A **Literature** Review

The President's Commission
On Americans Outdoors

INT4901 Publication #165

RESOURCE IMPACTS CAUSED BY RECREATION

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THE IMPORTANCE OF THE TOPIC

The pursuit of recreational activities inevitably has an effect on the resource--vegetation, soil, wildlife, and water. Whether these impacts are considered to be positive or negative depends on the management objectives of the area affected. The severity of the positive or negative response, which dictates the acuteness of the need for mitigation measures, is also influenced by management objectives. Generally, the problems associated with a given level of impact increase as we move from the more urban and developed end of the recreational opportunity spectrum toward the primitive and wild end of the spectrum (Clark and Stankey 1979). Impact problems are particularly common in wilderness. Vegetation impacts on campsites are reported to be, a problem by managers of 71 percent of all wilderness areas. Soil impacts on trails are a problem in 61 percent of wilderness areas. Wildlife disturbance and water pollution are reported to be problems in 33 and 18 percent of wilderness areas, respectively (Washburne and Cole 1983).

The reasons for concern about impacts are numerous. In wilderness and nature preserves, impacts compromise the objective of preserving natural conditions. Elsewhere impacts can make recreational areas and facilities less attractive, desirable, or functional. Loss of tree cover on campsites, erosion of trails, and attraction of pest wildlife species are examples. These impacts can substantially increase maintenance costs. Finally, onsite impacts can damage offsite areas, such as where erosion of off-road vehicle (ORV) trails causes siltation of streams.

ISSUES, PROBLEMS, AND RECOMMENDATIONS

From this literature review, the folIowing issues and problems seem particularly important:

1. The controversy between the strategies of concentrating or dispersing use particularly troublesome in dispersed use areas, especially wilderness.

concentration and facility' development are key strategies for minimizing impact in recreation areas (McEwen and Tocher 1976). In dispersed areas, however, concentration reduces solitude and leads to unacceptable levels of impact, human waste, water pollution, and bear encounter problems. Moreover, most facility development is deemed inappropriate. On the other hand, dispersal can lead to widespread proliferation of impacts. More guidance on the merits of dispersal ***or*** concentration in different situations is needed, particularly for wilderness. This will require more research on relationships between amount of use and site deterioration and rehabilitation, as well as experimentation with dispersal and concentration strategies.

2. Off-road vehicle impacts are particularly serious and difficult to manage. ORV impacts are particularly troublesome because impact potential is so high. Riders frequently seek out terrain that is particularly susceptible to impact and object to being confined to areas of concentrated use. We need more concensus on where ORV use is and is not appropriate. Then we need to experiment further with means of confining and mitigating ORV impacts where they are accepted.

3. Increased use of recreation areas during the off-season may be particularly detrimental to wildlife. Our understanding of wildlife impacts in general is insufficient. A primary concern should be given to evaluating the impacts of winter recreation use.

4. Our ability to rehabilitate impacted recreation sites is insufficient. Considerable time, money, and effort are being expended trying to rehabilitate damaged sites, but success has generally been poor. We lack the research base and personal experience (much rehabilitation work is done by untrained, short-term volunteers) to rehabilitate sites quickly and cost effectively. More basic research is needed on the impact process and how detrimental changes can be reversed. Rehabilitation efforts should also be given a higher priority; we need more experimentation, documentation, and communication of results.

5. Our ability and commitment to monitoring impacts are poor. Research has only been able to develop systems for monitoring the most obvious and readily observable impacts. Management seldom assigns monitoring a sufficiently high priority to ensure that it is conducted in a careful and systematic matter. Consequently, data collected are often of little or no value. Monitoring needs to be a higher priority task for recreation area managers. Only through monitoring can scarce resource management funds be efficiently allocated.

6. Research on recreational impacts has never been supported on a sustained basis. Nobody has ever been able to pursue a long-term career in this field. Consequently, the only research available tends to be short term and superficial in nature. This is inconsistent with the widely perceived importance of impact problems and the dozens of careers available in other recreation fields. Support for academic positions and positions with governmental research. organizations should be provided. This would encourage long-term and more significant research, promote transfer of technologies to managers, and improve the educational breadth of recreation managers.

