# Reflections on the early history of recreation ecology

**David N. Cole,** US Forest Service, Aldo Leopold Wilderness Research Institute [Emeritus]

David N. Cole
426 King Street
Missoula MT 59801
Dncole.home@gmail.com

## Abstract

A major challenge for managers of parks and other conservation lands where recreation is allowed is to ensure that visitors do not impair the natural values for which those lands were established. Recreation ecology is the academic discipline that provides a scientific foundation for managing the ecological impacts of outdoor recreation use. This article traces the development of recreation ecology from its disparate beginnings in the early 20th century, through a period of rapid growth starting in the 1970s, until its early maturity by the end of the 20th century. It introduces the reader to early recreation ecologists, such as E.P. Meinecke, Neil Bayfield, and Michael Liddle, and describes the important early investments in this work by US Forest Service Research. It reviews some of the most important early applications of recreation ecology: inventory and monitoring techniques, the Leave No Trace education program, and knowledge about how impact varies with factors that are subject to management control (e.g., amount of use, type of use etc.).

In most parks and related conservation lands, outdoor recreation is encouraged in order to provide human enjoyment and benefits. However, recreation use always compromises nature conservation goals to some degree, with the magnitude of recreation impact on park environments increasing greatly in recent decades along with increasing population, leisure time, and mobility. Today, we are all too familiar with the ecological impacts of recreation. They range from multiple trails scarring meadows and deeply eroded trails, to large barren campsites compacted to the point where it is a challenge to pound in a tent stake (Figure 1), to bears stealing food, to human waste and toilet paper in piles on the ground. Since at least the 1960s, concerned voices have been asking if we are loving our parks to death.

Management of visitors and the impacts they cause has long been among the primary responsibilities of park managers. For much of this time, visitor management has not been informed much by science. Management has had little to rely on other than tradition and common sense. Recently, however, this has changed. The contributions of recreation ecology—the study of the ecological effects of recreation—have become foundational to the scientific management of parks and other conservation lands. Less well known than such park-relevant scientific fields as wildlife biology and fire ecology, recreation ecology is arguably as important to park management.

In this paper I describe the early history of the field and introduce some of its most important contributors. I cover the development of recreation ecology from its infancy to its early maturity as a scientific discipline—the 1920s to about 2000. By that time, several individuals had pursued careers in

**Figure 1.** Examples of recreation impact (clockwise from upper left): Eroded trail in Torres del Paine National Park, Chile; barren backcountry campsite in Yosemite National Park, California; maze of informal trails and campsites, Alpine Lakes Wilderness, Washington; lodgepole stand with trees and soil degraded by stock use, Bob Marshall Wilderness, Montana. | DAVID COLE

recreation ecology, new studies were building on the findings of earlier work, methods were diversifying, syntheses of knowledge had been produced, and academic institutions were beginning to produce recreation ecologists. While my intent is to provide an accurate historical account, the paper is also a personal memoir, as it emphasizes the work and people that I am most familiar with. Above all, I hope to identify the foundational practices, ideas, and concepts of recreation ecology and trace where they came from, as these pioneering sources are sometimes obscure and are largely ignored in the current recreation ecology literature.

## Disparate beginnings

Although casual observations of recreation impact go back centuries (Liddle 1997), it is only within the past 100 years that these impacts have been the focus of rigorous scientific study. The earliest scientific contributions to recreation ecology date from the 1920s and 1930s. In Germany, a botanist described plant responses to mechanical damage, including trampling (Rasdorsky 1925), and in Switzerland, a microbiologist found differences in the bacterial populations of trampled and untrampled soils (Dügelli 1937). Because results were published in German and the researchers conducted no further recreation-related work, these studies had little influence (Garthe 2019). The work of G.H. Bates at the Rodbaston Farm Institute in Staffordshire, England, was more influential. Bates conducted a wide variety of agricultural research over his career, including studying the effects of trampling, particularly by animals, on plants. In his study of the vegetation of footpaths, Bates (1935) conducted the first trampling experiment, as a means of assessing variation in the susceptibility of different species to trampling. He found, for example, that plants with buds beneath the soil survived better than plants with buds at their base.

Prior to 1960, less than 20 recreation-ecology-related studies had been published. By far the most influential to park management was the work of E.P. "Doc" Meinecke, a forest pathologist with the US Department of Agriculture's Bureau of Plant Industry (Figure 2). As a consulting pathologist for the National Park Service (NPS), Meinecke (1926) found

**Figure 2.** E.P. "Doc" Meinecke, around 1928.
| NATIONAL PARK SERVICE HISTORIC PHOTO COLLECTION

that trampling and camping were endangering giant sequoia trees in Sequoia National Park. In perhaps the first substantive management application of recreation ecology research, NPS immediately began to curtail camping in the sequoia groves and replant the forest (Young 2014). Based on this work and a similar study of redwood groves in the California state parks, Meinecke devised a comprehensive plan for campground design that minimizes trampling damage and maximizes the visitor experience. His design was so universally accepted that the term "meineckizing campgrounds" was used until the 1950s, and even today the vast majority of public campgrounds in the US are laid out as Meinecke prescribed (Young 2014).

## The beginnings of institutional support

In response to burgeoning recreation use and concern about increasing ecological impact, the magnitude and diversity of recreation ecology studies increased in the 1960s. About 40 recreation ecology studies were published in the 1960s, with the number of participating countries expanding to include Canada (Underhill 1965), the Netherlands (Westhoff 1967) and Japan (Tachibana 1969). Some of the earliest observations of impacts on water quality and wildlife responses to recreation disturbance were published (Altman 1958; Barton 1969) and, although not reviewed in this paper, substantial work was conducted on the impacts and management of such recreational facilities as downhill ski areas, turf-covered sports fields, and golf courses.

As in years before, progress was hindered by the lack of long-term support for recreation ecology work, which meant that few researchers ever published more than one or two papers. Since the 1940s, NPS biologists had occasionally written with concern about recreation impacts (e.g., Sumner 1942) and by the 1960s, NPS had financially supported a number of site-specific studies in parks, most of which were published as theses or as internal park reports, limiting their influence (Figure 3). Examples include studies at Mount Rainier (Brockman 1959), Sequoia-Kings Canyon (Sharsmith 1959; Hartesveldt 1965), Grand Teton (Laing 1961; Merkle 1963), Yosemite (Gibbens and Heady 1964), Rocky Mountain (Dotzenko et al. 1967; Willard and Marr 1970), and North Cascades National Parks (Thornburgh 1970). Citations and annotations for most of the pre-1979 recreation ecology grey literature can be found in Cole and Schreiner (1981).

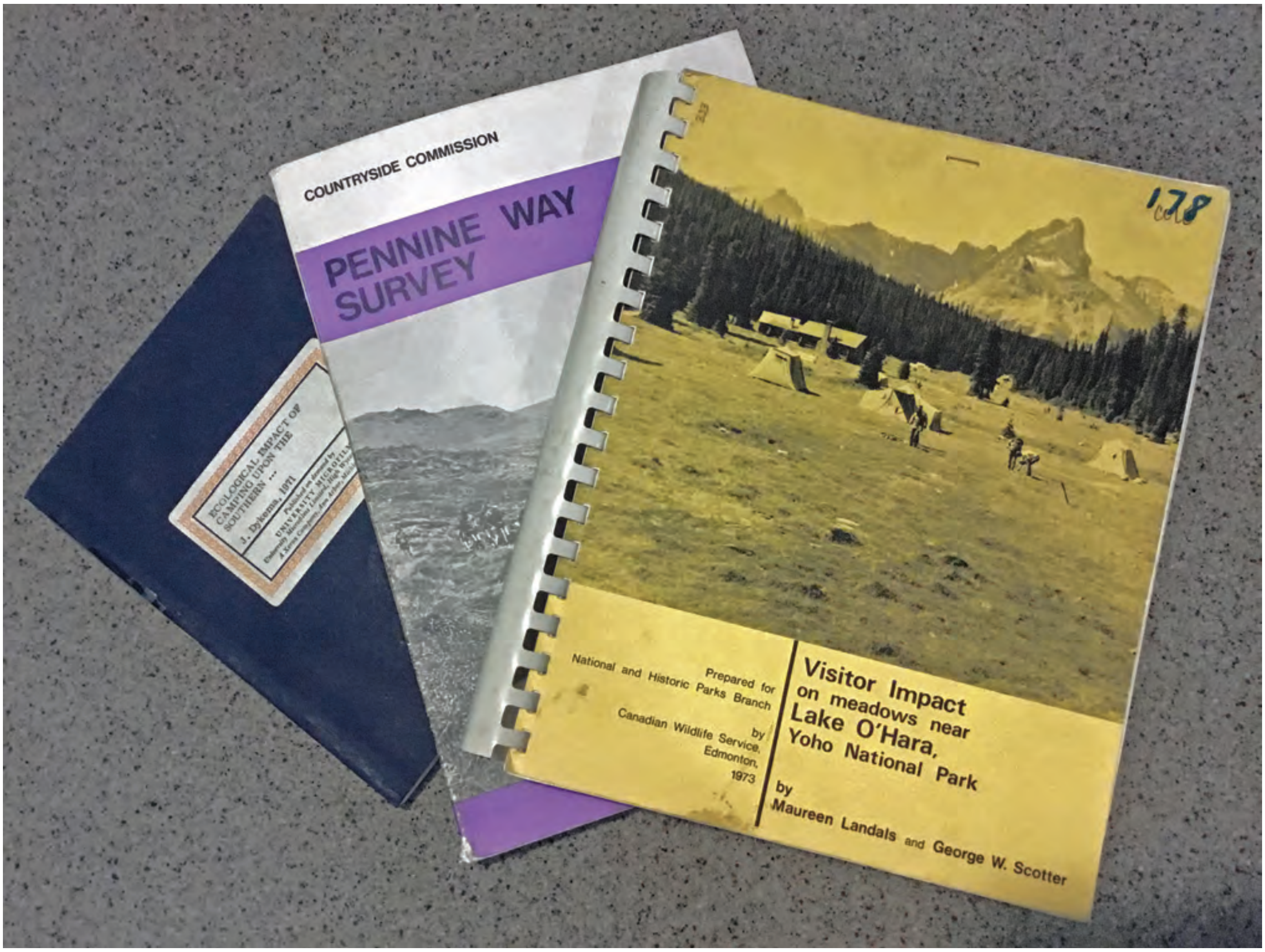



**Figure 3.** Early recreation ecology grey literature: Dissertations and reports commissioned by Parks Canada and the Countryside Commission of England.
| DAVID COLE

