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REVIEW PAPER

Ten Factors that Affect the Severity of Environmental Impacts of Visitors in Protected Areas

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Abstract Protected areas represent the major method for conserving biodiversity. However, visitor use can threaten their conservation value. Based on a review of recent research, I have categorized factors that affect the severity of environmental impacts of visitor use. These factors need to be considered or evaluated when assessing visitor use of sites in protected areas. They are: (i) the conservation value of the site, (ii) its resistance to use, (iii) its recovery from use, (iv) its susceptibility to erosion, (v) the severity of direct impacts associated with specific activities, (vi) the severity of indirect impacts, (vii) the amount of use, (viii) the social and (ix) ecological dimensions to the timing of use, and (x) the total area affected. Although the factors may not be of equal importance or necessarily assessed on an equal scale, they allow people to make more informed assessments of potential impacts, assist in identifying where monitoring may be required, and indicate where additional site- or activity-specific research may be appropriate.

Keywords Park management · Recreation ecology · Environmental impacts · Sustainable tourism

Introduction

Protected areas are considered to be the major method for conserving biodiversity worldwide (Worboys et al. 2005; Lockwood et al. 2006). They account for 12.2% of the land surface of the earth (Chape et al. 2005). Although the principal purpose of protected areas is the conservation of natural, and sometimes cultural values; they are also popular destinations for nature-based tourism (Lockwood et al. 2006; Newsome et al. 2002; Buckley 2004). Visitor use of protected areas has a wide range of negative impacts on the environment which need to be assessed, limited, and/or ameliorated (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). Use through a wide range of activities (bushwalking, mountain biking, horse riding, camping, sightseeing, rock climbing, canoeing, etc.) can affect soils, water, flora, and fauna (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). Therefore, those responsible for managing protected areas have to balance access against impacts on the environment. This involves assessing the potential severity of impacts that are likely to occur from a particular activity at a particular site within a protected area. Based on this type of assessment of likely impacts, managers may change the specific types of tourism activities allowed and/or the locations where they are permitted, provide new infrastructure (tracks, campgrounds, etc.), introduce or upgrade education programs, and/or close and rehabilitate sites that have been damaged (Newsome et al. 2002; Leung and Marion 2000). Managers need to incorporate the current understanding of visitor impacts into decision making. Using the 10 factors described here will assist in ensuring that the decision-making process is transparent and defensible.

How can they do this? There is a growing body of recreation ecology research that is used here to develop useful generalizations to help in decision making (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and

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Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). Recent reviews have summarized the environmental impacts of visitors and hence are an important source of information for managers (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). However, what is currently lacking, and addressed in this article, is a way to turn the generalizations from the literature into a practical way for managers to start to assess the potential severity of likely impacts from a particular type of visitor use at a particular site. There are 10 factors that are critical to assess. These 10 factors are listed in Table 1 along with an example for each factor of how it can vary from low impact to high impact in a particular situation. Although the 10 factors are not always of equal importance or assessed on an equal scale, they can be used to indicate the potential severity of impacts and to assess the likely impacts at a site by people with knowledge of recreation impacts and the local ecosystem. These factors allow people, including protected area managers, to identify where and when impacts are likely to be more severe, where and when monitoring is most likely to be useful, and where and when restoration is most likely to be required. They may also indicate that more research is required to determine if results for given activities or given ecosystems can be applied reliably to the site under consideration.

The 10 Factors

One: Conservation Value of Site

Sites are likely to vary—internationally, within a region, and even within a park—in their conservation value. Classifying protected areas on the basis of their conservation value, and hence assigning different management objectives, is well recognized internationally (Worboys et al. 2005; Lockwood et al. 2006). It is reflected in the different categories given to protected areas by the International Union for the Conservation of Nature (Lockwood et al. 2006). It is also reflected in other classification methods, such as the World Heritage Listing, where a protected area is listed only if it has been judged to be "of outstanding universal value." At a national scale, sites are often categorized based on their value as wilderness areas, threatened ecological communities, sites of national significance, and components of a national reserve system (Worboys et al. 2005). Even within a park, some areas or ecosystems are of greater value due to rarity, diversity, and the ecosystem services they provide to biota and to humans.

