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Impacts of tourism hotspots on vegetation communities show a higher potential for self-propagation along roads than hiking trails

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ABSTRACT

Vegetation communities along recreational tracks may suffer from substantial edge-effects through the impacts of trampling, modified environmental conditions and competition with species that benefit from disturbance.

We assessed impacts on trackside vegetation by comparing high and low usage tourism sites at a 1–10 m distance from recreational tracks in a popular arid-lands tourism destination in South Australia. The central aim was quantification of the strengths and spatial extent of tourism impacts along recreational tracks with a qualitative comparison of roads and trails.

Track-distance gradients were most prevalent at high usage sites. There, species community composition was altered, total plant cover decreased, non-native species cover increased, plant diversity increased or decreased (depending on the distance) and soil compaction increased towards recreational tracks.

Roadside effects were greater and more pervasive than trailside effects. Further, plant diversity did not continuously increase towards the road verge as it did along trails but dropped sharply in the immediate road shoulder which indicated high disturbance conditions that few species were able to tolerate.

To our knowledge, we are the first to demonstrate that the access mode to a recreation site influences the potential of certain impacts, such as the increase of non-native species, to self-perpetuate from their points of introduction to disjointed sites with a predisposition to disturbance. Due to this propulsion of impacts, the overall spatial extent of roadside impacts was far greater than initially apparent from assessments at the road verge. We discuss possible means of mitigating these impacts.

1. Introduction

An intricate network of recreational tracks admits visitor traffic to many natural tourism areas worldwide. Tracks traverse the landscape and fragment plant habitat which exposes abutting plant communities to edge-effects (reviewed by Murcia, 1995): The physiognomy of tracks as well as their perpetual use and maintenance may interfere with vegetation via a direct mechanical disturbance, a modification of the abiotic plant habitat and the facilitation of non-native and native species that thrive in disturbed areas. With a growth in tourism numbers, the expectation is that recreational demand will intensify conflicts with the protection of vegetation and other habitat resources. Thus we need to elucidate how vegetation varies in relation to visitor usage along travel corridors in order to mitigate adverse effects. Given the popularity of roads and hiking trails for facilitating easy access throughout protected areas, our key objective is to determine whether trackside impacts and their spatial extent differ between sites with vehicle and hiker access. So far, impacts of both modes of access on the total abundance of plants, the composition and diversity of plant communities have mostly been investigated independently. A direct comparison can aid tourism management in making informed decisions about access options to tourism sites.

Plant abundance next to recreational tracks may be lower (Cole, 1978) or greater (Hall and Kuss, 1989) than in less disturbed sites. Differences in abundance are dictated by complex processes that govern the trackside environment. For example, trampling (reviewed by Cole, 2004) may damage plant tissue (Meinecke, 1928) and cause an overall reduction in plant vigour and reproductive output (Liddle, 1997) which may in turn lead to a reduction in the total cover, height and biomass of vegetation (Cole, 2004). Plant abundance may further be affected indirectly through

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changes in the micro-environment next to tracks: soil abrasion and compaction are prominent examples of habitat modification that accrue from trampling (Belnap, 1998). Compression of the soil structure leads to a reduction in air and water movement, reduced water infiltration (Hammitt and Cole, 1998) and a decreased water retention, except for coarse-textured soils (Gallet and Rozé, 2002). Such conditions are inhospitable for root (Bhuju and Ohsawa, 1998) and vegetative growth (Settergren and Cole, 1970). Compaction also increases the force required for plant roots to penetrate the soil, restricting root elongation and soil pervasion (Materechera et al., 1991). However, plant species vary in their tolerance of soil compaction (Bassett et al., 2005; Kyle et al., 2007). Parker et al. (2010) for instance found that non-native but not native plant species richness in North American forests was positively correlated with increasing soil compaction.

Notwithstanding, the track shoulder may retain higher quantities of moisture due to an increased water runoff from the compacted and barren centre of most tracks which may stimulate vegetation growth (Amor and Stevens, 1976). The continuous use of roads by vehicles may further modify the plant habitat by impacting the trackside environment with emissions from exhaust fumes (Morgan, 1998), or raised dust may cover plants and inhibit various physiological processes (Farmer, 1993).

Under the semi-arid conditions in our South Australian study area, alterations in the physical and chemical environment next to recreational tracks are particularly potent at instigating changes in the community composition as native plants are adapted to a normally very limited water and nutrient supply (Friedel et al., 1993). Recreational tracks may therefore facilitate the establishment of invasive, non-native species that are well-known for their proficiency to withstand modified environmental conditions (Liddle and Greig-Smith, 1975), particularly if competition with other disturbance-sensitive species is alleviated (Frenkel, 1970). In Australian grasslands, for instance, a greater richness of exotic species adjacent to roadsides has been attributed to higher nutrient concentrations from vehicle emissions which fostered non-native species growth and suppressed the growth of native species (Morgan, 1998). Likewise, trailsides were susceptible to species invasions (Hall and Kuss, 1989; Tyser and Worley, 1992).