In the late 1960s, the Nature Conservancy in Great Britain, a governmental agency tasked with establishing nature reserves, conducting research, and advising on the successful management of flora and fauna for conservation purposes, began to support research on recreation impacts. In 1967, Eric Duffey, arachnologist and director of conservation research at the Nature Conservancy's Monks Wood Experimental Station, organized a symposium and edited a proceedings on "the biotic effects of public pressure on the environment" (Duffey 1967). Although most of the papers presented were either highly general or provided only preliminary results, the symposium and Nature Conservancy's interest spurred a number of British scientists to begin recreation impact studies. F.B. Goldsmith, conservation ecologist at University College London, and several students explored ways to bring more rigor to recreation ecology studies (Goldsmith et al. 1970; Burden and Randerson 1972). Importantly, these scientists and managers began meeting and working collaboratively, creating the Recreation Ecology Research Group (RERG) in 1973.

Even more influential were the efforts of the US Forest Service's (USFS's) research branch, which had recognized the need for recreation research as early as the 1940s and established a recreation research program in 1958. By 1962, the program employed 15 full-time scientists and their summer field assistants. Although the focus of this group soon shifted to the social sciences, the initial focus was largely on physical and biological concerns (Cole 2019). Research funded by the Forest Service in the 1960s included the first studies of change to established campsites over multiple years (Magill 1970) and on newly created picnic and camp sites (LaPage 1967; Merriam and Smith 1974), the first study of the effect of amount of use on recreation sites (Frissell and Duncan 1965), an early study of sites' variable susceptibility to impact (Ripley 1962), and Wagar's (1964) classic treatise on recreation carrying capacity.

## The first recreation ecologists

During the 1970s, recreation use continued to increase dramatically in more and more countries around the world. Resultant ecological impacts were increasingly obvious and a cause of concern. In response, visitor management programs became more regulatory, with the managers of quite a few parks and rivers starting to limit amount of use and restrict certain behaviors. The amount and diversity of recreation ecology research increased as well. More than 200 studies were conducted in the 1970s, including the first studies in Austria (Erlinger and Reichholf 1974), Finland (Kellomäki and Saastamoinen 1975), Poland (Falinski 1975), Sweden (Bryan 1977), the Soviet Union (Rogova 1976), and Australia (Edwards 1977). Institutions, including NPS and USFS, funded a flurry of studies regarding the impacts associated with snowmobiles (e.g., Neumann and Merriam 1972) and off-road vehicles (e.g., Davidson and Fox 1974; Leatherman and Godfrey 1979) and Parks Canada commissioned the Canadian Wildlife Service to conduct a series of site-specific studies in national parks (e.g., Landals and Scotter 1973), as was done in US parks a decade earlier.

As before, few researchers conducted more than a single study in one place at one time, a fact that continued to limit growth of the field. However, momentum was building. Enough information had accumulated to allow Speight (1973), with funding from the British Ecological Society, to publish the first review of outdoor recreation's ecological effects. Several other reviews were written during the decade (Liddle 1975; Satchell and Marren 1976; Wall and Wright 1977; Manning 1979). In Great Britain, RERG continued to meet regularly, and in 1978 more than a hundred people attended a conference on "Recreational Impact on Wildlands" in Seattle, Washington (Ittner et al. 1979).

By the 1970s, interest in and support for recreation ecology was sufficient to allow a few individuals to devote all or much of their career to it. The first was Neil Bayfield (Figure 4), an ecologist at the Institute of Terrestrial Ecology at Banchory, Scotland, one of the experiment stations administered by Britain's Natural Environment Research Council (an offshoot of the Nature Conservancy). In 1967, Bayfield began what proved to be long-term studies of impacts in the Cairngorm Mountains, particularly trampling along the web of footpaths that dispersed from the top of a newly constructed chairlift (Bayfield 1971). He expanded his work to other footpaths in Scotland and England, exploring relationships between impact and environmental variables. He found, for example, that path width increased with increasing path wetness, roughness, and steepness, and decreased as the surface adjacent to the path became increasingly rough (Bayfield 1973). Bayfield was active in RERG and coedited that group's most significant written output, the proceedings of an international recreation ecology conference, held in the Lake District in 1983 (Bayfield and Barrow 1985). Unfortunately for the field, Bayfield was not able to focus exclusively on recreation ecology. Recreation-related funding declined through the 1980s and 1990s, contributing to the dissolution of RERG around 1987 (Bayfield and Aitken 1992).

Bayfield's legacy is perhaps better defined by what he started than what he finished. Bayfield was the first to conduct a number of distinct studies that built on each other over decades and was probably the first to claim, if asked, that he was a recreation ecologist. He employed trampling experiments extensively, innovating analysis procedures and observing as much as eight years of recovery after

**Figure 4.** Neil Bayfield on an eroded footpath in Yorkshire Dales National Park, England, 1986. | DAVID COLE

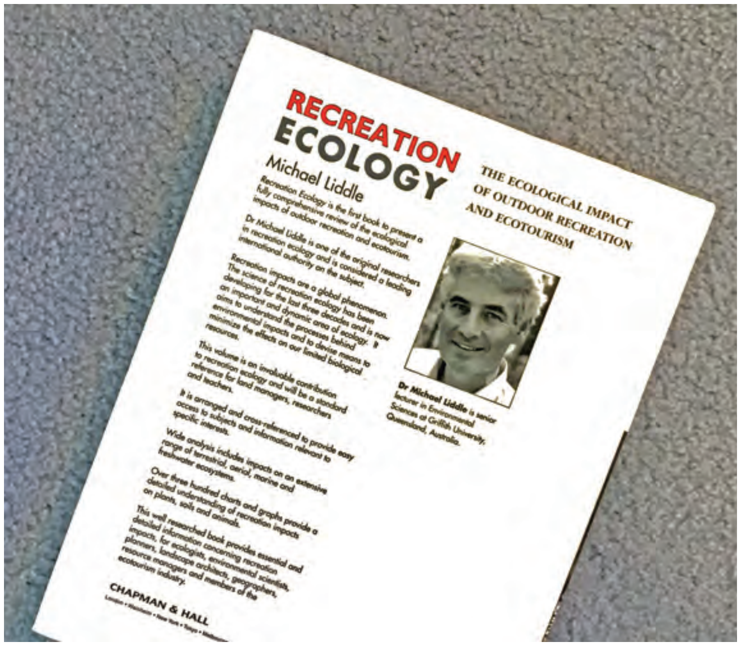



**Figure 5.** Back cover of Michael Liddle's comprehensive book, *Recreation Ecology.* | DAVID COLE

trampling (Bayfield 1979). Bayfield developed new techniques for extensive and intensive monitoring of footpaths and documented impact trends for up to 15 years (Bayfield 1986). He experimented with techniques for hardening footpaths, revegetating worn areas and increasing the trafficability of vegetation and soils. Much of this highly practical work is summarized in a report, co-written with fellow Scot and footpath expert Robert Aitken, *Managing the Impacts of Recreation on Vegetation and Soils: A Review of Techniques* (Bayfield and Aitken 1992). Since retirement, Bayfield has devoted much of his attention to keeping Morris dancing alive in Scotland.

Michael Liddle, the second recreation ecologist, had a more traditional academic career. As Bayfield began his recreation ecology work in Scotland, Liddle started a doctoral program at the University of Wales with the early quantitative plant ecologist Peter Grieg-Smith. Grieg-Smith suggested studying the effects of human trampling. So, with partial funding from Britain's Natural Environment Research Council, Liddle employed survey techniques, quantitative classification methods, and experimentation to explore the soils and vegetation on tracks and footpaths in a sand dune ecosystem in Wales (Liddle and Grieg-Smith 1975). Hired by Eric Duffey at the Monks Wood Experiment Station, Liddle collaborated on further trampling studies (Crawford and Liddle 1977) and wrote the first academic review of trampling effects (Liddle 1975). In the late 1970s, Liddle took a position in the School of Australian Environmental Studies at Griffith University in Australia, where he supervised recreation ecology work with several students in varied environments from eucalypt forests to coral reefs (Liddle 1991).

Liddle's academic approach to the subject contrasts with the work of most other early recreation ecologists, who placed more emphasis on management applications. With the innovative use of trampling experiments, he and Dan Sun explored how resistance to trampling varies with plant morphological characteristics, including stem flexibility, leaf strength, and tiller number (Sun and Liddle 1993). Most impressive, however, is his book *Recreation Ecology: The Ecological Impact of Outdoor Recreation and Ecotourism* (Liddle 1997). Over 600 pages long, the book compiles the results of more than 900 studies, organized into 28 chapters on the ecological attributes affected by recreation, including plant form and function and the physical reactions of plants to the living soil, along with chapters devoted to different types of animals (Figure 5). Having completed his magnus opus, Liddle retired in 1997. In a letter informing me of Liddle's death from cancer in 2001, his widow, Dawne Douglas, noted that his last years were spent "building large sculptures and a variety of installations, in an attempt to influence politicians and create environmental awareness."

