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Research Note

Indirect Impacts of Nature Based Tourism and Recreation: The Association Between Infrastructure and the Diversity of Exotic Plants in Kosciuszko National Park, Australia

Catherine M. Pickering, Roxana Bear and Wendy Hill
School of Environmental and Applied Sciences, Griffith University, Queensland, Australia

Tourism and recreation in protected areas results in a range of indirect impacts on the environment, including facilitating the spread of weeds. This research note examines the associations between tourism infrastructure and the diversity and frequency of exotic plants in a large and popular protected area in south-eastern Australia, Kosciuszko National Park. Of the 156 exotic taxa recorded in 18 vegetation surveys between 1986 and 2004, 152 were associated with tourism infrastructure; 64 taxa on road verges, 50 in ski resort areas, and a further 66 exclusively in the ski resort gardens. As many exotics become invasive environmental weeds, this study highlights the need to limit both the introduction of exotic propagules and the disturbance to natural vegetation during the construction, maintenance and use of tourism infrastructure in protected areas. If damage to vegetation has occurred, effective rehabilitation programmes are required.

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Introduction

Tourism and recreation in protected areas is increasing globally and in Australia, with nature-based tourism a particularly fast growing sector of the tourism industry (Buckley & Pannell, 1990; Worboys *et al.*, 2005). In Australia, there are an estimated 84 million visits per year to protected areas (Worboys *et al.*, 2005). While this provides considerable economic benefits to communities, the growing number of visitors inevitably causes negative environmental impacts (Buckley, 2004a, 2004b). Some of the most severe impacts are associated with the provision, maintenance and use of tourism infrastructure (Cole, 2004). The most obvious direct effect on vegetation is loss of cover during construction of infrastructure. Although damage may be localised, it is usually severe (Hill & Pickering, 2006; Pickering & Buckley, 2003; Turton, 2005).

Tourism infrastructure has a range of indirect impacts, which can be more severe and longer lasting than direct impacts (Buckley, 2004a; Cole & Landres,

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1996). For example, the introduction and spread of weed into protected areas is often associated with tourism (e.g. Turton, 2005). For many protected areas, a positive correlation has been demonstrated between visitation rate and the number of exotic species (Usher, 1988). Some exotics are able to colonise adjacent natural areas (e.g. Johnston & Johnston, 2004) and even become widespread, particularly if natural areas are subjected to anthropogenic or natural disturbance (Williams *et al.*, 2001).

Exotic plants can pose a threat to natural vegetation by competing with natives for light, space and nutrients and modifying natural ecosystem functioning (Blossey, 1999; MacDonald & Frame, 1988; Prieur-Richard & Lavorel, 2000; Williams & West, 2000). Community composition and structure may change, affecting food and shelter resources for native fauna (Adair, 1995). These negative interactions see some exotic plants posing a serious threat to biodiversity (Adair, 1995). Therefore 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 modifications to indigenous species and ecosystem function) being recognised as major threats to conservation in Australia (Williams & West, 2000; Williams *et al.*, 2001).

Weeds benefit from disturbances associated with construction and use of tourism facilities such as roads, car parks, visitor centres, picnic areas, lookouts and camping grounds (Spellerberg, 1998). Tourists using these facilities can also act as vectors, transporting weed propagules on vehicles, footwear, clothing and equipment (Lonsdale & Lane, 1994; Wace, 1977; Whinam *et al.*, 2005).

To demonstrate the association between tourism infrastructure and weeds in protected areas diversity and frequency of exotic taxa was examined in Kosciuszko National Park, a large and popular national park in New South Wales in south-eastern Australia.

Site and Methods

Site

Kosciuszko National Park is a popular destination for winter tourism principally in ski resorts with estimates of nearly 1.5 million skier days per year (Worboys & Pickering, 2004). During non-snow periods the Park is also popular for backcountry and sight seeing activities including ascending the tallest mountain in continental Australia, Mt Kosciuszko 2228 m (Worboys & Pickering, 2004). The Park has high conservation value and is a UNESCO Man and the Biosphere Reserve (Good, 1992).

There is a wide range of infrastructure in the Park, some of which was established for grazing (some roads, huts and trails) or during construction of a large hydro-electric scheme (dams, aqueducts, abandoned construction sites and some management trails). However, much infrastructure is for tourism use including sealed and gravel roads, walking tracks, ski resorts, car parks, campsites, picnic grounds and informal tracks (Worboys & Pickering, 2004). Vegetation, soils and hydrology has been changed during construction and use of tourism facilities (Johnston & Johnston, 2004; Mallen-Cooper, 1990).