SUMMARY OF FINDINGS

Of the four resources impacted by recreation, vegetation and soil have been studied much more frequently than wildlife, water, or air. Even for vegetation and soil, however, most studies have been rather cursory descriptive studies.

Most descriptive studies fall into one of four categories. In the first category are studies of the effects of specific activities. Examples would be the effects of trampling or of riding off-road vehicles. Other studies have examined specific locations where impact occurs, such as trails or campsites. In these studies, the impacts described may result from a number of different activities. A third type of study--and these studies are rare--describes the spatial distribution of impact. Finally, several studies have examined changes

in impact levels over time. Useful reviews of the recreational impact literature have been written by Speight (1973), Liddle (1975), Satchel1 and Marren (1976), Wall and Wright (1977), Manning (1979), Ream (1979), Hart (1982), Kuss and others (1985), Price (1985), and Cole (in press b).

Most research on specific activities has focused on the effects of human trampling. Numerous studies have documented effects on vegetation in the form of reduced height, vigor, reproductive capacity, and abundance. In many cases, all vegetation is eliminated except in protected places. Because tolerance of trampling varies between species, the species composition of recreation areas is also affected by use. One common finding, particularly in studies of forested campsites, is that tree seedlings are highly fragile and are quickly eliminated from most campsites (for example, Frissell and Duncan 1965). Trampling usually has little effect on the overstory, but when the overstory eventually dies, there may be no trees to replace them.

Trampling also abrades the organic horizons of soils and compacts mineral soils. Compaction reduces water infiltration rates, which leads to increased runoff and erosion. Erosion is a particularly serious problem on trails and ORV areas (Webb and Wilshire 1983). For the impacts of trampling on both vegetation and soil, only the most obvious impacts have been documented. We know almost nothing' about effects on plant physiology or. soil microbiology, for example. This is unfortunate because this knowledge is likely to be critical to our search for effective means of rehabilitating severely trampled places.

The only other activity that has been studied in much detail is the use of ORV's--both terrestrial vehicles and snowmobiles. Terrestrial ORV's have many of the same effects as trampling, but their capacity to impact is much greater than that of humans (Weaver and Dale 1978; Webb and Wilshire 1983). Erosion is a particularly serious consequence of ORV use. At an ORV site in the San Francisco Bay area, the rate of erosion was 30 times greater than the rate that the Bureau of Reclamation considers to be a serious problem (Wilshire and others 1978). Another special problem associated with ORV use is. their ability to cover and impact large areas. For example, fragile vegetation and animal species have been disturbed over sizable parts of the California desert (Vollmer and others 1976; Luckenbach and Bury 1983).

Snowmobiles have less effect on vegetation and soil because snow, if sufficiently deep, shields these from impact. The impact of snowmobiles on wildlife is more of a concern. To date, research suggests that the most serious impact is to small mammals that live between the snow and the soil (Bury and others 1976). However, we know very little about the impacts of recreationists on wildlife, particularly in winter when impacts can be especially detrimental to weak and stressed animals.

There is also very little research into the effects of pack and saddle stock. These animals can have a pronounced impact in backcountry and wilderness areas, particularly in the West. In addition to trampling effects on trails and campsites, these animals can significantly alter meadows and grasslands 'where they trample and graze the vegetation. A research program at Sequoia and Kings Canyon National Parks is one of the few attempts to study impacts and devise a rational packstock management program (DeBenedetti and Parsons 1983).

Only a handful of studies have directly examined the effects of recreation on wildlife (Ream 1980). Because adequate controls are lacking, and because animals are mobile, it is extremely difficult to design studies that will give conclusive results. We know that recreationists disturb certain wildlife species, causing displacement and even death (Stalmaster and Newman 1978; Ream 1979; MacArthur and others 1982). We also know that other species are attracted to recreation areas. For many species, including bear--probably the most frequently studied animal--this is highly undesirable. Disturbance during winter may be particularly detrimental, because animals frequently strive to conserve their energy during winter (Moen 1976). The popularity of snowmobiling and cross-country skiing and active promotion of winter use may have dire consequences for wildlife. Unfortunately, there is insufficient research to evaluate how widespread and serious wildlife impacts are at any season.