Meanwhile in the United States the USFS recreation research program, established in 1958, continued, but by the 1970s was staffed almost exclusively by social scientists. The exception was Ray Leonard, who for a few years did research specific to New England on trails, backcountry facilities, and human waste disposal (Leonard and Whitney 1977; Leonard et al. 1979).

In 1978, one of those USFS programs, the Wilderness Management Research Unit in Missoula, Montana, hired me specifically to do recreation ecology research (Figure 6). Trained as a biogeographer at the University of Oregon, I had recently completed a doctoral study on human impacts on vegetation in the Eagle Cap Wilderness. My temporary assignment with USFS was to organize and synthesize recreation

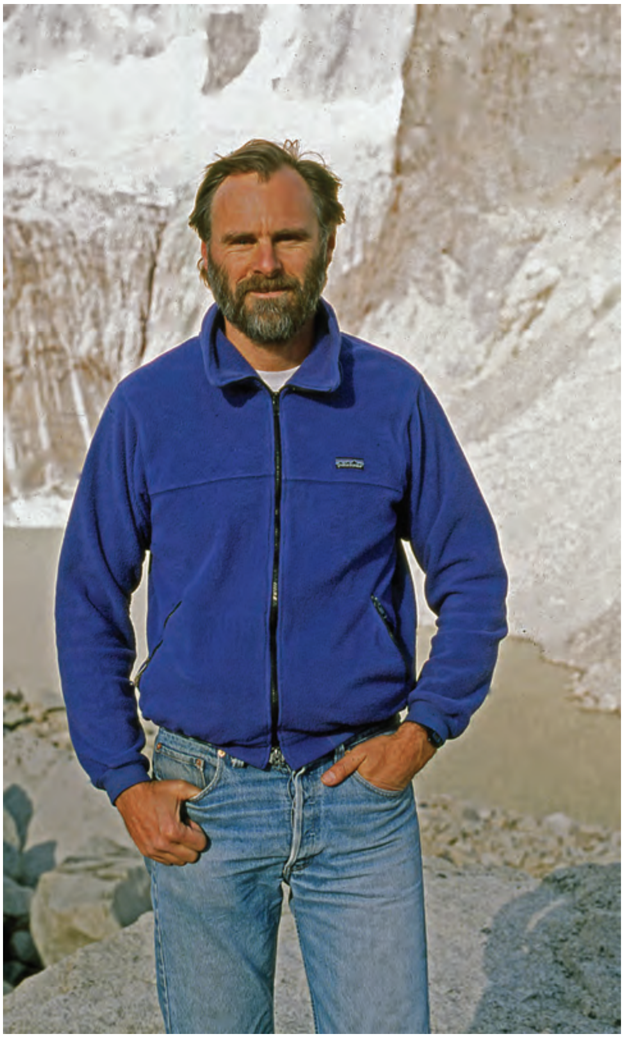


**Figure 6.** David Cole at Torres del Paine National Park, Chile, 1996, where he was conducting a recreation impact monitoring course for park managers with Jeff Marion and Chris Monz. | JEFF MARION

**Figure 7.** Jeff Marion trampling resistant grassland in Montana, 1981. | DAVID COLE

ecology research, suggest management applications of that work, and develop a research program to assist managers of large, remote wilderness and backcountry areas tasked with managing the ecological impacts of recreation. Completing those tasks, my supervisors decided to invest further in recreation ecology research. I was given a permanent assignment in 1987 and worked mostly on recreation ecology until retiring in 2013.

The NPS, in an attempt to rebuild its scientific capacity, began hiring scientists at some of the more heavily used parks in the 1970s. Although these scientists had other specialties (e.g., fire ecology, wildlife biology), they often did some recreation ecology research, particularly on inventory and monitoring techniques (Box 1). For example, general surveys of impact, particularly on campsites and trails, were conducted in Olympic (Schreiner and Moorhead 1976), Great Smoky Mountains (Bratton et al. 1978, 1979) and Sequoia-Kings Canyon National Parks (Parsons and McLeod 1980).

In 1985, NPS hired Jeff Marion specifically to be a recreation ecologist and stationed him first at Delaware Water Gap National Recreation Area, Pennsylvania, and later in the Forestry Department at Virginia Tech. In 1981, Marion had worked with me conducting trampling experiments and studying how campsite impact varied with type of use (backpacker, private horse rider, or outfitter-led packstock party) in the Bob Marshall Wilderness, Montana (Figure 7). Subsequently, he completed a doctoral dissertation on campsite impacts in the Boundary Waters Canoe

## Box 1. Inventory and monitoring

One practical contribution of recreation ecology was development of inventory and monitoring techniques, particularly for trails and campsites. The general process of technique development began with someone measuring localized impacts in a replicable way. Then techniques were adapted so they could be applied over large areas. Once a number of techniques had been developed, a sourcebook would be written, describing available techniques and their pros and cons, particularly the trade-off each technique makes between quantity of information, quality of information, and cost. Then techniques would be refined to make them more broadly applicable, efficient, and precise.

The earliest measures of trail condition and trend began in the late 1960s. In the Adirondack high country of New York, Ketchledge and Leonard (1970) assessed trail erosion rates by establishing transects across the trail and repeatedly measuring the vertical distance from a taut cord to the trail surface (Figure 8). In the Cairngorm Mountains of Scotland, measures of the width of bare ground and of damaged vegetation along trails, begun in 1969 by Neil Bayfield, have been repeated to quantify trends (Lance et al. 1989). The earliest surveys of entire trails were conducted in Canada (Root and Knapik 1972) and England (Bayfield and Lloyd 1973). Along the 400-km Pennine Way, for example, Bayfield and Lloyd (1973) took samples every 50 m along the trail, measuring width and the presence or absence of parallel trails and detracting features, such as gullying and muddiness. Bratton et al. (1979) adapted these techniques to the entire trail system of Great Smoky Mountains National Park.

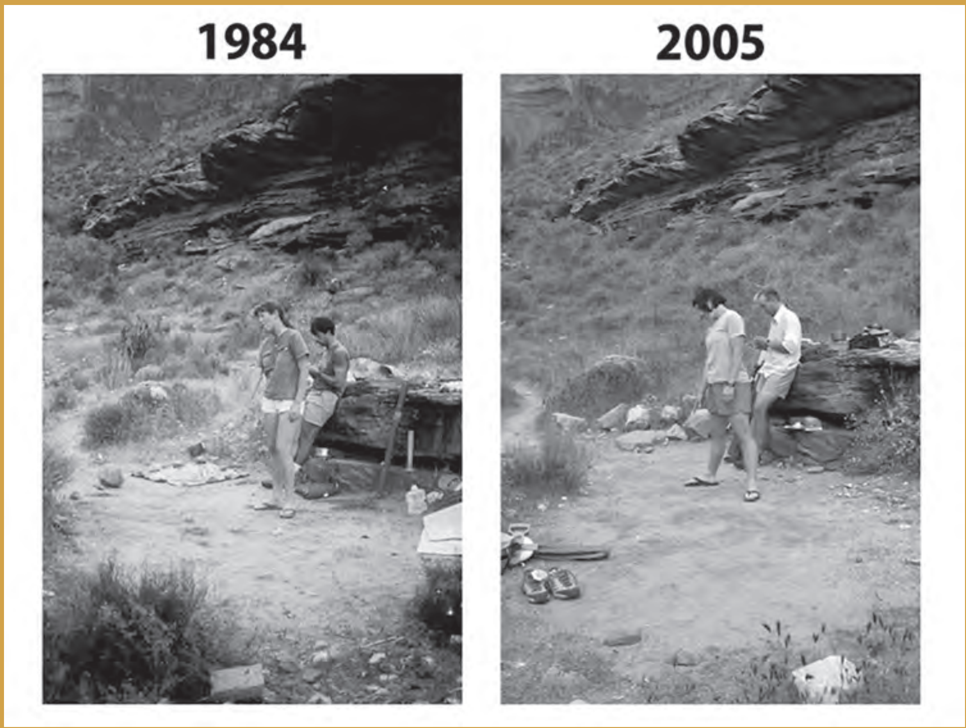
By 1980, three types of trail monitoring techniques were being used: replicable measurements of a small sample of trail segments, rapid surveys of a large sample of trail segments, and complete censuses of trail problems or conditions. In addition, aerial photography could be used in some open environments. Details about each approach, its pros and its cons, were included in a trail monitoring sourcebook (Cole 1983a). Since then, subsequent scientists, most notably Jeff Marion and his first graduate student, Yu-Fai Leung, have refined these approaches substantially (Marion and Leung 2001).

**Figure 8.** Martin Hawes measuring trail width in the Tasmanian Wilderness World Heritage Site, Australia, during a Track Management Workshop held in 1994. | DAVID COLE

Most of the early work on campsite monitoring came out of USFS recreation research, beginning in 1961 with work on developed campgrounds in three California national forests. Repeat measures in 1966 suggested that campground conditions had improved more than deteriorated (Magill 1970). The earliest inventory of campsites across a large area occurred in the Boundary Waters Canoe Area, Minnesota, where by 1968, 1,600 campsites had been inventoried (McCool et al. 1969). Meanwhile, Frissell (1973) who had done his Master's in the early 1960s on Boundary Waters campsites, developed a campsite condition class rating system and, in 1972, applied it to all sites with any evidence of camping impact in what is now the Lee Metcalf Wilderness, Montana. Later in the 1970s, these techniques were refined and applied across entire national parks, most notably Olympic (Schreiner and Moorhead 1976), Great Smoky Mountains (Bratton et al. 1978), and Sequoia-Kings Canyon (Parsons and MacLeod 1980), where about

8,000 campsites were assessed. Again, a sourcebook described and discussed the pros and cons of three types of monitoring technique: estimates of condition, measurements on permanent sampling units, and photographs (Cole 1983b). Since then, techniques have been further refined, most notably by Marion (1991), and changes in condition on some of these campsites have been followed for more than 30 years (Cole 2013; Figure 9). Techniques have continued to evolve since 2000. Notable developments include the use of drone-based photogrammetry and the development of GIS as a core tool in recreation ecology generally and impact monitoring specifically.

