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ABSTRACT

This report reviews research into impacts of recreation and tourism on vegetation in Australian protected areas and identifies key areas for future research. The chief goal of Australia’s system of protected areas, which includes World Heritage Areas, Biosphere Reserves and national parks, is the conservation and functional maintenance of representative areas of the range of ecosystems. Australia’s unique flora is of international significance and this has significantly contributed to increasingly high levels of tourism and recreation use of protected areas. However, use rarely takes place without some form of environmental degradation.

Recreational ecology has focused on the environmental impacts of: (1) tourism infrastructure; and (2) tourism activities, principally trampling, camping, horse-riding and off-road vehicles. Impacts to vegetation from the construction and use of infrastructure are usually localised, but often severe and may compromise conservation and ecosystem functioning. The construction of roads, tracks, car parks, toilets, visitor centres and accommodation causes irreversible loss of extensive areas of vegetation and direct and indirect impacts in adjacent undisturbed natural vegetation. High impact activities such as horse-riding and off-road vehicles, and even low impact activities such as bushwalking and back country camping, also have direct effects through physical damage to vegetation, changes to community composition, the formation of tracks, compaction and erosion of soil and introduction and spread of exotic plants and pathogens.

Indirect effects of tourism and recreation may be more severe and widespread than direct impacts but many have been underestimated or not recognised and little studied. Indirect effects include introduction and spread of exotic species and pathogens such as the soil fungus Phytophthora cinnamomi (P. cinnamomi). Many indirect impacts are underestimated or not recognised and little studied.

The extent of damage to vegetation from tourism and recreation will be influenced by factors such as type of infrastructure, amount of use, type of activity, behaviour of tourists, season of use, and site specific abiotic characteristics. The sensitivity of vegetation communities will affect the degree of damage with communities and species varying in their resistance and resilience to damage. Rare and threatened plants and plant communities are often very sensitive and vulnerable to damage.

Based on the literature and consultation with industry representatives, major issues for future research include: (1) less obvious but ecologically significant indirect impacts of tourism and recreation including limiting spread of invasive weed species; (2) dispersal of dieback fungus, P. cinnamomi, by tourists, vehicles and infrastructure; (3) restoration ecology; how far and how fast impacted sites can recover if closed to visitor access, and how recovery can be accelerated; (4) designing monitoring programs to detect impacts of tourism in protected areas in different ecosystems; and (5) extent and degree of ‘impact creep’, i.e. gradual cumulative increases in impacts associated with more visitors, such as incremental hardening of sites and displacement of activities from high use tourism nodes into backcountry areas.

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SUMMARY

Objectives
- Review the impacts of tourism and recreation on vegetation in Australian protected areas.
- Identify priority areas for further research.

Methods
- Comprehensive literature review of Australian and overseas research on tourism and recreation impacts on vegetation in protected areas.
- Discussions with industry including staff from park agencies, as well as researchers in recreational ecology.

Key Findings
- Australian flora internationally significant.
- Protected areas are a major way of conserving biodiversity.
- Recreational ecology in protected areas has focused on environmental impacts of tourism infrastructure and activities, principally trampling, camping and off-road vehicles.
- Tourism and recreation in protected areas have a wide range of direct and indirect impacts on vegetation.
- Strong association between tourism and recreation and introduction and spread of weeds through disturbance of natural vegetation which provides habitat.
- Spread of weeds and pathogens such as the root rot fungus *P. cinnamoni* in protected areas are of particular concern because impacts are severe and self-sustaining (i.e. continue even without further use).
- Some rare and threatened plants and communities in protected areas are affected by tourism and recreational use.
- Impacts on vegetation are influenced by type of infrastructure, amount of use, type of activity and behaviour of tourists; timing/seasonality of activities and the characteristics of the vegetation communities and local environment.
- There is limited research on recreation and tourism impacts in Australian protected areas particularly indirect impacts.

Recommendations for Future Research
Based on the literature review and discussions with researchers and parks agency staff it is recommended that research be continued to examine:
1. Less obvious but ecologically significant indirect impacts of tourism and recreation including limiting the spread of invasive weed species.
3. Restoration ecology; how far and how fast can impacted sites recover if closed to visitors, and how can this recovery be accelerated.
4. How to design monitoring programs to detect impacts of visitors in protected areas in different ecosystems.
5. The extent and degree of ‘impact creep’, i.e. the gradual cumulative increase in impacts associated with increasing visitor numbers through incremental hardening of sites or displacement of activities from high intensity tourism nodes into backcountry areas.

Management Options
1. *Infrastructure*: In some high use areas it might be appropriate to introduce/upgrade tourism infrastructure to minimise damage to vegetation. However, the type of infrastructure should be selected to minimise direct damage to vegetation during construction and use, and to limit the spread of environmental weeds. Issues of ‘impact creep’ will also need to be considered.

2. *Education*: Continuing and increased emphasis on educating visitors to minimise impacts. Examples include encouraging visitors to avoid sensitive vegetation types when walking off track; encouraging use of hygiene procedures for walkers and park staff to prevent the spread of pathogens.
3. **Regulation:** Regulation/restriction of activities in some sensitive areas. Examples include limiting the use of areas characterised by vegetation with low resistance and resilience, and limiting the use of open fires. For example there is a clear need for increased recognition and emphasis on preventing or limiting the spread of pathogens such as *Phytophthora*. This may involve closures of roads or tracks passing through infected areas, restricting use of infected areas, no new construction of tracks from infected catchments into uninfected catchments, and construction and use of wash down facilities on major high risk roads and tracks.

4. **Research:** Continued research by park agencies and others into ways to minimise impacts of visitor use.

5. **Monitoring:** Effective monitoring of visitor use and evaluation and reporting of effectiveness of visitor management.

**Future Action**

- Support for research in the area of recreation ecology.
- Evaluation of and reporting on the effectiveness of current visitor and visitor impact management practices.
- Effective monitoring of activities/programs established to reduce or remove visitor impacts.
Chapter 1

CONTEXT: IMPORTANCE OF AUSTRALIAN PLANT BIODIVERSITY

Significance of Australian Flora

Australian flora is internationally recognised for its biodiversity, endemism, ancient origins and distinctive adaptations (Barlow 1994; DEST 1994). This has contributed to Australia’s recognition as one of the 17 megadiverse countries in the world based on the total number of species in the country and the degree of endemism at the species, genus and family level (Williams et al. 2001). Together, the megadiverse countries contain more than 70% of the world’s species. Australia has around 23,000 species of native vascular plants, approximately 85% of which are endemic (DEST 1994). There are also 14 endemic plant families of which several represent early stages in the evolution of flowering plants (DEST 1994; Williams et al. 2001, Figure 1). The south-west of Western Australia and the rainforests of northern Queensland are particularly important in terms of the diversity and endemism of the flora with both areas internationally recognised as diversity ‘hotspots’ (DEST 1994; Williams et al. 2001).

