Environmental Impacts of Outdoor Recreation in Wildlands

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Although often considered to be a nonconsumptive use, outdoor recreation inevitably alters attributes of the environment in which it occurs: soil, vegetation, animals, and water bodies. Following a brief review of how and when recreation ecology developed, the primary research findings of this nascent discipline are reviewed. Recreational impacts on vegetation and soil are emphasized, particularly those caused by non-motorized use of wildlands, because our understanding of those impacts is most advanced and sophisticated. The chapter concludes with a discussion of the managerial significance of this topic and some thoughts on future directions for recreation ecology.

Historical Development of Recreation Ecology

Although informal studies of recreational impacts on the environmental had been conducted occasionally since at least the 1920s (Meinecke, 1928), it was not until the 1960s that more rigorous recreation ecology studies were first conducted (Wagar, 1964; Frissell & Duncan, 1965). In the 1970s, the first long-term research programs were initiated. During this decade Bayfield (1973) began his work on trail and trampling impacts in Scotland, Liddle (1975) began his work on trampling effects in Great Britain and Australia, and Cole (1978) began his work on trail, camping, and hiking impacts in wildernesses in the United States. During the 1980s and 1990s, the number of recreation ecology studies increased greatly, although few researchers ever conducted more than one study. Nevertheless, considerable progress was made in applying recreation ecology research to the development of impact monitoring protocols, management strategies, and low-impact educational messages, especially in national parks and wilderness areas (e.g. Cole, 1981a, 1989; Marion, 1995; Hampton & Cole, 1988). This led to publication of the first recreation ecology textbook in 1987 (Hammitt & Cole, 1987). Descriptive field studies became more sophisticated, with the adoption of cross-sectional and longitudinal designs, and were augmented by experimentation. Although general principles and consistent findings emerged from this work, theory remains poorly developed.

Rigorous and cumulative research programs concerning impacts on vegetation and soil developed before research programs devoted to impacts on wildlife and water. By the 1980s, research was accumulating on disturbance of animal species (e.g. bighorn sheep; MacArthur, Geist, & Johnston, 1982) and the first textbook on recreation impacts on wildlife was published in the 1990s (Knight & Gutzwiller, 1995). Despite the conduct of hundreds of studies, however, little progress has been made in uncovering broad generalizations and principles regarding recreational disturbance of wildlife. Research on the impacts of recreation on water remains even more sparse and disparate.

Research Findings

Descriptive Knowledge

As is common during the first decades of a new field of inquiry, most recreation ecology studies have been largely descriptive. Substantial progress has been made in describing the nature and quantifying the magnitude of recreational impacts, particularly on vegetation and soil. Trampling, the most prevalent recreation impact process, damages and kills plants, displaces soil organic horizons, and compacts mineral soils. These immediate, direct trampling effects, in turn, have additional longer lasting and cascading effects (Liddle, 1997). Models of trampling effects often contain positive feedback loops. For example, trampling eliminates vegetation cover, which reduces inputs of organic matter and root exudates into the soil. Along with the physical effects of soil compaction, this alters the microorganisms that live in the soil. Since soil microorganisms are critically important both to the alleviation of soil compaction and the establishment and growth of vegetation, soil and vegetation are further altered by these changes to the soil biota. Consequently, sites can remain compacted and barren, even in the absence of further trampling.

The ultimate result of even modest levels of repetitive trampling is a severe but localized (and often long-lasting) alteration of virtually all aspects of the structure, composition and functioning of ecosystems. The most commonly studied ecosystem attributes are readily observable vegetation and soil characteristics (e.g. plant cover, species composition, and soil compaction) and the most common scale of analysis is the site scale (. 0.1 ha). Recent studies, however, have enlarged the array of ecosystem effects that have been documented. For example, Zabinski and Gannon (1997) have documented reductions in the functional diversity of microbial populations growing on campsites and Belnap (1996) has shown that disturbance of surface cyanobacterial-lichen soil crusts reduces nitrogenase activity and, therefore, alters nitrogen cycles.

