first approach, *applied behavior analysis*, uses behavioral prompts, environmental manipulation, rewards and punishment to increase the frequency of desired behavior. An example of this approach would be to provide incentives, such as discount coupons from an outdoor equipment store, when visitors use appropriate behavior. The need for continuous contact with visitors--to keep them behaving appropriately--suggests that this approach contributes little to development of an enduring land ethic. It seems heavy-handed, particularly in wilderness, and is probably more appropriate in more developed recreational settings.

The second approach—referred to as the *central route to persuasion*—is more appropriate in wilderness. With this approach, carefully constructed messages are transmitted to visitors. Visitors receive and process the messages, accept the advice as making good sense, and change their behavior accordingly. Any behavioral changes should continue into the future because they result from and are reinforced by beliefs and attitudes the visitors have internalized. Most wildland education efforts take this approach. The challenge of this approach is daunting, however. For such an approach to be successful, visitors must have high motivation, the ability to process information and accept the arguments in messages, and the skills to respond appropriately. That means educators must spend as much time as possible with the visitor and “they must know their audience, tailor messages to meet the audience at their interest and knowledge level, develop interesting, relevant, and well-supported messages, use media which permits self-pacing of

message processing (usually the written word), and manage the situation so that distractions are few and the message reaches the recipient on time” (Roggenbuck and Manfredi 1990, p.106).

The third approach is the *peripheral route to persuasion*. This approach is characterized by little attention to messages and is common in situations of information overload and excessive distraction. Persuasion, if it occurs, is triggered by something other than the message itself. Often the cue comes from the source of the message--the basketball star wearing the shoes you are compelled to run out and buy. This may be the only approach with much chance of success at noisy visitor centers, at trailheads when visitors are anxious to start their trip, or if recreationists are simply not highly motivated to give their attention to messages. Unfortunately, this approach is unlikely to produce long-term behavior change.

This body of theory suggests that low impact education is a difficult task. The value of this work--beyond dashing some illusions about simply going out and telling people what they should do--is that it points out ways to increase the likelihood of success. Managers should use as many of these approaches as they can. They also should learn more about the variables that increase likelihood of success. Roggenbuck and Manfredi (1990) have distilled the findings of social psychologists on five factors that influence success: timing of the message, message content, recipient characteristics, source characteristics, and characteristics of the communication channel.

Timing is critical when attempting to use behavioral prompts, incentives, or peripheral cues. Prompts (such as a wilderness pin) must be closely associated with a desired outcome (such as leaving a clean camp), for the behavior to be learned. Peripheral cues need to be provided at decision points, such as when visitors are deciding what trail to take, whether to use a stove, or whether to

camp on a lakeshore. It is easy to achieve proper timing for some decisions, but virtually impossible for others. Timing is less important to the central route to persuasion, but the message must reach visitors in time for them to process and use the information. It is clearly too late to inform visitors about the importance of using stoves when they reach the trailhead.

Message content is important. If managers use the central route to persuasion, the message should provide arguments that are strong, relevant, novel, and simple enough to comprehend. Ending arguments with questions rather than statements can increase the likelihood that recipients will think about the message. Repetition of messages is likely to increase comprehension and acceptance.

Visitor characteristics also influence success. Visitors are more receptive to messages if they (1) think of themselves as being a part of the problem, (2) have relatively low levels of prior knowledge and experience, and (3) are part of small groups. Group leaders are likely to be more receptive than group members, unless they are highly experienced (Roggenbuck and Manfredro 1990).

Characteristics of the educator, or message source, are most important when the peripheral route to persuasion is used or when the visitor is not very motivated to listen to or think about messages. In these kinds of situations--“learning situations where the recipient is in a hurry, in a distracting environment, is tired, is part of a large group, or is in a situation where the flow of complex information is forced and fast paced (as in some video programs)”, agencies should seek out attractive or well-respected individuals to deliver messages (Roggenbuck and Manfredro 1990).

The final variable is communication channel. Personnel-based techniques and certain audio-visual techniques are more conducive to peripheral learning than techniques relying on written material. With personnel-based and audio-visual techniques, attention to the message source may be as important as attention to the message itself. Written materials need to be delivered in

situations where visitors have the time to process the information. A variety of channels should be used to help ensure visitors get the message. Since the educational process is so complex, it is important to focus on a few messages rather than try a shotgun approach. For example, Cole and others (1997) studied visitor attention to low impact messages posted on a trailside bulletin board and the extent to which visitors gained new knowledge from these messages. They found that visitors' knowledge was increased by exposure to messages. However, knowledge gain was as great when just two messages were posted as when eight messages were posted. They concluded that, in this situation, most visitors were only willing to allocate enough attention or able to process about two bits of information. In addition, Cole (1998) found that attention to messages on bulletin boards was greatly increased by including the simple written appeal, "Please take time to read these messages."

Relatively little research has examined the effectiveness of educational programs in reducing recreation impact problems. The only inappropriate behavior that has been studied extensively is littering. Numerous studies have shown that littering can be reduced with persuasive communication techniques. Successful programs have been based on rewards, punishment, and environmental cues such as trash cans (applied behavior analysis), written appeals about the need to keep places free of litter (central route), and demonstrations in which role models pick up litter (peripheral route) (Roggenbuck 1992). Written messages are often least effective. Punishment-oriented themes are often most effective. At Mt. Rainier National Park, the mere presence of a uniformed ranger was the most effective of various techniques designed to keep visitors on established trails in meadows (Swearingen and Johnson 1995).

The following six principles of low impact education have been compiled from both experience and research:

1. *Educational Programs Should Be Guided By Specific Objectives.* It is important to identify specific problems and the users that are the primary cause of the problems. Messages should be targeted to these specific users and problems. Certain behaviors and user groups will be more amenable to change than others. Oset's (1990) two-pronged approach to education is to (1) deal with specific problems caused by specific users and (2) invest in the education of future users (such as through grade school programs).

2. *Messages Should Be Clear, Concise, and Consistent.* Visitors may be overloaded with information and, consequently, miss the most important points if managers don't target their messages. Target a few specific behaviors. Short statements that demonstrate the desired behavior and why it is important are most likely to be effective. When more than one educational channel is used, or when different personnel are involved, the message should be consistent. Otherwise, visitors are likely to be confused. Unfortunately, the complexity of certain judgments essential for low impact recreation (such as where to camp) often defies concise, consistent answers.

3. *Timing of Educational Messages Is Important.* To steer visitors away from heavily-used areas, or to influence the equipment they take, messages must be sent to prospective visitors when they are planning their trip. Timing of messages should be varied for maximum effectiveness.

4. *A Combination of Techniques Is Likely To Be Most Effective.* A combination of techniques allows messages to be repeated. It also makes it more likely that most visitors will be contacted. Different messages and media may be needed for different user groups. There is no reason, for example, to burden backpackers with all of the details of low-impact stock use. However, backpackers are more effectively contacted through messages on bulletin boards than stock users are (Cole and others 1997).

5. *Messages Should Be Presented in a Professional Manner.* Productions need not be slick, but they should not be perceived as amateurish. If they are, credibility will suffer. Text and dialogue should be accurate and easy to understand. High-quality equipment and materials should be used for graphics and productions. The options for effective communication increase if celebrities or respected individuals will deliver the messages.

6. *Personnel Must Be Personable, Well Trained and Committed.* Personnel who contact the public should be cheerful, polite, outgoing, and have a positive attitude. The ability to speak well, give accurate directions, and read a map are helpful, as is the ability to listen attentively to the visitors' experiences. Personnel need to be trained in communication skills and low impact techniques. They should have personal knowledge of the area. Finally, they must believe in the value of minimizing recreation impact and the importance of education in achieving that goal.

## MANAGING CAMPSITE IMPACTS

In virtually all wilderness areas, the most common and profound impacts of recreation are those associated with campsites and trails. In many areas, the management of packstock is also a significant issue. The rest of this chapter is devoted to a discussion of these problems and their management.

## CAMPSITE IMPACTS

Most visitors spend more time on the campsite than anywhere else in wilderness. Unfortunately, this focuses impacts on the very places where visitors spend most of their time. Although natural conditions are desirable, some amount of impact can actually make a campsite more habitable. Some clearing of brush and trees, for example, provides better tent sites, causing many visitors to select sites with some vegetation loss. Problems arise when damage to campsites becomes extreme or where sites proliferate over entire destination areas, providing constant reminders of the large numbers of people using the area.

### Vegetation Change

Many studies have examined changes in vegetation on wilderness campsites. In most cases trees are mechanically damaged and reproduction is suppressed. Generally, there is little evidence that vigor of large trees is reduced, and aside from outright felling of trees and girdling as a result of tethering stock, tree mortality is uncommon. An exception to this generalization was documented in the Boundary Waters Canoe Area Wilderness (BWCAW), Minnesota, where severe erosion of shallow soil around tree roots has caused high mortality (Marion and Merriam 1985). Ground-level vegetation is more profoundly affected. Plant cover is reduced, usually to bare ground in the central part of the campsite, and species composition changes. Species diversity is usually reduced, and exotic plants often become a significant component of the flora (Marion and others 1986).

To illustrate the magnitude of campsite changes, consider the median change on 22 campsites located in subalpine forests in the Eagle Cap Wilderness (Cole 1982a). On the median campsite, more than 2,000 square feet had been obviously disturbed by camping. Almost 90 percent of the ground cover had been lost on the site--as inferred by comparing campsite conditions to those of an undisturbed

control site close by. Half of the site, the central area around the firering, was entirely devoid of vegetation. The surviving vegetation was very different in composition from undisturbed vegetation. Two species, a huckleberry and a heather, contributed almost 40 percent of the cover on undisturbed sites but only 6 percent of the surviving cover on campsites. In contrast, a sedge and a rush that contributed only 8 percent of the cover on undisturbed sites contributed almost 30 percent of the cover on the campsites. Overall, low shrubs and mosses were greatly reduced in cover. Grasses and grasslike plants, while losing some coverage, were less drastically affected, so they became the most abundant type of plant on the campsites.

Essentially all of the trees growing on these sites, 96 percent, had been damaged. Although much of the damage was minor, consisting of broken lower branches and nails driven into the trunk, one-fourth of the trees bore trunk scars from chopping and another one-fourth had been felled. About one-third of the trees had exposed roots, usually a result of tying stock to tree trunks. About 90 percent of the tree seedlings had been eliminated by trampling, which does not bode well for perpetuating forested campsites. Along with the felling of most of the saplings on the site, death of seedlings suggests that overstory trees will not be replaced when they die.

Typical campsite impact levels vary greatly between different wilderness areas, as well as between campsites within the same area. For example, in the Bob Marshall Wilderness, Montana, campsites are typically much larger (mean of about 3000 ft<sup>2</sup>) than in the Eagle Cap, while in Grand Canyon National Park, they are much smaller (mean of about 500 ft<sup>2</sup>)(Cole and Hall 1992). Mean campsite size varied between 500 ft<sup>2</sup> and 800 ft<sup>2</sup> in four wilderness areas in the south-central United States and was about 1000 ft<sup>2</sup> at Great Smoky Mountains National Park (Marion and Leung 1997).

### Changes in Soil Condition

The changes in soil condition most frequently noted are loss of the organic litter horizon, exposure of bare mineral soil, and compaction of the soil. Various measures of compaction have been employed, the two most common being bulk density and resistance to penetration. A few studies have also documented decreases in water infiltration rates and changes in organic matter content and soil chemistry.

On the Eagle Cap campsites, the depth of the organic horizons was cut in half (Cole 1982a). In some places all litter was lost. Exposure of bare mineral soil was 1 percent on control plots compared to 31 percent on campsites. Although some of the surface organic matter pulverized by trampling is probably removed by erosion, some evidently moves downward and accumulates in the uppermost mineral horizons because soil organic matter content increased 20 percent on campsites. Similar studies have found both increases and decreases on campsites. Loss of vegetation cover and changes in the organic content of soils will have a profound influence on the biota that live in soil. Zabinski and Gannon (1997) report evidence for a dramatic reduction in the functional diversity of the soil microbial population on campsites. Such a change is likely to represent a significant barrier to any attempts to revegetate disturbed campsites.

Bulk density increased 15 percent and infiltration rates were reduced by about one-third on the Eagle Cap sites. These relatively small changes may result from the sandy, granitic substrate of these campsites, which makes them relatively resistant to compaction. In similar studies, infiltration rates were reduced by two-thirds in the Bob Marshall Wilderness (Cole 1983a) and three-fourths in Grand Canyon National Park (Cole 1986). Finally, several changes in soil chemistry were found. Values of pH increased, soils became less acidic, and there were sizable increases in the concentrations of magnesium, calcium, and sodium. These chemical changes probably reflect input from campfire ashes, excess food, soap, and other substances scattered about the site.

In sum, almost every parameter examined on the Eagle Cap campsites had been substantially altered by camping (see fig. 16.3). By no definition of the phrase can we conclude that “natural conditions” are being preserved on these wilderness campsites. And remember, these are typical sites--not worst cases or atypical examples.