**Figure 9.** Repeat photographs, in 1984 and 2005, of the center point location at a backcountry campsite, Grand Canyon National Park, Arizona. | DAVID COLE (left), MATTHIEU BROWN (right)




Area Wilderness under Larry Merriam at University of Minnesota. Marion was among the NPS scientists who were reassigned in 1994 to what is now the US Geological Survey (USGS), where he was still doing recreation ecology in 2021.

In the United States, early leadership in recreation ecology was concentrated in federal agencies that manage large acreages of wildland rather than in academic institutions. The result was more work in backcountry than in frontcountry areas, less adherence to the boundaries of academic disciplines, and more emphasis on the application of science to the practicalities of land management.

## Organizing the field of recreation ecology

The number, diversity, and variety of study settings continued to increase through the 1980s and beyond. Studies were conducted in Asian countries other than Japan (e.g., Jim 1987), in Africa (Garland 1987) and in Central and South America (Boucher et al. 1991). Although most early recreation ecology work was conducted in high-mountain or coastal environments, more recent work was conducted at lower elevations in the mountains (Hall and Kuss 1989), on reefs and intertidal areas (Liddle and Kay 1987) and in deserts (Cole 1986). One impetus for expanded work was the emergence in the 1980s of tourism and ecotourism specifically as phenomena in need of scientific study (Buckley 2004). New specialists, courses, and journals appeared, as did institutions such as the International Centre for Ecotourism Research at Griffith University, established in 1993.

By the 1980s, many hundreds of recreation ecology studies had been conducted and a few people were making a career as recreation ecologists. One early task was to organize the subject more effectively, so it could be applied to improved management of parks and related areas. Early reviews had catalogued the types of impact that recreation causes (Speight 1973, Wall and Wright 1977) and the array of research designs that can be used (Liddle 1975), but given only cursory attention to management application. Although better known for his subsequent studies of national park visitors, a young Robert Manning wrote a perceptive review of recreation impacts (1979). He went beyond earlier reviews to note distinctive spatial and temporal patterns of impact and more fully discuss management implications. The spatial patterns he noted were the high degree to which impacts were concentrated in space and a pattern of progressive expansion of impact areas over time. This testifies to the importance of channeling use and, thereby, minimizing the areal extent of disturbance, the ultimate goal of Meinecke's campground design principles. The primary temporal pattern he noted was the tendency for significant resource impact to occur even when use levels are quite low and when a site is initially opened to recreation use. From this, Manning concluded that impact is inevitable where any regular use occurs, resting and rotating sites seems impractical, and site hardening and cultural treatments to increase the durability of vegetation may be necessary.

By the mid-1980s I had the opportunity to present my synthesis of recreation ecology literature and early results from my research program at the 1983 RERG conference in England and a 1985 wilderness research conference in Colorado (Cole 1985a, 1987). Given my assignment to provide practical guidance to wilderness managers, I for the first time organized knowledge according to the activities that cause impact: hiking, camping, and the use of packstock. In addition, I organized findings according to the factors that influence amount of impact: amount and frequency of use, type and behavior of use, location of use, timing of use, and spatial distribution of use. Each of these influential factors can be manipulated by a unique set of management actions. For example, amount of use can be controlled by limiting use with permits, and type of use can be influenced through visitor education programs or by prohibiting certain types of use (Cole et al. 1987). By studying the importance of each of these factors, research results can be more directly translated into management.

Work on the first textbook on recreation ecology was begun by Bill Hammitt, a professor of recreation at the University of Tennessee who remained interested in ecological impacts despite having been convinced by a mentor that he would have a much more successful career working on social science aspects of recreation. Having written chapters on the resources impacted by recreation—soil, vegetation, wildlife and water—Bill asked me to help him finish the book (Hammitt and Cole 1987). Now in its third edition, the book's focus on management problems, along with its emphasis on wildland recreation, contrasts sharply with—and is complemented by—the academic, disciplinary approach of Liddle's textbook published a decade later (Liddle 1997).

## New generations of recreation ecologists

By the early 1990s, the field of recreation ecology had advanced significantly. Inventory and monitoring techniques had been developed for trails and campsites (Box 1) and a substantial base of knowledge had been developed on factors that influence the magnitude and areal extent of impact, particularly the effect of amount of use (Box 2). Leave No Trace educational messages, based on recreation ecology research, had been institutionalized (Box 3) and a textbook had been written (Hammitt and Cole 1987). However, the number of practicing recreation ecologists in the world could still be counted on one hand.

One reason for slow growth of the field is the fact that most support for recreation ecology came from land management institutions, most notably USFS research, rather than from academic institutions. Neil Bayfield advised a few Scottish students on their theses and a number of students did doctoral work with Mike Liddle, at Griffith University, most notably Dan Sun (e.g., Sun and Liddle 1993). However, none of these students did much additional research in the field.

I was fortunate enough to have funding that allowed me to offer fieldwork opportunities for students, such as Jeff Marion, who went on to do doctoral work in recreation ecology. Marion was probably the first person to go to school with the intent of becoming a recreation ecologist and succeeded in doing that. In

## Box 2. A cautionary tale about the use–impact relationship

It seems logical to assume, if ecological impact is caused by recreation use, that excessive impact must be the result of too much use. This assumption led to great interest in the concept of carrying capacity, starting in the 1960s, as well as in studying the relationship between amount of use and amount of impact. This relationship has been explored theoretically and empirically, both through controlled experiments and field observation of recreation sites with different levels of use. The earliest of each type of empirical study, both funded by USFS recreation research, were Wagar's (1964) "tamping" experiments and Frissell and Duncan's (1965) study of campsites in the Boundary Waters Canoe Area. Each of these studies found that low levels of use cause substantial impact, and that once substantial impact occurs, further increases in use cause little additional impact. Similar results have been reported in scores of subsequent experimental and field studies, leading to the conclusion that the use-impact relationship is typically curvilinear and asymptotic and, therefore, that concentrating use is usually the most effective way for managers to minimize impact (Cole 1982, 1987).

Unfortunately—and I am more guilty of this than anyone—the asymptotic model, due to its managerial significance, was overemphasized. It is not the complete story; it does not always apply. This was clear from early on. In my first study of the effect of amount of use on campsites, the use-impact relationship was asymptotic for most types of campsite impact, but the relationship between use and loss of organic soil horizons was linear across the range of use levels examined (Cole 1982). In my first trampling experiments in Montana, the relationship between vegetation loss and amount of use was asymptotic in five forested vegetation types. but exponential in a much more resistant grassland (Cole 1985b). While 1,200 passes (a one-way walk through the vegetation) removed 80–90% of vegetation in most of the forested types, that level of trampling had no effect on the grassland. Beyond 1,200 passes, however, a threshold was passed and 1,600 passes removed 30% of the vegetation. The asymptotic relationship is inadequate when more durable surfaces are trampled. Why is this?

Growcock (2005) provided the most cogent explanation for differing results, suggesting the use-impact relationship approximates a logistic curve rather than an asymptotic one. Again, this was not a new idea. Much earlier, Hylgaard and Liddle (1981) had used a logistic curve to plot the results of a trampling experiment in sand dune vegetation but did not remark on its significance. In my early literature review (Cole 1987), I noted that the use-impact relationship sometimes "exhibits the form of a logistic curve with two inflection points" (thresholds). Later, in an attempt at a more theoretical approach, I used simple analytical models of campsites to explore the influence of factors that influence amount of impact, deducing that the relationship between use and impact should be a logistic curve (Cole 1992). This was subsequently found to be the case in a study of the spatial development of experimental campsites (Cole and Monz 2004). Monz et al. (2013) suggest use of the more general term "sigmoid" rather than "logistic," which is simply one example of a sigmoid function.

The use-impact relationship is curvilinear, but a sigmoid curve describes the relationship more *completely* than an asymptotic curve. A sigmoid curve has three phases: (1) an initial exponential phase in which the effect of increasing use slowly accelerates; (2) a linear phase in which impact increases greatly with increasing use; and (3) an asymptotic phase in which the effect of increasing use decelerates to zero (Figure 10). Because studies observe the effect of a fixed range of use levels on ecological parameters that vary in durability, they observe different phases of the sigmoid curve. When I applied between 5 and 1,600 passes per year to the fragile vegetation of Montana forests, I was only observing the linear and asymptotic phases, while applying that same range of trampling in the grassland only allowed me to observe the exponential phase. To observe the sigmoid curve in its entirety, for all these vegetation types, it would have been necessary to apply a much wider range of trampling, from as low as 1 pass every few years to as high as perhaps 3,000 passes per year.