A number of studies have examined the physical, chemical, and/or bacteriological qualities of surface waters in and around recreation areas. Generally, these studies have found little evidence of impact on water caused by second home development (Ponce and Gary 1979), swimming (Nelson and Hansen 1984), use of developed campgrounds (Aukerman and Springer 1976), or dispersed recreation use (Werner and others 1985). However; a few studies have identified recreation-caused bacterial contamination (Varness and others 1978) and physical, biological, and chemical changes (Taylor and Erman 1979). We also know that use of roads and ORV's can lead to sedimentation of streams and detrimental effects on fisheries. We do not have sufficient research to evaluate the severity and frequency of recreational impacts on water.

The few studies that have examined the spatial distribution of impact have found it to be highly concentrated (McEwen and Tocher 1976; Cole 1981). Although heavily used campsites, picnic sites, trails, or scenic overlooks may be highly impacted, neighboring areas are often virtually undisturbed. This applies more to the stationary resources (vegetation and soil) than to the mobile resources (wildlife and water), however. Concentration of use and impact is one of the most important strategies for managing impacts. As will be discussed later, problems with managing impacts are most serious where concentration is either deemed inappropriate (as in many wilderness areas), or rejected by users (as in many ORV areas).

Very few studies have followed change on recreation sites to determine how rapidly conditions are either improving or deteriorating. On both developed and wilderness campsites, initial use causes most of the impact (LaPage 1967; Merriam and Smith 1974), while changes on long-established sites are relatively minor (Magi11 1970; Cole in press a). Recovery rates vary greatly between environments, being particularly slow where growing seasons are short and moisture is limited, as in mountainous areas (Willard and Marr 1971) and deserts (Webb and Wilshire 1983). Rapid impact and slow recovery also argue for the wisdom of concentrating use on a small portion of a recreation area--a portion of the area that is "sacrificed" so that most of the area is spared serious impact.

Some areas have tried to increase recovery rates by using cultural means of rehabilitating sites. In certain environments, watering, fertilization, seeding, and/or transplanting have increased recovery rates (see, for example, Beardsley and others 1974). Where recovery rates are naturally slow, such

attempts have met with limited success (Cole in press a). This lack of success reflects our limited understanding of the impacts associated with recreational use and how these impacts inhibit rehabilitation of sites. It also reflects little experimentation with rehabilitation techniques, inadequate documentation of techniques and conditions, and poor communication of results.

Beyond descriptive studies, some research has examined the importance of various factors that influence amount of impact. The most important of these factors appear to be amount of use, type of use, season of use, and environmental conditions on the site being used (Cole in press b). Understanding these factors is critical, because it is through manipulation of these factors that impacts can be managed.

The importance of amount of use has received most attention, probably as a result of the desire to establish carrying capacities for recreational areas. All studies have found that impact increases rapidly as use increases from no use to low use levels. Above low use levels, however, further increases in use have less and less effect on amount of impact (see, for example, Marion and Merriam 1985). The exact location of the use threshold, above which further increases in use have, little effect on amount of impact, varies with type of use, season of use, environmental durability, and the type of impact under consideration (Cole in press b). Generally, once use levels exceed quite low levels, amount of use primarily affects the area of impact (Kuss and others 1985). This, too, argues for the advisability of concentrating use as much as possible, using restrictions on amount of use where too much of an area is being impacted.

Users vary greatly in their potential to cause impact. Impact potential generally increases from humans to stock to motorized vehicles (Weaver and Dale 1978; Webb and Wilshire 1983). Other user characteristics that influence impact potential include party size, length of stay, and knowledge and commitment to minimizing impacts. While we know that these characteristics must influence impact potential, they have never been studied.

Impact potential also varies between seasons. When snow is on the ground in winter, impact to vegetation, soil, and water is often reduced, while impact on wildlife is increased. Spring, when soils are water-saturated and prone to disturbance, plants are initiating growth, and animals are recovering from the winter and giving birth, is probably the most vulnerable season. Again, however, conclusive research is lacking.

Finally, impact potential varies with site durability. Serious trail deterioration problems have been linked to certain soil characteristics, vegetation types, landforms, and design features (Bratton and others 1979; Leeson 1979; Summer .1980, Coleman 1981; Cole 1983a). This information can be used to route trails through durable environments and to design trails adequately where they must cross fragile areas. Use of such information would greatly reduce trail maintenance and rehabilitation costs. Impacts on camp and picnic sites have been shown to vary with such factors as overstory canopy cover (Ripley 1962) and vegetation type (Cole 1981). Meadow types also vary in their ability to tolerate grazing pressure from pack and saddle' stock (DeBenedetti and Parsons 1983). Clearly, impacts could be reduced substantially by directing use to durable sites. However, the factors that contribute to durability are numerous, they interact with each other, and they are quite site specific.

