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Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts

Christopher A Monz^{1*}, Catherine M Pickering², and Wade L Hadwen³

Recreation ecology – the study of the environmental consequences of outdoor recreation/nature-based tourism activities and their effective management – is an emerging field of global importance. A primary research generalization in this field, the use–impact relationship, is commonly described as curvilinear, with proportionally more impact from initial recreation/tourism use. This finding has formed the basis of visitor management strategies in parks, wilderness, and protected areas in many parts of the world. In this paper, however, we argue that the current generalization may be an oversimplification derived from one ecological response: the response of vegetation cover in some plant communities to trampling. Use–response functions for other plant communities, wildlife, soils, and aquatic/marine systems, for example, can differ and require alternative management strategies for sustainable use. On the basis of the available literature, we propose several alternative response relationships.

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Worldwide, recreation and tourism activities in parks, wilderness, and protected areas continue to show trends of increasing participation (Cordell 2008; Balmford *et al.* 2009). Associated with this rise in visitation are anthropogenic disturbances that result in environmental impacts, which in turn raise concerns as to whether recreation and tourism activities in protected areas can be managed sustainably.

In response to these concerns, a specialized field of study – recreation ecology – has emerged. Recreation ecology began in earnest in the early 1960s (Wagar 1964) and is commonly defined as the study of the impacts of outdoor recreation and nature-based tourism activities in

natural or semi-natural environments (Liddle 1997; Hammitt and Cole 1998). Several recent reviews have identified more than 1000 articles on recreation ecology published in the past few decades (Leung and Marion 2000; Buckley 2004; Monz *et al.* 2010; Steven *et al.* 2011; Newsome *et al.* 2012). Although recreation ecology research has been conducted throughout the world, most studies have occurred in North America, Europe, and Australia (Buckley 2005; Steven *et al.* 2011).

Research in recreation ecology has examined the impacts of hiking, camping, and other activities where use is concentrated, such as along formal trails or at high-use destinations, or dispersed, where visitors are not confined to specific routes or destinations (Figure 1). Research on concentrated-use includes examining changes along established trails and sites, including relating impacts to patterns of use-associated, environmental, and managerial factors (Leung and Marion 2000). By way of comparison, research on dispersed-use tends to examine recreation as a type of ecological disturbance and often relies on controlled experimental designs to quantify the resistance (ability to withstand disturbance) and resilience (ability to rebound after disturbance) of ecosystems to particular types of use (Monz *et al.* 2010).

The impact of trampling on vegetation is one of the most common and systematically researched topics in recreation ecology (eg Wagar 1964; Bayfield 1971; Cole and Bayfield 1993; Hill and Pickering 2009; Pickering *et al.* 2010). This includes assessing the response of vegetation and soils to increasing levels and different types of use. Experimental trampling protocols (eg Cole and Bayfield 1993) have been widely used to examine a range of factors that influence the intensity and extent of impacts including: (1) amount of use, (2) type and behav-

In a nutshell:

- Experimental studies of outdoor recreation/nature-based tourism activities and their resultant ecological impacts have been generalized as a curvilinear use–impact relationship
- This generalization has guided visitor management strategies in many parks to minimize impacts
- The curvilinear relationship, while useful in characterizing some vegetation responses, does not adequately describe all vegetation responses or other important ecosystem effects
- Linear, exponential, and step function models may more adequately describe many ecosystem responses and consequently lead to alternative management strategies

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Figure 1. Common vegetation, soil, and tree disturbance from nature-based recreation/tourism activities in parks and protected areas. Disturbance to aquatic systems is also common, due in part to their desirability as destinations for visitors.

ior of use, (3) timing of use, and (4) type and condition of the environment. Because protected area managers can influence some of these factors, this research has contributed substantially to the development of sustainable visitor management strategies (Hammit and Cole 1998).