In addition to trampling, substantial environmental effects are caused by such activities as firewood collection and campfire building, trail construction and maintenance, grazing of pack animals, human intrusion into wildlife habitat, and the use of motor vehicles. Many of these impacts are described in detail in recent textbooks (Liddle, 1997; Newsome, Moore, & Dowling, 2002).

Magnitude of impact is a function of both the intensity of impact (impact per unit area) and the extent (area) of impact. Many studies assess the size of impacted sites and several have aggregated data over large areas to informally enlarge the scale of analysis. For example, Cole (1981b) reported that vegetation loss from camping, at the scale of several wilderness watersheds, was less than 0.2%, despite exceeding 90% on individual campsites. This illustrates the importance of carefully choosing the appropriate scale of analysis and of explicitly defining a study's scale when reporting results that quantify the magnitude of impact. More useful, but virtually nonexistent, would be studies that describe the effects of recreation on attributes that are unique emergent properties of large-scale ecological systems. For example, even highly localized trampling can result in a loss of global biodiversity if it happens to be concentrated on the only population of a rare plant species.

Lack of information about impacts at critical scales of analysis may partially explain our poor understanding of wildlife impacts and their significance, despite the large number of impact studies that have been conducted. Numerous studies assess the short-term responses of individual animals to recreational disturbance. For example, Cassirer, Freddy, & Ables (1992) document, for a portion of Yellowstone National Park, that elk typically flee from cross-country skiers when they approach within 400 meters. But little is known about whether such disturbances have significant long-term impacts on elk or populations of other animals. However, more experimental studies are being conducted in an attempt to understand the impacts of recreation on populations and communities of animals. Examples include studies of reproductive success after elk were approached and displaced by study personnel during peak calving season (Phillips & Alldredge, 2000), studies of trail effects on bird communities (Miller, Knight, & Miller 2001) and studies of human intrusion on avian richness and abundance (Riffell, Gutzwiller, & Anderson, 1996).

Spatial and Temporal Patterns

Although Leung & Marion (1999a) discuss spatial strategies for managing recreation impacts, spatial patterns of impact have received little attention. At large spatial scales (>10 ha), a given aggregate area of impact may be distributed as either a few large impacts or a larger number of smaller impacts. These impacts can be distributed in a pattern that is either more clumped (underdispersed) or more regular (overdispersed) than a random pattern. The significance of recreation impacts is likely to vary as much with spatial pattern as it does with the nature and intensity of impact.

The primary general findings of longitudinal studies of recreation impact are that (1) impacts often occur rapidly, (2) for many environmental variables, amount of impact can be stable over long periods of sustained use, and (3) recovery rates are highly variable but almost always slower than rates of deterioration. For example, most of the impact that occurred over six years following the initial creation of canoe campsites along the Delaware River occurred during the first year of use (Marion & Cole, 1996). Evidence of camping on closed campsites largely disappeared in six years along the Delaware River (Marion & Cole, 1996), where soils are fertile and growing seasons are long. In the alpine meadows of Glacier National Park, in contrast, residual effects of trampling remain 30 years after disturbance ceased (Hartley, 1999). At larger spatial scales, unless recreation use distribution is tightly controlled, impacts tend to increase over time, more from the creation of newly impacted sites than from the deterioration of established sites (Cole, 1993). Site proliferation occurs because, as use shifts across the landscape, deterioration of new sites occurs more rapidly than recovery of old sites.

Knowledge About Functional Relationships

Perhaps the best measure of progress in recreation ecology is the knowledge that has accumulated regarding factors that influence the magnitude of recreation impact. As first proposed in a state-of-knowledge review (Cole, 1987), characteristics of use, environment, and management all combine to influence the magnitude of recreation impact. The most important factors are amount of use, type and behavior of use, timing of use, resistance and resilience of the environment, and the spatial distribution of use.