Figure 1: Number of endemic vascular plant species in 17 megadiverse countries

[N.B. Australia has the fifth highest number of species in this group (Source: Williams et al. 2001)]

Origin of Australian Flora

The distribution and characteristics of Australian flora is the result of continental drift (Barlow 1994). Australia experienced a long period of isolation and a general warming and drying of the environment before it collided with the Asian plate (Barlow 1994). There are four main elements to the flora: Antarctic, indigenous, indo-Malaysian and exotic species (Barlow 1994). The Antarctic flora consists of Gondwanic vegetation that was widespread when Australia was still attached to the Antarctica landmass (Barlow 1994). This vegetation has experienced little diversification and is mainly confined to rainforest pockets and alpine areas in Tasmania and the east coast of the mainland. It shows similarities to other Gondwanic flora in New Zealand and South America as well as to fossils in Antarctica (Barlow 1994). Examples include the Southern Beech (*Nothofagus*) and *Araucaria* pines. The most famous example is the Wollemi Pine (*Wollemia nobilis*), one of the world’s rarest plants, which is restricted to a few stands in the Greater Blue...
Mountains World Heritage Area in New South Wales.

The ‘indigenous flora’ is Gondwanic in origin but has undergone considerable diversification and endemism during a long period of isolation when the continent became drier and warmer (Beadle 1981; Barlow 1994). The indigenous flora is dominated by just a few families: the Proteaceae (*Banksia*, *Grevillea* etc.), Mimosaceae (*Acacia*), Poaceae (e.g. the hummock grasses which dominate the arid interior) and the Myrtaceae (*Eucalyptus*) (Beadle 1981; Barlow 1994). These families have distinctive adaptations to low rainfall, low soil fertility and fire (Beadle 1981; Barlow 1994).

The third element of Australian flora is the intrusive flora that arrived after Australia came in contact with the Indo-Malayan region (but not as a result of human activities) (Barlow 1994). They include a tropical sub-element with taxa recently derived from tropical south-east Asia, a cosmopolitan sub-element of widely distributed taxa and a neoaustral sub-element of mainly temperate species derived by recent migration from the northern hemisphere. The fourth element is exotic species that have recently been introduced as a result of human activities (Barlow 1994).

**Threats to Australian Flora**

There are numerous threats to the biodiversity of Australian flora, the most significant of which is loss of habitat through land clearance (Williams et al. 2001). Australia has experienced large-scale alteration to its vegetation in the last 200 years. In the eastern temperate zone over 90% of the native vegetation has been removed and over 50% of rainforests have been cleared (DEST 1996). Unfortunately, despite the increasing recognition of the importance of the ecosystem services provided by native flora, Australia currently clears the fifth highest area of land in the world. Over 564,800 ha of native vegetation were cleared in 2000, the highest rate of clearance of any developed country (Williams et al. 2001). Large areas of Australia are under private freehold or leasehold ownership with most land allocated to agricultural production and grazed by either sheep or beef cattle (Hajkowicz & Young 2002, Figure 2). Degradation and loss of biodiversity are also the result of changed fire regimes, changed hydrology and the spread of weeds and feral animals (Williams et al. 2001; Csuches & Edwards 1998). It is important that the remaining native vegetation is managed in a sustainable way (Williams et al. 2001).
Protected Areas and Australian Flora

Protected areas are one of the main strategies by which Australia fulfils its national and international obligations to conserve biodiversity (Worboys, De Lacy & Lockwood 2005). Ideally they allow for sustainable use of the landscape without compromising biodiversity or other intrinsic environmental or cultural values. A protected area is defined by the World Conservation Union (IUCN) as ‘an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources and managed through legal or other effective means’ (IUCN 1994).

In Australia, 602,730 ha (10.08% of the land) are conserved in over 6,700 protected areas (Environment Australia 2003, Figure 3). There are at least 50 categories of reserve types within the national reserve system, from specific-purpose areas such as scientific reserves to very large multi-zoned areas such as the Great Barrier Reef Marine Park. The IUCN definition of protected areas and its six level system describing management intent was adopted by Australia in 1994 (Environment Australia 2003). Australian protected areas are managed by nine separate jurisdictions; six State agencies, two self governing Territories and the Commonwealth in accordance with principles set out by the IUCN for protected areas and World Heritage legislation (Worboys et al. 2005).

Many protected areas were established because of the importance of their flora, including most of the 14 World Heritage Areas (Worboys et al. 2005). For example, the Greater Blue Mountains World Heritage Area west of Sydney contains 91 species of eucalypts, the majority of which are endemic. This area conserves an outstanding example of the evolutionary adaptation and diversification of eucalypts (NSW NPWS 1998). The diversity of eucalypts, together with the evolutionary relic species the Wollemi Pine (Wollemia nobilis), and 120 nationally rare and threatened plant taxa, were key factors in achieving World Heritage Status in 2000 (IUCN 1999). Adequate representation of bioregions has been recognised as a key to achieving biodiversity conservation (NSCAAB 1996).

While the number of protected areas in Australia has increased since the 1990s, some bioregions are poorly represented (NLWRA 2001; Williams et al. 2001, Figure 3). This is particularly important as high numbers of nationally listed threatened plants and animals are concentrated in some of the lesser represented bioregions (Williams et al. 2001).
Figure 3: Australian terrestrial bioregions and protected areas derived from IBRA Version 5.1
(Source: Environment Australia 2003)
PROBLEM: RECREATION AND TOURISM IN AUSTRALIAN PROTECTED AREAS AND THEIR IMPACTS ON VEGETATION

Having established the international significance of Australia’s plant biodiversity, the significant threats to biodiversity, and the role of protected areas in conserving biodiversity, this chapter briefly describes visitor use of protected areas in Australia. It then summarises the results of an extensive literature review of visitor impacts on soils and vegetation with an emphasis on recent Australian research in order to identify: (1) key areas for future research; and (2) management options for park agencies. In addition the authors consulted with academic colleagues, park agency staff, and made use of their own published and unpublished data to provide an up-to-date report of our current state of knowledge of visitor impacts on plants in Australian protected areas, including two issues of particular concern; the spread of environmental weeds, and the spread of the pathogen *Phytophthora cinnamomi* (*P. cinnamomi*).