Associated with human use of the region over the last 200 years has been increasing diversity of exotic plants with at least 235 exotic species recorded in the Park (Bear *et al.*, 2006). Some species were deliberately or accidentally

introduced during the period of livestock grazing between the 1830s and 1960s. Others were used to rehabilitate areas severely damaged as a result of grazing. Many exotics have been deliberately planted in ski resort gardens or used to alter ski slope vegetation to enhance skiing conditions (Johnston & Pickering, 2001). Disturbance has favoured establishment and spread of numerous exotic species, some of which are part of an international environmental weed flora (Godfree *et al.*, 2004; Johnston & Johnston, 2004; Mallen-Cooper, 1990).

Distribution of exotics

We tested the relationship between exotic species and disturbance using records of exotic species collated from 18 recent vegetation surveys undertaken at a total of 401 sites/quadrats (277 in natural vegetation and 125 in disturbed areas such as along tracks and trail verges) from 1986 to 2004 in the montane to alpine zones Kosciuszko National Park (Table 1). Sampling methodology varied among studies, with differences in the number of quadrats per site, in the size of the quadrats and in the way in which the quadrats/transects were assessed (Table 1). Despite these methodological issues, by pooling the data it was possible to compare the effect of disturbance at a greater number of sites, and obtain a better indicator of the total species richness of exotics in disturbed and undisturbed vegetation in the park, than would be possible by examining any single study.

The pooled data was analysed using chi-square statistics to test if their were differences in number of species or frequency (number of records of exotics) between natural vegetation and areas affected by tourism infrastructure (road verges, alpine walking tracks, around ski resort infrastructure and surrounds and ski resort garden). This type of chi-squared is based on the assumption that there are equivalent numbers in each category, for example, same number of species in disturbed and natural areas. Therefore the expected value would be the sum of the dependent variables in the disturbed and natural areas divided by number of categories being tested (here two). However, as fewer sites/quadrats in natural areas were assessed than in disturbed areas, the number of categories being tested was adjusted. For example, the expected value for species richness in disturbed sites (75) was calculated as the sum of the species recorded in natural and disturbed areas ($48 + 154 = 202$) divided by the number of categories adjusted (e.g. total number of sites-quadrats divided by the number sites-quadrats that were disturbed e.g. $440/163 = 1.6$).

Lists of exotic species associated with natural areas and human disturbance have been published in other papers (Bear *et al.*, 2006; Goodfree *et al.*, 2004; Johnston & Pickering, 2001; McDougall *et al.*, 2005; Mallen-Cooper, 1990). Some of these studies have also reported lower species richness and frequency of exotics with increasing altitude (Bear *et al.*, 2006; Johnston & Pickering, 2001; McDougall *et al.*, 2005; Mallen-Cooper, 1990). This paper investigates in more detail the association between tourist infrastructure and weeds including examining if species deliberately planted in ski resort gardens have become naturalised.

Results

Of the 235 exotic plant species previously recorded in Kosciuszko National Park, 156 were recorded in 18 vegetation surveys covering alpine to montane zones (Bear *et al.*, 2006) (Table 2). Of species recorded in these surveys, 82 were

Table 1 Details of 18 general vegetation surveys conducted between 1986 and 2004 in montane to alpine zones of Kosciuszko National Park, Australia

Data source	*Floristic zone, vegetation & disturbance type*	*Details of site, sampling unit & sampling method*	*Survey year*
(1) Bear & Pickering (2006)	(1) Subalpine zone (2) Natural tall alpine herbfield burnt in 2003 bushfires and adjacent unburnt tall alpine herbfield	Number of sites: 6, 2 paired quadrats per site Number of quadrats with exotics: 10 Size of quadrat: 6 × 20 m Survey method: 200 point quadrats in each quadrat	2004
(2) Bear and Pickering (unpublished data) Impacts of fire on road verge and adjacent natural areas [1]	(1) Subalpine zone (2) Disturbed road verge vegetation and adjacent natural grassland	Number of sites: 11, 2 paired quadrats per site Number of quadrats with exotics: 21 Size of quadrat: 6 × 20 m transects at each site Survey method: 200 point quadrats in each quadrat	2004
(3) Campbell (2004)	(1) Alpine zone (2) Natural short alpine herbfield and tall alpine herbfield	Number of sites: 5 with three transects per site Number of transects with exotics: 1 Area of each transect: 0.3 m * 34–68 m Survey method: 40 point quadrats for random sample of 0.3 * 0.5 m photo-quadrats along each transect	2004
(4) GLORIA Global (unpublished data) Research Initiative in Alpine Environments (2004 sampling)	(1) Alpine zone (2) Natural tall alpine herbfield and heath	Number of sites: 5, 1 large quadrat per site Number of sites with exotics: 5 Size of quadrat: at least 50 × 50 m Survey method: visual estimation	2004