Numerous studies show that the relationship between amount of use and amount of impact is not linear. In most situations, soil and vegetation has little ability to resist being altered by recreation use and the use-impact relationship is asymptotic. Initially, small increments of use cause substantial impact, with the rate of increase in impact decreasing as use increases. This relationship was first documented on campsites in the Boundary Waters Canoe Area (Frissell & Duncan, 1965). However, it was sometime later (Cole, 1981a) that the important management implications of this relationship were highlighted. Impacts can usually be minimized by encouraging the repetitive use of a small number of sites, concentrating use. This consistent finding is now at the core of management policies (e.g. requirements that visitors camp on designated sites) as well as the curriculum of Leave-No-Trace messages that encourage concentrating use and impact in popular locations (Hampton & Cole, 1988).

The asymptotic nature of the use-impact relationship is among the most important generalizations produced by recreation ecology. However, it should be noted that in some situations use levels are so low and/or environmental parameters are so resistant (e.g. organic soil horizons; Marion & Cole, 1996), that the initial increments of recreation use have virtually no impact. The relative lack of documentation regarding effects of recreation on water bodies (Hammitt & Cole, 1987) may reflect the resistance of water bodies to low levels of recreational disturbance. Hylgaard and Liddle (1981) were correct in hypothesizing that the general shape of the use-impact relationship approximates that of a logistic function. In most situations, however, vegetation in particular is not sufficiently durable for the initial exponential portion of the curve to be expressed. Where use levels are sufficiently low and/or environmental characteristics sufficiently durable, impact can be reduced by dispersing use. This is another of the fundamental guidelines contained in Leave-No-Trace messages.

Although more resistant to empirical quantification, the relationship between impact and type of use is also profound. There are qualitative differences in the nature of impacts caused by different users. Groups that gather firewood and build campfires cause impacts that groups that forego campfires do not. Groups that graze recreational pack stock cause impacts that groups that travel on foot do not. There are also quantitative differences in the magnitude of impact caused by different user groups. Horses have been shown to cause substantially more trail erosion than hikers, llamas or mountain bikers (Wilson & Seney, 1994; DeLuca, Patterson, Freimund & Cole, 1998). Hikers with dogs disturb wildlife more than hikers without dogs (MacArthur et al. 1982; Miller et al. 2001).

In recent experimental work in France, Gallet and Rozé (2002) demonstrate that heathlands are more tolerant of trampling in winter than in summer. Tolerance is also dependent on weather conditions at the time of trampling, but the nature of the effect varies between species (Gallet & Rozé 2002). Trail erosion is often greater when soils are wet than when they are dry (DeLuca et al. 1998). Wildlife are more vulnerable to disturbance at certain times of the year, such as when birthing, as well as at certain times of the day, such as when feeding (Knight & Gutzwiller, 1995).

Perhaps the largest and most diverse body of knowledge concerns the myriad of environmental factors that influence the magnitude of impact. Much of this knowledge has been developed, beginning with the early work of Wagar (1964), from careful application of controlled levels and types of use, under experimental conditions. Such studies have shown that it is important to distinguish between a site's *resistance* (it's ability to tolerate use without being damaged) and it's *resilience* (it's ability to recover from damage). Some vegetation types can tolerate more than 30 times as much use as others, with no more impact (Cole, 1995). Leung & Marion (1996) provide a useful review of how environmental conditions influence trail impacts, while several of the textbooks (Hammitt & Cole, 1987; Liddle, 1997) provide access to the voluminous literature on this topic.

Managerial Significance of Recreation Ecology

Descriptive studies of the nature of recreation impacts and studies relating magnitude of impact to influential factors have contributed directly to knowledge about how to efficiently monitor recreation impacts and effectively manage them. Monitoring methods are well developed for trail and campsite impacts, but poorly developed for the impacts of grazing and impacts on wildlife and water bodies. For campsite impacts, protocols have been developed ranging from quick assessments of condition classes (Frissell, 1978) to more precise and informative but time-consuming detailed measures (Cole, 1989). Jeff Marion and his associates (e.g. Leung & Marion, 1999b) have been particularly diligent in working to increase the efficiency of campsite and trail monitoring methods. When replicated over time, impact studies also document how conditions are changing over time, suggesting either the success of management or the need for alternative or more aggressive management approaches.