Despite their severity, campsite impacts are highly concentrated. For the Eagle Cap Wilderness as a whole, less than 0.2 percent of the area has been affected by camping (Cole 1981). Marion and Leung (1997) estimate that less than 0.01 percent of Great Smoky Mountains National Park has been affected by camping. In most places, only occasional campsites are encountered. But large numbers of campsites are concentrated in a few popular destination areas. For example, camping has impacted at least 144 sites at one popular lake in the Eagle Cap (Cole 1993b). Over half of these sites had lost more than 25 percent of their vegetation and most were in sight of the trail. Although this represents little threat to the ecological integrity of the Eagle Cap Wilderness, it does provide conspicuous evidence of human use. Not only is there scant opportunity to camp on an undisturbed site, but pronounced impacts are found around almost every corner and behind every tree clump.

#### Temporal Patterns of Impact

Studies of individual campsites show that they have a typical “life history” (fig. 16.11). Impact usually occurs rapidly after a previously unused site is first used as a campsite. On newly-established canoe campsites at Delaware Water Gap, for example, most of the impact that occurred over the 6 years following campsite opening occurred during the first year of use (Marion and Cole 1996). Impact did continue to increase each year for the first three years, but at a decelerating rate. Actual rates of deterioration during the

“development” phase vary between kinds of impact and with amount of use and environmental durability. Loss of vegetation occurs rapidly, while exposure and compaction of mineral soil occurs more slowly. Deterioration occurs more rapidly as amount of use increases and as site durability decreases.

The “development” phase is followed by a more stable phase of “dynamic equilibrium”. Where amount and type of use is relatively constant, seasonal and year-to-year fluctuations dictated largely by climatic variation may exceed unidirectional change for many kinds of impact. For example, on long-established campsites in the Eagle Cap Wilderness, mean vegetation cover was 15 percent in 1979, 12 percent in 1984 and 19 percent in 1990 (Cole and Hall 1992). Vegetation cover on these sites might be expected to fluctuate between 10 and 20 percent indefinitely, as long as use characteristics are relatively stable. Devegetated area and soil compaction are also impacts that tend to be stable on established campsites. Other impacts tend to deteriorate more steadily because recovery processes are so slow. For example, mineral soil exposure on Eagle Cap campsites increased from 33 percent in 1979 to 41 percent in 1984 and 44 percent in 1990 (Cole and Hall 1992). In these western coniferous forests, the accumulation of new litter cannot keep pace with the rate of litter loss from campsite use. In eastern forests, however, the amount of mineral soil might be more stable because litter production is greater. Tree damage, in particular, tends to be cumulative, worsening over time because recovery does not occur.

Once a campsite is effectively closed, the “recovery” phase begins. The rate of recovery is highly variable but is always slower than deterioration. Recovery rates vary between kinds of impact and environments, as well as with amount of previous impact. After 15 years without use, litter accumulation and soil penetration resistance on subalpine campsites in Kings Canyon National Park had

returned to predisturbance levels, but tree mutilations and vegetation loss were still evident (Parsons 1979). Hartley (1999) reports residual effects 30 years after trampling experiments were conducted at Logan Pass in Glacier National Park, Montana. In contrast, most visual evidence of camping on closed riparian campsites at Delaware Water Gap disappeared within 6 years (Marion and Cole 1996).

Given the same environmental setting, more highly impacted sites will require longer periods to recover. When different environments are compared, however, it is difficult to predict how long recovery will take merely on the basis of how impacted the site is. Some of the environments that are most readily disturbed by camping (such as lush herbaceous vegetation in riparian zones) are capable of relatively rapid recovery once camping stops. There is some evidence that differences in recovery rates, between different environments, may exceed differences in deterioration rates.

Temporal patterns at larger spatial scales are especially important. There is a tendency for impacts to proliferate and spread across the landscape where the distribution of recreation use is not tightly controlled. For example, in two drainages in the Eagle Cap Wilderness, the number of campsites increased from 336 in 1975 to 748 in 1990 (Cole 1993b). Such proliferation occurs because sites deteriorate rapidly and recover slowly. As use shifts across the landscape, new campsites appear more rapidly than old campsites disappear.

#### FACTORS THAT INFLUENCE AMOUNT OF IMPACT

In order to better understand how to minimize camping impacts, it is important to understand why some sites are more seriously damaged than others. Total impact is a produce of both the intensity of impact at any one place and the areal extent of impacted places. *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 would be a fourth important factor, except that in most places, campsites are seldom outside of a single main use season. The areal extent of impact is primarily a result of the spatial distribution of recreation use.

Of the factors that influence amount of impact, the usual assumption has been that the amount of use a site receives is most important. Numerous studies suggest, however, that this assumption is misleading at best. In the Eagle Cap (Cole 1982a), for example, even campsites used no more than a few nights per year (light-use sites) have been severely altered (table 16.1). Most overstory trees have been damaged, most seedlings have been eliminated, most of the vegetation has been lost, soil has been compacted, and soil chemistry has been changed. Sites used an estimated five to 10 times more frequently, about one night per week during the main use season (moderate-use sites), differed in the following ways: the disturbed area was usually much larger, as was the devegetated area; exposure of tree roots was pronounced; organic horizons were thinner; and changes in undergrowth species (indicated by the floristic dissimilarity value) 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. In an experimental study, one night of camping on previously-unused sites caused significant vegetation loss in all four vegetation types studied (Cole 1995b). Four nights of camping caused less than twice the impact of one night.

These and similar results from across the country suggest a general relationship between use and impact similar to that in Fig. 16.12. Only when comparing sites receiving very low levels of use do differences in amount of use make any sizable difference in amount of impact.

Certain types of impact on campsites are determined almost entirely by the behavior of campers. The best examples are damage to trees and “pollution” of the site with campfire ashes, charcoal, food, and so on. Not all parties build campfires or damage trees. A campsite could be heavily used and yet not suffer tree damage or changes in soil chemistry caused by building campfires or discarding wastes. Other types of impact are little affected by behavior, however. Even campers who carefully practice low-impact use will still trample vegetation and compact soil.

*Three other characteristics of user groups also influence campsite impact—size of the party, length of stay, and whether or not they use packstock.* The effect of party size on campsite impact has never been formally studied. One can assume that large parties will increase the disturbed area of individual campsites. Campsite area and size of the devegetated area are therefore likely to be much larger than on sites used by small parties. But there is little reason to believe that party size should affect any other characteristic of established campsites. On undisturbed sites, however, large parties will cause impact more rapidly than small parties. Therefore it is considerably more difficult for a large party to cause minimal impact when visiting relatively undisturbed places.

Campsites used for long periods of time by the same party tend to be more heavily impacted than other sites. Two factors seem to be at work here. First, use patterns on the site are repeated day after day, leading to severe disturbance of certain parts of the site. For example, places where tents are set up and used for a week or more are likely to be highly altered. Long lengths of stay can be highly

damaging on previously unused sites, while length of stay may be of little importance on a site where impact levels are already high. The second factor—and this applies even to well-impacted sites—is the natural tendency for people to “improve” and “develop” their campsite the longer they stay.

The effect of packstock will be discussed in more detail later. Parties with packstock disturb a larger area than hikers because the campsite includes an area where stock are confined.. Such camps often show more soil disturbance, a result of trampling by heavy, shod animals, and more tree damage, a result of tying horses to trees for extended periods (Cole 1983a).

The final factor determining intensity of impact is the durability of the site used for camping. Trail condition provides a useful illustration of the importance of location. It is common to find badly eroded or boggy sections of trail alternating with sections that are in good shape, despite the fact that the very same number and type of people are using both good and bad trail segments. Environmental differences such as steepness of slope, soil texture, and moisture content account for most of these differences in condition. On campsites, soil characteristics, depth of surface organic horizons, and vegetation type can greatly influence amount of impact.

A number of studies have examined, through experimentation, the effects of increasing amounts of trampling on different types of vegetation. Trampling disturbance, particularly loss of vegetation, varies widely between vegetation types. In experimental trampling studies, Cole (1993a) found that as few as 20 hikers can destroy 50 percent of the vegetation cover in some vegetation types; in other vegetation types, 50 percent cover is lost only after 600 hikers have crossed the area. This suggests that campsites in some vegetation types could absorb more than 30 times as much use as campsites in other types, with no more vegetation damage. Clearly, where people camp is critical in determining loss of vegetation.

Environmental influences on campsite susceptibility are complex and our understanding is still rudimentary. Any environmental setting may be susceptible to one type of impact and resistant to another. There also may be little relationship between a site's resistance—its ability to tolerate use without changing, and its resilience, its ability to recover from changes that do occur. Characteristics of durable campsites include (1) either lack of ground cover vegetation or presence of tolerant vegetation (grass-like plants are most tolerant—short woody plants are least tolerant), (2) an open rather than closed tree canopy, (3) thick organic soil horizons, and (4) a relatively flat but well-drained site.

It is commonly believed that sites located close to lakes and streams are more fragile than sites away from water bodies. When examined in the Eagle Cap Wilderness, this did not prove to be the case (Cole 1982a). Campsites close to lakes were no more highly impacted than sites located away from lakes.

The final factor—the one that influences the areal extent of impact—is the spatial distribution of visitors. Cole (1992a) has shown theoretically that the factor that most influences amount of campsite impact is the degree to which activities are spatially concentrated. Campsite impacts in the backcountry of Grand Canyon National Park are relatively low—campsites are extremely small—because the rough terrain forces campers to confine their activities to small flat spots, free of rocks and thorny vegetation (Cole 1986). Marion (1995) documented the effects of management actions taken to increase the concentration of use at two spatial scales on canoe campsites at Delaware Water Gap over a 5 year period. Intersite concentration of use was increased by reducing the number of designated sites 25 percent. Managers also increased the intrasite concentration of use by installing fire grates on each site. This centralized activities more than in previous years when visitors built fires on many different parts of the site. As a result, mean

campsite area decreased more than 30 percent. The effect of these combined actions was to reduce the aggregate area of campsite disturbance 50 percent—from 2.8 ha in 1986 to 1.4 ha in 1991. Although these actions increased the intensity of use on individual campsites, there was no resultant increase in intensity of impact on individual sites (Marion and Cole 1996).

## MANAGEMENT STRATEGIES AND TECHNIQUES

Each of the factors that influence amount of impact offers a strategy for reducing site impacts. For example, four primary strategies for minimizing impacts involve: *(1) reducing amount of use on campsites, (2) changing type of use and behavior in such a way that per capita impact is reduced, (3) shifting use to more durable sites or actively increasing site resistance through hardening and provision of facilities, and (4) containment of impacts—recognizing situations where impacts are inevitable and can best be minimized by limiting their areal spread.* A fifth strategy—site cleanup and rehabilitation—treats symptoms rather than causes (table 16.2). These strategies can be implemented by various techniques or actions. Effective campsite management programs call for an evaluation of objectives, problems, and all potential solutions before selecting a series of coordinated actions, often using several different strategies. Further information on alternative management options can be found in Cole and others (1987) and Anderson and others (1998).

### Limiting Amount of Use

Currently, overnight use is limited in most of the 44 National Park Service wildernesses (Marion and others 1993), as well as in about 20 Forest Service wildernesses, two Bureau of Land Management wildernesses and one Fish & Wildlife Service wilderness. This is little

different than the situation in 1980, when overnight use was limited in 16 classified and 15 potential wildernesses (Washburne and Cole 1983). Managing campsite impact is just one of many reasons for limiting use. What we know about the relationship between amount of use and amount of impact—that a little use causes most of the impact—suggests that limiting use, by itself, is likely to do very little to improve the condition of well-established campsites. In most cases, unless all visitation is curtailed on a site, there is little chance for recovery. The only exception to this rule is where use levels are kept very low and dispersal is practiced (see next technique).

In places where use levels are high—the usual case where rationing has been implemented—use limits are likely to be more effective in limiting the *number* of campsites than the *severity* of impacts on individual sites. To limit the number of campsites, however, it is necessary to simultaneously employ the containment strategy (discussion follows) and get campers to use existing or designated sites, rather than make new sites. In general, then, use limits are likely to be effective only when supporting containment or when they maintain extremely low use levels. Use limits can, however, be effective in dealing with other management problems, particularly crowding.

#### Dispersal of Use

Use dispersal is a much less common management strategy today than it was in the past. In 1980, managers were attempting to disperse use in 50 percent of all wildernesses and likely additions to the wilderness system (Washburne and Cole 1983). Goals ranged from shifting use to less frequently visited areas, to discouraging camping on impacted campsites. Any dispersal of use will affect the number, distribution, and condition of campsites and recent research has shown that dispersal is more likely to increase than to decrease impact.

As in the case of use limitation, use dispersal is unlikely to improve the condition of individual sites unless use levels are very low. Studies in wilderness areas in the West suggest that even a night or two of use per year usually inflicts persistent damage. We also know that only a slight increase in use will significantly alter previously unused or seldom-used sites. In the Eagle Cap, even the lightly used sites away from trails had typically lost more than 70 percent of their vegetation. Therefore, increased use of little-used areas or sites will increase both the number of impacted sites and their level of impact. The more than 220 campsites around Mirror and Moccasin Lakes in the Eagle Cap (where the average number of parties probably does not exceed 10 per night) is partially a result of a management decision, made in the late 1970s and early 1980s, to remove existing rock firerings and to request visitors not to camp on heavily used sites (Cole 1982b). At such popular destinations, directing use away from heavily used sites actually spreads campsite damage. Encouraging more use of less popular parts of the wilderness will also increase campsite impacts in these places, with little compensatory improvement in the condition of popular locations. More recently, Eagle Cap managers have stopped removing all firerings, in places where campfires are allowed, and no longer encourage visitors to avoid heavily used campsites.