Propagule pressure, defined as the quality, quantity and frequency of invading organisms (Groom et al., 2006), was proposed as a key deciding factor for the successful establishment of introduced populations (Lockwood et al., 2005). Propagule sources accrued locally were considered important in some cases where the abundance of non-native species along transportation corridors may not have imposed sufficient pressure to sustain colonising populations (Levine, 2001; Sullivan et al., 2009). In our study area we suspected that nearby pasturelands exposed to intense grazing, logging and land development provided an abundant local supply and constant influx of non-native species via transport corridors and waterways.

We conducted our study in selected gorges in the Flinders Ranges, a popular tourism destination in South Australia where some of the gorges are accessible via unpaved but well-maintained backcountry roads and others are restricted to hiker access. The central question was how tourism impact indicators (Belnap, 1998) respond to an increase in usage along roads or hiking trails. To address our question we assessed vegetation variables and soil compaction at the 1–10 m distance to roads or hiking trails at high and low usage tourism sites. We focused on this particular distance band as we expected that it would encompass the zone of greatest environmental change due to road (Godefroid and Koedam, 2004) and trail (e.g., Benninger-Truax et al., 1992) usage.

Even though many of the described impact mechanisms may affect vegetation communities equally along roadsides and trailsides in our study area, we suspected that changes in plant metrics and soil compaction emanating from an increase in usage would be more severe and more pervasive along roads than along hiking trails for several reasons. Most visitors explore vehicle-access gorges throughout their entire length but camp or stop only at some of multiple sites (Wolf et al., 2012). In contrast, hikers concentrate their activities (such as hiking and break stops) around their entry from favoured access points through to the middle of hiker gorges and rarely pursue any camping activities whatsoever. Consequently, high usage regions of roads result from greater camping usage and stopping of visitors whereas they result from a greater number of passing and stopping visitors along trails. Camping, being a temporally extended and physically more involved form of usage, should aggravate impacts. Impacts on plants and their habitat may further be exacerbated along roads because vehicles cause heavy-weight trampling and pollution; particularly in high usage sites where camping or stopping visitors manoeuvre their vehicles more in order, for instance, to seek optimum parking. Roads that receive frequent usage also require maintenance (e.g., grading) which typically affects the surroundings more than the maintenance needed for well-used trail sections.

The following non-exclusive hypotheses were tested: (1) Plant metrics and soil compaction will differ between high and low usage sites. (2) Changes in univariate plant metrics and soil compaction emanating from an increase in usage will be more severe and more pervasive along roads than along hiking trails. (3) Species' reactions to tourism usage will manifest through multivariate compositional changes between high and low usage sites. (4) Impacts such as an increase in species that thrive on disturbed sites will self-perpetuate from tracks to other sites where conditions are naturally disturbed. This will increase the ecological effect zone to the banks of neighbouring creek beds that traverse recreation sites.

2. Methods

2.1. Study area

This study was conducted in a popular tourism destination in South Australia, the central and northern Flinders Ranges, from the Flinders Ranges National Park (Wilpena: lat. 31° 30′ S, long. 138° 30′ E) into the Vulkathunha-Gammon Ranges National Park (Balcanoona: lat. 30° 30′ S, long. 139° 30′ E). The geomorphologically diverse Flinders Ranges encompass six bioclimatic regions (Nix, 1982) and provide a versatile mixture of habitats for a rich vegetation community with a record of 1233 native plants, including more than 200 species under conservation threat and 14 endemic taxa (Brandle, 2001). Given the sporadic rainfalls that vary from approximately 200 to 500 mm per annum (Brandle, 2001) much of the vegetation is typical of semi-arid communities (Kuchel, 1980). The vegetation of the Flinders Ranges is adapted to sporadic and unpredictable rainfall and low nutrients as typical of the southern Australian rangelands (Caughley, 1987). The ephemeral vegetation is fast-growing and short-lived but the perennials are typically slow-growing and long-lived (e.g., saltbushes and bluebushes) and have low resilience to degrading impacts (Freudenberger et al., 1997) which may manifest from tourism use.

Our study focused on gorges as they attract intense visitor traffic due to their iconic and scenic values. Moreover, they support high plant species richness due to their propensity to retain water and to provide shady refuges from the drier, surrounding plains. With an average of approximately 70 plant species per site, gorges hosted by far the richest plant community compared to 14 other landform elements that were assessed in a comprehensive, biological survey of the Flinders Ranges (Brandle, 2001). Morton et al. (1995) in their