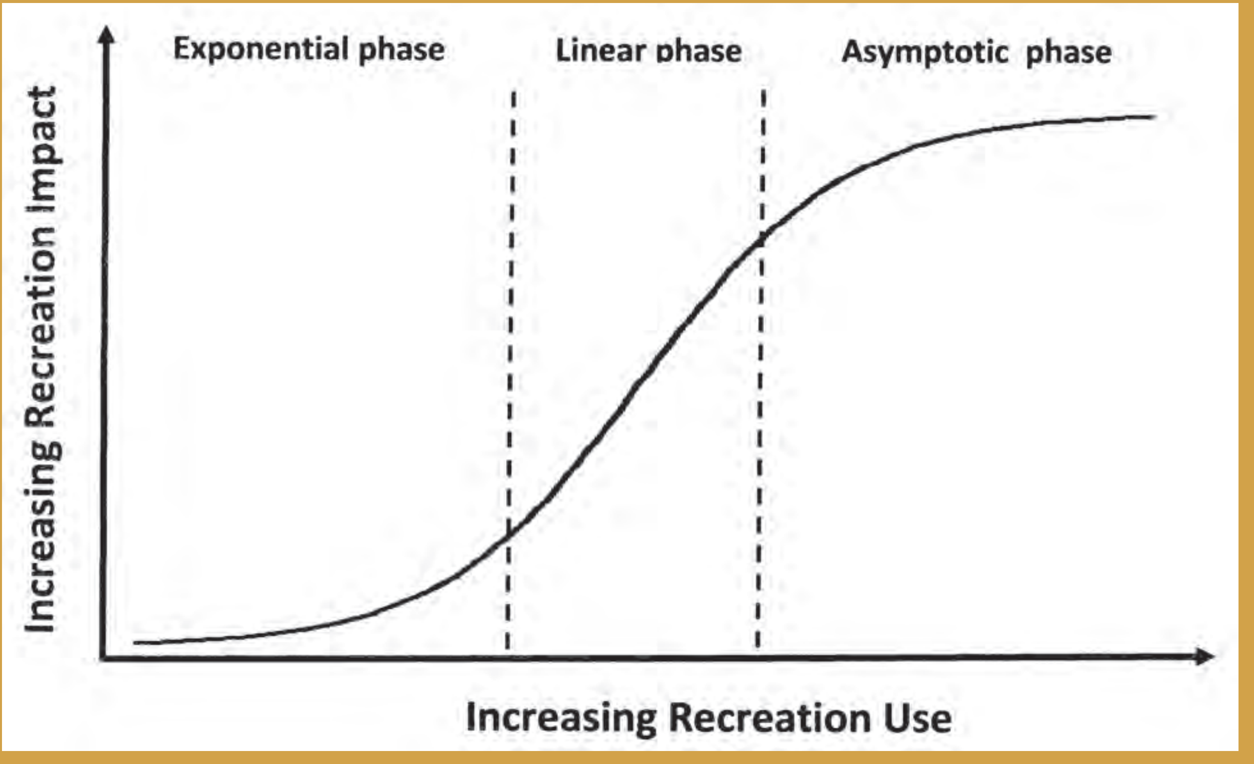



**Figure 10.** Exponential, linear and asymptotic phases of the sigmoid curve that approximates the use-impact relationship.

This is a cautionary tale of overgeneralization and lack of precision in one's use of certain terms. From an academic point of view, it is helpful to move beyond overemphasizing the asymptotic phase of the use-impact relationship to consensus that the use-impact relationship is best conceived of as a sigmoid curve, with thresholds between the exponential and linear phases and between the linear and asymptotic phases (Growcock 2005). However, the importance of these two thresholds has been recognized and reflected in management suggestions that go back to Wagar's (1964) observation that land managers should concentrate use on trails and fixed campsites and, away from these facilities, disperse use to prevent one area from receiving frequent damaging use. "Meinickizing" campgrounds, confining use to designated campsites and trails, severely limiting use in trailless areas, and implementing many other common park management policies are consistent with this understanding of the use-impact relationship. Indeed, the three phases of the sigmoid curve are central to three of the original principles of Leave No Trace education:

- In popular places, concentrate use and impact.
- In pristine places, disperse use and impact.
- Stay off places that are lightly impacted or just beginning to show effects.

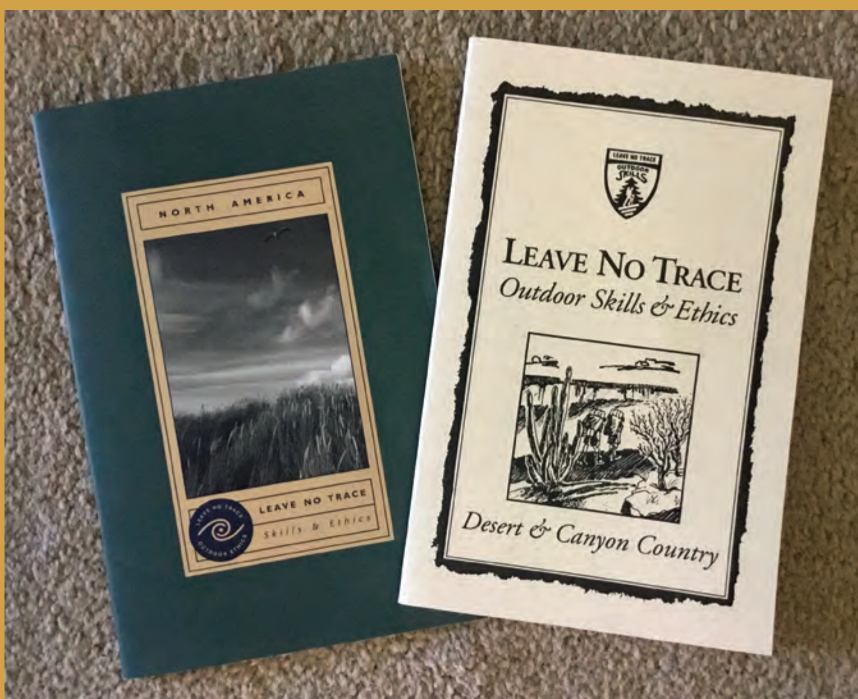
That is, minimize impact by avoiding the linear phase, having as few "popular" places as possible, well above the upper threshold, and many places kept "pristine" by keeping use levels well below the lower threshold. This nuanced understanding of the sigmoid nature of the use-impact relationship was lost when these three principles were collapsed into the single principle, "travel and camp on durable surfaces."

## Box 3. Leave No Trace

One of the early applications of recreation ecology to management was development of the Leave No Trace (LNT) visitor education program. As with recreation ecology itself, this effort began in a disparate manner, with hundreds of individual rangers and managers suggesting ways visitors could minimize their impact. These suggestions, based on personal experience and common sense, were often good ideas but sometimes were inconsistent and even counterproductive. In 1985, the National Outdoor Leadership School (NOLS) brought a group of academics and managers together in the Popo Agie Wilderness, Wyoming, to discuss NOLS' interest in establishing a research department. Of particular note, they wanted to begin by building a more scientific basis for what they called Conservation Practices and similar low-impact practices advocated by management agencies (Cole 2018).

With joint funding from NOLS and USFS, I gathered educational materials on low-impact practices from across agencies and around the world. I evaluated them for both their internal consistency and how consistent they were with relevant research. The end result was 75 science-based practices that were written up in book format (Hampton and Cole 1988) and became the foundation for the LNT curriculum. To present these practices in video format, they were organized around six LNT "principles"—some of them direct translations of research on the relationship between amount of use and amount of impact (Cole 2018). NOLS and the managing agencies developed a series of booklets describing not only general LNT practices, but specific ones for different activities (e.g., boating or traveling with packstock) and for different environments (e.g., alpine and coastal; Figure 11). Interest in these materials was so great that, in 1994, a nongovernmental organization, Leave No Trace Inc., was created to expand the reach of these efforts. Leave No Trace Inc. (now called the Leave No Trace Center for Outdoor Ethics) is now more than 25 years old and has an estimated reach of more than 15 million people every year. The LNT Center continues to rely on recreation ecologists, such as Jeff Marion, who has served on LNT Center committees, written a recent book for them on LNT practices (Marion 2014), and done much to incorporate LNT into programs for the Boy Scouts of America.

**Figure 11.** General and desert-specific Leave No Trace booklets | DAVID COLE



1990, Troy Hall, currently head of the Department of Forest Ecosystems and Society at Oregon State University, helped me reassess campsites in the Bob Marshall Wilderness that Marion had worked on in 1981 (Cole and Hall 1992). She went on to get a recreation-ecology-related doctorate at Oregon State University in 1996. Starting in the mid-1990s, Chris Monz, then director of research at the National Outdoor Leadership School and currently professor and head of the Recreation Ecology Lab at Utah State University, worked with me on a series of trampling and camping experiments in the Wind River Mountains, Wyoming (e.g., Cole and Monz 2002) and then got his doctorate in 2000 from Colorado State University.

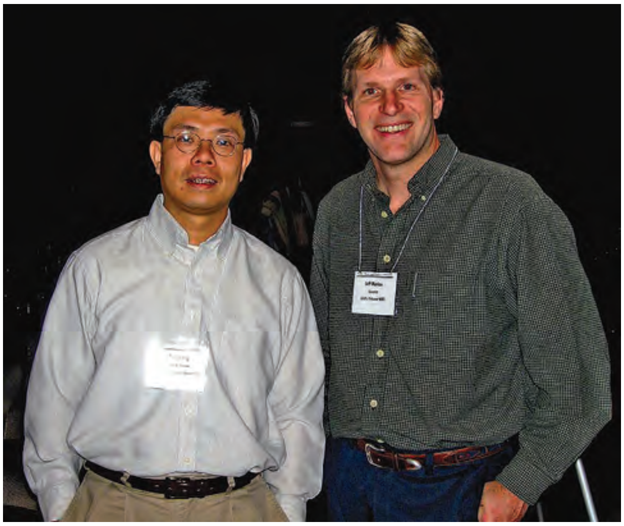


**Figure 12.** The first recreation ecologist to obtain a doctorate studying under a recreation ecologist was Yu-Fai Leung, shown here with his major professor, Jeff Marion, at the 2005 George Wright Society Conference, Philadelphia.
| LAURA LEUNG

The big step forward in training recreation ecologists came when NPS moved Jeff Marion from his field location to the Forestry Department at Virginia Tech. As an adjunct professor there, Marion had the opportunity to take on graduate students. In the early 1990s, Marion accepted Yu-Fai Leung as his first doctoral student. Leung, who had done a master's thesis on trail degradation at the Chinese University of Hong Kong, became the first recreation ecologist to obtain a doctorate under someone specialized in recreation ecology (Figure 12). Over the past several decades, more recreation ecologists have studied both with Marion and Leung, now a professor at North Carolina State University. As a reflection of maturation of the field, many universities now offer courses in recreation ecology, many students are getting this training, and recreation ecology research is contributing to improved park management around the world. Although progress is being made, knowledge about recreational effects on wildlife and water—in contrast to vegetation and soil—remains less well organized and applied (Box 4).