Table 1 Ten factors to consider when assessing impacts of visitor use at a site

Factor	1. Conservation value of site	2. Resistance of site	3. Recovery of site	4. Susceptibility of site to erosion	5. Severity of indirect impacts	6. Severity of possible indirect impacts	7. Likely amount of use	8. Timing of use—social	9. Timing of use—ecological	10. Total area likely to be directly affected
Less impact likely	Low—already extensively modified ecosystems	High resistance (grasslands)	Faster (rainforest)	Low (rock or hardened soils)	Low impact (e.g., trampling)	Low (e.g., temporary displacement of predators)	Rare (limited use likely)	Constant low use	Dryer seasons, warmer	Small (short, narrow track)
Impact spectrum		Medium resistance (herb fields, etc.)			Medium impact (horse riding in some ecosystems)					
Greater impacts likely	High—biodiversity hot spot, limited distribution, etc.	Low resistance (bogs, heaths)	Slower (higher altitude areas)	High (deep humus soils, bog area)	High impact (e.g., 4WD vehicle use)	High (spread of invasive plants)	Popular—many people at all times, or very high usages at key times	Periods of very high usage	Wetter, critical times for ecological events	Large (long track, etc.)

Examples of how impacts could vary within each factor are given here. Details and references for each factor are provided in the text

The conservation value of sites must be matched by the types of recreation activities that are suitable. For example, high-impact recreational activities (cars, bikes, horses, etc.) may not be permitted in sites of high conservation value. The relative conservation value—and hence the types of use that may be appropriate—is often made explicit by the use of zoning systems, including the recognition of wilderness areas.

Zoning systems can involve the provision of different types of recreation opportunities and different levels of infrastructure to support such activities. One common method is the Recreational Opportunity Settings (ROS) system, whereby sites within a park are allocated to different zones on the basis of the level of site development, site regulation, contacts between visitors, modification of the environment, and ease of access (Worboys et al. 2005; Newsome et al. 2002). In *primitive* (e.g., undeveloped, or wilderness) sites there is no motorized access; sites are large, remote, and completely natural; there is no site development or structures; visitor impacts are unacceptable; there are few social contacts among visitors; and often there is only self regulation (Worboys et al. 2005; Newsome et al. 2002). In contrast, sites that are classified as *developed* often have high levels of motorized use and parking, and parts of the site might be highly modified, including through the provision of roads and accommodations. There is likely to be frequent contacts among visitors, some impacts are evident and accepted, and obvious controls and signs are used to regulate visitor behavior (Worboys et al. 2005; Newsome et al. 2002).

Two: Resistance of Ecosystem and Vegetation Types

The resistance of vegetation to visitor use is defined as the ability of the vegetation to withstand disturbance before damage occurs (Newsome et al. 2002; Liddle 1997; Cole 1995a). Plant species, life forms, vegetation communities, and ecosystems can vary in their resistance to use. A common measure of the resistance of a site is the number of passes (by horses, bikes, cars, or people) required to cause a 50% decline in vegetation cover (resistance index, Liddle 1997). Resistance index values can vary from 20 passes in a subalpine forest erect fern-forb community in North America to 1,475 passes in a mixed forest ground cover community in the subtropics of Australia (Liddle 1997; Cole 1995a; Hill and Pickering 2009). Based on a large number of experimental trampling trials using modifications of a standardized methodology, some generalizations can be made about the resistance of different ecosystems (rainforests vs. coastal dunes, etc.), vegetation types (grasslands vs. heathlands, etc.), and growth forms (shrubs vs. herbs, etc.) (Newsome et al. 2002; Liddle 1997; Cole 1995a; Hill and Pickering 2009).

Certain growth forms appear to be more likely to be damaged by trampling, with forbs more sensitive then ferns, which are more sensitive than shrubs, which are more sensitive than graminoids (Leung and Marion 2000; Hill and Pickering 2009; Yorks et al. 1997; Cole 2004). Therefore, communities dominated by more resistant growth forms, such as grasslands, are likely to be more resistant than those in which ferns, mosses, and shrubs are important components of the vegetation. The common pattern of resistance is sand dune grasslands > grasslands > sand dune heaths > forest understory > heaths ~ herb fields (Hill and Pickering 2009).

