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

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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.

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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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 (Hammitt 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 (i.e., 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 (e.g., Schlacher and Thompson 2012), and (2) boating impacts, including pollutants and physical damage to marine environments (e.g., 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.

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 (e.g., 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...
Experimental studies have focused on the use–soil-loss relationship in association with trampling (Kuss 1983). 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).

**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).

Figure 2. 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 “flight 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.
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 (Hammitt 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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