This means there is a need for much more site-specific research along the lines of the work by Fay and others (1977), Summer (1980), and DeBenedetti and Parsons (1983).

Very little applied management-oriented impact research has been conducted. Some research on the rehabilitation of damaged recreation sites has been published (see, for example, Beardsley and others 1974; Little and Mohr 1979; Legg and others 1980). Again, however, results are quite site specific, so most of the nation's recreation areas have no guidance for how to rehabilitate sites. There has also been some research on how to monitor impacts in a systematic and meaningful manner. Considerable progress has been made on how to monitor trails (Leonard and Whitney 1977; Cole 1983a), campsites (Parsons and MacLeod 1980; Cole 1983b; Brewer and Berrier 1984), and water (American Public Health Association 1975). Implementation of effective systems has been more of a problem, as has development of techniques to monitor mobile features (such as wildlife) and more intangible aspects of environmental quality.

CASE STUDIES

Innovative management programs are less common than desired and are seldom advertised where they exist. Efforts by such managing agencies as the Bureau of Land Management and California Department of Parks and Recreation have reduced ORV impacts in California (Smith 1980), although the sufficiency and success of the program are still controversial. Yellowstone National Park is adopting a winter recreation management program that, among other things, addresses the issue of wildlife impacts in winter. Finally, the Bob Marshall Wilderness complex, in Montana, provides a good example- of a monitoring program designed to trigger management response when objectives are not met (Stankey and others 1984). Clearly, higher levels of innovation and communication of successes and failures need to be encouraged.

KNOWLEDGE GAPS

The area in which our knowledge is most lacking is wildlife disturbance. For this topic we cannot even describe the severity and significance of effects. Effects on water are also poorly understood. Our understanding of vegetation and soil impacts is too superficial to contribute to improvement of site rehabilitation techniques. While we have made considerable progress in understanding the factors that influence amount and type of impact, these results tend to be rather site specific. Similar research (such as on the use/impact relationship and the characteristics of durable sites) is needed in a wider variety of situations. We need improved means of monitoring significant but less readily observable impacts (such as effects on wildlife behavior and soil biota). Finally, we need to improve our knowledge of the effectiveness of management techniques in current use.

RESEARCH ASSESSMENT

The amount and quality of research on this topic are surprisingly low given the importance of impact problem's and the fact that impacts have been studied for some 50 years now. The problem of insufficient research is not confined to the

United States. In their review of the impact literature in Europe, Satchel1 and Marren (1976) state "We found a great disparity between the relative abundance of data on recreational demand such as numbers, origins and attitudes of visitors, and the paucity of data on the ecological consequences of recreational activities.... We consider that the current level of research is not commensurate with the magnitude of the problem of reconciling the maintenance of amenity and conservation interest in areas used for public recreation with the demand for outdoor leisure pursuits in increasingly urban societies." If anything, support has declined in recent years. Essentially no careers exist in this field. Consequently, most research merely documents the obvious; time frames are too short; theory is lacking: and few studies are comparable. Such research has been of limited utility to management.

Research on recreational impacts could contribute significantly to the efficient achievement of management objectives. Although impacts cannot be eliminated, they can be controlled and kept within acceptable limits. To do so, we will finally need to make a serious investment in impact research and management, as we have in most other resource management disciplines.

KEYWORDS

Recreation, impact, management, vegetation, soil, wildlife, water, trampling, trails, campsites, monitoring

REFERENCES

American Public Health Association. 1975. Standard methods for the analysis of water and wastewater. 14th ed. New York: American Public Health Association, 1193 p.

Aukerman, R.; Springer, W. T. 1976. Effects of recreation on water quality in wildlands. Eisenhower Consortium Bull. 2. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, 25 p.

Beardsley, W. G.; Herrington, R. B.; Wagar, J. A. 1974. Recreation site management: how to rehabilitate a heavily used campground without stopping visitor use. Journal of Forestry. 72: 279-281.