For ecosystems, the pattern is dependent on factors such as the dominant types of vegetation as well as the general abiotic environment, including climate. As a result, the order of resistance for ecosystems is subtropical > alpine ~ subalpine ~ arctic ~ temperate > montane. However, there can be considerable variation in resistance within each growth form, climatic zone, and vegetation type (Cole 1995a; Hill and Pickering 2009; Cole 2004). As a result, site-specific research using experimental trials may be required to determine the level of resistance at a specific site, particularly if it has high conservation value (Cole and Bayfield 1993).

The potential variation in resistance among vegetation types within a single reserve is illustrated by the results from experimental trampling trails in the subtropics of South East Queensland in Australia (Hill and Pickering 2009). In a single conservation reserve, a fern understory of a *Eucalyptus* forest was found to have low resistance to trampling (resistance index of 210 passes), a tussock grass understory in a paperbark forest showed moderate resistance (resistance index of 360 passes), while a disturbed grassland community dominated by native and introduced lawn grasses had the highest resistance, with a resistance index of 860 passes. Therefore, trampling is likely to do little damage to the disturbed grassland, but would be an inappropriate use of the fern understory.

Three: Resilience of Ecosystem and Vegetation Types

As with resistance, there is variation in the time required for different species of plants, life-forms, and ecosystems to recover from disturbance (Liddle 1997; Cole 1995a; Yorks et al. 1997). This resilience of vegetation to damage, combined with resistance, gives a measure of a site's capacity to tolerate damage; that is, a measure of how easily it is damaged and an estimate of how quickly it can recover (Liddle 1997; Cole 1995a; Cole 2004; Cole and Bayfield 1993). Again, like resistance, resilience has been assessed in a range of growth forms, vegetation types, and ecosystems, often using experimental methods (Liddle 1997; Cole 1995a; Cole 2004; Cole and Bayfield 1993).

Generally, plants that are slow growing are likely to have lower resilience than those that are fast growing. Correspondingly, ecosystems that are characterized by fast growth can often recover more rapidly than ecosystems in which growth is slow.

Sites with high resistance may not have high resilience, and vice versa (Liddle 1997; Cole 1995a; Cole 2004). Therefore, both the resistance and the resilience of a site must be determined to assess its tolerance of a particular type and level of visitor use. For example, the subalpine and alpine grasslands of the Australian Alps show relatively high resistance to trampling compared to many other alpine vegetation types (Growcock and Pickering in press). Based on this information, it might appear that trampling is appropriate in these sites. However, when resilience was tested by assessing sites 1 year after experimental trampling, there was little recovery from moderate to high levels of use (500 and 700 passes). As a result, these grasslands are only moderately tolerant to trampling due to high resistance but low resilience; therefore, they can only tolerate relatively low levels of use (Growcock and Pickering in press).

It is possible to obtain information about the potential resistance and resilience of a site not only from recreation ecology studies, but also by accessing more general literature on the recovery of ecosystems from a range of human and natural disturbances. For example, high-altitude (alpine) and high-latitude (arctic) communities are generally considered to recover more slowly from disturbance than those with more energy in the system (temperate, subtropical, and tropical communities) (Liddle 1997; Growcock and Pickering in press). It is important to remember, however, that the level of disturbance to an ecosystem may be so great that it may not return to its predisturbance state (Newsome et al. 2002; Liddle 1997). Some ecosystems have less capacity to fully recover from disturbance, with secondary succession potentially resulting either in only partial recovery or in an entirely different ecosystem compared to that present prior to the disturbance (Newsome et al. 2002; Liddle 1997; Leung and Marion 2000). One obvious indicator that a site has exceeded its tolerance to a particular type of use, and that recovery may be limited or may result in a different state, is soil erosion. The loss of soil at a site has long-term effects, reducing the capacity of vegetation to regenerate, particularly when it is so severe that the bedrock is exposed.