Dispersal could improve campsite conditions in lightly used remote parts of wildernesses, if visitors can be encouraged to spread out and camp on undisturbed sites. In this vast majority of wilderness acreage, dispersal can help perpetuate the “ideal” wilderness situation where no sites become heavily impacted. But if use increases significantly, it may be necessary to impose limits. Ironically, use limits may be more effective in low use situations than in the high use places they are most commonly applied. The dispersal strategy must be supported with an intensive educational program wherein campers are taught minimum impact camping techniques and how to select apparently unimpacted and resistant sites. Indeed, concentrating use and impact in popular places and dispersing use and impact

elsewhere is one of the most critical Leave No Trace messages. This allows sites to fully recover before being used again; otherwise sites will deteriorate and dispersal will merely spread lasting impacts. Because of this possibility, the monitoring of campsites and their condition is particularly important to a dispersal program.

### Temporary Campsite Closures

Rest-rotation systems—where certain heavily impacted sites are temporarily closed to allow recovery before being used again—are likely to be effective only if required recovery periods are short in relation to periods of use and deterioration. This is seldom the case, however. Recovery almost always is slower than deterioration. The effectiveness of a temporary campsite closure program was monitored around Big Creek Lake in the Selway-Bitterroot Wilderness, Montana, where seven out of 15 campsites were closed to allow recovery. Eight years after closure, vegetation on closed sites was still only one-third as extensive as that on controls, and mineral soil exposure was 25 percent, compared with only 0.1 percent on controls (Cole and Ranz 1983). The most profound change since initiation of the closures was the creation of seven new campsites, close to the closed sites, on which conditions have rapidly deteriorated. Within eight years of their creation, loss of vegetation and soil exposure were as high on new sites as on long-established sites. The likely effect of a rest-rotation system, then, is an increase in the number and area of impacted sites without any significant improvement in the condition of sites in use.

### Limitations on Length of Stay

Limits have been placed both on the maximum number of nights allowed in the wilderness and at individual campsites. The imposition of areawide length-of-stay limits is unlikely to have any effect on site impacts. The major benefit of such a regulation is to allow more people to use an area in which total use is limited. Length-of-stay limits for campsites are also likely to do little to improve campsite conditions in popular parts of wildernesses or on popular campsites because new parties are likely to occupy sites shortly after they are vacated. Such a limit is likely to prevent “homesteading”, although this is more a social than an ecological problem. It can also prevent serious deterioration of sites that had not been heavily impacted previously and avoid the tendency for sites used for long periods to become developed or improved. But in these cases the common 14-day limit is too long. To avoid damaging little-used areas, sites should never be used more than a night or two in succession.

Reducing length of stay to a minimum, by sleeping and eating in different places, can significantly reduce per capita impact in little-disturbed areas. Using this technique, a party traveling through the wilderness will prepare and eat supper in one location, clean up, and travel farther to a good bed site. In the morning, the party gets up and moves on to a good breakfast site. A typical camp is never established.

Generally, the most valuable use of length-of-stay limits is minimizing time spent at little-used sites. This goal is most effectively accomplished through education, particularly when such limits are not imposed on heavily used sites. For social reasons it may also be beneficial to prohibit occupancy of one site for more than 14 days as a means of dealing with “homesteading”.

#### Party Size Limits

A majority of wildernesses limit the number of people per party. Limits range from six to 60 persons, the most common being 10 (Monz 2000). As noted earlier, larger parties are likely to disturb larger areas, but in the most highly disturbed part of the campsite, severity of impact is unlikely to be much greater than with small parties. Establishing lower party size limits could reduce the size of campsites and devegetated zones; however, such an action might result in the need for more campsites. To be effective in maintaining small campsites, limits probably should be 10 or fewer and users should be educated to not spread out on campsites. Excessively large sites may require partial revegetation and some means of keeping visitors off the periphery. The Boundary Waters Canoe Area, Minnesota, limits party size, teaches minimum impact camping, monitors all campsites, and where site expansion is occurring, “plants” rocks and logs to keep people off the periphery (Marion and Sober 1987).

Party size limits are of most value in lightly used parts of wilderness where dispersal is being practiced. Rate of impact tends to increase with party size, so a small party will find it much easier to leave little trace of their visit than a large party. Again, limits must be quite low and might be most effectively implemented as part of a program to foster appropriate use of places off the beaten track. Impacts of larger groups can be reduced if party members will spread out during travel and break up into small dispersed camping units.

#### Encouraging Use of Resistant Sites

Because certain sites are much more durable than others, managers can minimize impact by directing use either to resistant sites or away from fragile sites. This can be done through regulation or through education. Camping in meadows is often discouraged or prohibited. Such campsites—both when occupied and after use—are much more obvious and aesthetically displeasing than sites set back in forests.

Most research suggests, however, that grassland and meadow vegetation, particularly if it is dry, is much more resistant to damage than the forest undergrowth (Cole 1993a). Therefore, in lightly used areas, where the dispersal strategy is being practiced, visitors should be encouraged to camp on meadows and grasslands (fig. 16.13). Here, encounters with other parties are unlikely and it is most important to minimize trampling damage. In heavily used areas, where even resistant vegetation will be lost, one should encourage camping in forested areas with thick organic horizons, so impacts and other campers will be screened by trees.

#### Setbacks From Water

One of the most common management actions is to discourage camping close to streams and lakes. Such setbacks have social and ecological justifications as well as repercussions. Three conditions that might make lakeshores particularly vulnerable are (1) moist soil with great potential for vegetation damage and soil compaction, (2) steeply sloping shores prone to erosion, and (3) potential for water pollution. Soil moisture and slope steepness do not necessarily decrease with distance from water, however. Flat rock outcrops close to shores are undoubtedly much more tolerant of use than moist or sloping sites a considerable distance from the lake. Most water quality studies suggest that even in high-use areas pollution from human sources does not present a significant health problem (Silverman and Erman 1979). But in at least one case heavy use appears to have altered benthic plant populations and the concentration of certain ions (Taylor and Erman 1979). More monitoring is necessary to determine whether or not this is a common problem. Around heavily used lakes, particularly in areas where lakes are rare, setbacks may be justified as a means of reducing pollution.

Another justification for setbacks is the tendency of visitors to develop trails from campsites to the lake. Social reasons—maintenance of public access and the aesthetic qualities of the lakeshore, plus reducing the visibility of campers—may also justify setbacks. This action will keep visitors from camping where they most like to camp. Moreover, Christensen and Cole (2000) report that visitors report that social justifications for lakeshore setbacks are less persuasive than ecological justifications. Setbacks will also increase the area altered by camping, at least for the short-term, because visitors will develop a second set of campsites away from the lake. Moreover, a setback will often eliminate most of the potential places to camp. Setbacks should be instituted not because it is a faddish management action but because it will solve a specific problem. Often much could be accomplished by persuading visitors to prevent water pollution; this would avoid imposition of rigid setbacks. Elsewhere, setbacks may be necessary only in a few heavily used places. Many wildernesses are adopting more flexible setback policies than in the past. This may involve a rigid minimum setback of, say 50 feet, with the suggestion that camps be at least 100 feet back if the terrain permits. Where setbacks are established, the old sites should be actively rehabilitated.

#### Site Hardening and Facilities

True site hardening, wherein a site's durability is increased through manipulation, such as planting hardy grasses, is almost nonexistent in wilderness. More common is the provision of facilities that absorb or concentrate impact: fireplaces, tent pads, shelters, stock-holding facilities, toilets, and trash cans. Building facilities is a controversial action. We support the installation of such facilities to protect resources or for visitor safety, but not for visitor comfort and convenience. Trails are an example of an almost universally accepted

facility that serves to absorb and concentrate impact. The most common other facilities in wilderness are toilets, shelters, constructed fireplaces, tables, and a drinkable water supply.

Facilities should be the exception rather than the rule—a means of dealing with concentrated use, particularly by novices, in a few places in the wilderness. In Great Smoky Mountains National Park, for example, shelters receive 37 percent of the backcountry use, but because they concentrate impact, they account for only 10 percent of the disturbed area on campsites in the park (Marion and Leung 1997). Although shelters may seem inappropriate to many in wilderness, they are effective in reducing resource impact. We feel that wilderness should offer a range of recreational opportunities, including a few places that must accommodate heavy, localized use. The provision of facilities may help prevent excessive deterioration of these places, while their judicious use preserves quality experiences for those who choose to visit such popular locations.

The facilities that can be most readily defended as necessary are constructed fireplaces, stock facilities, and toilets. Stock facilities will be discussed in the section on packstock management. Fireplaces are most appropriate in areas of high fire hazard, for example, wildernesses in southern California. But in a number of other places they are used to confine campfire damage and to designate an acceptable campsite. Generally, we feel that this is unfortunate, although perhaps necessary if visitors will otherwise build new firings or disturb new sites.

Toilets are also an undesirable but sometimes appropriate facility, particularly where use is so high that the likelihood of visitors digging up fecal material becomes substantial. Much can be accomplished by teaching people to defecate far from high-use camps. But in

some situations toilets become a necessity. The most common toilet is a box a few feet high. In some areas, however, outhouses are enclosed, and in some wildernesses, composting toilets have been installed.

### Containment of Use

Containing use is a well-developed principle of site management outside of wilderness and, while many consider it to be inappropriate—labeling it the “sacrifice site” concept—it is already being consciously and unconsciously applied within wilderness. The label “sacrifice site” is an unfair one, because it implies that managers have the option of not “sacrificing” sites. This is only possible if recreation use is not allowed. Given that recreation use will be allowed, the choices are between having relatively large or relatively small numbers of impacted (“sacrificed”) sites. The containment strategy is an attempt to keep the number of impacted sites relatively small. For example, a trail contains and concentrates use. Exhorting visitors to stay on trails, and not to shortcut switchbacks, are examples of appropriate containment. Applied to campsites, the same concept would encourage use of existing sites to avoid rapid deterioration of new sites. Currently a number of wildernesses, particularly those managed by the National Park Service, allow camping only on designated sites, at least in certain parts of the wilderness. Others encourage the use of existing campsites.

Most sites deteriorate substantially even when used only a few nights per year. Therefore, at a heavily used destination area the choice is between a few deteriorated sites—the result of containment—or many deteriorated sites—the result of dispersal. Containment is a better strategy for minimizing impacts, unless management is willing to reduce use to extremely low levels and actively rehabilitate deteriorated sites. Generally, this is neither practical nor desirable. Wilderness can and should accommodate a range of opportunities;

having a few popular locations with a handful of well-impacted campsites seems appropriate as long as the vast majority of the area remains largely undisturbed.

While this conclusion may be disturbing to those who want pristine wilderness, we find it a sensible compromise that allows generous opportunities for recreational use. The finding that heavily used sites show little more impact than sites used a few times per year has its positive side; concentrating use on a few sites will not result in ever-increasing deterioration, provided that sites are well-located and inappropriate visitor behavior is discouraged. Moreover, as long as most people want to visit popular areas and use the most heavily impacted sites—as most currently do—natural conditions will be preserved throughout most of the wilderness; opportunities for solitude will be preserved for those who seek it; and the need to manipulate visitor distributions and behavior, which results in loss of freedom, will be minimized.

Containment can be accomplished either through regulation, by allowing camping only on designated sites; or through education, by encouraging the use of existing campsites. Sites can be either clustered or dispersed. Although easier to administer and patrol, we feel that clustered sites are usually undesirable because they reduce campsite solitude and exacerbate problems such as bear encounters, waste disposal, and depletion of firewood supplies. Where use is so high that unacceptably large numbers of campsites are required, use limits may have to be established.

Where use limits are established, managers often set up a reservation and fixed itinerary system, too. Visitors are required to stay at sites they reserve before entry. With such a system, the number of sites necessary to accommodate a given number of parties is minimized because the need for overflow sites is eliminated. Reservations and a fixed itinerary greatly reduce freedom and spontaneity,

however, and are among the most unpopular actions taken in wilderness (Lucas 1980). Compliance with fixed-itinerary systems is often low, defeating their efficiency (Stewart 1989). Such regulations should be written only if absolutely necessary. Visitor freedom can be maintained by limiting use at trailheads and then allowing free movement within the area. This approach has been successful in a number of wildernesses, including the Boundary Waters Canoe Area Wilderness and both NPS and FS wilderness areas in the Sierra Nevada of California. Based on historic use patterns, trailhead quotas can be set to keep use levels in destination areas within acceptable limits most of the time (Parsons and others 1981).