In this paper, we focus on the most commonly studied factor relating to the ecological impacts of recreation activities – the amount of use. The relationship between increasing use and ecological change is often generalized as a curvilinear, asymptotic relationship (Figure 2a; Hammit and Cole 1998). This generalized form of the relationship has been used to formulate management strategies in a range of parks, wilderness, and protected areas (Hammit and Cole 1998; Newsome *et al.* 2012). Studies examining the efficacy of management based on the curvilinear response have demonstrated both success and failure in limiting ecological impacts (eg Cole *et al.* 2008); moreover, these studies have typically relied on a limited set of ecological variables (such as vegetation cover) upon which to base findings. We suggest that the curvilinear response may not describe the use–impact relationship for many important ecological responses, including the response of all types of vegetation to trampling. Consequently, some management strategies may need to be modified because they could be unduly limiting recreation use or, alternatively, causing undesirable impacts.

On the basis of recent research, here we propose a conceptual framework of likely response relationships to guide future research and management. We provide examples of these relationships largely from experimental research where ecological responses, particularly initial resistance to disturbance, have been examined in relation to quantified levels of recreational use. We acknowledge that there may be relationships other than the ones identified here. In addition, recent long-term studies suggest that, in certain circumstances, ecological change may be

more dynamic and spatially diffuse than these generalizations imply (Kim and Daigle 2012). Regardless, the ideas in this paper provide an important update on current thinking in recreation ecology and indicate directions for future research to inform the development of management strategies.

■ Relationship between use and impact for vegetation

As mentioned, the relationship between amount of recreation use and impact on vegetation and soil is often expressed as asymptotic and curvilinear (Figure 2a). This relationship was first described by Frissell and Duncan (1965), further investigated by Cole (1981), and supported by a number of subsequent studies (eg Monz 2002; Hill and Pickering 2009), most of which examined

either vegetation and soil responses to trampling under controlled conditions or changes in vegetation and soil on sites with known levels of use. These results and the model of the relationship between use and impact indicate that on previously undisturbed sites, even small increases in the amount of initial use result in dramatic increases in impacts (Cole 1981; Hill and Pickering 2009). Consequently, where use levels are low, small differences in the amount of use can lead to substantial differences in impact. Alternatively, where use levels are high, additional impact has proportionally less effect. This relationship underpins strategies that seek to confine use to designated trails and sites in areas popular for nature-based tourism and recreation. Commonly called “confinement” strategies, these approaches assume that once a site is extensively disturbed, impacts will not change considerably despite substantial increases in use. Although the literature suggests some management challenges with confinement strategies (Cole *et al.* 2008), typically they can assist in limiting the total area impacted by visitors (Hammit and Cole 1998; Newsome *et al.* 2012).

In contrast to the curvilinear model, at least two studies (Cole and Monz 2004; Growcock 2005) observed a sigmoidal response to use (Figure 2b) as opposed to the more commonly reported single asymptote at the top of the curve. Sigmoidal models are useful in various ecological applications (eg Kuznar 2002), and the use of this model in recreation disturbance was suggested as a possibility in some earlier work on the subject (Liddle 1975; Cole 1992). This has practical implications for managing areas with dispersed low levels of use, particularly on non-vegetated substrates or trampling-resistant vegetation. In these cases, it may be more likely to effectively manage low levels and limit ecological change than the curvilinear response suggests. Growcock’s (2005) work further suggests that along the stress–response curve, different

impacts may be more pronounced at different levels of use (ie that plant physiological stress precedes mechanical damage and loss of plant cover). Also, this research indicates that more sensitive techniques for assessing change may be required than those previously used in trampling studies. Recent work addressing this issue has modeled the shape of the relationship with more replicates and levels of use and has revealed that, in more resistant plant communities, the disturbance–use relationship was closer to linear than curvilinear (Hill and Pickering 2009).

■ Responses in other systems

Recreation ecology researchers are increasingly examining the effects of recreation/tourism activities beyond those of trampling on vegetation and soils, including research on aquatic systems, wildlife, and to a lesser extent, air quality. Despite several recent syntheses of this research (Buckley 2004; Monz *et al.* 2010; Steven *et al.* 2011; Newsome *et al.* 2012), few generalizations have emerged. Here we draw on examples of this research, particularly from aquatic systems and wildlife that suggest different use–impact responses than the vegetation–soil models (described earlier) that tend to underpin visitor management strategies.