Four: Susceptibility of Site to Erosion

One of the major types of damage associated with higher-impact activities, such as mountain biking, horse riding, and four-wheel-drive vehicle use, is soil erosion (Liddle 1997; Leung and Marion 2000; Newsome et al. 2008). In sites that have experienced intensive use, vegetation and litter may no longer protect the soil from erosion. Often, straight commonsense can be used to assess the risk of soil erosion, such as the judgment that steeper slopes are at higher risk of erosion. However, other factors, such as soil type, patterns of rainfall, and intensity of use, all influence erosion (Liddle 1997; Leung and Marion 2000). Generally, areas with more rock and/or soils that are already compacted will experience less erosion than sandy or deep humus soils (Liddle 1997). Information can be obtained from the recreation ecology literature and can also be derived from more general research into disturbance and erosion (Leung and Marion 2000). In studies comparing the impact of different types of activities, four-wheel-drive vehicles often cause more erosion than horse riding, horse riding causes more erosion than walking, and walking can cause more erosion than sitting or lying down (Liddle 1997; Leung and Marion 2000; Newsome et al. 2008). This is partly just a simple reflection of the physics of weight over area.

Five: Severity of Direct Impacts

Different activities have different impacts on ecosystems. Activities can vary in the types of impacts they have and in the severity of a given type of impact (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). Generally, some activities are considered to have high impacts (four-wheel-drive vehicle use, mountain biking, and horse riding), while others, such as bushwalking, are considered to have fewer and/or less severe impacts (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). A simple, but commonly used measure to assess the relative impact of different activities is their ground pressure (e.g., determined by dividing weight by the area of contact with the ground, often expressed as g cm^2) (Liddle 1997). The total weight and area of contact vary among different recreation activities, resulting in different total pressures. Some activities have much higher pressure due to a greater weight (e.g., four-wheel-drive vehicles), while others have a higher pressure because of a smaller area of contact (e.g., hooves). For example, pressure can range from 7 g cm^{-2} for snowmobile use (weight = 75,000 g, contact area = 10,880 cm^2) to 4,380 g cm^{-2} for a horse with shoes and rider (weight = 613,000 g, contact area = 140 cm^2) (Liddle 1997). Differences in pressure will affect the amount of damage to vegetation and soils associated with a given activity, with both the pressure and the total area affected being important (Liddle 1997).

Other factors that can vary with the type of usage include levels of noise, air, water, and light pollution; ecological disturbance; damage and death of plants and animals; soil compaction and loss; and the potential for the spread of weeds and pathogens (Newsome et al. 2002; Buckley 2004; Liddle 1997; Leung and Marion 2000; Higginbottom 2004; Newsome et al. 2008; Leung and Monz 2006; Pickering and Hill 2007a). The range and degree of impacts associated with different recreation activities is still being discovered, with trampling the only activity for which there are enough studies to be able to start making reasonably reliable generalizations (Newsome et al. 2002; Liddle 1997; Leung and Marion 2000; Cole 1995a; Hill and Pickering 2009; Cole 2004).

Six: Severity of Indirect Impacts

Most recreation ecology research has examined the direct impacts of different types of activities, with far fewer studies documenting the severity of indirect impacts (Newsome et al. 2002; Liddle 1997; Buckley 2003). However, compared with direct impacts, indirect impacts can be even more severe, can occur over a wider area, and may be more likely to be self-sustaining (i.e., they may continue to cause damage even if the activity itself stops) (Liddle 1997; Buckley 2003). One of the most important indirect impacts is the spread of weeds (Newsome et al. 2002; Liddle 1997).

Visitor use can result in increased weeds in a site through the accidental introduction of propagules and by altering the habitat in a way that favors weeds (trampling, nutrient addition, etc.). A wide range of seeds have been collected from tourists, their equipment, and their animals. This includes seeds from the mud on boots (Clifford 1956); seeds in the cuffs, pockets, Velcro, and seams of clothing (Whinam et al. 2005) and in day packs (Whinam et al. 2005); seeds from cars (Wace 1977; Schmidt 1989; Lonsdale and Lane 1994; Von Der Lippe and Kowarik 2007); and seeds germinating from the manure of horses (St-John Sweeting and Morris 1991; Campbell and Gibson 2001). Many of the species collected are common track and roadside weeds, even though the samples came from people, horses, and cars in very different ecosystems (temperate Australia, subtropical Australia, temperate Europe, temperate United States, and tropical Nigeria). In the same way that there are similarities in the propagules carried by people and their equipment, there are similarities in the weed species associated with tourism infrastructure, including roads and tracks (Liddle 1997). Some of the same species are often found on walking trails, at horse riding sites, and in campgrounds around the world (Liddle 1997; Campbell and Gibson 2001; Pickering and Hill 2007b). For example, the seven most common weeds found associated with tracks and roads in the Snowy Mountains in Australia are also common in high-altitude sites in Europe (where they are native), New Zealand, North America, and South America (Pickering and Hill 2007b).