## Box 4. Research on effects on wildlife and water

Compared to recreation effects on vegetation and soil, knowledge about impacts on wildlife and water lagged. With wildlife research, this lag was not the result of a lack of studies. The first bibliography on wildlife impacts, completed for USFS's Wilderness Management Research Unit, included 232 references (Ream 1980). For their 1983 bibliography, Boyle and Samson (1985) found a total of 536 references to the effects of nonconsumptive recreation on wildlife, 166 of which included original data. Garthe (2019) found another 13 wildlife studies in the pre-1980 German-language literature. Compared to vegetation and soil research, however, the study of mobile animals is more difficult; animals disturbed at one time and place may only show effects much later and in a different location. Generalizing about wildlife responses is also particularly challenging, given the degree to which response varies with attributes of the situation and the animals themselves. For example, while white-tailed deer were less disturbed by motorized traffic than by hikers (Behrend and Lubeck 1968), loons were more disturbed by motorized boats than non-motorized canoes (Titus and van Druff 1981). Even within a given species, the response of hunted populations differs from that of populations that are not hunted (Geist et al. 1985). Perhaps because of these challenges, even as recently as 2000, only a few wildlife researchers had done more on the subject than conduct a single study, at one point in space and time.

Valerius Geist was probably the first to study and periodically write about human-wildlife interactions over a multi-decade career. Born in Ukraine and raised in Germany and Austria, Geist did his doctoral work in the late 1960s on the biology, behavior, and social dynamics of bighorn sheep. A member of the Faculty of Environmental Design at the University of Calgary, Geist pursued a wide range of interests and sometimes held controversial views, but throughout his career maintained an interest in whether harassment of big game was harmful. He gave papers at both of the early recreation ecology conferences—the 1978 "Recreational Impact on Wildlands" conference in the US (Ittner et al. 1979) and the 1983 RERG conference in the UK (Bayfield and Barrow 1985). He recognized that while animals have the potential to adjust to disturbance, they also do best in a predictable environment (Geist et al. 1985). With students, Geist employed heartrate telemetry to study how bighorn sheep responded to recreation intrusion, finding that the arousal of animals increased with the unpredictability of human activity. Sheep reacted more to hikers than to motorized traffic on a road, when approached from above than below, and when hikers were accompanied by a dog (Macarthur et al. 1982).

A few others did multiple studies of wildlife impacts. For example, Burger (1981, 1991) devoted her career to studying birds on beaches and associated coastal habitats, with much of that work devoted to people-bird interactions. More recently, Bob Steidl and students have done a number of studies on recreational effects on raptors (e.g., Steidl and Anthony 1996).

In the late 1980s, USFS's Wilderness Management Unit invested in an attempt to accelerate progress in wildlife impact research. Rick Knight, a wildlife professor at Colorado State University who had studied the effects of boating on bald eagles (Knight and Knight 1984), was commissioned to organize and draw generalizations from the hundreds of existing wildlife studies. Meanwhile, Kevin Gutzwiller, wildlife professor at Baylor University, was funded to do a multi-year experimental study of the effects of human intrusion on subalpine forest bird and mammal communities (e.g., Gutzwiller and Anderson 1999). Outcomes of this effort included a new review of the literature (Knight and Cole 1991), a chapter on wildlife disturbance assessment and management in The Wildlife Society's influential wildlife techniques manual (Gutzwiller and Cole 2005), and the first book on wildlife and recreation (Knight and Gutzwiller 1995). Knight, who retired in 2017, is still in the newspapers commenting on recreation impacts on wildlife (Bastone 2019) and working to help groups such as the Malpai Borderlands Group, devoted to protecting natural wildlife habitat and productive ranch land in far southeastern Arizona and adjacent areas of New Mexico by preventing subdivision and development (Figure 13).

In contrast, our understanding of recreation effects on water remains poor today. People have been writing about recreation impacts on water for more than half a century (Barton 1969), but nobody has systematically studied water the way recreation ecologists have studied vegetation, soil, and animals. The nature of impacts on water are generally known, from changes in the physical, chemical, and biological properties of water and resultant effects on aquatic vegetation and even human health (Hammitt et al. 2015), as are the activities that cause impact, from boating to camping to driving off-road vehicles (Kuss et al. 1990; Liddle 1997). Although research in this arena has slowly increased (e.g., Hadwen et al. 2003), fundamental questions remain unanswered, such as how much dispersed camping can be allowed before inadequate disposal of human waste causes problems with drinking water.

**Figure 13.** Rick Knight, co-editor of the first book on recreation impacts on wildlife, headed out to repair fence line with the Malpai Borderlands Group | HEATHER KNIGHT

## Concluding remarks

In 2005, Jeff Marion, Yu-Fai Leung, Chris Monz and I met, with Ralf Buckley on the phone from Australia, to brainstorm ways to increase the viability of recreation ecology teaching and research. Our first action was to establish the Recreation Ecology Research Network, for which Leung agreed to host a listserv at North Carolina State University. Within a few months, the network had about 50 members; now, in 2021, there are almost 200 subscribers to the listserv. This is probably a reasonable metric of how interest in recreation ecology has expanded since the handful of people working in the field in the 1970s. Recreation ecology will never be as substantial as other branches of disturbance ecology, like fire ecology or even grazing or mining ecology. However, it appears to be an established field that will continue to contribute to the scientific management of parks and related conservation lands.

The past few decades have seen some shifts in emphasis. Academic institutions have replaced public land management institutions as the primary home for recreation ecology research. Little research has come out of Britain's Natural Environment Research Council or other institutions that funded the work of Bayfield and other early recreation ecologists in Great Britain. USFS chose not to replace me when I retired; NPS did not replace Marion when he moved to USGS; and USGS is unlikely to replace him when he retires. In academia, perhaps in response to shifts in available funding and the evolving interests of social scientists, many formerly strong recreation management programs have redefined themselves more broadly as programs working on the human dimensions of natural resource management. Meanwhile, the field of tourism has expanded greatly. Today, recreation ecologists are as likely to be housed in institutions with strong tourism programs as in those with strong recreation programs. Related to this, given the emphasis on tourism and the productivity of Catherine Pickering and her students at institutions such as Griffith University, Australia has joined the United States as a center for recreation ecology research in the world.

The current state of scholarship is such that few researchers search the literature beyond the peer-reviewed journal articles they can locate with an internet search. In their writings, they are much more likely to cite a recent article, so they appear familiar with current literature, than to cite the researchers who originally developed an idea, concept, or finding. Since much of the early work in recreation ecology was published in the grey literature that is seldom cited, or in ecological rather than tourism or environmental management journals (Sumanapala and Wolf 2019), the legacy of the pioneers of recreation ecology is being lost. My hope is that this article will acquaint readers with such pioneers of recreation ecology as "Doc" Meinecke, Neil Bayfield, and Mike Liddle.

## References


Altman, M. 1958. The flight distance in free-ranging game. *Journal of Wildlife Management* 22: 207–209.

Barton, M.A. 1969. Water pollution in remote recreational areas. *Journal of Soil and Water Conservation* 24: 132–134.

Bastone, K. 2019. Are trails in Colorado harming wildlife? *5280: Denver's Mile High Magazine* (August). https://www.5280.com/2019/07/are-trails-in-colorado-harming-wildlife/.

Bates, G.H. 1935. Vegetation of footpaths, sidewalks, cart-tracks, and gateways. *Journal of Ecology* 23: 470–487.

Bayfield, N.G. 1971. Some effects of walking and skiing on vegetation at Cairngorm. In *The Scientific Management of Animal and Plant Communities for Conservation*. E. Duffey and A.S. Watt, eds. Oxford: Blackwell Scientific: 469–485.

Bayfield, N.G. 1973. Use and deterioration of some Scottish hill paths. *Journal of Applied Ecology* 10: 639–648.

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

Bayfield, N.G. 1986. Penetration of the Cairngorms Mountains, Scotland by vehicle tracks and footpaths: Impacts and recovery. In *Proceedings—National Wilderness Research Conference: Current Research*. R.C. Lucas, comp. General Technical Report INT-212. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Research Station: 121–128.

Bayfield, N.G., and R. Aitken. 1992. *Managing the Impacts of Recreation on Vegetation and Soils: A Review of Techniques.* Banchory, Scotland: Institute of Terrestrial Ecology.

Bayfield, N.G., and G.C. Barrow, eds. 1985. *The Ecological Impacts of Outdoor Recreation on Mountain Areas in Europe and North America.* R.E.R.G Report no. 9. Wye, UK: Recreation Ecology Research Group.

Bayfield, N.G., and R.J. Lloyd. 1973. An approach to assessing the impact of use on a long distance footpath—The Pennine Way. *Recreation News Supplement* 1973: 11–17.

Behrend, D.F., and R.A. Lubeck. 1968. Summer flight behavior of white-tailed deer in two Adirondack forests. *Journal of Wildlife Management* 53: 713–719.

Boucher, D.H., J. Aviles, R. Chepote, O.E. Dominguez-Gil, and B. Vilchez. 1991. Recovery of trailside vegetation from trampling in a tropical rain forest. *Environmental Management* 15: 257–262.

Boyle, S.A., and F.B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: A review. *Wildlife Society Bulletin* 31: 110-116.

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

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

Brockman, C.F. 1959. Ecological study of subalpine meadows, Paradise Valley Area, Mt. Rainier National Park, Washington. Unpublished report. Ashford, WA: Mount Rainier National Park.

Burger, J. 1981. The effect of human activity on birds at a coastal bay. *Biological Conservation* 21: 231–241.

Burger, J. 1991. Foraging behavior and the effect of human disturbance on the piping plover (*Charadrius melodus*). *Journal of Coastal Research* 7: 39–52.