Aquatic systems

Since the mid-1990s, recreation ecology research has examined a diversity of recreation uses and their impacts on organisms, physical attributes, and chemical processes in marine systems. Two topics that have received particular attention are: (1) trampling impacts, including those from diving on intertidal and coral reef communities (eg Schlacher and Thompson 2012), and (2) boating impacts, including pollutants and physical damage to marine environments (eg Bishop and Chapman 2004; Milazzo *et al.* 2004a; Herbert *et al.* 2009). Although few studies have specifically focused on recreational boating, pertinent literature reviews conclude that boating can have considerable effects on marine environments, particularly where use levels are high. So far, few generalizations regarding the use–impact relationship have been developed. However, the complexity of responses was highlighted by Schlacher and Thompson (2012), who reported no impacts, linear impacts, and curvilinear impacts on macroinvertebrate communities subjected to trampling on unvegetated sandy beaches.

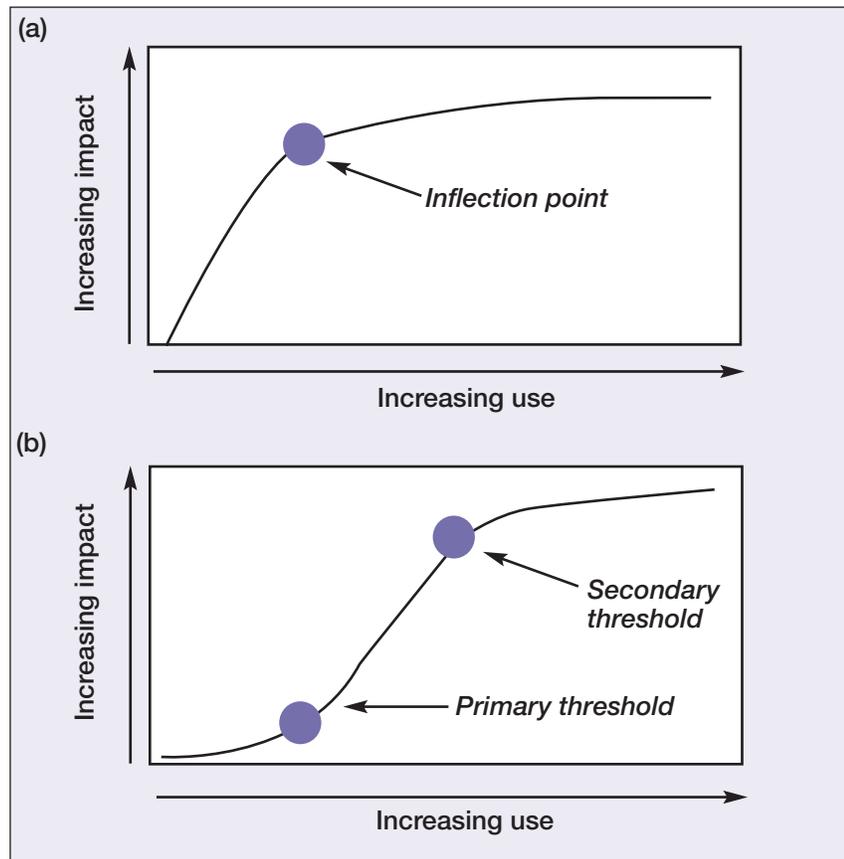


Figure 2. (a) Common generalization about the relationship between use and impact and (b) an alternative model. Sources: (a) Cole (1981); Hammitt and Cole (1998); and (b) Liddle (1975); Cole and Monz (2004); Growcock (2005).