Containment need not—and usually should not—be practiced throughout an entire wilderness. For example, in many wildernesses managed by the National Park Service, the wilderness is divided into a number of use areas. In the most heavily used areas, camping is allowed only at designated sites. Elsewhere, visitors can camp wherever they choose. Both dispersal and containment can be practiced in the same wilderness area. Visitors who are properly equipped, skilled, and sensitized to low-impact use can be dispersed, while those who are novices or poorly equipped for low-impact use can be contained on designated sites. Once a containment strategy is established, with or without use limits, the existing number of campsites can be reduced. This requires keeping people off closed sites and actively rehabilitating them. Usually, closed sites are identified through signing or a string enclosure. Open sites can also be signed, but a less obtrusive tactic might be leaving firerings only on open sites. It is important to leave open sites where people want to camp and to have a few more sites open than the maximum number of parties anticipated at any time. Spildie and others (2000) evaluated the effectiveness of a containment strategy in a subalpine lake basin in the Selway-Bitterroot Wilderness, Idaho. Actions taken included closing certain campsites to all use, requiring groups with stock to camp in one of nine designated stock sites in the lake basin, and

restoring closed sites and portions of sites still available for use. In just five years, disturbed area decreased 37 percent and bare area decreased 43 percent. They project that, in a few decades, disturbed and bare area can be reduced to just 36 percent and 24 percent, respectively, of what it had been prior to imposition of the containment program.

### MONITORING CAMPSITE CONDITIONS

Effective campsite management requires detailed information about the location and condition of campsites and trends over time. Sites should be inventoried to identify locations and problems that need attention, and to plan the types of corrective actions that will be required. If done carefully, the inventory can provide a baseline for identifying trends in campsite number and condition and possibly relating changing conditions to changes in visitor traffic and management actions. Finally, the inventory and monitoring system can be a critical part of the Limits of Acceptable Change (LAC) planning process (Stankey and others 1985). Ideally, an inventory would include sites that visitors might use if they were aware of them. Knowledge of potential sites would be useful in implementing a dispersal system or establishing new campsites if poorly located ones were closed.

Considerable progress has been made recently in the implementation of campsite monitoring programs. Several decades ago, very few wildernesses had any monitoring data. In a recent survey of wildernesses, we found that campsites are being monitored in at least a portion of 50 percent of all wildernesses. A variety of different campsite monitoring techniques have been developed. Refer to Cole (1989b) and Marion (1991) for further detail on available techniques than can be provided here. Techniques vary in the quantity and quality of the information produced, as well as in cost. Techniques that produce precise, reliable information on a number of separate

impact parameters require more time—and therefore cost more—than those which produce either relatively little information or less precise information.

One common monitoring method uses photographs. Photographs can be compared from year to year, but one must record date, time of day, the precise location of the photopoint, distance and direction to subject, height of the camera above the ground, camera make and model, focal length of the lens, filter, and film type. These conditions should be replicated to as great an extent as possible when subsequent photographs are taken (Brewer and Berrier 1984). From experience, photographs have not proven to be reliable substitutes for field measurements or estimates of parameters, such as vegetation cover or tree damage. Patches of sunlight and shade often make interpretation of ground cover difficult, and it is seldom possible to distinguish features beyond the closest trees. Nevertheless, as supplementary documentation, photos are indispensable. They can help identify the site for future remeasurements, record campsite features not measured in the field, and provide a visual supplement to collected data.

Where it can be afforded, the best data comes from careful measurements in the field, using techniques similar to those employed in campsite impact research studies (for example, Cole 1982a and Marion and Cole 1996). However, such techniques often require spending several hours on each campsite. Since it is important to collect monitoring data on all campsites—to permit assessments of change in the number and distribution of campsites over time—such techniques are prohibitive except in wildernesses with small numbers of campsites.

Most wildernesses have so many sites—Kings Canyon and Sequoia National Parks had more than 7,400 sites—and funding levels are so low that a system using visual estimates will be most practical. Frissell (1978) developed a condition class estimate system in which each campsite is located and assigned a condition rating between one and five based on the following classes:

1. Ground cover flattened but not permanently injured. Minimal physical change except for possibly a simple rock fireplace.
2. Ground vegetation worn away around the fireplace or center of activity.
3. Ground vegetation lost on most of the site but humus and litter still present in all but a few areas.
4. Bare mineral soil widespread. Tree roots exposed on the surface.
5. Soil erosion obvious. Trees reduced in vigor or dead.

Condition class systems are inexpensive and produce quite reliable precise information. Their primary drawbacks are that they are not very sensitive and the amount of information produced is limited. This system is most helpful in showing the location of campsites, which campsites are most heavily impacted and how the distribution of sites changes over time. It reveals nothing about which types of impact are most serious and, by the time campsite conditions have changed enough to be reflected in a changed condition class rating, a profound amount of change will have occurred.

A slightly more time-consuming technique, first developed in Sequoia and Kings Canyon National Parks (Parsons and MacLeod 1980) involves quick estimates of a number of different impact parameters. Fig. 16.14 shows one side of a form, based on this system, used to inventory all campsites in the Bob Marshall, Great Bear, and Scapegoat Wildernesses in Montana. With training, this form can be completed in five to 10 minutes. Modifications of this system are currently being applied in many other USFS wildernesses.

Nine impact parameters are used to evaluate campsite condition:

1. Loss of vegetation is expressed as the difference in vegetation cover between the campsite and its undisturbed surroundings. A vegetation cover class (percent cover of vegetation) is circled for both the campsite and an undisturbed comparative area. This undisturbed comparative area should be as similar as possible to the campsite in slope, canopy cover, and the composition of plants growing in protected places. The vegetation loss rating is based on the difference between these cover classes.
2. Mineral soil increase is a similar comparison between the campsite and an unused comparative area. In this case areas of mineral soil, devoid of vegetation and organic litter, are compared.
3. The number of trees that have been damaged (trunk scars, nails, stumps, and so on) is noted and used to rate tree damage. Large scars and felled trees are especially significant.
4. The number of trees with pronounced root exposure is noted.
5. The presence or absence of such facilities as firerings, log or stone seats, and more elaborate structures is used to rate level of development.
6. The presence and amount of charcoal, blackened logs, other campfire evidence, litter, toilet paper, human waste, and horse manure is used to rate level of cleanliness.
7. The number of informal trails providing access to water sources, the main trail, or adjacent campsites is noted. Well-worn trails are considered to be more significant than faint, barely discernible trails.
8. The total area of the campsite, including satellite tent areas and stock-holding areas, is paced off or tape measured.

9. The area devoid of vegetation, centered around the firering, is estimated.

In addition to measuring many of these parameters, each is rated on a scale of one to three. These ratings can simply be summed to arrive at the impact index or, as in Fig. 16.14, they can be multiplied by weighting factors reflecting the perceived relative importance of each parameter. These weights are the second column of numbers in the calculation box. In this case the impact index becomes the sum of the weighted ratings (the product of rating times weight). Although not strictly appropriate mathematically, such a procedure provides a useful relative index of impact.

Both the impact index and the individual parameter ratings can be mapped. Fig. 16.15 shows the location and overall condition (impact index) of campsites in a portion of the Bob Marshall Wilderness. Such a map is valuable for identifying problem areas and specific types of problems. This makes it much easier to tailor a campsite management plan to the area. Obviously, different management strategies are necessary for Upper Holland Lake, with many highly impacted sites; Koessler Lake, with only one site, but a highly impacted one; and George Lake, with many sites, none of which are highly impacted.

Such a system provides considerable information at relatively low cost; however, the information is not very precise. It is not uncommon, for example, for different evaluators to give the same campsite very different ratings for individual parameters. We have found, however, that overall index ratings do not vary greatly between different evaluators. This suggests that the primary limitation to these techniques is in drawing conclusions about changes over time—for separate types of impact, such as amount of vegetation loss—on individual campsites.

Marion (1991) has developed a technique that is a compromise (in both cost and precision) between research level techniques and the rapid estimates used in the Bob Marshall Wilderness. Certain parameters—such as campsite area—are measured carefully, while other parameters are visually estimated. In application of this technique in a number of parks in the eastern United States, Marion reports that it takes two trained evaluators about 30 minutes to monitor a campsite. Another compromise approach is to inventory all campsites using a condition class rating and then to carefully monitor a sample of campsites to identify subtle trends.

Regardless of the technique employed, the wilderness should be reinventoried periodically, perhaps every five years. This will show whether the number of sites is increasing or decreasing and whether conditions on individual sites are improving or deteriorating. If standards have been established for campsite condition, the ratings can be related to specific standards to determine where and what type of management is needed. By relating documentation of existing conditions (through monitoring) to specific objectives (standards) and then carefully choosing solutions from the array of possible management strategies described above, campsite management should become more effective and efficient.

## CAMPSITE RESTORATION

As we noted, temporary closures as part of a campsite rest-rotation system are unlikely to succeed. However, campsites may be *permanently* closed to enforce setbacks from lakes, to close poorly located sites, or to reduce the number of sites in places where containment is being tried. Closed campsites are common in wilderness. In many cases, closed sites are simply left alone. Increasingly, however, managers are realizing that they need to assist the recovery process because recovery rates are so slow. Most restoration

programs are run by highly committed but untrained volunteers. Experimentation, documentation, and communication of what does and does not work are usually lacking. Barriers to restoration success are challenging and poorly understood. Moreover, suitable techniques and materials can be highly area- and site-specific. For all of these reasons, success and the ability to generalize about site rehabilitation has been limited.

The likelihood of success can be increased through careful planning. Common problems that can be avoided through careful planning include: (1) destruction of restoration work because the cause of the problem was not adequately dealt with; (2) failure of plantings due to inadequate site preparation and plant selection; (3) loss of plantings due to inadequate long-term maintenance of the site; and (4) an inability to learn from successes and failures due to insufficient monitoring. Although there are many appropriate formats for a restoration plan, all are likely to contain the following five steps.

1. *Establish Restoration Goals and Objectives.* Goals define the intended result of the project—for example, whether to return the site to its predisturbance condition or to simply reduce current levels of impact. Objectives provide specific measurable targets. It is critical to simultaneously consider goals for both the site and the larger landscape in which the site occurs. For example, in addition to restoring the lakeshore, what are the goals for the entire lake basin? Goals might be to confine camping impacts to places more than 200 feet from lakes or to confine them to other existing campsites. Without statements of goals for larger areas, restoration programs may do little more than push impacts around.

2. *Conduct a Situational Analysis.* Describe and analyze the site and its context, answering the following questions: (1) what is the nature and extent of the problem, (2) what caused the problem, (3) what ecological and visitor use characteristics constrain the

restoration effort, and (4) what are the ecological and visitor use characteristics of a fully successful project? It is helpful to place the problem in a historical context. Is the problem recent or has it existed for decades? Is it relatively stable or getting worse? Does the problem result from visitor use, natural events, management actions or some combination of these? Evaluate the difficulty of restoring the site. Sites can be difficult to restore because they are harsh, unproductive or have short growing seasons. They can also be difficult because the needs and desires of visitors in the area are such that visitors cannot be kept off the site.

3. *Design the Site.* Lay out the physical and ecological characteristics of the site-to-be, including accommodations for visitor use and management. The design should prescribe the desired topographic configuration and drainage, as well as spatial arrangements of vegetation and substrate—usually in an attempt to emulate characteristics of the natural site. When designing vegetation planting, both vertical and horizontal structure should be considered.

4. *Develop Implementation Procedures.* Describe the procedures necessary to achieve the site design. Procedures to be specified, discussed in more detail below, include (1) site stabilization, (2) site preparation, (3) propagation or collection of vegetation or propagules, (4) planting procedures, (5) maintenance procedures, and (6) visitor management.

5. *Develop Monitoring Procedures.* “Monitoring provides the means to quantify and verify success in achieving the objectives of the plan, and offers insight into reasons for success or failure” (Nuzzo and Howell 1990). A monitoring program should (1) define the area to be monitored, (2) decide which parameters should be monitored, (3) prescribe techniques for each parameter, (4) define a sampling/monitoring plan, and (5) include records of planting, maintenance and management programs. Be sure to note when monitoring should be done, by whom and how it will be used.

As noted before, experience with wilderness campsite restoration is not well documented and generalizations are difficult. However, a few guidelines related to steps in the process of implementing a restoration design can be suggested.

### Visitor Management

The first step in any rehabilitation program is to effectively close the site to all use. Even day use, where horses are tied to trees or people inadvertently walk across the site, can frustrate a rehabilitation attempt. This is one of the real problems with rehabilitating closed sites close to lakes. Even if people do not camp there, they may use the site for picnicking or walk across it to go fishing or swimming. The most effective approach to closure consists of helping people understand the reasons for closures and letting them know about other desirable places to camp. It is best to get this information to visitors before they enter the area so they can adjust plans. In a number of cases, rope or string between stakes or trees has been honored. A sign declaring the site closed, the reason for the closure, and the location of alternative open sites in the vicinity promotes compliance (fig. 16.13). Use of the site can also be discouraged by partially burying large rocks and logs (iceberging) or planting dead trees and shrubs (vertical mulching).