Bryan, R.B. 1977. The influence of soil properties on degradation of mountain hiking trails at Grövelsjön. *Geografiska Annaler* 59A(1–2): 49–65.

Buckley, R., ed. 2004. *Environmental Impacts of Ecotourism.* Wallingford, UK: CABI Publishing.

Burden, R.F., and P.F. Randerson. 1972. Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. *Journal of Applied Ecology* 9: 439–457.

Cole, D.N. 1982. *Wilderness Campsite Impacts: Effect of Amount of Use.* Research Paper INT-284. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Forest and Range Experiment Station.

Cole, D.N. 1983a. *Assessing and Monitoring Backcountry Trail Conditions.* Research Paper INT-303. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Forest and Range Experiment Station.

Cole, D.N. 1983b. *Monitoring the Condition of Wilderness Campsites.* Research Paper INT-302. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Forest and Range Experiment Station.

Cole, D.N. 1985a. Management of ecological impacts in wilderness areas in the United States. In *The Ecological Impacts of Outdoor Recreation on Mountain Areas in Europe and North America.* N.G. Bayfield and G.C. Barrow, eds. R.E.R.G Report no. 9. Wye, UK: Recreation Ecology Research Group: 138–154.

Cole, D.N. 1985b. *Recreational Trampling Effects on Six Habitat Types in Western Montana.* Research Paper INT-350. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Forest and Range Experiment Station.

Cole, D.N. 1986. Recreational impacts on backcountry campsites in Grand Canyon National Park, Arizona, USA. *Environmental Management* 10: 651–659.

Cole, D.N. 1987. Research on soil and vegetation in wilderness: A state-of-knowledge review. In *Proceedings—National Wilderness Research Conference: Issues, State-of-knowledge, Future Directions.* R.C. Lucas, comp. General Technical Report INT-220. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Research Station: 135–177.

Cole, D.N. 1992. Modeling wilderness campsites: Factors that influence amount of impact. *Environmental Management* 16: 255–264.

Cole, D.N. 2013. *Changing Conditions on Wilderness Campsites: Seven Case Studies of Trends over 13 to 32 Years.* General Technical Report RMRS-GTR-300. Ft. Collins, CO: US Department of Agriculture–Forest Service, Rocky Mountain Research Station.

Cole, D.N. 2018. Leave No Trace: how it came to be. *International Journal of Wilderness* 24(3): 54–65.

Cole, D.N. 2019. Pioneers of wilderness research: The wilderness management research unit. *International Journal of Wilderness* 25(1): 42–57.

Cole, D.N., and T.E. Hall. 1992. *Trends in Campsite Condition: Eagle Cap Wilderness, Bob Marshall Wilderness and Grand Canyon National Park.* Research Paper INT-453. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Research Station.

Cole, D.N., and C.A. Monz. 2002. Trampling disturbance of high-elevation vegetation, Wind River Mountains, Wyoming, U.S.A. *Arctic, Antarctic, and Alpine Research* 34: 365–376.

Cole, D.N. and C.A. Monz. 2004. Spatial patterns of recreation impact on experimental campsites. *Journal of Environmental Management* 70: 73–84.

Cole, D.N., M.E. Petersen, and R.C. Lucas. 1987. *Managing Wilderness Recreation Use: Common Problems and Potential Solutions.* General Technical Report INT-259. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Research Station.

Cole, D.N., and E.G.S. Schreiner, comps. 1981. *Impact of Backcountry Recreation: Site Management and Rehabilitation—An Annotated Bibliography.* General Technical Report INT-121. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Forest and Range Experiment Station.

Crawford, A.K., and M.J. Liddle. 1977. The effect of trampling on neutral grassland. *Biological Conservation* 12: 135–142.

Davidson, E., and M. Fox. 1974. Effects of off-road motorcycle activity on Mojave Desert vegetation and soil. *Madroño* 22: 381–390.

Dotzenko, A.D., N.T. Papamichos, and D.S. Romine. 1967. Effects of recreational use on soil and moisture conditions in Rocky Mountain National Park. *Journal of Soil and Water Conservation* 22: 196–197.

Duffey, E., ed. 1967. *The Biotic Effects of Public Pressure on the Environment.* Monks Wood Experiment Station Symposium 3. Huntington, UK: Nature Conservancy.

Dügelli, M. 1937. Wie wirkt das öftere Betreten des Waldbodens auf einzelne physikalische und biologische Eigenschaften? *Schweizerische Zeitschrift für Forstwesen* 88: 151–165.

Edwards, I.J. 1977. The ecological impact of pedestrian traffic on alpine vegetation in Kosciuszko National Park. *Australian Forestry* 40: 108–120.

Erlinger, G., and J.H. Reichholf. 1974. Störungen durch Angler in Wasservogel-Schutzgebieten. *Natur und Landschaft* 49: 299–300.

Falinski, J.B. 1975. Reaction of forest soil vegetation to trampling in the light of experimental research. *Phytocoenologia* 2: 451–564.

Frissell, S.S. 1973. The impact of wilderness visitors on natural ecosystems. Unpublished report. Missoula, MT: US Department of Agriculture–Forest Service, Aldo Leopold Wilderness Research Institute.

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

Garland, G.G. 1987. Rates of soil loss from mountain footpaths: an experimental study in the Drakensberg Mountains, South Africa. *Applied Geography* 7: 41–54.

Garthe, C.J. 2019. Early recreation ecology research in Europe—disciplinary development and review of German-language research results. *Journal of Nature Conservation* 51: 1–10. https://doi.org/10.1016/j.jnc.2019.125718.

Geist, V., R.E. Stemp, and R.H. Johnston. 1985. Heart-rate telemetry of bighorn sheep as a means to investigate disturbances. In *The Ecological Impacts of Outdoor Recreation on Mountain Areas in Europe and North America.* N.G. Bayfield and G.C. Barrow, eds. R.E.R.G Report no. 9. Wye, UK: Recreation Ecology Research Group: 92–99.

Gibbens, R.P., and H.F. Heady. 1964. *The Influence of Modern Man on the Vegetation of Yosemite Valley.* Manual 36. Berkeley, CA: California Agricultural Experiment Station.

Goldsmith, F.B., R.J.C. Munton, and A Warren. 1970. The impact of recreation on the ecology and amenity of seminatural areas: Methods of investigation used in the Isles of Scilly. *Biological Journal of the Linnaean Society* 2: 287–306.

Growcock, A.J.W. 2005. Impacts of camping and trampling on Australian alpine and subalpine vegetation and soils. Ph.D. dissertation. Brisbane, Australia: Griffith University, Gold Coast.

Gutzwiller, K.J., and D.N. Cole. 2005. Assessment and management of wildland recreational disturbance. In *Techniques for Wildlife Investigations and Management*. C.E. Braun, ed. Bethesda, MD: The Wildlife Society.

Gutzwiller, K.J., and S.H. Anderson. 1999. Spatial extent of human-intrusion effects on subalpine bird distributions. *Condor* 101: 378–389.

Hadwen, W.L., A.H. Arthington, and T.D. Mosisch. 2003. The impact of tourism on dune lakes on Fraser Island, Australia. *Lakes and Reservoirs: Research and Management* 8: 15–26. https://doi.org/10.1046/j.1440-1770.2003.00205.x.

Hall, C.N., and F.R. Kuss. 1989. Vegetation alteration along trails in Shenandoah National Park, Virginia. *Biological Conservation* 48: 211–227.

Hammitt, W.E., and D.N. Cole. 1987. *Wildland Recreation: Ecology and Management.* New York: John Wiley.

Hampton, B., and D. Cole, D. 1988. *Soft Paths: How to Enjoy the Wilderness without Harming It.* Harrisburg, PA: Stackpole Books.

Hartesveldt, R.J. 1965. An investigation of the effect of direct human impact and of advanced plant succession on *Sequoia gigantea* in Sequoia and Kings Canyon National Parks, California. Unpublished report. San Francisco, CA: National Park Service.

Hylgaard, T., and M.J. Liddle. 1981. The effect of human trampling on a sand dune ecosystem dominated by *Empetrum nigrum*. *Journal of Applied Ecology* 18: 559–569.

Ittner, R., D.R. Potter, J.K. Agee, and S. Anschell, eds. 1979. *Recreational Impact on Wildlands Conference Proceedings.* R-6-001-1979. Portland, OR: US Department of Agriculture–Forest Service, Pacific Northwest Region.

Jim, C.Y. 1987. Trampling impacts of recreationists on picnic sites in a Hong Kong country park. *Environmental Conservation* 14: 117–127.

Kellomäki, S., and V.L. Saastamoinen. 1975. Trampling tolerance of forest vegetation. *Acta Forestalia Fennica* 147: 5–19.

Ketchledge, E.H., and R.E. Leonard. 1970. The impact of man on the Adirondack high country. *The Conservationist* 25(2): 14–18.

Knight, R.L., and D.N. Cole. 1991. Effects of recreational activity on wildlife in wildlands. *Transactions of the North American Wildlife and Natural Resources Conference* 56: 238–247.

Knight, R.L., and K.J. Gutzwiller, eds. 1995. *Wildlife and Recreationists: Coexistence through Management and Research*. Washington, DC: Island Press.

Knight, R.L., and S.K. Knight. 1984. Responses of wintering bald eagles to boating activity. *Journal of Wildlife Management* 48: 999–1004.

Kuss, F.R., A.R. Graefe, and J.J. Vaske. 1990. *Visitor Impact Management: A Review of Research*. Washington DC: National Parks and Conservation Association.

Laing, C.C. 1961. A report on the effect of visitors on the natural landscape in the vicinity of Lake Solitude, Grand Teton National Park, Wyoming. Unpublished report. Moose, WY: National Park Service, Grand Teton National Park.

Lance, A.N., I.D. Baugh, and J.A. Love. 1989. Continued footpath widening in the Cairngorm Mountains, Scotland. *Biological Conservation* 49: 201–214.