Likewise, impacts of a range of recreational activities on freshwater environments have also been examined (Hammitt and Cole 1998; Hadwen *et al.* 2010), including the effects of swimming (Hadwen *et al.* 2003, 2005; Hadwen and Bunn 2004) and recreational power boating and water skiing (Mosisch and Arthington 2004). In addition to direct physical disturbance from recreational uses of the water bodies, inland freshwater environments are subject to nutrient influx, pathogen introduction, and sedimentation (Hadwen *et al.* 2005, 2010). While numerous site- and activity-specific influences exist, recreation effects on freshwater quality appear to be more density dependent (eg Figure 3a) than in terrestrial environments (Hadwen *et al.* 2005). For example, Hadwen and Bunn (2004) found that increasing numbers of visitations to dune lakes on Australia's Fraser Island was positively correlated with a shift in the aquatic food web toward a stronger reliance on algal resources, the production of which is stimulated by nutrient inputs from visitors (Hadwen and Bunn 2005; Hadwen *et al.* 2005).

Highly resistant environments

Highly resistant substrates can obviously display a different relationship between use and impact than that observed for vegetated areas. These types of substrates

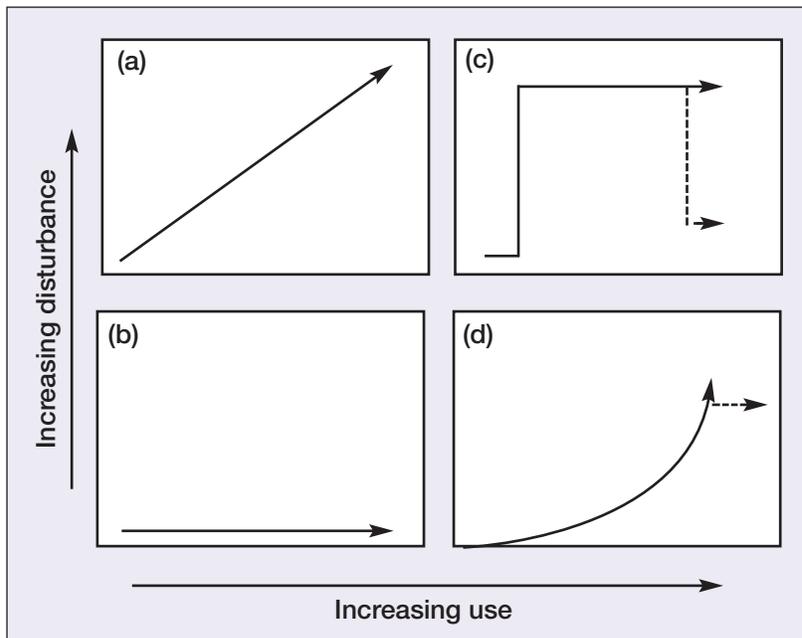


Figure 3. Hypothetical response curves for various ecological responses to recreation disturbances: (a) *Escherichia coli* concentrations in aquatic ecosystems (Hadwen *et al.* 2010); (b) use on a highly resistant substrate (ie exposed rock; Hill and Pickering 2006); (c) wildlife “fight or flight” response (Knight and Gutzwiller 1995; Buckley 2004); (d) recreational use and soil erosion (Liddle 1997). Dashed lines represent alternate responses: in (c), a return of individuals upon cessation of disturbance; in (d), complete soil loss.

can occur naturally (eg exposed rock on a mountain summit or on rocky shores), can result from excessive use eliminating vegetation and compacting soils, or can be created by park agencies via the maintenance of trails and sites with resistant substrates (eg gravel, rock). Concentrating use on these hardened surfaces reduces ecological change, and sites characterized by these hard surfaces will exhibit a flat (zero slope) relationship with increasing use (Figure 3b). An example of how concentrated use of these surfaces can protect vulnerable ecosystems is seen in the application of raised walkways, where complete native vegetation cover can exist under the walkway despite high levels of visitor use (Hill and Pickering 2006). As a result, changes in use will have no effect on the vegetation or soils under the walkway. A different relationship between use and impact on a hardened surface was seen in a study examining the effects of human trampling on the tolerance of algal communities on rocky shorelines (Milazzo *et al.* 2004b). In this instance, impacts were more subtle than those in some terrestrial systems, and some relationships may more closely resemble the curvilinear relationship (Figure 2a) than what has been typically assumed (Figure 2b).