Recreation and tourism in natural areas, including protected areas, is increasing worldwide (Buckley & Pannell 1990; Buckley 2002; Newsome, Moore & Dowling 2002a; Worboys et al. 2005), is currently considered to account for around 20% of all leisure travel, and to be worth in the order of US$20 billion a year (Newsome et al. 2002a). Australia attracts large numbers of local and international tourists who come to see the numerous rich and diverse natural systems in national parks and World Heritage Areas, such as the Wet Tropics of Queensland, Kakadu National Park, Uluru-Kata Tjuta National Park, the Central Eastern Rainforest Reserves, Fraser Island, Tasmanian Wilderness World Heritage Area and the Greater Blue Mountains World Heritage Area (Worboys et al. 2005). Tourism and travel are two of the largest industries in Australia, with nature-based or ecotourism a particularly fast growing sector (Newsome et al. 2002a; Worboys et al. 2005). It is estimated that there were 84 million visits annually to protected areas in Australia (Worboys et al. 2005). Tourism is often the only commercial use permitted in most protected areas (Buckley 2002; Worboys et al. 2005).

Although the primary goal of protected areas is conservation, a key legislative objective for many protected areas is to provide recreational opportunities in a natural setting (IUCN 1994; Buckley 2004a; Worboys et al. 2005). The balance however, is rarely maintained as recreational use of protected areas inevitably has negative impacts on the environment (Hill & Pickering 2002; Liddle 1997; Leung & Marion 2000; Buckley 2004a; Turton 2005). Although the consequences of visitor impacts may not be as severe as impacts of previous human activities in parks (e.g. livestock grazing, forestry, and mining), they are of concern at a local scale where impacts can be severe (Cole 1981; Liddle 1997; Newsome et al. 2002a; Turton 2005). Both direct and indirect impacts from recreational use of protected areas are widespread and are of increasing concern as visitor numbers to protected areas continue to rise (Monz 2000; Buckley 2004a; Buckley 2005).

Recreation and tourism activities in protected areas are usually restricted to those activities that have been considered to have less environmental impact and emphasise enjoyment of the natural values of the area (Buckley 2004a, Worboys et al. 2005). Tourism and recreation use of protected areas is usually managed through zones, which range from multiple use (where high impact activities such as horse-riding are allowed) to restricted access wilderness areas (Buckley, Pickering & Warnken 2000; Hill & Pickering 2002; Newsome, Cole & Marion 2004). Some zones are highly developed and extensively modified through infrastructure such as sealed roads, car parks, toilets, visitor centres, picnic areas, camping areas and accommodation. These areas often attract large numbers of people. In contracts, other zones, often within the same protected areas may be classified remote (wilderness) where there is limited access, no or few facilities, and only small numbers of visitors permitted, with considerable restriction on the types of activities permitted (Worboys et al. 2005). For example, activities permitted under certain conditions in urban/developed zones of New South Wales national parks included snow sports (alpine skiing, snowboarding, cross-country skiing, ice climbing), camping in formal campsites, scenic driving, canoeing/kayaking/white water rafting, motorised boating, sailing/sail boarding, fishing, cycling, bushwalking on formal tracks, caving, organised mountain biking, powered and non-powered flight (Worboys et al. 2005). In contrast in remote/wilderness areas, activities are mainly limited to bushwalking on non-hardened trails, fishing, camping without facilities, and cross-country skiing (Hill & Pickering 2002).

Impacts of Recreation and Tourism on Vegetation

The most important visitor impacts are those that: (1) affect a large area; (2) are intense; (3) are long lasting; (4) affect areas that are irreplaceable (in terms of ecosystem function); and/or (5) affect species/communities that are rare or threatened (Cole & Landres 1996). There are almost always negative impacts on natural vegetation and other
components of the environment from tourism and recreation (Sun & Walsh 1998; Leung & Marion 2000; Buckley 2004a; Turton 2005). The scientific study of visitor impacts on the environment has been termed ‘recreation ecology’. There is a growing body of research in this area which has been summarised in recent reviews by Liddle (1997), Sun and Walsh (1998), Leung & Marion (2000), Newsome et al. (2002a), and Buckley (2004b). However, much of this research has been in North America and Europe with limited research in Australia. This is of concern as there are clear differences between the continents in ecosystems and it is expected that there will be differences in the response of vegetation communities to visitor use (Sun & Walsh 1998). Buckley’s (2005) review found that out of 768 recreational ecology studies, only 69 studied impacts in Australia, and only 36 of those examined activities likely to directly affect vegetation. Therefore, this review uses Australian studies of tourism and recreation impacts where available, or general principles that have been established for recreation impacts overseas. This is done while recognising and emphasising the clear need for Australia specific research.

Research into the impacts of tourism and recreation in natural areas has concentrated on two areas: (1) environmental impacts associated with tourism infrastructure (Buckley & Pannell 1990; Newsome et al. 2002a; Turton 2005); and (2) environmental impacts of activities, principally trampling, camping, off-road vehicles and horse-riding (Sun & Walsh 1998; Newsome et al. 2002a; Buckley 2005; Turton 2005).

**Impact of Tourism Infrastructure on Vegetation in Protected Areas**

Although there tends to be limited tourism infrastructure within protected areas there are often tracks, trails, roads, lookouts, fixed campsites, car parks and sometimes visitor centres and accommodation. Although the total area allocated to infrastructure may be relatively small compared to the total area of the park, the impacts at that site are severe and often permanent (Smith & Newsome 2002; Pickering & Buckley 2003; Turton 2005). The most obvious and direct impact is vegetation clearance, however, damage is not restricted to the initial removal of native vegetation, there are usually indirect effects in adjacent natural vegetation (e.g. Sun & Walsh 1998).

The construction and use of roads and tracks can result in changes to hydrology and soils in adjacent areas including sedimentation and pollutant runoff (Spellerberg 1998, Newsome et al. 2002a; Turton 2005). A recent study comparing vegetation and soils on road verges and adjacent areas in the subalpine zone of Kosciuszko National Park in New South Wales (Johnston & Johnston 2004) found that soils on the road verges had significantly lower levels of humus, more gravel and sand, lower levels of nutrients and lower pH and electrical conductivity than soils sampled ~10 m away from the roads where there was native vegetation. In drainage areas just below the road, soils were also affected with significantly higher amounts of sediment, soil pH, and exchangeable levels of calcium and potassium than the roadside or natural areas. Vegetation composition and cover also differed among these three areas, with roadsides having more bare ground (28%) and weed cover than the natural areas (2% bare ground, 6% weed cover). The drainage areas were dominated by one weed (*Achillea millefolium* – yarrow), which accounted for 91% of the ground cover (Johnston & Johnston 2004).

This and other recent studies illustrate how road and tracks can act as corridors for the introduction and spread of weeds and pathogens and also contribute to an exponential loss of native vegetation through loss of natural ecosystem function from pollutants, sedimentation etc. (Buckley & Pannell, 1990; Cowie & Werner 1993; Whinam & Comfort 1996; Spellerberg 1998; Newsome et al. 2002a; Donaldson & Bennett 2004; Johnston & Johnston 2004; Pauchard & Alaback 2004; Worboys & Gadek 2004, Turton 2005).