Relatively few studies have directly assessed the effectiveness of actions taken to mitigate recreation impact, using a before-and-after experimental design. However, the knowledge that has developed about how various factors influence the magnitude of impact provides the foundation for development of management strategies. Management suggestions are often included in descriptive papers on recreation impact. Recreation ecology research has provided the foundation of message content for the Leave-No-Trace educational program.

Issues for the Future of Recreation Ecology

As the future unfolds and trends and fads in outdoor recreation develop and play out, recreation ecology will consistently be faced with the need to understand the impacts of new activities in new environments. Recently, for example, substantial literature has developed on the impacts of scuba diving and snorkeling (e.g. Rouphael & Inglis, 2002). The ecotourism literature generally has borrowed heavily from recreation ecology (Newsome et al. 2002) and will continue to do so.

Currently, the impacts we understand best are those that occur at the human, meso-scale. Future work needs to provide a better perspective on the large-scale implications of recreation impacts. We know that recreation causes severe impacts at small scales, but does recreation cause substantial impacts on watersheds and landscapes, or on parks and wildernesses? Attempts to address this question should increase our ability to draw useful conclusions about the ecological significance of impacts. Equally important is the need to understand impacts occurring at the microscale, such as impacts on soil biota and soil-plant interactions. Managers often close recreation sites in attempts to restore them. They are often not very successful and a major contributor to poor success is our rudimentary understanding of microscale and belowground impacts.

Finally, we need to integrate social and ecological research regarding recreation impacts. Managers are faced with difficult decisions about limiting impacts to appropriate levels. There is little clarity about which criteria to use when setting limits or about which stakeholders to listen to. Attempts to describe visitor perceptions of impact suggest that most visitors abhor the idea of impact but many fail to recognize it. There is little evidence that the experiences and behaviors of most visitors are significantly affected by recreation impacts (Farrell, Hall & White, 2001). Should limits be set on the basis of concerns about ecological integrity, about aesthetics, or about the symbolic nature of human impacts on the environment? Answers to these questions lie at the intersection of social and ecological science and offer an excellent opportunity for interdisciplinary research.

Conclusion

Recreation ecology is only about 30 years old and only a handful of people have ever identified themselves as recreation ecologists. Nevertheless, approximately 1000 recreation ecology studies have been conducted and substantial progress has been made in integrating this body of work in such a way that it has a high degree of managerial relevance. Progress is constrained by the small number of recreation ecologists, the relative lack of theory (and funding for more conceptual and theoretical work) and by insufficient attention to impacts at scales that are larger and smaller than the human scale.

First among the primary conclusions of recreation ecology is the simple notion that impact is inevitable with recreation. Avoiding impact is not an option, unless all recreation use is curtailed. Managers must make conscious decisions about appropriate levels of impact and implement management strategies that keep impacts to acceptable levels. Impacts occur rapidly and recover slowly. This effectively negates management strategies based on periodically resting sites. It emphasizes the importance of proactive management, avoiding impacts instead of repairing them. This can be counter to visitor management principles that stress avoiding regulation until indirect management has been tried and has failed. It also explains the common finding that impacts proliferate over time unless the distribution of use is controlled. The proliferation of newly impacted sites is usually more problematic than the deterioration of established sites.

The primary factors that influence magnitude of impact (amount of use, type of use, timing of use, spatial distribution of use, and environmental attributes) can all be manipulated by managers to develop strategies for limiting impacts. In particular, our understanding of the curvilinear relationship between use and impact provides a foundation for visitor and site management, as well as education programs.

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