Bratton, S. P.; Hickler, M. G.; Graves, J. H. 1979. Trail erosion patterns in Great Smoky Mountains National Park. Environmental Management. 3: 431-445.

Brewer, L.; Berrier, D. 1984. Photographic techniques for monitoring resource change at backcountry sites. General Technical Report NE-86. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 13 p.

Bury, R. L.; Wendling, R. C.; McCool, S. F. 1976. Off-road vehicles--a research summary, 1969-1975. College Station, TX: Texas A & M University, Agricultural Experiment Station. 84 p.

Clark, R. N.; Stankey, G. H. 1979. The recreation opportunity spectrum: a framework for planning, management, and research. General Technical Report PNW-98. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, 32 p.

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

Cole, D. N. 1983a. Assessing and monitoring backcountry trail conditions. Research Paper INT-303. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 10 p.

Cole, D. N. 1983b. Monitoring the condition of wilderness campsites. Research Paper INT-302. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 10 p.

Cole, D. N. in press a. Changes on campsites in Eagle Cap Wilderness: 1979 to 1984. Research Paper. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Cole, D. N. in press b. Research on soil and vegetation in wilderness: a review. In: Lucas, Robert C.; compiler. Proceedings, National Wilderness Research Conference: Perspectives, state of knowledge, and future directions. 1985. July 23-26; Fort Collins, CO. General Technical Report. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Coleman, R. 1981. Footpath erosion in the English Lake District. Applied Geography. 1: 121-131.

DeBenedetti, S. H.; Parsons; D.. J. 1983. Protecting mountain meadows: a grazing management plan: Parks 8(3): 11-13.

Fay, S. C.; Rice, S. K.; Berg, S. P. 1977. Guidelines for design and location of overnight backcountry facilities. Broomall, PA: U.S. Department of Agriculture, Forest Service; Northeastern Forest Experiment Station, 23 p.

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

Hart, J. B., Jr. 1982. :Ecological effects. of recreation use on campsites. In: Countryman; D. W.; Sofranko, D. M., eds. Guiding land use decisions: planning and management for forests and recreation. Baltimore, MD: Johns Hopkins University Press, 150-182.

Kuss, F. R.; Vaske, J.; Graefe, A. 1985. A review and synthesis of recreationa1 carrying capacity literature. Final report to National Parks and Conservation Association. Washington, DC, 210 p.

LaPage, W. F. 1967. Some observations on campground trampling and groundcover response. Research Paper NE-68. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 11 p.

Leeson, B. F. 1979. Research on wildland recreation impact in the Canadian Rockies. In: Ittner, R.; and others, eds. Proceedings, Recreational impact on wildlands. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 64-65.

Legg, M.; Farnham, K.; Miller, E. 1980. Soil restoration on deteriorated campsites in Texas. Southern Journal of Applied Forestry. 4: 189-193.

Leonard, R. E.; Whitney, A. M. 1977. Trail transect: a method for documenting trail changes. Research Paper NE-389. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 8 p.

Liddle, M. J. 1975. A selective review of the ecological effects of human trampling on natural ecosystems. Biological Conservation. 7: 17-36.

Little, S.; Mohr, J. J. 1979. Reestablishing understory plants in overused wooded areas of Maryland State Parks. Research Paper NE-431. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 9 p.

Luckenbach, R. A.; Bury, R. B. 1983. Effects of off-road vehicles on the biota of the Algodones Dunes, Imperial County, California. Journal of Applied Ecology. 20: 265-286.

MacArthur, R. A.; Geist, V.; Johnston, R. H. 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. Journal of Wildlife Management. 46:351-358.

Magill, A. W. 1970. Five California campgrounds...conditions improve after five years' recreational use. Research Paper PSW-62. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, 18 p.

Manning, R. E. 1979. Impacts of recreation on riparian soils and vegetation. Water Resources Bulletin. 15: 30-43.

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

McEwen, D.: Tocher, S. R. 1976. Zone management: key to controlling recreational impact in developed campsites. Journal of Forestry. 74: 90-93.

Merriam, L. C., Jr.; Smith, C. K. 1974. Visitor impact on newly developed campsites in the Boundary Waters Canoe Area. Journal of Forestry. 72: 627-630.