With linear disturbances such as tracks and roads, the total area of disturbance may appear small, but due to the length of the roads and verge effects, the actual footprint can be much larger (Spellerberg 1998; Priskin 2003; Donaldson & Bennett 2004; Johnston & Johnston 2004; Turton 2005). A study on different track types in the alpine zone in Australia, demonstrated that the direct footprint on native vegetation (e.g. area of exotic plants or bare ground associated with the track) was 4290 m$^2$ per km for wide gravel tracks (1 car width), 2940 m$^2$ per km for narrow gravel tracks, and 2680 m$^2$ per km for a track made from pavers. However, a raised steel mesh walkway that was installed in the 1980s was not associated with bare ground or a significant cover of exotics, indicating that carefully choice of track types can dramatically reduce direct environmental impact of tourism infrastructure on vegetation (Hill & Pickering 2006).

A common problem is that increasing visitor use can result in incremental hardening of sites with a gradual change from a natural to an urbanised environment (Buckley & Pannell 1990; Donaldson & Bennett 2004; Worboys et al. 2005). In addition, there may be displacement of park users and/or changes in the expectations of tourists, with those participating in mass tourism often requiring more sophisticated facilities, than those engaging in nature or adventure tourism (Worboys et al. 2005).
Impact of Tourism Activities on Vegetation in Protected Areas

In addition to the impacts associated with infrastructure, research has been done on impacts associated with recreation and tourism activities, including those that require little or no infrastructure. Most studies have focused on impacts of trampling, camping, horse-riding and off-road vehicles. Recent studies on a range of vegetation communities in Australian protected areas have quantified the effect of tourism and recreation activities either by comparing vegetation at previously impacted sites with control areas, or using experimental trials. Results demonstrate that impacts found overseas also occur in Australia. Indirect impacts, for example, lower soil moisture and increased erosion as a result of soil compaction from trampling, have been studied less in Australia and overseas.

The most obvious impacts from activities such as horse-riding, walking, off-road driving and mountain biking include vegetation being crushed, sheared off, bruised and uprooted (Good & Grenier 1994; Good 1995; Whinam & Comfort 1996; Liddle 1997; Whinam & Chilcott 1999; Goeft & Alder 2001; Landsberg, Logan & Shoothouse 2001; Newsome, Milewski, Phillips & Anear 2002b; Phillips & Newsome 2002; Smith & Newsome 2002; Talbot, Turton & Graham 2003; Whinam & Chilcott 2003; Turton 2005). These studies have found that the damage from these activities resulted in changes including loss of height, productivity (biomass), photosynthetic material, reproductive structures (flowers, fruit etc.), reduction in cover, and change in species composition (Whinam & Comfort 1996; Liddle 1997; Whinam & Chilcott 1999; Newsome et al. 2002b; Phillips & Newsome 2002; Smith & Newsome 2002; Whinam & Chilcott 2003; Talbot et al. 2003; Growcock, Pickering & Johnston 2004; Turton 2005). While some damage can be immediately apparent, other damage may only be observed days, weeks or even years later (Bayfield 1979; Cole & Bayfield 1993; Liddle 1997; Whinam & Chilcott 1999).

Controlled trampling trials of a fen, bolster heath, shrubland and grassland in the high country of Tasmania found a range of negative effects of trampling on vegetation with biomass and vegetative cover lower two weeks after trampling by walkers with packs (Whinam & Chilcott 1999). The extent of damage from trampling increased with the number of passes and varied with the life form of the plants, with shrubs more susceptible to damage than graminoids. The time taken for recovery also varied with intensity of use and life form type with damage (changes in species richness, amount of bare ground, lower surface profile) still evident in some communities a year after 700 passes (Whinam & Chilcott 1999).

Damage to vegetation from visitor activities is not just limited to grassland and shrubland but has also been found in different types of forests in north Queensland where day-use and camping reduced canopy cover and decreased cover of seedlings compared to controls, with the extent of damage varying among rainforests, wet sclerophyll forest and littoral rainforest in the Wet Tropics World Heritage Area (Turton, Kluck & Day 2000). In old growth Karri (Eucalyptus diversicolor) forests in Western Australia, camping also damaged vegetation, with loss of total understory vegetation cover and native vegetation cover and fewer tree seedlings at formal and informal campsites compared to controls (Smith & Newsome 2002).

These types of activities (camping and trampling) often result in changes in species richness, with taxa more susceptible to damage being lost from a community, but others able to colonise disturbed sites. Trampling of the fragile feldmark vegetation along the highest mountain ridges in Australia resulted in a decline in native species richness on the track compared to adjacent vegetation, as well as a decline in the abundance of species (McDougall & Wright 2004). This reflects the low resistance of these native taxa to trampling damage. Other studies found an increase in species richness such as occurred in shrubland and grassland in the Tasmanian high country, where two low growing native shrubs and one native graminoid were found at sites after trampling (Whinam & Chilcott 1999). Often it is weed species that are found post trampling/camping. This occurred in the Karri (Eucalyptus diversicolor) forests where weeds were only found in formal and informal campsites (Smith & Newsome 2002).

Other well documented direct impacts of visitor activities to vegetation include root damage to trees from tethered horses, cutting trees for firewood and/or other vandalism such as harvesting wildflowers and epiphytes etc. or damage from holes dug to dispose of human or other waste, (Liddle 1997; Turton et al. 2000; Newsome et al. 2002b; Phillips & Newsome 2002; Smith & Newsome 2002; Bridle & Kirkpatrick 2003). The impacts of digging ‘cat-holes’ was experimentally tested across a range of vegetation types in Tasmania and digging resulted in lower overlapping cover values for a wide range of plant species in most communities sampled (Bridle & Kirkpatrick 2003).

Direct impacts from human activities may also be exacerbated by indirect impacts (Good 1995; Hammitt & Cole 1998; Buckley 2003). Although there has been increasing recognition of the importance of indirect impacts of visitors on native vegetation in protected areas, there has been far less research in this area (Buckley 2003; 2005). Also some indirect impacts can be self-sustaining, that is they can continue to occur even in the absence of further use of the site (Buckley 2003). Soil compaction can occur from a range of visitor activities in protected areas such as trampling, camping, horse-riding and mountain biking (Good 1995; Goeft & Alder 2001; Smith & Newsome 2002; Talbot et al. 2003; Turton 2005). For example, both formal and informal campsites in Warren National Park in Western Australia were found to have higher penetration resistance and bulk density than controls with formal campsites having 304% greater penetration resistance than controls. This was likely to result in decrease in soil moisture and increased erosion.