(*Continued*)

Table 1 Continued

Data source	*Floristic zone, vegetation & disturbance type*	*Details of site, sampling unit & sampling method*	*Survey year*
(5) Growcock (2005)	(1) Alpine and subalpine zone (2) Natural tall alpine herbfield and subalpine grassland	Number of sites: 10 Number of sites with exotics: 1 Area of site: 2.16 m^2 Survey method: visual estimation	2003
(6) Hill and Pickering (unpublished data) Effect of drought and fire on vegetation	(1) Alpine and subalpine zone (2) Natural tall alpine herbfield, wind-swept feldmark, heath and subalpine grassland burnt in 2003 bushfires and natural unburnt vegetation	Number of sites: 31, 1 quadrat per site Number of sites-quadrats with exotics: 22 Size of quadrat: 30×20 m quadrat Survey method: 200 points sampled by step pointing systematically over quadrat. Rare/uncommon species not detected by step pointing were also recorded and attributed a small default cover value	2003
(7) Johnston and Johnston (2004)[1]	(1) Subalpine zone (2) Disturbed road verge and adjacent natural subalpine grasslands	Number of sites: 6, with 3 quadrats per site Number of quadrats with exotics: 18 Size of quadrat: 1 m^2 quadrat Survey method: visual estimation	2001
(8) Johnston (2005)[1]	(1) Subalpine zone (2) Disturbed road verge vegetation and nearby natural subalpine grassland	Number of sites: 10, with 3 quadrats at each site Number of quadrats with exotics: 2 Size of quadrat: 0.5 × 0.5 m quadrats Survey method: visual estimation	2001
(9a) Mallen-Cooper (1990)[1]	(1) Alpine, subalpine, montane and tableland zones along Kosciuszko road (2) Disturbed road verge vegetation and nearby natural vegetation	Number of sites: 10, paired quadrats at each site Number of quadrat with exotics: 19 Size of quadrat: 20 × 6 m Survey method: visual estimation	1986–89

(10) Pickering *et al.* (2002)[1]	(1) Alpine and subalpine zone (2) Natural tall alpine herbfield, heath, subalpine grassland and woodland. Disturbed areas in and around ski resorts	Number of sites: 45 Number of sites with exotics: 45 Number of sites in ski resort gardens: 3 Area of each site: at least 50 × 50 m Survey method: visual estimation	2002
(11) Pickering and Hill (2006)[1]	(1) Alpine zone (2) Disturbed vegetation on verges of walking tracks and adjacent natural tall alpine herbfield	Number of sites: 35, with 2–3 quadrats per site, total 86 quadrats Number of quadrats with exotics: 41 Size of quadrat: 1.5 m × 0.5 cm Survey method: visual estimation	2002
(12) Pickering *et al.* (unpublished data) Long Plain: disturbed through prior grazing[1]	(1) Montane zone (2) Woodland and grassland disturbed by livestock grazing practices (>40 years previously)	Number of sites: 7 with paired woodland and grassland sampling Number of sites with exotics: 14 Area of each site: combined results from 6, 1 m^2 quadrats Survey method: visual estimation	2003
(13) Pickering *et al.* (unpublished data) Long Plain: natural areas	(1) Montane zone (2) Natural woodland and grassland	Number of sites: 14 Number of sites with exotics: 14 Area of each site: combined results from 6, 1 m^2 quadrats Survey method: visual estimation	2003
(14) Pickering *et al.* (unpublished data) Long Plain: power lines[1]	(1) Montane zone (2) Disturbed heath and grassland under powerlines	Number of sites: 7 Number of sites with exotics: 7 Area of each site: combined results from 6, 1 m^2 quadrats Survey method: visual estimation	2003