Moen, A. N. 1976. Energy conservation by white-tailed deer in the winter. Ecology 57: 192-198.

Nelson, D.; Hansen, W. R: 1984. Fecal coliform in the Salt River Recreation Areas of Arizona. Journal of Forestry. 82: 554-555.

Parsons, D. J.; MacLeod, S. A. 1980. Measuring impacts of wilderness use. Parks. S(3): 8-12.

Ponce, S. L.; Gary, H. L. 1979. The effect of lake-based recreation and second -home use on surface water quality in the Manitou Experimental Forest. Research Paper RM-211. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, IO p.

Price, M. F. 1985. Impacts of recreational activities on alpine vegetation in Western North America. Mountain Research and Development. 5: 263-278.

Ream, C. H. 1979. Human-wildlife conflicts in backcountry: possible solutions. In: Ittner, R.; and others, eds. Proceedings, Recreational impact on wildlands. R-6-001-1979. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 153-163.

Ream, C. H. 1980. Impact of backcountry recreationists on wildlife: an annotated bibliography. General Technical Report INT-84. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 62. p.

Ripley, H. T. 1962. Recreation impact on southern Appalachian campgrounds and picnic sites. Research Paper SE-153. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeast Forest Experiment Station, 20 p.

Satchell, J. R.; Marren, P. R. 1976. The effects of recreation on the ecology of natural landscapes. Nature and Environment Series No. 11. Strasbourg, France: Council of Europe, 117 p.

Smith, T. C. 1980. ORVs and the California Department of Parks and Recreation resource management efforts: a summary. In: Andrews, R. N. L.; Nowak, P. F., eds. Off-road vehicle use: a management challenge. Ann Arbor, Ml: University of Michigan, 169-172.

Speight, M. C. D. 1973. Outdoor recreation and its ecological effects: a bibliography and review. Discussion Paper in Conservation 4. London: University College, 35 p.

Stalmaster, M. V.; Newman, J. R. 1978. Behavioral responses of wintering bald eagles to human activity, Journal of Wildlife Management. 42: 506-513.

Stankey, G. H.; McCool, S. F.; Stokes, G. L. 1984. Limits of acceptable change: a new framework for managing the Bob Marshall Wilderness complex. Western Wildlands. lO(3): 33-37.

Summer, R. M. 1980. Impact of horse traffic on trails in Rocky Mountain National Park. Journal of Soil and Water Conservation. 35: 85-87.

Taylor, T. P.; Erman, D. C. 1979. The response of benthic plants to past levels of human use in high mountain lakes in Kings Canyon National Park, California, USA. Journal of Environmental Management. 9: 271-278.

Varness, K. J.; Pacha, R. E.; Lapen, R. F. 1978. Effects of dispersed recreational activities on the microbiological quality of forest surface water. Applied and Environmental Microbiology. 36: 95-104.

Vollmer, A. T.; Maza, B. G.; Medica, P. A.; Turner, F. B.; Bamberg, S. A. 1976. The impact of off-road vehicles on a desert ecosystem. Environmental Management. 1: 115-129.

Wall, G.; Wright, C. 1977. The environmental impact of outdoor recreation. Department of Geography Publication Series 11. Waterloo, Ontario, Canada: University of Waterloo, 69 p.

Washburne, R. F.; Cole, D. N. 1983. Problems and practices in wilderness management: a survey of managers. Research Pa per INT-304. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 56 p.

Weaver, T.; Dale, D. 1978. Trampling effects of hikers, motorcycles and horses in meadows and forests. Journal of Applied Ecology. 15: 451-457.

Webb, R. H.; Wilshire, H. G., eds. 1983. Environmental effects of off-road vehicles: impacts and management in arid regions. New York: r - Verlag, 4 p.

Werner, R. G.; Leonard, R. E.; Crevelling, J. 0. 1985. Impact of backcountry recreationists on the water quality of an Adirondack lake. Research Note NE-326. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, 4 p.

Willard, B. E.; Man, J. W. 1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biological Conservation. 3: 181-190.

Wilshire, H. G.; Nakata, J. K.; Shipley, S.; Prestagaard, K. 1978. Impacts of vehicles on natural terrain at seven sites in the San Francisco Bay area. Environmental Geology. 2: 295-319.