Weeds have a range of negative impacts on the natural environment, including the alteration of nutrient levels in the soil (members of the Fabaceae, or pea family), the hydrology of sites (Willows [*Salix* spp.]), recruitment levels by shading (several species with dense canopies, such as *Lantana* spp.), the flammability of sites (Gamba grass [*Andropogon gayanus*] in northern Australia), and changes in native biodiversity (*Mimosa pigra*) (Csurches and Edwards 1998; Williams and West 2000).

Seven: Likely Amount of Use

Generally, more use results in more impact (Liddle 1997). Therefore, information on how many people use a site is very important when assessing their impacts. The common model of the relationship between increasing use and damage is curvilinear, such that proportionally more damage occurs at lower levels of use (Newsome et al. 2002; Leung and Marion 2000; Cole 1995a; Cole 2004; Cole and Bayfield 1993; Cole 1995b). That is, the first footfall (or hoof fall, or bike wheel, or car tire) causes proportionally more damage than the 10th or the 100th footfall. However, recent research indicates that, in more resistant vegetation communities, the relationship is closer to linear; that is, each footfall may cause proportionally similar amounts of damage (Hill 2007).

Another factor that affects the relationship between the amount of use and the amount of damage is the behavior of users of parks. Users vary in their behavior, including the extent to which they remember and follow minimum impact codes (Schmidt 1989). As a result, users do not equally cause damage, with some people causing far more damage than others (Marion and Reid 2007; Rouphael and Inglis 2002; Littlefair and Buckley 2008). This can involve making noise, leaving formal trails and roads, causing deliberate damage to trees, littering, using fires in areas where they are banned, and damaging coral when diving (Marion and Reid 2007; Rouphael and Inglis 2002; Littlefair and Buckley 2008; Growcock 2005). As a result, management of these visitors should be a priority, as reducing their impact can have a disproportionate benefit, both environmentally and socially.

Eight: Social Aspects of the Timing of Use

Visitor use is rarely constant. Rather, the use of many protected areas tends to be sporadic, with long periods of low usage, and then short periods of high usage. Visitation often varies with public and school holidays, season, time of week, and time of day (Pickering and Buckley 2003). Variation in the timing of visitation, with short periods of intensive use, is found in a wide range of parks, including those on the summit of the highest mountain in Australia (Pickering and Buckley 2003), adjacent to large urban centers in Austria (Arnberger and Brandenburg 2002), in forests in the Netherlands (Visschedijk and Henkens 2002), and in mountain ranges in Canada (Scott et al. 2007). Peak periods often occur on weekends, on public holidays, and in the middle of the day and/or in the early afternoon (Pickering and Buckley 2003; Arnberger and Brandenburg 2002; Visschedijk and Henkens 2002). Depending on the climate of the region, there can also be strong seasonal effects, both in peak usage and in the types of activities undertaken (Pickering and Buckley 2003; Scott et al. 2007). As a result of this variation in the timing of use, managing visitors is often about managing usage during a few hours on a few days in a year—that is, managing peak usage.

At peak times, facilities can often be overwhelmed, with overflow from car parks, trails, toilets, huts, campgrounds, view points, and bins occurring. As a result, some visitors may do things they are less likely to do when sites are not as crowded. This could include defecating away from toilets, leaving litter outside of full bins, parking on verges, camping outside of formal sites, and walking off track (including the formation of parallel tracks). As a result, far more environmental damage can occur during peak usage than would be indicated by total annual usage figures. This highlights the importance of knowing when people use a site (Hadwen et al. 2007).