### Site Stabilization and Preparation

Once closed, the site should be cleaned up, eliminating firerings, charcoal, excess firewood, and trash. Erosion is usually not a serious problem on campsites; however, if it is occurring it must be dealt with, usually through drainage manipulation. Then the soil needs to be prepared. Compacted soil should be cultivated (scarified) to a depth of about 4 inches, to facilitate seed germination, root and plant growth and water infiltration. Clods need to be broken up, leaving a crumb texture. Long-established campsites usually have soils lacking

in organic matter and a healthy soil biota. Legg, Farnham and Miller (1980) showed that scarification may have little effect if organic matter is not either incorporated into the soil or spread on top of the soil. Peat moss or raw organic matter can be mixed with the scarified soil (fig. 16.16). This may not be desirable in grasslands because grasses generally prefer more neutral soils. In a recent study on subalpine campsites in the Eagle Cap Wilderness, we found that revegetation success was increased by adding compost to soils (Cole and Spildie 2000). Other types of organic fertilizers—which largely increase the organic content of soil, while slowly adding low levels of limiting nutrients—are also available but have not been evaluated on wilderness campsites. Inorganic fertilizers can be added at this stage, but they have seldom improved revegetational success (Beardsley and Wagar 1971) and they tend to favor exotic species.

#### Propagation, Collection and Planting

Under some favorable circumstances, natural revegetation may occur without much assistance within a short period of time. In the West, at least, natural revegetation is likely to be most rapid at lower elevations, on more productive soils, and in areas that receive plenty of light and moisture. Elsewhere, revegetation is likely to require decades, if not centuries (Parsons 1979; Willard and Marr 1971). In these places, revegetation can be facilitated by transplanting whole plants or plant cuttings, or by seeding.

Transplanting, a technique used frequently and successfully, is time consuming and can disturb adjacent areas from which plants are removed. Consequently, in a number of areas, plants grown in nurseries, from seed, cuttings or root divisions obtained close to the restoration site, are transported to the backcountry for transplanting (Rochefort and Gibbons 1992). Transplanting is more successful than seeding in certain environments. Transplants can provide an early seed source, “nurse” plants that shelter and facilitate the germination

and survival of seedlings and may be the only effective way to get late successional plants established on sites. Experience in the Pacific Northwest suggests the following procedure for transplanting:

1. Select species adapted to grow on the site. Species that naturally colonize disturbed sites are good choices, as are plants that reproduce vegetatively. Choose relatively short plants with healthy looking foliage.
2. Water both the plants to be transplanted and the area to be transplanted one day before transplanting.
3. Place the plant upright in a hole slightly larger than the root ball. Make certain that roots are not doubled over on themselves. Fill in the excess space with organic matter and soil. When tamped down firmly, the top of the root ball should be slightly below the ground to facilitate watering and to reduce the risk of damage from frost heaving.
4. Water thoroughly. If it is warm or dry, it may be necessary to water the plants daily or to shade them. Where this is not feasible, survival rates can be increased by pruning some flowers, leaves, and branch tips and by providing large root balls.
5. Add a 1-inch layer of mulch over the transplanted area and around the base of the transplants. Mulch can be leaves, pebbles, commercial mulch, decaying wood, grass, or any other material that insulates yet allows free movement of air and moisture. Lightweight mulches may have to be anchored by limbs, stones, or similar objects.

Seeding is less complicated. Again, seed should be gathered close to the restoration site (to maintain genetic integrity) from plants adapted to the site. In some cases, nonnative species have been used because seed is more readily available and it was thought that such plants would be replaced by native species. In Mount Rainier National Park, for example, red fescue, a nonnative species, was planted as a cover crop to reduce erosion, soil temperatures, and frost action, and to increase the organic matter of disturbed area. In four years,

native plants did not invade red fescue sites; bare areas that were not planted with red fescue showed better revegetation (Van Horn 1979). To us, seeding with nonindigenous plants is an unacceptable alteration of natural conditions; the finding that it is frequently unsuccessful confirms this belief.

When seeding, it is important to become familiar with special germination requirements, such as scarification or stratification, of the species used. Seeds should either be scattered over the prepared soil and covered with one-half inch of soil or dropped into holes one-half inch deep. Soil should be tamped, mulched, and watered.

#### Site Maintenance

It may be necessary to water plantings for years, if conditions are droughty. It will also be necessary to maintain ropes and signs that keep visitors off sites.

Even with all this effort, restoration is likely to require long time periods. Transplants on road cuts in the alpine zone of Rocky Mountain National Park were surviving after 40 years, but they had not spread significantly (Stevens 1979). Three years after being planted, only 19 percent of transplants on closed subalpine campsites in Yosemite National Park were alive and total vegetation cover had increased only 1 percent (Moritsch and Muir 1993). Clearly, it is much better to avoid damage than to try to fix it after it occurs.

Site rehabilitation is an appropriate means for correcting past abuses, but it should be used judiciously. In addition to being costly, it interjects horticulture and landscaping into the wilderness. As a general principle, we believe rehabilitation should be used to restore sites that could then be protected through a new management program. Rehabilitation should not be used to bandage sore spots where no other change in management is implemented.

## MANAGING TRAIL IMPACTS

### COMMON PROBLEMS AND MANAGEMENT

Impacts on and along trails result from the trampling of hikers and packstock and the effects of trail construction and maintenance. As discussed in more detail earlier in this chapter, these impacts include loss of vegetation and shifts in species composition, exposure of bare mineral soil, soil compaction, and changes in microhabitats, including changes in drainage.

Where trail construction is carefully planned, most of these changes are of little concern; although pronounced, most changes are localized and deliberate. Most wilderness trails were originally constructed to provide administrative access, particularly for firefighters, but currently are maintained primarily for recreational purposes. Most trail impacts only warrant concern when they provide obtrusive evidence of human use, become difficult to use, or require large amounts of money and manpower to maintain. Although trail problems are usually highly localized, maintaining and relocating trails usually costs more than any other aspect of wilderness management.

*The most common problems with trails are (1) excessive erosion, (2) muddy stretches in areas of water-saturated soils, and (3) development of impromptu trails*, either adjacent to existing trails or in areas where no trails were planned. The first two problems make the trail difficult to use; all three suggest either “overuse” or improper use to visitors (table 16.3). Two other problems result from attempts to correct the three primary ones: excessive engineering and the proliferation of open and closed trails where trails have been

frequently relocated. Both of these situations provide abundant evidence of human use and manipulation of the resource—evidence that cannot be eliminated but should be kept to a minimum.

### Erosion

Although erosion can be significant on parts of a trail system, studies of trails in the Selway-Bitterroot Wilderness, Montana, and Guadalupe National Park, Texas, showed that little erosion is occurring over entire trail systems (Cole 1991b, Tinsley and Fish 1985). Material eroded from trail “banks” or the tread itself is usually deposited elsewhere on the trail. Soil is lost from the trail system only where water drains off the trail, and much of that can be compensated for by sediment washed onto the trail from above by overland flow. Although trail troughs often change—either deepening through erosion or being filled in through deposition—trail systems as a whole usually exhibit a relatively steady state.

What is critical, however, are those stretches where erosion is pronounced. Severe erosion does occur and it can make a trail difficult to use, either because it is too deep and narrow or because exposed roots and rocks make footing difficult. This tempts people to leave the trail and make a new trail. Deeply rutted trails also exacerbate their own erosion problems by more effectively channeling water.

Although trampling can cause limited amounts of erosion, the primary effect of trampling is to make a trail susceptible to erosion by loosening up the soil (DeLuca and others 1998), reducing infiltration rates, and removing vegetation. Running water is the principal agent of erosion. Streams, snowmelt water, and water from springs all cause erosion when channeled down the trail. In some places, rainfall can also be intense enough to erode trails. For this reason, the main factors that determine degree of erosion damage are trail

grade, orientation, and drainage—factors that affect the channelization and erosive force of water in the trail—and soil texture, the primary factor determining how readily the soil is detached and carried away. Leung and Marion (1996) provide a useful review of what is known about the influence of environmental factors on trail degradation.

Amount and type of use are generally less important than the location and design features. Studies in the northern Rocky Mountains concluded that trails were not substantially deeper where use levels were higher (Cole 1991b; Dale and Weaver 1974). This is not to say that 1,000 hikers per day would not cause more erosion than only one hiker per day. Rather, it means that beyond a low threshold of use—the amount of use required to eliminate vegetation and render the trail vulnerable to water erosion—location and design are more important determinants of erosion than amount of use. Therefore, to prevent erosion, use levels would have to be so low that bare trails do not form. Virtually eliminating use in order to avoid trail problems is inefficient—not to mention unpopular with the public—given that trails can be designed to accommodate heavy use.

It has been suggested that type of footwear is an important determinant of amount of damage. Bainbridge (1974) wrote, “Indications are that Vibram lug soles may be 50 to 100 times more destructive than tennis shoes or flat soles but the conclusive research has not been completed.” Studies indicate, however, that lug soles are not substantially more destructive than other types of footwear. Kuss (1983), for example, found no significant difference in the volume of soil eroded from a stretch of trail after being trampled by lug-soled and corrugated rubber-soled boots. This lack of difference was found despite increases in soil yield, after 600 and 2,400 trampling passes, amounting to 1.4 and 1.7 times the yield of undisturbed trail, respectively.

Whether trail use is by hikers or by parties with pack and saddle stock is an important indicator of potential erosion problems. A small bearing surface carrying heavy weight, a horse's hoof can generate pressures of up to 1,500 pounds per square inch (Bainbridge 1974). These pressures, along with sharp shoes, cause stock to break up, not compact the trail surface. Detached soil is more easily eroded, and makes trails dustier when dry and muddier when wet. In a recent experimental study, DeLuca and others (1998) found that horse traffic resulted in much higher sediment yields (an indicator of erosion potential) from established trails than either hikers or llamas. Hooves also tend to punch holes through meadow turf and disrupt wet soils (fig. 16.17). Use of stock on frequently used, properly located, and well-maintained trails is unlikely to aggravate problems. But on little-used trails that are steep, pass through wet meadows, and are seldom maintained, stock use can be much more damaging than hiker use. Limiting stock use in such areas could therefore reduce trail problems.

For most trails, the most effective solution to erosion problems lies in locating the trail where it is resistant to erosion and, where this is not possible, designing it to minimize erosion. Studies have found that erosion is most severe where trails are located in soils of homogeneous texture and that lack rocks. Erosion-prone soils consist primarily of sand, silt, or clay, rather than a combination of these different particle sizes; fine sand and silt soils are particularly prone to erosion (Bryan 1977). Such soils are frequently encountered in glacial deposits, particularly in valley bottoms and enclosed basins. Meadows also often have homogeneous, fine-textured soils. Meadow soils can also be highly organic, and organic soils are particularly prone to deterioration (Stewart and Cameron 1992). Steep slopes and places where drainage or snowmelt run down the trail are also prone to erosion. Streambanks, with steep slopes, abundant moisture, and, in many places, fine-textured soils, can frequently experience excessive erosion.

For these reasons, in the mountainous West at least, erosion problems are frequently avoided by locating trails on ridges, talus slopes, and bedrock, away from alluvial plains and the glacial deposits of valley bottoms (Summer 1980). South- and west-facing slopes are often preferred locations because snow melts earlier there. Where trails receive regular use, trails are best located in forests outside of meadows. Although the vegetation in meadows is relatively resistant (Cole 1993a), regular trail traffic use will eliminate even resistant vegetation and expose soils that are highly prone to erosion.

It is important to avoid steep grades by locating trails on sidehills and by providing switchbacks where necessary. To divert water off the tread, trails are usually outsloped and often incorporate dips and rises (often called a rolling grade) rather than long, continuous downslope stretches. Water bars—logs, boards, timbers, or rocks installed across a trail, usually on an angle and sloping out—are common means of directing water off the tread and minimizing erosion. Water bars must be spaced closely enough so that water cannot build up excessive speed and erosive power. They must be securely anchored and large enough to keep water from running around or over them, forming destructive little waterfalls; and they must be maintained frequently because they cease to function when dislodged or buried in the sediment deposited behind them. Finally, all of these techniques need to be part of the original trail design; once a deep trough has eroded, none of these techniques will be effective. Proudman and Rajala (1981), Birkby (1996), and Hesselbarth and Vachowski (1996) provide good how-to instructions on these techniques.

It will also be necessary to keep water from flowing onto the trail. The most common devices used are cross ditches (rock- or log-armored ditches crossing the trail), culverts (wood, metal, or fiberglass drainages buried underneath the trail), and parallel ditches

(depressions that carry water adjacent to but lower than the trail tread). All of these devices must be carefully placed and maintained or they can aggravate problems.

Erosion of streambanks can be minimized by locating stream crossings where banks are low, gentle, and stable. Where this is not possible, angling the trail across rather than directly up the bank and incorporating drainage devices can help minimize damage.

### Muddiness

Muddy stretches are particularly disturbing to recreationists; both hikers and stock balk at walking through quagmires. In an attempt to skirt the problem, hikers and stock enlarge the muddy area until it can be hundreds of yards long and occasionally almost as wide. These quagmires usually result from trampling while soils are water-saturated. Again, amount and type of use are of little importance because it takes only a little trampling to do most of the damage; however, damage is much more rapid with stock use than with hiker use (Stanley and others 1979). Muddiness can be a season-long problem in places where the water table is always close to the surface, or it can be temporary, occurring during snowmelt or when heavy rains fall on trails that have been churned to dust. The solution is to either locate trails on dry soils or shield the wet soils from trampling through trail engineering (fig. 16.18). Relocation is preferred, if a better location exists.