7
Association between Tourism and Weeds

Currently there are over 1,060 species of environmental weeds in Australia (Williams & West 2000). They have been identified as a significant threat to the conservation of biodiversity (Cowie & Werner 1993; Williams & West 2000; Williams et al. 2001). The Australian flora appears to be particularly susceptible to invasion by exotic taxa, in part due to the long period of isolation in its evolution (Williams & West 2000). The distribution of exotics in protected areas is strongly linked with tourism, particularly in disturbance associated with the provision and use of tourism infrastructure and certain types of activities (Macdonald & Frame 1988; Cowie & Werner 1993; Williams & West 2000; Johnston & Pickering 2001; Smith & Newsome 2002; Donaldson & Bennett 2004; Godfree, Brendan & Mallinson 2004; Pauchard & Alaback 2004). This is because tourism and recreation activities, and the construction and maintenance of tourism infrastructure can benefit environmental weeds in two ways; by facilitating the introduction and spread of weed propagules within a protected area, and by disturbing the natural vegetation and thereby providing a habitat for exotics.

The introduction and spread of weed propagules can be deliberate or accidental. In some cases weed seed can be attached to machinery and imported material used for road and building construction in protected areas. In other cases, exotic taxa that become environmental weeds were deliberately introduced into parks as part of seed mixes used for rehabilitation of natural vegetation or in gardens around resorts and other tourism facilities (Macdonald & Frame 1988; McDougall & Appleby 2000; Johnston & Pickering 2001; McDougall 2001). For example, over half the exotics found in the Australian Alps National Parks occur in the gardens of ski resorts (McDougall & Appleby 2000; Johnston & Pickering 2001; Pickering et al. 2002).

Tourists themselves can be vectors for the dispersal of weeds. Propagules can be carried on vehicles (Wace 1977; Macdonald & Frame 1988; Lonsdale & Lane 1994) and in clothing (Whinam et al. 2005). For example, a recent evaluation of the risk of cargo, food and tourists as vectors for the introduction of exotic plants into subantarctic islands found a wide diversity of exotic seeds in the clothing of tourists including taxa that are classified as environmental weeds (Whinam et al. 2005). They found that equipment likely to contain weed seed included day packs and the cuff and Velcro closures on jackets, although propagules were also found on walking boots (Whinam et al. 2005).

Tourism infrastructure and activities provide habitat for exotics by disturbing the natural vegetation in protected areas. As a result there is often a high diversity and abundance of exotics along road and track verges and around other types of infrastructure (Cowie & Werner 1993; Johnston & Pickering 2001; McDougall 2001; Smith & Newsome 2002; Godfree et al. 2004; Pauchard & Alaback 2004). For example, the majority of the 175 alien plant taxa in the Australian Alps National Parks are found in disturbed areas – along roadsides/walking tracks (78% of taxa) (Johnston & Pickering 2001). Many of these taxa appear to be restricted to disturbed sites, while others have spread into native vegetation and a few have become important environmental weeds (Johnston & Pickering 2001; McDougall 2001; Godfree et al. 2004).

Exotic plants pose a threat to natural vegetation by competing with natives for light, space and nutrients and modifying the natural functioning of the ecosystem (Macdonald & Frame 1988; Blossey 1999; Prieur-Richard & Lavorel 2000; Williams & West 2000). Community composition and structure may change, affecting availability of
food and shelter resources for native fauna (Adair 1995). These negative interactions see some exotic plants posing a serious threat to the biodiversity (Adair 1995). Therefore the increasing diversity and abundance of exotics in protected areas is of concern. This has been acknowledged with environmental weeds (plants that invade natural ecosystems and can cause major modification to indigenous species and ecosystem function) and sleeper weeds (those species that have naturalised, but not yet exponentially expanded their populations) being recognised as major threats to conservation in Australia (Williams & West 2000; Williams et al. 2001).

Exotics that become serious environmental weeds require active and often expensive management. Limiting further disturbance to natural vegetation and active and ongoing rehabilitation of disturbed sites are critical to the successful management of exotic taxa in protected areas (Cowie & Werner 1993; Spellerberg 1998; Johnston & Pickering 2001; Pauchard & Alaback 2004). This includes evaluating the relative impact of different types of tourism infrastructure such as comparing weed cover and diversity associated with different track types (Hill & Pickering 2006).

The control of exotics in protected areas requires greater recognition of the importance of prevention and early eradication. Prevention includes limiting the introduction and spread of weed propagules in rehabilitation programs (Macdonald & Frame 1988). In some ways it is even more important to reduce the area of suitable habitat for exotics, as some seeds self-disperse, and there is always the risk of some seed being introduced on vehicles etc. As the exotics are strongly associated with disturbance, a major method of limiting their establishment in protected areas is to limit disturbance to areas of natural vegetation (Spellerberg 1998; Johnston & Pickering 2001; Pauchard & Alaback 2004; Hill & Pickering 2006). Where disturbance has already occurred, active and ongoing rehabilitation of areas is critical. These approaches are reflected in integrated management practices which involve containing the spread of existing weeds, managing the environment to prevent the spread of new weeds and rehabilitating disturbed ecosystems (Williams & West 2000; Williams et al. 2001).

Tourism Impacts on Rare & Threatened Plants & Communities

Impacts of recreation and tourism on rare and endangered species occurring in protected areas, intensively used for recreational purposes, are of particular concern. Despite the importance of assessing and then monitoring the environmental impacts of tourism and recreation on susceptible plant species, there is a lack of academic research internationally and particularly in Australia (Sun & Walsh 1998; Kelly, Pickering & Buckley 2003). As a result, threats from tourism may not be adequately considered in recovery plans or plans of management.

Kelly et al. (2003) collated information about taxa listed as rare or threatened to determine which are threatened by tourism or recreation. Tourism was identified as a threat to 72 taxa (21% of listed rare or threatened taxa), over half of which occur in a protected area. The particular impact mechanism differed among taxa but the most common threat listed was the spread of *P. cinnamomi* associated with tourism activities. Other threats included direct trampling damage by visitors and/or illegal collection of whole plants/flowers by tourists. Construction of tracks and other tourism facilities, horse-riding, off-road vehicles, camping, firewood removal and the spread of weeds, were also listed.

Tourism not only affects taxa at risk of extinction, it can also adversely affect ecological communities at risk, many of which are in protected areas. Increasingly there is recognition of the need to conserve vegetation communities as well as individual species. As a result threatened ecological communities have been included in listings at the State and Federal level in Australia. Currently there are 36 ecological communities listed under the Federal Government Environment Protection and Biodiversity Conservation Act 1999. Threats to these communities associated with tourism and recreation included land clearing and habitat fragmentation, physical damage from recreational activities such as trail bikes, horse-riding, vehicular use and bushwalking, as well as from *P. cinnamomi* (Kelly et al. 2003).