(*Continued*)

Table 1 Continued

Data source	*Floristic zone, vegetation & disturbance type*	*Details of site, sampling unit & sampling method*	*Survey year*
(15) Scherrer *et al.* (2004)	(1) Subalpine zone (2) Natural subalpine grassland and heath	Number of sites: 2, 1 transect per site Number of transects with exotics: 2 Length of each transect: 320 m Survey method: 3300 evenly spaced point quadrats per transect	2003–2004
(16) Scherrer (2003) Chapter 4	(1) Alpine zone (2) Natural tall alpine herbfield	Number of sites: 6, 1 long transect per site (assessed as 12 sections per transect) Number of transects with exotics: 5 Length of each transect section: 183 m Survey method: 1188 evenly spaced point quadrats per transect	2002
(17) Scherrer and Pickering (2005)	(1) Alpine zone (2) Natural tall alpine herbfield	Number of sites: 30 photoquadrats Number of photoquadrats with exotics: 4 Size of photoquadrat: 0.7 × 0.9 m Survey method: 130 point quadrats per photoquadrat	2001
(18) Scherrer and Pickering (2006)	(1) Alpine zone (2) Disturbed tall alpine herbfield on rehabilitated walking track 15 years ago and adjacent natural tall alpine herbfield	Number of sites: 22, with 2 paired quadrats at each site Number of quadrats with exotics: 18 Size of quadrat: 1 m^2 Survey method: visual estimation	2001

[1]Survey examined effect of anthropogenic disturbance on vegetation, therefore more likely to record exotic species

Table 2 Number of exotic species from 18 vegetation surveys conducted between 1986 and 2004 associated with different types of tourism infrastructure, in the Kosciuszko National Park, Australia

Exotic species	*Road verge*	*Track verge*	*Ski resort*[1]	*Garden*[2]	*Tourism total*	*Total*
Species richness	64	4	50	66	154	156
Number of records (%)	378 (37.6)	35 (3.5)	138 (13.7)	92 (9.1)	643 (64.0)	1004

[1]Excludes species recorded exclusively in ski resort gardens
[2]Species exclusive to gardens

restricted to ski resorts (66 taxa exclusive to gardens, and 16 species exclusive to ski slopes and/or around resort infrastructure) (Table 2). To determine if resort gardens and surrounds are a source of propagules for exotic species occurring in natural areas we determined if exotics occurring in gardens and/or other resort areas (but not in road verges) also occur in natural areas. Six species were found in both gardens and natural areas (but not on road verges). However, they are not considered gardens escapees, but are actually weeds in gardens. Six species found in both resort areas (other than gardens) and natural areas (but not road verges) were recorded at very low frequency.

Sixty-four species were found in both resort areas and road verges with 44 of these also found in natural areas (Table 2). These species may be considered to be naturalised, although few taxa were recorded frequently. These nine most common taxa, *Acetosella vulgaris, Achillea millefolium, Agrostis capillaris, Anthoxanthum odoratum, Cerastium* spp., *Dactylis glomerata, Hypochaeris radicata, Taraxacum officinale* and *Trifolium repens* accounted for 68% of records.

Tourism infrastructure had clear effect both on species richness and number of exotic records (Table 3). There was significantly greater species richness in areas affected by tourism infrastructure (152 species; chi-square statistic = 130, $p < 0.001$) and number of exotic records (68% chi-square statistic = 378, $p < 0.001$) than in natural areas (48 taxa, 32% of records).

The infrastructure types with highest weed species richness were verges of roads (64 species, 38% frequency) and ski resort gardens (66 taxa, 9% frequency) (Table 2). Track verges had the least number of species, as would be expected (4 taxa, 3.5% frequency) and the area and extent of disturbance to

Table 3 Species richness and number of records of exotics in areas of natural vegetation and areas where the vegetation has been disturbed by tourism activities and infrastructure

	Natural vegetation	*Disturbed area*	*Total*
Number species	48	152	156
Number of records	322	682	1004

native vegetation, soils and hydrology was also less with tracks than roads (Hill & Pickering, 2006; Mallen-Cooper, 1990).