Snowfields that do not melt until late in the season should be identified, and trails should be located away from meltwater channels. Identifying areas where the water table is close to the surface is more difficult. By noting the plant species and plant communities that grow in places along existing trails where muddiness is a problem, one can identify reliable vegetation indicators of

potential problems. In the Selway-Bitterroot Wilderness, for example, more than two-thirds of the muddiness problems in one trail system were found in one vegetation type, which, along with vigorous growth of four individual species, can be used to identify sites to avoid (Cole 1983b).

Where trails must be built through water-saturated soils and it is not possible to improve the drainage, some sort of bridging is necessary to shield the vulnerable soil from trampling. Stepping stones sometimes provide a simple solution. A common type of bridging—corduroy—consists of three or more logs laid on the ground as stringers and bound together with wire or nails. It is notorious for not lasting long and should only be a temporary measure (Hesselbarth and Vachowski 1996). More permanent solutions include (1) puncheon, a deck or flooring placed on stringers to elevate the trail and (2) turnpiking, an elevated trail of earth or gravel fill supported either by logs or flat rocks. Turnpikes may or may not be ditched on either side or may use culverts to facilitate drainage. Although such a trail is a permanent improvement and shows a “substantially noticeable imprint of man’s work,” huge quagmires are also noticeable and undesirable. Therefore it is our opinion that such engineering is appropriate where necessary to cope with mud as long as (1) relocation is not feasible, (2) the design fits the environment, and (3) the practice is not carried to the extreme where every miniscule wet place is bridged.

### Impromptu Trails

The three most common types of undesirable impromptu trails are multiple, parallel, or braided trails; shortcuts on switchbacks; and informal trail systems that traverse popular trailless areas or that fan out across popular destination areas. Each of these situations is the

result of a unique set of circumstances; consequently very different management approaches are required for each. The one element they have in common is that they are caused by people leaving the existing trail system—either out of dissatisfaction with the trail itself or a desire to go someplace else. Therefore, understanding visitor behavior and possibly accommodating their desires, as well as informing them of the damage they are doing, are common means of dealing with these three situations.

*Multiple trails* are common in areas that are poorly drained or have homogeneous fine-grained textures. Trails in such places present difficult footing due to their slippery, muddy surface or their being deep and narrow. In either case, hikers and horses walk beside the trail, forming a new one (fig. 16.19). Multiple trails also tend to form in open areas where it is easier for users to spread out; therefore they are a particular problem in meadows. Other than educating people to stay on existing trails, the best solution to multiple trailing is relocation. Over the past few decades, there has been a strong trend is to get trails out of meadows into adjacent forested areas. However, trails abandoned in meadows usually need to be actively rehabilitated or they may continue to erode and may take centuries to recover.

In some places, such as Yosemite National Park, it has been very difficult to get people to stop using trails in the meadows or along other preferred routes. In these cases engineering solutions, such as turnpiking have been employed to overcome the problems that encouraged users to form multiple trails. Although engineering may be preferable to doing nothing, we feel it should be a last option. Widening the trail trough can be a means of making it easier for visitors to stay on the trail tread. Armoring the trailside with rock—by making it uncomfortable to leave the tread—can also be helpful.

*Shortcutting switchbacks* is a common problem that has received considerable attention and it is usually dealt with by trying to change visitor behavior and through trail design. Whether through education or regulation, visitors are asked not to shortcut switchbacks.

In some places signs have been erected along the trail; this is an undesirable intrusion and should not be used unless absolutely necessary. Designs that can effectively reduce shortcutting include screening one switchback from another, building barriers of rock or vegetation, avoiding the use of numerous short switchbacks, and using wide turns.

*Informal trail systems* indicate too much use of an area intended to be kept trailless (fig. 16-20). They are difficult to control. In popular destination areas managers should consider developing an “official” trail system based on existing use patterns and encouraging its use. This strategy should control the size of the informal trail network and keep trails out of fragile environments. When laying out an official trail it is critical to provide access to the places visitors seek to go. If this is not done, the informal system will continue to be used, frustrating this management strategy.

Informal trails can also be controlled by reducing use, closing and rehabilitating trails, and persuading visitors to spread out. This is probably only realistic in remote, lightly used parts of the wilderness, where management objectives are to keep the area trailless. In remote portions of the Tasmanian Wilderness World Heritage Area, signs at the beginning of trailless areas ask hikers to spread out. Once trails begin to develop, use must be reduced or an official trail should be designated. Although it may seem inappropriate to reduce use in lightly used places—particularly if use is not limited in much more heavily used destination areas—this may be the only means of meeting the objective of avoiding trails. Several actions can be taken at an early stage to make such an action less likely. Users of such areas should be educated about the need to travel in small parties, to spread out rather than follow in each other’s footsteps, and to avoid using incipient trails. Of particular importance, management should not attempt to disperse use from heavily used destination areas to these lightly used areas unless they are willing to accept trails in these places.

## Engineering

As much of the preceding discussion concludes, next to proper trail location, engineering—surfacing, bridging, ditching, and so on—is the most effective means of avoiding trail problems. Problems that cannot be reduced or avoided by trail relocation will generally require an engineering solution. Although engineering is an appropriate means of providing for use without excessive resource damage, it is counter to the wilderness ideal and therefore should be kept to a minimum.

## Excessive Relocation

Frequent relocation can produce a maze of closed trails. Managers must therefore exercise restraint when relocating trails. This problem can be reduced by actively rehabilitating trails. A good rule of thumb, however, is not to relocate a trail unless (1) the new section is in a more resistant environment or is better designed, and (2) hikers can be kept off the old section of trail (Proudman and Rajala 1981).

Unless both these conditions are met, relocation will only compound problems by disturbing new sites.

## MONITORING TRAIL CONDITIONS

Monitoring of trails can be used to ascertain trends in trail condition, where and how to locate and design trails, whether trail management programs are working, and where and how trails need to be fixed. For the purpose of assessing trend in condition, rapid survey techniques are quick and easy and usually provide adequate precision. One approach is to sample conditions along trails at a periodic specified

distance, such as every 100 meters. Using such an approach on a trail system in Montana, Cole (1991b) showed that mean trail width (the zone disturbed by trampling) increased from 100 cm to 125 cm between 1980 and 1989; however, bare width (the zone without any vegetation) and trail depth did not change significantly. Such data can also be used to assess the portion of a trail that exceeds certain depth or width standards or that contains certain “detracting features” (such as root exposure or muddiness). Recently, Leung and Marion (1999a) assessed the influence of sampling interval on the accuracy of estimates of the lineal extent of “detracting features” on trails at Great Smoky Mountain National Park. They report that a sampling interval of less than 100 m is best, although an interval of 100-500 m is probably acceptable. They advocate using a sampling approach to assess the lineal extent of problems but advise against using a sampling approach to estimate the frequency of occurrence of problems.

Frequency of problems—and also lineal extent—is most accurately and usefully assessed with a census of the trail system. The first step here is to define in precise terms exactly what is or is not considered a problem. As trails are walked, the number and length of problems are recorded and their location is mapped. Such information is useful not only to assess trend, but also in budgeting for trail maintenance and in allocating resources to certain trail segments. In a recent application of this approach at Great Smoky Mountains National Park, Leung and Marion (1999b) were able to show that (1) soil erosion and wet soil were the most extensive problems, (2) water bars were more effective than drainage dips in diverting water off trails, and (3) although serious impact problems were fairly well distributed through the park, trails with wet muddy treads were concentrated in places with high horse use.

An extension of the census—focused exclusively on decisions regarding where and what trail work is needed—is the prescriptive work log (Williams and Marion 1992). As the trails are hiked, problems are noted. Assessors note the distance along the trail of each problem, describe the problem and attempt to prescribe the maintenance work needed to fix the problem.

For the purpose of assessing the effectiveness of management programs or maintenance techniques on specific trail segments, the expense of more detailed replicable measurements may be justified. Typically, these techniques provide accurate measures of trail cross-sectional area at fixed locations that can be precisely relocated. Increases in trail cross-sectional area indicate erosion has occurred. Cole (1991b) used this technique to show that while there was no net trail erosion over an 11-year period, one poorly-located section of trail exhibited a two ft<sup>2</sup> increase in cross-sectional area. Warner and Kvaerner (1998) describe a photographic technique that can provide accurate estimates of trail erosion,

As mentioned earlier, it can be quite useful to census problem trail segments and look for associations between deterioration problems and environmental indicators such as vegetation type. These indicators, once identified, can be used to guide trail location and relocation and to indicate where engineering and maintenance are necessary. Although such a survey involves an initial outlay of funds, the investment will be recovered quickly in reduced trail relocation, maintenance, and rehabilitation costs. It is not necessary to survey all trails. Just choose a few examples that represent the range of conditions in the area of concern, develop guidelines for these conditions, and extrapolate the results elsewhere.

## TRAIL REHABILITATION

Much of the information about rehabilitating campsites also applies to trails, particularly the techniques available for reestablishing vegetation and the need to eliminate all use. The major difference is the need, in many places, to stop erosion and to replace the soil lost by erosion. It also may be more difficult to keep people from using the trail if it leads where they want to go.

To minimize use of a trail one must first provide a desirable alternative route. This may require observation of use patterns and visitor behavior, and even some questioning of users about their itinerary and what alternative routes might be acceptable. Once the alternative has been provided, one should try to mask the old trail. Careful selection of a starting point for the relocation can make it easier to hide the old trail. If it cannot be hidden, block it with logs, rocks, or brush. Finally, if this does not work it will be necessary to erect signs such as "Please stay on the trail to prevent damage."

Avoiding further trail erosion starts with looking for the erosion source. Sometimes runoff has been directed down the trail and it must be diverted elsewhere. Ditches and water bars across the trail can be used to keep water off the trail. Where trails are deeply eroded, it may be necessary to place rock or log check dams in the trail to reduce water velocity and to allow backfilling of sediment (Rochefort and Gibbons 1992). Material used to fill in trail troughs--other than what is deposited behind check dams--must be judiciously selected. Where the trail follows the contour, it is often possible to move material deposited below the trail, as a result of construction, back into the tread. Other good sources of material include soil from streambeds and rock from talus slopes or other trail work. It is best not to remove too much material from any single place and to make certain the source area is blended into its surroundings and masked from view. Regardless of where the material comes from, revegetation will be most effective if the trough is filled to grade with soil.

One of the few documented tests of rehabilitating multiple trails was tried along a section of trail in Tuolumne Meadows in Yosemite National Park (Palmer 1979). Of 22 techniques tried, the most successful one involved cutting off the sod ridges between the multiple trails at the level of the trail tread and stacking it in the shade (fig. 16.21). The soil beneath both the trails and the ridges was dug up to eliminate compaction, and sand was added to bring the trail up to the level of the surrounding meadow. Finally, the sod was divided into transplant plugs and planted. While this technique will work only in certain environments, it is well-suited to multiple trails in meadows--a very common problem in many areas. Eagen and others (2000) report on the continued success of this basic technique in Tuolumne Meadows.

#### MANAGING PACK AND SADDLE STOCK

Although the backpacking “boom” of the late 1960s and 1970s relegated pack and saddle stock to a minority use in all but a few wildernesses, stock use is still an accepted tradition in much of the National Wilderness Preservation System (NWPS). This is in contrast to some other Nations, such as Australia, where use of stock in wilderness is not allowed. As of 1990, stock use occurred in about one-half of all wilderness areas (McClaran and Cole 1993). It is only explicitly prohibited in 14 percent of wilderness areas. About one of every 9 parties entering wilderness, in 1990, traveled with stock. About one-third of all non-administrative use of stock is commercial, as opposed to private. In 1980, although packstock accompanied more than 2 percent of parties in only 72 wildernesses and more than 50 percent of parties in only six areas, packstock impacts were reported to be a problem in 76 wildernesses (Washburne and Cole 1983).

Despite the prevalence of such problems, the published literature on packstock impacts and their management is sparse. Certain impacts are similar to those caused by hikers and can be managed similarly; others are qualitatively different and require very different sorts of management techniques.

#### TYPES OF STOCK IMPACT

Generally the impact of stock on trails is similar to that caused by hikers except that it is more pronounced. Weaver and Dale (1978) examined the effects of controlled amounts of use by horses and hikers on trail width and depth, percentage of bare ground, and soil compaction (bulk density). Trails produced by 1,000 horse passes were 2 to 3 times as wide and 1.5 to 7 times as deep as trails produced by 1,000 hiker passes. Compaction increased about 1.5 to 2 times as rapidly on horse trails as on hiker trails. Finally, one-half of the vegetation was lost after 1,000 hiker and 600 horse passes on a grassland, and after 300 hiker and only 50 horse passes in a forest. In a more recent experimental trampling study in Montana, Cole and Spildie (1998) report that just 25 horse passes cause more loss of vegetation cover than 150 passes by hikers or llamas. In a Tasmanian shrubland, Whinam and Chilcott (1999) report that broken plant material, as a percentage of plant biomass, was 0.1 percent after trampling by hikers, compared to 39.2 percent after trampling by horses. These experimental results suggest that the creation of multiple trails and new trails in trailless areas will occur much more rapidly with stock use than with hiker use. The trails created will also be wider, deeper, more compacted, and less vegetated.