As the most common threat from tourism to plant taxa already at risk was the spread of root rot fungus, *P. cinnamomi*, this will be discussed in more detail. Tourism use of protected areas is contributing to the spread of the *P. cinnamomi* (Schahinger, Rudman & Wardlaw 2003; Buckley, King & Zubrinich 2004; DPIWE 2005; Turton 2005). This fungus has caused extensive damage to vegetation, including threatened ecological communities and many taxa listed as threatened with extinction. It is currently found in Western Australia (Stirling Range National Park), South Australia (Mount Lofty Ranges, Fleurieu Peninsula, Kangaroo Island), Victoria (Wilson’s Promontory), New South Wales (Barrington Tops and northern Sydney), Tasmania (Southwest National Park, Freycinet National Park and others) and Queensland (Wet Tropics World Heritage Area) (Environment Australia 2001; Newsome et al. 2002a; Schahinger et al. 2003; Buckley et al. 2004; Worboys & Gadek 2004; DPIWE 2005; Turton 2005). Tourist activities can contribute to the spread of *P. cinnamomi* by transporting spores in mud on footwear, tent pegs, trowels, horse hooves, bike tyres and other types of vehicles. It is also spread during the construction, maintenance and use of tourism infrastructure (Buckley et al. 2004; Worboys & Gadek 2004; DPIWE 2005). Tourism can also contribute to the severity

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1 Information available on Australian threatened species management and recovery plans.
2 Taxa listed in the National Database of Rare or Threatened Plants (ROTAP) Briggs and Leigh (1996) or listed in relevant State legislation.
of the pathogen’s impact by increasing the stress on plants within areas already infected (Buckley et al. 2004). Unfortunately there are a wide range of taxa listed as endangered or vulnerable that are susceptible to *P. cinnamomi* (Barker & Wardlaw 1995; Environment Australia 2001; Schahinger et al. 2003). In Western Australia *P. cinnamomi* is a threat to at least 31 taxa listed as at risk of extinction and a threat to another 39 taxa listed as susceptible (Environment Australia 2001). In Tasmania, 39 taxa listed as at risk of extinction are susceptible to the fungus (Environment Australia 2001; Schahinger et al. 2003; DPIWE 2005). Its significance as a threat to endangered or vulnerable plant species has been recognised nationally and it is listed as a ‘Key Threatening Process’ by the Federal Government (Environment Australia 2001).
Chapter 3

FACTORS AFFECTING IMPACTS OF TOURISM ON VEGETATION

Recreation activities can affect many components of the environment including soil, vegetation, water and wildlife (Whinam et al. 1994; Liddle 1997; Sun & Walsh 1998; Goeft & Alder 2001; Newsome et al. 2002a; Smith & Newsome 2002; Bridle & Kirkpatrick 2003; Turton 2005). An intact vegetation cover, for example, minimises compaction or erosion of soils, while conversely compaction of soils can restrict further vegetation growth. As such, a single activity can cause multiple impacts and one impact may exacerbate or compensate for others (Hammit & Cole 1998). Some of the relationships between these components are outlined in Figure 4.

![Figure 4: Relationships among major environmental components that can be affected by recreational activities](modified from Hammit and Cole 1998)

One of the most distinctive characteristics of recreation is that it often occurs within a concentrated area (Cole 1981). Within that area the relationship between use and the amount of damage at a site is affected by a number of interrelated factors including:

- amount of use (includes intensity of use, party size, user distribution);
- type of activity and behaviour of tourists;
- season of use; and
- environmental characteristics including resistance and resilience of the vegetation

(Good & Grenier 1994; Whinam et al. 1994; Good 1995; Whinam & Comfort 1996; Liddle 1997; Sun & Walsh 1998; Goeft & Alder 2001; Landsberg et al. 2001; Newsome et al. 2002a; Smith & Newsome 2002; Bridle & Kirkpatrick 2003; Talbot et al. 2003; Turton 2005).
Amount of Use

Increasing the amount of tourism use within an area usually results in increased disturbance to vegetation (Whinam et al. 1994; Whinam & Comfort 1996; Smith & Newsome 2002; Talbot et al. 2003; Turton 2005). A common model suggested by Cole (1987) is that the relationship is curvilinear (Figure 5). Along this curve, an inflection point (or threshold) marks the point at which substantial impacts have already occurred with increasing use causing minimal, further damage (Marion 1998; Cole 2004).

![Figure 5: Relationship between frequency of use and amount of disturbance](modified from Cole 2004)

From this relationship, two generalisations have been made. The first is that initial users of a site are likely to cause the greatest proportion of impact to the environment, especially to vegetation (Hammit & Cole 1998; Cole 2004). As such, any minor reductions in use levels beneath this point can have a significant reduction in damage. The second generalisation is that as the frequency of use to an area increases, the proportion of impact associated with that change decreases (Hammit & Cole 1998). While the gradient of this curve will decrease as vegetation resistance increases, the general relationship remains the same (Cole 1995a; Cole & Monz 2002). Trampling studies can provide good examples of this threshold, often identifying the point at which damage to vegetation has exceeded the inflection point (Overseas: Kuss & Hall 1991; Cole 1993; Cole & Monz 2002; Cole & Monz 2004; In Australia: Sun & Liddle 1993; Talbot et al. 2003; Whinam & Chilcott 2003).

Some studies have found a different relationship between increasing amounts of use and suggest that the there can be low levels of use that do not result in damage. It is also likely that there will be thresholds for damage that can result in continuing, self-sustaining damage even if there is no further tourism use.

Type of Tourism Activity and Behaviour of Tourists

Some recreational activities in protected areas are likely to cause more environmental damage than others. This is a result of the nature of activities, whether the activity is passive or active, intensive or extensive, concentrated or dispersed (Kuss, Gruef & Vaske 1990). For example, recreation activities that have the greatest physical contact with the environment tend to cause the most damage to vegetation. The same number of people horse-riding, for example, where a horse and rider exerts ground pressure ~27 times greater than that of a walker, can have more impact along tracked and non-tracked areas than the same number of people bushwalking (Whinam et al. 1994; Whinam & Comfort 1996; Liddle 1997; Landsberg et al. 2001; Phillips & Newsome 2002; Newsome et al. 2002a). Damage to campsites used by horse riders also differ from impacts at campsites used principally by bushwalkers with more damage to trees, increased reductions in vegetative cover, increased compaction of soil, exposure of tree root and introduction and spread of weeds (Cole 1983). Mountain biking can also cause considerable impacts and is increasing in popularity. A recent study of impacts in the south-west of Australia found that this activity caused soil erosion, soil compaction, trail widening as well as directly damaging vegetation (Goetz & Alder 2001). In the Wet Tropics of Queensland, trails used for mountain biking showed high levels of soil erosion and exposed rocks and tree roots compared to high use walking trails (Day & Turton 2000).