The second aspect of peak usage that is of concern for park managers is the interactions among visitors and their potential effect on visitor satisfaction (Worboys et al. 2005; Newsome et al. 2002). The visitor experience involved in accessing a protected area at times of low usage can be very different from that at times of high usage, even though the facilities provided by the park and the environment are the same. At periods of peak usage, there is a greater potential for user conflict, and a perception of crowding among visitors. In effect, more people are competing for what can be perceived to be limited resources (car park, toilet, access to tracks, campsites, huts, tethering areas, etc.). However, perceptions of crowding can be surprising. On the summit of the highest mountain in continental Australia, Mt. Kosciuszko, visitors during the peak period of usage expected a "wilderness" experience and were satisfied with their experience, even though they were often sharing the area with hundreds of others (Dickson 2007).

Nine: Ecological Aspects of the Timing of Use

A second important aspect of the timing of use is that the resilience and resistance of an ecosystem can vary over time due to factors such as seasonality and climatic variability. The most obvious example of this is that more damage can occur to vegetation and soils when conditions are wet than when dry (Liddle 1997; Leung and Marion 2000). Soil erosion, ribboning, and soil compaction can all be greater on a wet track than on a dry track (Liddle 1997; Leung and Marion 2000). Correspondingly, more damage might occur to a track after a prolonged drought when vegetation is brittle and soils friable than during an "ordinary" season. Other seasonal effects that are also important include those dependent on whether use occurs during critical periods of growth and reproduction for plants and animals. For example, noise from visitors can have a greater effect on animal behavior when the animals are calling for mates or taking care of young (Liddle 1997). Correspondingly, trampling damage during flowering and seed periods for plants can have a greater effect than during nonreproductive periods (Liddle 1997).

Ten: Total Area Likely to be Affected

Generally, the smaller the total area used or damaged the better. In addition to the total area damaged, some activities and facilities provided for visitors are likely to have larger ecological footprints than indicated just by the immediate area damaged. Roads and tracks are classic examples. First, because roads and tracks are long and narrow, the total area hardened may not be immediately apparent, although they might cover a larger area than other types of infrastructure, such as car parks (Hill and Pickering 2006). Second, because tracks are linear disturbances, they can actually have a greater impact on a site than what would occur from the same area in a more compact form. Roads and trails can fragment habitats; alter water flows; affect animal movements; result in animal deaths (roadkill); and facilitate the introduction of feral animals, weeds, and pathogens (Dickson 2007; Hill and Pickering 2006; Forman and Alexander 1998; Leung and Marion 1996). Also, they provide access to a greater area of the park and hence have an increased potential for any negative effects to impact more sites. A classic example of this is the increased risk of fires (deliberate or accidental) and poaching in more remote areas which comes with the greater access provided by roads and trails.

When to Use These 10 Factors

These factors provide people with critical guidance for managing protected areas and users. For example, tracks are one of the most common types of infrastructure provided for visitors in protected areas (Dickson 2007; Leung and Marion 1996). Managers could use these 10 factors to help decide: (i) where to locate a new track, (ii) where to monitor damage to an existing track, (iii) whether a track needs to be upgraded or hardened, (iv) whether a track should be closed or other methods used to reduce or spread out usage in time, and/or (v) whether a particular activity (e.g., horse riding, walking, or mountain biking) is a suitable use for a track. Some of the information managers may need to assess the likely effect of these 10 factors on the severity of impacts will be site specific, such as the ROS category or other system of evaluating the conservation status of the site, visitation patterns, the slope of the site, the type of vegetation, climatic conditions, etc. For others, it may be possible or necessary to make assumptions about the likely severity of impacts based on the generalizations presented here from the recreation ecology literature. However, where decisions are likely to be controversial and/or where the generalizations may not apply, additional recreation ecology research will often be required. The use of the 10 factors outlined here in combination with optimization methods, such as that used recently to plan the location of walking tracks (Ferrarinia et al. 2008), will allow managers to minimize the negative impacts from tourism and the recreational use of protected areas.

Conclusions

Ten factors that can affect the severity of the impacts of visitor use at sites within protected areas are described. They provide useful generalizations of the current state of knowledge about recreation ecology. They highlight how factors associated with the site (conservation value, resistance, resilience, and susceptibility to erosion) and with the use of the site (type of activity, timing of use, etc.) often affect environmental and some social impacts of visitor use.

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