Discussion

Kosciuszko National Park contains a number of popular tourism destinations, including the major winter ski resorts in New South Wales and the highest mountain on mainland Australia, Mt Kosciuszko (Worboys & Pickering, 2004). There is a clear association between tourism infrastructure and species richness and frequency of exotics in the Park. While road verges accounted for 66 exotic species and nearly half of all records, ski resorts and their surrounds provided habitat for an additional 82 exotic species. Most of these (66) were exclusively in gardens while 16 were in other resort areas, principally on ski slopes, around lifts and next to hotels/lodges. Six exotic taxa recorded around resort infrastructure but not road verges have also been recorded in the natural vegetation. Currently these are not considered environmental weeds as they are appear to be largely restricted to disturbed areas particularly around infrastructure.

The problem of 'gardens' in national parks is that they are source of exotic propagules that could spread into adjacent natural areas. While most resort garden species were not found anywhere else in Kosciuszko National Park, 18 were also recorded in other disturbed areas and six are naturalised. Although these six taxa (*Epilobium ciliatum, Juncus effusus, Leontodon taraxacoides, Myostis laxa, Rosa rubiginosa* and *Salix* sp.) are not as such, garden escapees, but likely to be part of the suite of 'weed' taxa in many places in the world and would also be considered 'weeds' in the ski resort garden (Johnston & Pickering, 2001; PlantNet, 2005).

Many environmental weeds in Australia are garden escapees (Williams & West, 2000). To counter this some parks and ecotourism facilities that are located in or near protected areas only use natives in gardens. This may be still be a problem as some plants, although native to the wider area, are outside their natural distribution and may become weeds in the protected area (Williams & West, 2000). Therefore it is recommended that only use local natives species are used gardens, in or facilities adjacent to national parks.

Other sources of weed propagules in protected areas are tourists themselves. Several studies have found weed seed on the shoes, tyres, clothes and other equipment of tourists (Lonsdale & Lane, 1994; MacDonald & Frame, 1988; Wace, 1977; Whinam *et al.*, 2005). Visitors as weed vectors has not been examined in Kosciuszko National Park to date, although large amounts of exotic seed has been found in soil seed banks adjacent to car parks in the resorts, including species that did not occur above ground (Mallen-Cooper, 1990). Many species of exotics in the Park were deliberately and accidentally introduced during the grazing period or during the restoration of areas damaged by grazing (Johnston & Pickering, 2001; Mallen-Cooper, 1990). However, since the cessation of grazing, the diversity of exotics continues to increase (Johnston & Pickering, 2001) reflecting the contribution of tourism and recreation usages of the Park in the introduction and spread of exotics.

In addition to potentially facilitating the introduction and spread of exotic propagules the construction, maintenance and use of tourism infrastructure

provides habitat for weeds to grow. Weeds benefit from disturbance to natural vegetation often doing better in cleared areas, than in areas with an existing intact cover of native vegetation (Pickering & Buckley, 2003; Smith & Newsome, 2002; Turton, 2005). They also benefit from additional nutrients often associated with tourism infrastructure, including nutrients washed of roads and tracks (Johnston & Johnston, 2004).

The control of exotics in protected areas requires greater recognition of the importance of preventing their establishment and their early eradication or control. Prevention includes limiting the introduction and spread of weed propagules, including in rehabilitation programmes (MacDonald & Frame, 1988). In some ways, it is even more important to reduce the area of suitable habitat for exotics, as some species have seeds that self disperse (e.g. wind) 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 areas of natural vegetation disturbed (Hill & Pickering, 2006; Johnston & Pickering, 2001; Pauchard & Alaback, 2004; Spellerberg, 1998). Where disturbance has already occurred, active and ongoing rehabilitation of areas is critical. These approaches should be incorporated into integrated management practices, which involve monitoring and evaluating the condition of natural vegetation at areas affected by tourism, 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).

Conclusions

Weeds are an important indirect impact of nature-based tourism and recreation. They benefit from disturbance to vegetation and soils associated with visitor use and infrastructure in protected areas. This can be seen in Kosciuszko National Park, where there is a higher diversity and number of records of exotic plants on road verges, edges of formal and informal tracks and in ski resorts. Limiting the potential for new weed invasions requires limiting any disturbance to the natural vegetation including during the construction and use of tourism and recreational facilities along with the ongoing effective rehabilitation programmes once disturbance has occurred.

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Correspondence

Any correspondence should be directed to Catherine M. Pickering, School of Environmental and Applied Sciences, Griffith University, PMB 50, Gold Coast Mail Centre, QLD 9726, Australia (c.pickering@griffith.edu.au).

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