The size of a user party can also influence the area of damage with larger parties often causing a disproportinate amount of damage. For example, larger groups at campsites tend to cause most damage (Cole 1989). In a study
comparing impacts at high-use formal campsites and low-use informal campsites, in old growth eucalypt forest in a protected area in Western Australia, the high-use formal campsites were larger (mean size 876 m²), had more tree damage, soil erosion, soil compaction, along with reduced vegetation cover and tree seedlings, greater degradation to riverbanks and more foot pads than the low-use informal campsites (177 m²) (Smith & Newsome 2002).

Tourist behaviour can affect the intensity of impacts that may occur. Where user groups are aware of minimal impact behaviour and practices, impacts may be reduced through careful consideration of campsite location, route for trampling or riding, disposal of waste etc. (Cole 1989; Hercock 1999). However, where these are ignored or unknown, there may be more impacts such as increases in litter, marking of trees and the creation of multiple or excessively sized fire rings. As such, some users may contribute to these impacts while others do not (Hercock 1999). For example, the impacts of visitation in the Wet Tropics in Queensland differed between high use and low use sites for day use and camping and that this appeared to be associated with the behaviour/type of user (Turton et al. 2000). Low use areas that were predominantly used by local residents were less clean, with more development of the site (fire rings, seating made from vegetation), more social trails and more tree damage (including for firewood) compared to high use areas where most visitors were not local.

Park managers have legislative support to manage recreation in ways that mitigate impacts and ensure that activities are undertaken in ways that are ecologically sustainable. This can include limiting areas where activities are conducted and limiting visitor numbers or the size of groups. There appear to be few instances in Australia where either a maximum group size or a maximum number of groups/season are imposed (Hill & Pickering 2002).

**Characteristics of Vegetation**

Individual species and vegetation communities vary in their response to recreational activities, with some able to tolerate substantial use while others can only withstand low use before damage occurs (Cole 1985; Whinam et al. 1994; Whinam & Comfort 1996; Arrowsmith & Inbakaran 2001; Bridle & Kirkpatrick 2003; Talbot et al. 2003; Whinam & Chilcott 2003; Whinam et al. 2003; Turton 2005). Vegetation can be classified as resistant, resilient or tolerant to impacts depending on the response. Resistance is the ability of individual plant species to withstand disturbances before being damaged. Resilience is the capacity of a plant to recover after disturbance and tolerance refers to the ability of vegetation to withstand a cycle of disturbance and recovery (Cole 1995b; Liddle 1997). The relative resistance, resilience and tolerance of vegetation communities/species to disturbance provide a baseline for identifying areas that may be better suited for recreational use than others (Cole 1995b; Liddle 1997; Arrowsmith & Inbakaran 2001; Talbot et al. 2003; Whinam et al. 2003; Turton 2005).

Characteristics that influence a plant’s resistance and resilience to damage include: (1) morphology (life form and size); (2) anatomy; and (3) life cycle (Liddle 1991, 1997). For example, communities dominated by shrubs can be easily damaged by trampling and are slow to recover (Edwards 1977; Whinam & Chilcott 1999). It appears that woody stems tend to be particularly sensitive to trampling and often break off or are abraded. As shrubs have vegetative buds near to the ground, broken and damaged stems reduce their capacity to recover from trampling (both low resistance and resilience) (Liddle 1988). In contrast, plants with leaves that form a basal rosette of small thick leaves (such as some mat forming herbs) tend to be more resistant to trampling and hence have a better rate of survival (Cole 1987; Liddle 1991; Hammitt & Cole 1998). As a result communities dominated by grasses and sedges are relatively resistant to trampling damage (Whinam et al. 1994; Whinam & Chilcott 2003). Rainforest understoreys, such as those in the World Heritage Wet Tropics in Queensland have species with broad thin leaves with year round growth and occur on moist friable soils that are easily compacted, have been found to have low resistance to trampling with reduction in vegetation cover occurring after as few as 25 passes (Talbot et al. 2003).

Topographic characteristics of an area can influence the potential for environmental damage. Slope steepness and soil loss are often correlated. For example, hiking, walking or bike riding on steep slopes has a greater potential to cause damage (Leung & Marion 1996; Goeft & Alder 2001; Whinam & Chilcott 2003). In Tasmanian alpine national parks experimental trampling of 200 passes or more on sloping buttongrass communities caused soil to become exposed and accumulate down slope (Whinam & Chilcott 2003). However, in a study of impacts of tracks in the Grampians National Park in Victoria, there was less damage to vegetation and soils along tracks at lower elevations where soils were deeper, than at higher elevations where the tracks traversed rocky outcrops (Arrowsmith & Inbakaran 2001).

Vegetation in different climatic zones responds differently to recreational use. For example, high altitude vegetation communities are often found to be more susceptible to damage from trampling and other activities than lower altitude communities in Australia (Calais & Kirkpatrick 1986; Liddle 1997; Whinam & Chilcott 1999; Bridle & Kirkpatrick 2003; Whinam et al. 2003). Within a climatic zone, vegetation types can differ in their response to various intensities and types of impacts. In the Wet Tropics World Heritage Area rainforest, littoral forests and wet sclerophyll forests differed in the effect of day-use and camping on canopy cover, mineral soil exposure, soil compaction, vegetation cover and seedling density (Turton et al. 2000). Wet sclerophyll forests were the most resistant, with rainforest intermediate
and littoral forest the least resistant.

Finally, the life cycle of plants may affect the resistance, resilience and tolerance of individual plant species to disturbance. Plants that begin seasonal regrowth from below the surface have resistance and resilience, while plants that can reproduce vegetatively and sexually or have a rapid regrowth will have an increased tolerance (Cole 1987).

**Season of Use**

The resistance and resilience of vegetation can vary seasonally affecting the intensity of damage that may occur from a particular activity (Gallet & Roze 2002; Turton 2005). For example, winter snow cover can protect soils and vegetation from many low intensity recreation impacts, but may increase the likelihood of damage to the same environment during spring when snow melts (Keane, Wild & Rogers 1979). The spread of pathogens such as root rot by *P. cinnamomi* by tourism is also likely to vary seasonally, with wet periods resulting in a greater rate of spread (Buckley et al. 2004; DPIWE 2005). In the Wet Tropics of Queensland, Turton (2005) found there were seasonal effects of tourism use with greater soil compaction and lower seedling densities adjacent to walking tracks compared to adjacent unused forest in the dry season.