Soil loss

The impact of increasing use on soil is highly variable. Experimental studies have focused on the use–soil-loss relationship in association with trampling (Kuss 1983)

and other activities (Weaver and Dale 1978; Deluca *et al.* 1998). Relational analysis has also examined soil loss on maintained trail systems and examined factors that may influence soil loss (Olive and Marion 2009).

From this literature, several use–soil-loss relationships emerge, including linear and exponential relationships (Figure 3, a and d). Where surfaces are hard, as discussed above, the relationship is flat, but where soils are soft and very deep, as in alpine humus soils in valley floors, the relationship can be linear and steep. Furthermore, as Liddle (1997) described, recreational disturbance is often the “trigger” for soil erosion by damaging the protective vegetation and litter cover, resulting in direct mechanical disturbance to exposed soil horizons and subsequent erosion from wind and water, leading to rapid soil loss.

Wildlife

Despite several reviews (Knight and Gutzwiller 1995; Hammitt and Cole 1998; Steidl and Powell 2006; Steven *et al.* 2011), it is difficult to make generalizations about

the effects of recreation on wildlife, due in part to the diversity of recreational activities, study methodologies, and observed responses. Much of the research has focused on behavioral responses of wildlife to visitors (Anthony *et al.* 1995; Clua *et al.* 2010; Steven *et al.* 2011) and subsequent alterations in species composition and diversity (Knight and Gutzwiller 1995; Steven *et al.* 2011). However, a growing number of species-specific studies have examined the effect of recreation and tourism activities on energetic and physiological stresses (Bélanger and Bedard 1990; Semeniuk *et al.* 2009; Marechal *et al.* 2011; Steven *et al.* 2011) and changes in reproduction rates and population levels (Burger 1995; Orams 2002; Steven *et al.* 2011). Recreation and tourism can also result in wildlife becoming dependent on humans as a source of food; such a dependence can be detrimental both for wildlife and visitors (Orams 2002; Newsome *et al.* 2012).

One widely reported generalization regarding increased use and impact is birds taking flight when approached by tourists (Buckley 2004; Steven *et al.* 2011). Sometimes described as a “flight or fight” response (Knight and Gutzwiller 1995), this kind of behavior results in a step relationship between use and impact, with a sudden reaction from the pre-disturbance steady state (Figure 3c) as numbers increase or visitors approach the animals (Buckley 2004; Steven *et al.* 2011). It can also induce complete avoidance of areas that are more intensively used by people, resulting in decreased animal diversity close to high-use sites (Buckley 2004; Steven *et al.* 2011; Newsome *et al.* 2012).

■ Conclusions

This paper advances recreation ecology theory by proposing new generalizations about the relationship between use and impacts, enhancing both future research opportunities and improving management. The original use–impact relationship stands as one of the few well-developed research generalizations in this field. This is largely due to research that focused on easily observable ecological responses, such as changes in vegetation cover and rapid assessment techniques, rather than more sensitive measurements (Monz *et al.* 2010). More recent research suggests several alternative models for some ecological responses. Future research could more directly model the use–response relationship through more sensitive methods of measurement and improved experimental designs.

The alternative models proposed also highlight the need for caution while employing standard dispersal and confinement management strategies. Although successful in minimizing the proliferation of certain impacts such as vegetation loss in many environments, these approaches may have unintended consequences, especially in situations where impacts do not “level off” with increased use.

Finally, we emphasize that increasing intensity of use is just one important factor influencing recreation/tourism impacts. Management decisions should not be solely based on any one factor (eg limiting use numbers). For example, visitor behavior, degree of site hardening/maintenance, trail design, and environmental durability all affect the severity and extent of impacts and may be more important than use level in some circumstances (Hammit and Cole 1998; Olive and Marion 2009). Moreover, protected area management involves integrating ecological, social/cultural, and managerial components to achieve the best possible overall outcome. Here, we have established that managers cannot simply accept that all ecological impacts follow a curvilinear response and then assume that a confinement strategy will minimize unacceptable changes.

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