The effect of stock on existing trails, which can differ from their effect on undisturbed sites, was examined experimentally in Great Smoky Mountains National Park (Whittaker 1978). Again, horse use caused more pronounced increases in trail width, trail depth,

and litter loss than hiker use. In Montana, horse traffic on existing trails resulted in more than double the sediment yield caused by a comparable amount of hiker traffic (DeLuca and others 1998). While hiker use generally tends to increase soil compaction on the trail, horse use loosens the soil, making it more susceptible to erosion (fig. 16.17). McQuaid-Cook (1978) has commented that this tendency for shod hooves to loosen soil leads to more pronounced incision of equestrian trails. Trail widening is accentuated by the tendency for stock to walk on the downslope side of the trail. This breaks down the outer edge of the trail so that new soil must be brought in to rebuild the trail. The result is a wide trail, a much wider area of disturbance, and an ongoing trail maintenance problem (Whitson 1974).

Equestrian trails require considerably more maintenance than hiking trails. They must be “brushed-out” to a greater height and width. Fallen trees must be quickly removed or detour trails will rapidly develop. Stock often break or dislodge drainage devices such as water bars. Stock disturbance of muddy trail sections can be particularly severe and can be corrected only with some type of bridging more elaborate than that required for foot travel.

On campsites, differences in the magnitude of impact caused by hikers as opposed to stock parties are even more pronounced than on trails. Moreover, stock parties cause a number of impact types that other parties do not. Unfortunately, very little data on differences between these two types of use are available. Unpublished data from Dr. Sidney Frissell’s work in the early 1970s, in what is now the Lee Metcalf Wilderness, indicate that campsites used by stock parties were, on the average, 10 times as large and had 7 times as much exposed mineral soil as sites used primarily by backpackers.

A more complete picture of differences in amount of impact between stock and backpacker campsites comes from a comparison of six sites of each type in the Bob Marshall Wilderness (Cole 1983a). When compared to backpacker sites, stock sites are much larger, have

many more damaged trees, have been more extensively invaded by exotic species, and have experienced much more profound soil disturbance (table 16.5).

Stock parties, generally being larger than backpacker parties, consequently disturb a larger area, to which is added an adjacent area where stock are kept (fig. 16.22). The animals are often tied to trees, resulting in a large number of damaged trunks and exposed roots. Because stock parties usually carry saws and axes to clean windfalls from trails, trees are often felled for tent poles to support large canvas tents and for firewood.

Although stock are usually kept adjacent to the camp, they occasionally are brought into the central camp area. Here, the action of their shod hooves can cause rapid deterioration of the site. Loss of organic soil horizons, increased compaction, and decreased infiltration rates typical of all campsites are particularly pronounced on sites used by stock parties. Seeds of exotic plants contained in horse feed readily germinate and grow on such disturbed sites. On Bob Marshall campsites, exotic species accounted for just 5 percent of the vegetation cover on backpacker sites, compared with 43 percent of the cover on stock sites (Cole 1983a).

In areas where stock are grazed or confined for the night, impacts result from both trampling and defoliation of plants. These impacts, described in the earlier section on grazing impacts, are unique to parties with stock and often affect a much larger area than all other recreational impacts combined. In a portion of the Eagle Cap Wilderness, an estimated 1.8 percent of the area had been significantly altered by recreational use. About three-fourths of this disturbed area consisted of areas used only by stock for grazing (Cole 1981). Moreover, in comparison to the forests, the meadows and grasslands used for grazing are often both rare ecosystems and aesthetic attractions; therefore their disturbance is particularly undesirable.

Meeting parties traveling with stock or finding evidence of stock use, such as manure or corrals, also detracts greatly from the experience of many wilderness users (Watson and others 1993). This is particularly true in the majority of wildernesses where stock use is a small minority. For example, in the Bridger Wilderness, Wyoming, where backpacking is the norm, 59 percent of parties preferred not to meet horse users; in the Bob Marshall Wilderness, where stock use is common, only 21 percent of parties preferred not to meet horse users (Stankey 1973). In the Rawah Wilderness, Colorado, where only 4 percent of the respondents to a survey used horses, 57 percent of those questioned wanted to see no horse users at all, not even small parties close to the trailhead. Only 23 percent wanted to see no other hiking parties at all. The only situation wherein a party of hikers would be considered more objectionable than even a small party of horse users seen near a trailhead, would be a large party of hikers walking or camped near the respondent's destination (Badger 1975).

In addition to dissatisfaction with meeting horse users, problems stem from finding evidence of horse use or dealing with inconveniences caused by their use. For example, in Yosemite National Park, Lee (1975) found that the presence of horse manure or facilities such as hitch rails were key sources of dissatisfaction with campsites. Unpublished results of a study by M. F. Trahan in Rocky Mountain National Park, Colorado, show that a majority of day hikers who disapproved of horse use (57 percent of all users) did so because they disliked horse manure and urine, and the flies and other insects attracted to it. Less common reasons for disapproval were concern with the damage stock do to trails, the dust they cause, and the large size of most stock parties. Fewer still disapproved because they disliked moving off the trail to let horse users pass or because they disliked the general idea of some people riding while others walked.

In addition to those that would rather not meet stock-equipped parties in the wilderness, many visitors believed that use of stock in wilderness is inappropriate. For example, in the Sierra Nevada less than 15 percent of the parties surveyed approved of horses as a means of recreational travel; 60 percent thought that use of stock was inappropriate even to render emergency aid (Absher and Absher 1979). Although 59 percent of hikers in the Sequioa-Kings Canyon Wilderness felt it was undesirable to meet horse riders, only 25 percent of these respondents felt that the behavior of horse riders had ever interfered with the quality of their experience on any visit to the wilderness (Watson and others 1993).

Several studies show—not surprisingly—that different kinds of stock vary in the impact they cause. Two recent studies show that llamas cause substantially less impact to existing trails and to vegetation than horses. In addition, visitor surveys suggest that hikers are less bothered by the use of llamas than the use of stock (Blahna and others 1985).

## MANAGEMENT STRATEGIES AND TECHNIQUES

Despite the strong tradition of stock use in wilderness, management needs to come to grips with the inescapable conclusion that social, environmental, and administrative costs associated with stock use are much more pronounced than those associated with comparable amounts of hiker use. This situation is aggravated by the large number of backpackers who feel that use of stock and its impacts are inappropriate. In many areas the solution is complicated by a strong tradition of stock use by administrative agencies. In areas where use is already highly restricted due to ecological and social impacts, management must strive, particularly, to minimize those impacts associated with stock use.

As with campsite and trail impact, a number of factors influence the *severity of stock impacts*. The most important are frequency and amount of use, party size and behavior, time of use, and location of use. These define *four primary management strategies*: (1) *limiting or reducing use*, (2) *encouraging less damaging behavior*, (3) *discouraging use during times of the year when the potential for damage is high*, and (4) *encouraging use of particularly resistant environments*. Because stock cause more impact than hikers, a *fifth strategy, containment*, is particularly valuable in controlling the spread of stock impact (table 16.6).

### Limiting Use

Numerous studies have concluded that impacts on trails and campsites are unlikely to be greatly diminished merely by reducing use, unless use levels are cut to almost nothing (Cole 1987). Because stock use causes impact even more rapidly than hiker use, this conclusion has even more serious implications for managing stock use. Unless all stock use is eliminated, there will be few situations where reducing stock use will produce substantial benefits in improved trail and campsite conditions. Reducing use can help minimize social and aesthetic impacts (horse user-hiker conflicts, manure, and so on), but other less drastic actions can also be taken. Except in cases where all recreational use must be limited, or where management objectives indicate that all stock use and impact are inappropriate--and all stock use is prohibited--there seems to be little justification for limiting the amount of stock use. Better solutions to stock-caused problems exist.

One important exception to this is the institution of limits on the use of specific meadows to avoid overgrazing. Managers of Sequoia and Kings Canyon National Parks, for example, have implemented a management plan with specific limits for use of certain

meadows with a history of being overgrazed. When the limit is reached, the meadow is temporarily closed. The need for closure is evaluated by monitoring meadow condition or by determining use levels from posttrip itineraries that each stock party is required to submit. Some of these meadows have length-of-stay limits so that more users can share the limited resource.

However, just as it is inequitable to ration stock use when hiker use is unlimited, it is also inequitable, where rationing is instituted, not to recognize that stock cause considerably more damage than hikers. In terms of comparable impact, more hikers than horse users can use an area. As the earlier review of impact studies shows, trampling by a horse typically causes four to eight times as much impact as trampling by a hiker. Thus a typical group of three horse riders, with two pack animals, are likely to cause about 7 to 14 times the impact of a group of three backpackers (everything else being equal). When the impacts of grazing and confining stock are factored in, a group of three, choosing to travel with stock, might typically cause about 20 times the impact of a comparable group of three choosing to travel on foot. Consequently, where use is rationed, an equitable allocation system would give a hiker 20 times the odds of a horse rider of obtaining a permit.

#### Encouraging Less-Damaging Behavior

Promoting minimum impact stock use has much promise for reducing impact, particularly on and around campsites. Outside of malicious or thoughtless chopping of trees, most tree damage--a particularly severe problem on stock sites--results from felling trees for firewood or tent poles and tying horses to trees. Available techniques and equipment (USDA FS 1981, Aaland 1993, Hampton and Cole 1995) can largely eliminate these practices and their resultant impacts. Also, stock do not need to be in camp areas after unloading; if stock were

kept off campsites, soil disturbance and horse manure would also be greatly reduced. If these ideas were adopted by stock users, campsites used by stock parties should suffer no more damage than sites used by comparably sized groups of backpackers.

Unfortunately, limited research suggests that it may be particularly difficult to persuade stock users to adopt Leave No Trace techniques. In a study of attention to low impact messages posted on trailside bulletin boards—the most common of educational media—Cole and others (1997) found that horse riders' knowledge of appropriate low-impact techniques was much lower than hikers' knowledge. Moreover, fewer horse riders (27 percent) than hikers (71 percent) stopped to read the messages; the horse riders who did read the messages gave them less attention; and the horse riders remembered less of the message after their trip. Given that stock groups have so much more potential to cause impact than hiking groups, these findings are disturbing. Hopefully, there are educational media other than trailside bulletin boards that can be effective in reaching horse riders.

Rather than rely on education, many areas have established regulations designed to prevent inappropriate behavior. As of 1990, 29 percent of the areas with regular stock use prohibited tying stock to trees (McClaran and Cole 1993). Eighteen percent required the use of hitchlines, while 7 percent required hobbles; nine percent prohibited picketing of stock.

The number of stock in a group affects both the disturbed area around campsites and loss of solitude. A large party detracts much more from visitor satisfaction than a small party (Stankey 1973). Although a limit on party size is currently the most common packstock management technique in wilderness—about one-half of wildernesses with stock use have a limit--the number allowed ranges from five to 35 animals per party, with 25 the most common limit (Monz 2000). Such high limits will have very little beneficial effect. Moreover, there is little equity in the common situation where the maximum allowable number of stock exceeds the allowable number of hikers. The

purpose of a party size limit is to restrict the impact that any given group can cause. Given that a horse will typically cause more than four times the impact of a hiker, a group of 10 riders and 15 stock will typically cause at least 10 times the impact of a group of 10 hikers. An equitable party size limit would reflect this difference in impact potential. Limits based on number of “heartbeats” are somewhat less discriminatory. Using this approach, it is permissible for any group to have a given maximum number of animals, say 10, which can consist of any combination of people, stock or dogs.

Stock impacts could also be reduced by requiring parties to carry stock feed, thus virtually eliminating grazing damage. Seventeen percent of wildernesses with stock use, mostly NPS areas, have taken this action (McClaran and Cole 1993). Another 65 percent of wildernesses recommend packing in feed. In many places, parties bring only enough feed to supplement grazing. Where deterioration is not yet critical, this approach may be more acceptable to users and may postpone or avoid the need for regulations. It is important, however, that the feed not contain exotic weeds. Certified weed-free hay is now required in many wilderness areas. Other possibilities include the prohibition of grazing where areas have been overgrazed.

#### Managing the Timing of Use

Although only 5 percent of areas prohibit stock use during certain seasons of the year (McClaran and Cole 1993), the impact of both grazing and trampling is highly dependent on seasonal variables, particularly the phenology or stage in the annual cycle of development of plants, and the moisture content of the soil. Generally, plants and soil are most vulnerable to disturbance during spring when plants are using stored nutrients for growth and when soils are water-saturated. This has led Sequoia and Kings Canyon National Parks--the backcountry area with the longest history of research and management of packstock impact--to make their primary management tool “a

system of opening dates that vary depending on the type of hydrologic year and the vegetation and soils in question” (DeBenedetti and Parsons 1983). A research program examined the composition and distribution of the parks’ major forage areas as well as their susceptibility to differing intensities, frequencies, and times of use. Opening dates were prescribed for three types of hydrological years (wet, normal, and dry), allowing the user to predict when use will be allowed.