The timing of growth and reproduction by plants is also important. Visitor activities during spring and early summer when plants are growing and reproducing may have more effect than when plants are dormant. Conversely, activities during late summer and autumn may have long lasting damage as there can be limited opportunities for vegetation to recover before winter (Cole 1994; Hammitt & Cole 1998).
PRIORITIES FOR FUTURE RESEARCH

Priorities for future research were identified from: (1) the literature review of visitor impacts on vegetation in protected areas; (2) plans of management for national parks, State of Park reports and other documents reporting on the integrity of the natural values of protected areas; (3) consultation with park agency managers and researchers and academic tourism researchers; and (4) recent evaluation of ecotourism industry and protected area managers priorities’ for general monitoring (Buckley 2002).

In Australia, as overseas, much of the published research on tourism impacts on vegetation had quite a narrow focus – concentrating on trampling and camping, with some studies of popular, high impact activities; horse-riding and off-road driving (Sun & Walsh 1998; Newsome et al. 2002a; Buckley 2005). There is limited research on the impacts of tourism infrastructure in protected areas or on evaluating the relative impact/benefit of different types of infrastructure. Research into indirect impacts, including those that are self-sustaining, is limited in Australia and overseas (Buckley 2002; 2003; 2005).

The views of current and former park agency staff on the impact of tourism on vegetation were also obtained and compared with the priorities as identified in the scientific literature. A summary of the park agency staffs input and priorities are:

• Roger Good, formally a Senior Manager in NSW National Parks and Wildlife Service. He emphasised the importance of examining impacts of weeds and impacts of trampling etc. that can become self sustaining.

• Andrew Growcock is currently working in the policy section of Parks and Wildlife Division of the NSW Department of Environment and Conservation. Andrew’s PhD research onto the impacts of trampling was used in this review. He also provided extensive comments on the draft report. He highlighted the need for further work on trampling, and on indirect impacts.

• Dr Ken Green, researches ecologies (wildlife) in NSW National Parks and Wildlife Service. He provided insight into some of the impacts of tourism on fauna that affects vegetation. He felt that further research into the spread of weeds and of snow manipulation in ski resorts was important.

• Mr Tim Rudman, Flora Protection Officer, Department of Primary Industries, Water and Environment, Tasmania. On a field trip and in discussion, he identified the seriousness of the impact of *P. cinnamomi* on plants in protected areas in Tasmania and the role of tourism in its spread. He emphasised the importance of research into such pathogens.

• Graeme Worboys, formally Senior Manager, and Executive Manager NSW National Parks and Wildlife Service. Graeme provided feedback based on his role as a senior manager, and based on his current international and national survey of the priorities for effective management of protected areas. Based on his experience directly in managing a range of protected areas, he highlighted the importance of further research into weeds and pathogens, and into indirect impacts of tourism. He also provided feedback based on the national and international park agency staff he has surveyed. There is near universal recognition among park agency staff of the importance of the scientific information into the condition and trend in condition of flora in protected areas and into threats to the flora, including from tourism.

• Ralf Buckley, in his role on the advisor panels for protected areas including CERRA and the Wet Tropics. He emphasised the importance for these parks of scientific research and monitoring of tourism impacts particularly indirect impacts. This is reflected in recent Plans of Management from these and other Parks.

The priorities as identified by current and former park agency staff correspond with those from general reviews of protected agency plans of management, surveys of parks staff, and the scientific literature. Therefore, the following key areas for future research are identified:

1. Ecologically significant indirect impacts of tourism and recreation such as limiting the spread of environmental weeds. Weeds have been identified as an important issue at all levels of government in Australia (Csuches & Edwards 1998; Williams & West 2000; Environment Australia 2006; NSW NPWS 2006a). It is also a major practical management issue for park agencies and is often identified as a key threat in Park Management Plans and State of Park reports (e.g. Environment Australia 2003; NSW NPWS 2006b). The literature review of recreational ecology in this report highlights the importance of research into the effective management of visitor activities and infrastructure in parks to reduce the spread of weeds.

2. Impacts of tourism infrastructure has been little studied in Australia, including comparisons of costs/benefits of various types of tourism infrastructure.

3. Dispersal of the fungus, *P. cinnamomi*, by visitors and vehicles. The severity of the threat from *P. cinnamomi*
has been recognised nationally (Key Threatening Process Environment Australia 2001), by park agency staff and researchers (Schahinger et al. 2003). A range of studies have examined the fungus and its impacts but agency staff and other experts have clearly identified the need for more research including monitoring and evaluating the success of management practices such as regulation of visitor access to infected areas.

4. Restoration ecology – how far and how fast impacted sites can recover if closed to visitors and how recovery can be accelerated. Restoration of damaged areas including damage to vegetation in protected areas is an important area of research. Rehabilitating sites damaged by infrastructure and visitor use is often expensive, ongoing and unfortunately, not always successful. Evaluating the success of different restoration methods remains a priority for many park agencies.

5. Designing coordinated monitoring programs to detect impacts of visitors in different ecosystems in protected areas. Increasing recognition of the range of impacts of visitors including on vegetation into protected areas (this review) along with increasing expertise in park management has resulted in increased recognition of the need for effective monitoring (Environment Australia 2003; Tonge et al. 2004; Worboys et al. 2005). This is reflected in recent monitoring strategies/frameworks developed by researchers from the Rainforest CRC for the CERRA World heritage Area and the Wet Tropics World Heritage Area) and research supported by the Sustainable Tourism CRC into developing frameworks and indicators for determining tourism impacts in terrestrial and aquatic systems in protected areas.

6. Extent and degree of ‘impact creep’, i.e. the gradual cumulative increase in impacts associated with increasing visitor numbers through incremental hardening of sites or displacement of activities from high intensity tourism nodes into backcountry areas. This important issue needs to be addressed in protected areas.

Management Options

Corresponding to the key areas for research, it is possible to identify management options based on the scientific literature and input of park agency staff. These are:

1. Infrastructure: In some high use areas it might be appropriate to introduce/upgrade tourism infrastructure to minimise damage to vegetation. However, the type of infrastructure should be selected to minimise direct damage to vegetation during construction and use, and to limit the spread of environmental weeds. Issues of ‘impact creep’ will also need to be considered.

2. Education: Continuing and increased emphasis on educating visitors to minimise impacts. Examples include encouraging visitors to avoid sensitive vegetation types when walking off track; encouraging use of hygiene procedures for walkers and park staff to prevent the spread of pathogens.

3. Regulation: Regulation/restriction of activities in some sensitive areas. Examples include limiting the use of areas characterised by vegetation with low resistance and resilience, and limiting the use of open fires. For example there is a clear need for increased recognition and emphasis on preventing or limiting the spread of pathogens such as Phytophthera. This may involve closures of roads or tracks passing through infected areas, restricting use of infected areas, no new construction of tracks from infected catchments into uninfected catchments, and construction and use of wash down facilities on major high risk roads and tracks.

4. Research: Continued research by park agencies and others into ways to minimise impacts of visitor use.

6. Monitoring: Effective monitoring of visitor use and evaluation and reporting of effectiveness of visitor management.
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