Landals, M., and G.W. Scotter. 1973. Visitor impact on meadows near Lake O'Hara, Yoho National Park. Unpublished report. Edmonton, AB: Canadian Wildlife Service.

LaPage, W.F. 1967. *Some Observations on Campground Trampling and Ground Cover Response.* Research Paper NE-68. Broomall, PA: US Department of Agriculture–Forest Service Northeastern Forest Experiment Station.

Leatherman, S.P., and P.G. Godfrey. 1979. *The Impact of Off-road Vehicles on Coastal Ecosystems in Cape Cod National Seashore: An Overview*. Report 34. Amherst, MA: National Park Service.

Leonard, R.E., E.L. Spencer, and H.J. Plumley. 1979. *Backcountry Facilities: Design and Maintenance.* Gorham, NH: Appalachian Mountain Club.

Leonard, R.E., and A.M. Whitney. 1977. *Trail Transect: A Method for Documenting Trail Changes.* Research Paper NE-389. Broomall, PA: US Department of Agriculture–Forest Service Northeastern Forest Experiment Station.

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

Liddle, M.J. 1991. Recreation ecology: Effects of human trampling on plants and corals. *Trends in Ecology, Evolution and Systematics* 6:13–17.

Liddle, M.J. 1997. *Recreation Ecology: The Ecological Impact of Outdoor Recreation and Ecotourism.* London: Chapman and Hall.

Liddle, M.J., and P.J. Greig-Smith. 1975. A survey of tracks and paths in a sand dune ecosystem. *Journal of Applied Ecology* 12: 893–930.

Liddle, M.J., and A.M. Kay. 1987. Resistance, survival and recovery of trampled corals on the Great Barrier Reef. *Biological Conservation* 42: 1–18.

MacArthur, R.A., V. Geist, and R.H. Johnston. 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: US Department of Agriculture–Forest Service, Pacific Southwest Forest and Range Experiment Station.

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

Marion, J.L. 1991. *Developing a Natural Resource Inventory and Monitoring Program for Visitor Impacts on Recreation Sites: A Procedural Manual.* USDI National Park Service Natural Resources Report NPS/NRVT/NRR-91/06. Denver: National Park Service.

Marion, J. 2014. *Leave No Trace in the Outdoors.* Mechanicsburg, PA: Stackpole Books.

Marion, J.L., and Y. Leung. 2001. Trail resource impacts and an examination of alternative assessment techniques. *Journal of Park and Recreation Administration* 19: 17–37.

McCool, S.F., L.C. Merriam Jr, and C.T. Cushwa. 1969. *The Condition of Wilderness Campsites in the Boundary Waters Canoe Area.* Minnesota Forestry Research Note 202. St. Paul, MN: University of Minnesota.

Meinecke, E.P. 1926. Memorandum on the effects of tourist traffic on plant life, particularly Big Trees, Sequoia National Park, California, May 13–16, 1926. Unpublished report. Vallejo, CA: US Department of Agriculture–Forest Service.

Merkle, J. 1963. Ecological studies of the Amphitheater and Surprise Lakes cirque in the Teton Mountains, Wyoming. Unpublished report. Moose, WY: National Park Service, Grand Teton National Park.

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

Monz, C.A., C.M. Pickering, and W.L. Hadwen. 2013. Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. *Frontiers in Ecology and the Environment* 11(8): 441–446. https://doi.org/10.1890/120358

Neumann, P.W., and H.G. Merriam. 1972. Ecological effects of snowmobiles. *Canadian Field Naturalist* 86: 207–212.

Parsons, D.J., and S.A. MacLeod. 1980. Measuring impacts of wilderness use. *Parks* 5(3): 8–12.

Rasdorsky, W. 1925. Uber die Reaktion der Pflanzen auf die mechanische Inanspruchnahme. *Berichte Der Deutschen Botanischen Gesellschaft* 43: 332–352.

Ream, C.H. 1980. *Impacts of Backcountry Recreationists on Wildlife: An Annotated Bibliography.* General Technical Report INT-81. Ogden, UT: US Department of Agriculture–Forest Service, Intermountain Forest and Range Experiment Station.

Ripley, T.H. 1962. *Recreation Impact on Southern Appalachian Campgrounds and Picnic Sites.* Research Paper SE-153. Asheville NC: US Department of Agriculture–Forest Service, Southeastern Forest Experiment Station.

Rogova, T.V. 1976. Influence of trampling on vegetation of forest meadow and whortleberry-moss-pine forest cenoses. *Soviet Journal of Ecology* 7: 356–359.

Root, J.D., and L.J. Knapik. 1972. *Trail Conditions along a Portion of the Great Divide Trail Route, Alberta and British Columbia Rocky Mountains.* Report 72-5. Edmonton, AB: Resource Council of Alberta.

Satchell, J.R., and P.R. Marren. 1976. *The Effects of Recreation on the Ecology of Natural Landscapes.* Nature and Environment Series no. 11. Strasbourg, France: Council of Europe.

Schreiner, E.G., and B.B. Moorhead. 1976. Human impact studies in Olympic National Park. In *Proceedings, Symposium on Terrestrial and Aquatic Ecological Studies of the Northwest.* Cheney, WA: Eastern Washington State College: 59–66.

Sharsmith, C.W. 1959. A report on the status, changes and ecology of backcountry meadows in Sequoia and Kings Canyon National Parks. Unpublished report. Three Rivers, CA: Sequoia and Kings Canyon National Parks.

Speight, M.C.D. 1973. *Outdoor Recreation and its Ecological Effects: A Bibliography and Review.* Discussion Papers in Conservation Number 4. London: University College.

Steidl, R.J., and R.G. Anthony. 1996. Responses of bald eagles to human activity during the summer in interior Alaska. *Ecological Applications* 6: 482–491.

Sumanapala, D., and I.D. Wolf. 2019. Recreation ecology: A review of research and gap analysis. *Environments* 6(7): 81. doi: 10.3390/environments6070081

Sumner, E.L. 1942. The biology of wilderness protection. *Sierra Club Bulleti*n 27(8): 14–22.

Sun, D., and M.J. Liddle. 1993. Plant morphological characteristics and resistance to simulated trampling. *Environmental Management* 17: 511–521.

Tachibana, H. 1969. Vegetation changes of a moor in Mt. Hakkoda caused by human treading. *Ecological Review* 17: 177–188.

Thornburgh, D.A. 1970. Survey of recreational impact and management recommendations for the subalpine vegetation communities at Cascade Pass, North Cascades National Park. Unpublished report. Sedro Wooley, WA: North Cascades National Park.

Titus, J.R., and L.W. van Druff. 1981. Response of the common loon to recreational pressure in the Boundary Waters Canoe Area, northeastern Minnesota. *Wildlife Monographs* 79: 5–59.

Underhill, J.E. 1965. Wear from people in Black Tusk Meadows. Unpublished report. Victoria, BC: British Columbia Provincial Parks Branch, Department of Recreation and Conservation.

Wagar, J.A. 1964. *The Carrying Capacity of Wild Lands for Recreation.* Forest Science Monograph 7. Washington, DC: Society of American Foresters.

Wall, G., and C. Wright. 1977. The Environmental Impact of Outdoor Recreation. Department of Geography Publication Series no. 11. Waterloo, ON: University of Waterloo.

Westhoff, V. 1967. The ecological impact of pedestrian, equestrian and vehicular traffic on vegetation. In *Proceedings, International Union for the Conservation of Nature and Natural Resources New Series* 7: 218–223.

Willard, B.E., and J.W. Marr. 1970. Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park, Colorado. *Biological Conservation* 2: 257–265.

Young, T. 2014. "Green and shady camps": E.P. Meinecke and the restoration of America's public campgrounds. *The George Wright Forum* 31(1): 69–76.

The Interdisciplinary Journal of Place-based Conservation

Co-published by the Institute for Parks, People, and Biodiversity, University of California, Berkeley and the George Wright Society. ISSN 2688-187X

Citation for this article

Cole, David N. 2021. Reflections on the early history of recreation ecology. *Parks Stewardship Forum* 37(2): 379–400.

*Parks Stewardship Forum* explores innovative thinking and offers enduring perspectives on critical issues of place-based heritage management and stewardship. Interdisciplinary in nature, the journal gathers insights from all fields related to parks, protected areas, cultural sites, and other place-based forms of conservation. The scope of the journal is international. It is dedicated to the legacy of George Meléndez Wright, a graduate of UC Berkeley and pioneer in conservation of national parks.

*Parks Stewardship Forum* is published online at https://escholarship.org/uc/psf through eScholarship, an open-access publishing platform subsidized by the University of California and managed by the California Digital Library. Open-access publishing serves the missions of the IPPB and GWS to share, freely and broadly, research and knowledge produced by and for those who manage parks, protected areas, and cultural sites throughout the world. A version of *Parks Stewardship Forum* designed for online reading is also available at https://parks.berkeley.edu/psf.



The journal continues *The George Wright Forum*, published 1981–2018 by the George Wright Society.

*PSF* is designed by Laurie Frasier • lauriefrasier.com


## On the cover of this issue

A montage of images from One Tam, a collaborative partnership to manage the landscape of Mount Tamalpais in California, along with one from Alcatraz Island in Golden Gate National Recreation Area.

TOP RAY LEE / RAY LEE PHOTOGRAPHY
SECOND ROW LEE JESTER; VIVIEN KIM THORP / GOLDEN GATE PARKS CONSERVANCY; PAUL MYERS / GOLDEN GATE PARKS CONSERVANCY
THIRD ROW PAUL MYERS / GOLDEN GATE PARKS CONSERVANCY (BOTH PHOTOS)
BOTTOM RYAN CURRAN WHITE / GOLDEN GATE PARKS CONSERVANCY
COVER LAYOUT GARY E. DAVIS & DOROTHY A. DAVIS