#### Controlling Location of Use

A common action is to keep stock away from streambanks and lakeshores, where trampling can be particularly destructive and, in some cases, cause accelerated erosion. This will also reduce the risk of water pollution. Forty percent of areas with packstock have this regulation, making it the second most common restriction on use of packstock (McClaran and Cole 1993). Many more areas encourage this practice through educational programs.

#### Containment of Impact

Probably the most effective way to manage the impact of stock is to control where stock use is and is not allowed. Reasons for this include (1) the high potential for damage wherever stock use occurs; (2) the high environmental, social, and maintenance costs of stock use that, in most areas, benefits only a small proportion of users; (3) the large numbers of impacts that are caused exclusively by stock; (4) the area affected only by packstock, mostly grazing areas, is often much larger than the area affected by hikers; and (5) grazing impacts

are concentrated on meadows that are often a rare and aesthetically important ecosystem type. In those few wilderness areas where stock use is the norm, confining use may be less justifiable and will be a less important strategy than changing behavior and practices.

In most National Park Service wilderness (91 percent), stock use is only permitted on established trails (McClaran and Cole 1993). Moreover, some parks—like Glacier National Park—only allow overnight stock use in selected areas judged to be resistant to stock impact. Less restrictive alternatives exist, although resultant impact will be greater. One approach is to permit stock use on mainline trails and selected trails into destination areas. For example, imagine a series of lakes up a tributary valley. Stock use might be permitted as far as a stock camp at the first lake above the valley bottom. However, foot traffic only is allowed beyond this first lake. Through this compromise, horse riders are provided with access to the tributary valley without opening up the entire string of lakes to the heavy impacts typically associated with stock traffic. Where certain trails are closed to stock use, trail maintenance costs can be substantially reduced.

Sequoia and Kings Canyon National Parks have an even less restrictive policy. They prohibit stock use only in places that have never received regular stock use and in certain meadows being maintained as representative examples of pristine ecosystems (DeBenedetti and Parsons 1983). Such a policy provides opportunities for horse users to enjoy much of the wilderness while avoiding degradation of currently undamaged areas and providing protection for some representative examples of meadow types that might be entirely altered by unrestricted grazing. It also provides places for hikers to go where they know they will not see stock parties.

Confinement of stock impacts appears to offer the optimal compromise between providing horse riders with access to wilderness while confining the heavy impacts typically associated with stock use. Nevertheless, this approach is seldom taken outside of the

wilderness areas managed by the National Park Service. Horse users complain that such an approach discriminates against them because they cannot go everywhere hikers can. Whether or not this is discriminatory depends on whether equity should be based on assuring that everyone has an equal opportunity to enter an area or an equal opportunity to cause impact problems that degrade the wilderness and that require management response. Since the job of management is to control impacts, it seems more sensible to equitably distribute the opportunity to cause impact. From this perspective, the confinement of stock to certain trails and areas is not discriminatory because it is necessary to compensate for the greater impact potential of stock users.

Confining stock use and impacts within destination areas also can be advantageous. For example, Spildie and others (2000) evaluated the effectiveness of a confinement strategy designed to reduce the impact of stock in a subalpine lake basin in the Selway-Bitterroot Wilderness. Stock users were permitted to camp overnight at any of the lakes in the lake basin, but were required to stay in a designated stock site provided at each lake. They were required to tie their stock to a hitchline that was to be strung between two designated trees, confining the impacts of stock containment to a very small area. The benefits of this program—in reducing impact—have been phenomenal. In just five years, disturbed area has decreased 37 percent and bare area has decreased 43 percent. Disturbed and bare area in the lake basin should eventually decline to just 36 percent and 24 percent, respectively, of what they were in the early 1990s. Moreover, costs to stock users are minimal. They retain the ability to access the entire lake basin, as long as they use specific campsites.

Forty-five percent of NPS wilderness areas require that stock parties camp at certain sites specifically designated for their use. This confines damage to one site in a particularly resistant area. In Yellowstone National Park, Wyoming, grazing is allowed only in designated meadows that are periodically closed to allow recovery. Corrals, drift fences, and hitch rails can also be used to confine the

spread of impact (fig. 16.23). Where studied, most visitors support both restricting stock use in certain areas and requiring stock parties to use certain campsites (Badger 1975; Lucas 1980).

#### THE CHALLENGE OF STOCK MANAGEMENT

Managing stock and its impacts is a difficult and serious problem. The damage caused by stock is generally much greater than that caused by hikers, many types of impact can be attributed solely to stock, and in most areas only a very small proportion of visitors benefit from and are associated with this impact. Many hikers consider this to be an inappropriate impact on the wilderness resource and this along with other inconveniences, such as exposure to horse manure and moving off the trail to let horse users pass, creates conflicts between backpackers and horse users. These conflicts appear to be growing. Complaints about stock are the most common complaint from visitors in many wilderness areas.

On the other hand, some stock use is a generally accepted, traditional type of wilderness use. Managers must grapple with the questions of how much of this impact is acceptable and where it should be allowed. A particularly difficult question is whether to allow stock use in places now suffering from too much use. Stock impacts are likely to be less severe here than elsewhere because impacts are already so serious that further impact is unlikely. However, because such places receive heavy hiking use, horse-hiker conflicts are likely to be severe here. Where impacts are excessive, managers can implement programs to reduce them. Managers can attempt to persuade stock users to use low-impact camping techniques, or they can confine stock use to certain trails and campsites. The most effective management programs will use a variety of techniques to reduce damage resulting from use of stock.

## SUMMARY

This chapter has identified the various environmental effects of recreational use and described many techniques for managing them. Several general points can be made in summarizing this material.

First, impact is inevitable wherever recreation use is allowed. Therefore, consistent with the goal of providing recreational opportunities, management can only limit impact, not prevent it. Nevertheless, to prevent impact from increasing incrementally, with little ability to keep track of cumulative impacts, it is imperative to set specific objectives and standards that will place a limit on impact. Then, through monitoring of conditions, managers will be able to more clearly identify when specific impacts have become so pronounced as to demand management attention.

Second, many available strategies and techniques help managers deal with each type of impact. Too often managers try only one technique--often the one they are most familiar with or one the neighboring manager is using. In most cases, however, using several techniques simultaneously will be much more effective than using just one. An appropriate process for selecting a suite of management techniques is to identify the source of the problem, to formulate actions that can eliminate the problem at its source, to implement a preferred set of actions, and, most importantly, to monitor results.

Managers have been preoccupied with "too much" use as the major cause of problems and limiting use to a "carrying capacity" as the principal solution. Amount of use is just one of many factors influencing amount of impact; often it is one of the less influential factors. Likewise, limiting use to a carrying capacity is only one of many alternative management techniques, and often it is not very

effective. However, there clearly are situations where use must be limited. More consideration should be given to limiting use of wilderness that is still relatively lightly used and impacted—to see that it remains in that state. Where use is limited, other actions—such as confinement of impact—is often necessary if use limits are to be beneficial.

Finally, managers must show equal concern for both quality of experience and environmental impacts. The two are inextricably bound together; actions that affect one will affect the other--sometimes in positive and sometimes in negative ways. Therefore managers must clearly define problems and how alternative actions will deal with them. Managers must also consider how an action to correct a problem in one specific place will affect other places and other wilderness conditions. Only through more effective integration of ecological and experiential concerns, both in research and management, can we develop the more holistic approach that will make wilderness management proactive and truly effective.

### STUDY QUESTIONS

1. Select two impact “situations” (type of impact, environmental type, and location) that represent substantial alterations of natural conditions and two situations that do *not* represent substantial alterations. Defend your choices.
2. Provide a detailed description of at least one example of (a) direct, (b) indirect, and (c) cyclic effects of trampling on vegetation and soil.

3. Suggest three actions that managers might take to influence the amount of use that campsites receive and, thereby, reduce impact. Contrast the appropriateness of each action on campsites in popular destination areas and campsites in lightly used remote places in the wilderness.
4. Compare and contrast the magnitude and nature of impacts caused by (a) small parties and large parties and (b) hiker parties and stock parties. Describe where impacts are similar and where they differ. Suggest and defend management actions that might be taken to minimize differences.

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Table 15.1. Relationship between selected campsite impact parameters and the amount of use a site receives.

Impact parameter		Light-use sites	Moderate-use sites	Heavy-use sites	Kendall's tau (%= 0.05)
		(N = 6)	(N = 6)	(N = 10)	
		-----Median-----			
Camp area	(m <sup>2</sup> )	48	224	205	NS
Devegetated area	(m <sup>2</sup> )	19	122	93	0.30
Trees 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

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Source: Cole 1982a.

Table 15.2. Factors that influence impact on campsites. Each factor defines a strategy and set of specific techniques (of which only one example is provided here) for managing impacts.

Factor	Strategy	Technique (example)
Amount/frequency of use	Reduce use	Institute quotas
Type/behavior of use	Change type/behavior of use	Party size limits
Environmental/site conditions	Increase site resistance	Bridge unavoidable bogs along trails
Use distribution	Contain use	Camping in designated sites only

Table 16.3. Campsite conditions and recommended user responses.

<i>Condition class</i>	<i>Visible indicators</i>	<i>Recommended user responses</i>
1. Pristine	The site appears never to have been used before.	USE WITH CAUTION IN CERTAIN SITUATIONS Ideal sites in low-use areas if parties are careful to minimize impacts. Parties should be small, without packstock and experienced in low-impact camping. Moderately impacted sites preferable for other parties and in high-use areas. Select resistant sites away from attractions and popular locations. Keep stays short.
2. Semi-pristine	Sites are barely recognizable as campsites. Vegetation has been flattened, but bare soil is not evident.	DO NOT USE Sites will rapidly deteriorate if use continues. In low-use areas, moderately impacted and pristine sites preferable; in high-use areas, moderately impacted sites preferable.
3. Lightly impacted	Ground vegetation worn away around the fireplace or center of activity.	USE ONLY IF NECESSARY Unless particularly resistant (sandy beaches, rocky rocky outcrops, dry meadows, or grasslands), sites will deteriorate if use continues. Moderately impacted sites always preferable. In low-use areas, pristine sites also preferable.
4. Moderately impacted	Ground vegetation worn away on most of the site, but humus, litter, decomposing leaves, and needles usually present on much of site.	USE WHERE POSSIBLE Sites not prone to further damage. They retain most desirable attributes; site impact not irreversible. Choose screened, forested sites, out of sight and sound of other parties. Do not damage overstory trees. Collect only dead and down firewood, broken by hand. Avoid trampling seedlings.
5. Highly impacted	Ground vegetation, humus and litter worn away on most of site, exposing gritty, dusty, or muddy mineral soil. Tree roots may be exposed if stock have been tied to trees. Firewood is usually scarce near the campsite. Campsites may overlay.	USE ONLY IF NECESSARY Never use in low-use areas; moderately impacted and pristine sites preferable. Encourage closure and rehabilitation. In high-use areas, moderately impacted sites preferable. But in some places, such sites must be accepted. Avoid practices that enlarge site; avoid wood fires.

Source: Adapted from Cole and Benedict 1983.

Table 15.3. Common trail impact problems and strategies and techniques for mitigating each problem.

<u>Problem</u>	<u>Strategy</u>	<u>Technique (example)</u>
Erosion	Improve location and/or design	Build water bars
Muddiness	Improve location and/or design	Route trails around boggy areas
Multiple trails	Improve location	Relocate trails
Shortcutting switchbacks	Change user behavior	Convince visitors to stay on existing trails
Informal trail systems	Reduce use	Reduce use quotas

Table 15.4. Differences in amount of impact between sites used primarily by backpackers and sites used primarily by parties with stock, Bob Marshall Wilderness, MT.

	Backpacker sites	Stock sites
	-----Median-----	
Disturbed area (m <sup>2</sup> )	76	456
Area devoid of vegetation (m <sup>2</sup> )	3	13
Number of damaged trees	5	56
Number of felled trees	0	8
Number of trees with exposed roots	1	25
Seedling loss (%)	100	100
Ground cover vegetation loss (%)	26	33
Relative cover of exotic plants (%)	5	43
Increase in mineral soil exposure (%)	4.6	9.3
Depth of organic horizons (cm)	2.2	1.2
Penetration resistance (kg/cm <sup>2</sup> )	2.6	4.0
Infiltration rate (cm/min)	1.0	0.1

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 Source: Cole 1983a.

Table 15.5. Factors that influence packstock impacts. Each factor defines a strategy and set of specific techniques (of which only one example is provided here) for managing impacts.

<u>Factor</u>	<u>Strategy</u>	<u>Technique (example)</u>
Amount/frequency of use	Reduce use	Close overgrazed meadows
Party size/behavior	Change behavior	Promote low-impact use
Season of use	Change timing of use	Prohibit use during spring
Environmental/ site conditions	Increase site resistance	Reinforce trail with log cribbing
Use distribution	Contain use	Prohibit off trail travel with stock