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Research Paper

Recreational trails are an important cause of fragmentation in endangered urban forests: A case-study from Australia

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HIGHLIGHTS

- Over 5.7% of 829 ha of endangered forest was lost to 46.1 km of recreational trails and their edge effects.
- Fourteen different trail types contributed to this loss most of which were narrow informal bare earth trails.
- The amount of forest lost to trails approaches that of recent urban development.
- In urban remnants with numerous entry points, fragmentation was higher.
- Recreational trails, particularly those unregulated, contribute significantly to the loss and fragmentation of endangered forest remnants.

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ABSTRACT

Remnant urban forests are often popular sites for recreational activities such as hiking, biking and motorised recreation. This can result in the formation of extensive trail networks, fragmenting vegetation into patches separated by modified edge effects and ultimately contributing to the degradation of the ecosystem as a whole. Here we use a GIS approach to assess the extent and diversity of trail-based fragmentation across 17 remnants of endangered urban forest (total area 829 ha, Tall Open Blackbutt Forest) in southeast Queensland, Australia. Fourteen different trail types totalling 46.1 km were mapped with informal biking and hiking trails the most common (57%, 26.5 km). More than 47 ha (5.7%) of forest have been lost to trails and their edge effect, nearly equal to the area recently cleared for urban development. The degree of fragmentation in some remnants was in the same order of magnitude as found for some of the most popular nature-based recreation sites in the world. In localised areas, the fragmentation was particularly severe as a result of wide trails used by motorised recreation, but these trails were generally uncommon across the landscape (5%). Spatial regression revealed that the number of access points per remnant was positively correlated with the degree of fragmentation. We encourage more landscape-scale research into trail-based fragmentation due to its capacity to impact extensive areas of endangered ecosystems. Management should seek to minimise the creation of informal trails by hardening popular routes, instigating stakeholder collaboration and centralising visitor flow.

1. Introduction

Recreational use of natural areas is increasing worldwide (Balmford et al., 2009; Monz, Cole, Leung, & Marion, 2010; Newsome, Moore, & Dowling, 2013). In urban regions, remnant natural areas are important resources providing opportunities for people to engage with nature (Florgård & Forsberg, 2006; Swanwick, Dunnett, & Woolley, 2003). Benefits of this include health, education and social connectedness with outdoor recreation largely viewed as a positive opportunity in areas otherwise lacking natural experiences (Lee & Maheswaran, 2011; Shafer, Lee, & Turner, 2000; Takano, Nakamura, & Watanabe, 2002). Recreational activities and the infrastructure provided for them, however, can also have negative environmental impacts where they are not effectively designed or managed. Despite rapid urbanisation globally, ecological research into the impacts of recreational activities and infrastructure in urban natural areas has lagged in comparison to similar research in protected and wilderness areas (Gaston, 2010).

Trails are among the most common forms of infrastructure provided for, or created by, visitors to many natural areas (Marion &

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Leung, 2001; Marion & Wimpey, 2007). In urban areas, recreational trails planned by management are often bordered by greenways of linear natural or semi-natural vegetation and thus have perceived benefits for community connectivity, varied recreational opportunities, alternative transportation, pollution reduction and environmental protection (Conine, Xiang, Young, & Whitley, 2004; Shafer et al., 2000). In this light, judiciously planned urban trails can provide important benefits for local people and the local environment and extensive planning has been undertaken in such areas to maintain their sustainability (Conine et al., 2004; Gobster & Westphal, 2004). However, trails can become important environmental threats where their construction, maintenance and use are inadequately designed and managed causing a range of direct and indirect impacts on flora, fauna, soils and water (Cole, 2004; Liddle, 1997; Monz, Pickering, & Hadwen, 2013) as well as on the user experience itself (Lynn & Brown, 2003).

The environmental impacts of recreational trails have been comprehensively studied worldwide (Liddle, 1997; Monz et al., 2010). Some of the most well-documented impacts include reduced height and cover of vegetation and changes in composition as a result of trampling (Bernhardt-Römermann et al., 2011; Hill & Pickering, 2009; Pescott & Stewart, 2014; Zhang, Xiang, & Li, 2012), changes in soil compaction and erosion (Farrell & Marion, 2002; Nepal & Nepal, 2004; Olive & Marion, 2009; Wilshire, Nakata, Shipley, & Prestegaard, 1978), increasing nutrient leaching (Godefroid & Koedam, 2004; Müllerová, Vítková, & Vítek, 2011), changes to soil microbiology (Malmivaara-Lämsä et al., 2008), introduction of weed species and pathogens (Barros, Gonnet, & Pickering, 2013; Baret & Strasberg, 2005; Dickens, Gerhardt, & Collinge, 2005; Hemp, 2008) and wildlife disturbance (Marzano & Dandy, 2012; Taylor & Knight, 2003). Other impacts however have received less attention in the literature, particularly large scale processes such as the extent to which trails may cause landscape fragmentation (Leung, Newburger, Jones, Kuhn, & Woiderski, 2011; Pickering, Castley, & Richardt, 2012).

Fragmentation is a process by which once-contiguous areas of habitat are physically separated by human disturbance creating a network of isolated patches (Lindenmayer & Fischer, 2006). Tourism and recreation can contribute to this process through the clearance of vegetation for infrastructure such as resorts and hotels (Fenu, Mattana, & Bacchetta, 2011; Peñas et al., 2011), as well as internal fragmentation of remaining vegetation by trail networks (Pickering et al., 2012). Trail networks are essentially complex linear arteries of disturbance with varying geometry that contribute to fragmentation by decreasing the total amount of undisturbed habitat in a given area (Geneletti, 2004; Leung, Newburger, et al., 2011; Pickering et al., 2012). Moreover they can act as barriers to the movement of native organisms and conduits aiding the dispersal of invasive or feral ones (Benninger-Truax, Vankat, & Schaefer, 1992; Drayton & Primack, 1996). Trails also cause change at varying distances into adjacent vegetation, so-called edge effects, that alter abiotic factors such as light, wind and nutrient levels and hence, important facets of biodiversity such as community structure, function and composition (Pickering et al., 2012). In high use areas with extensive networks of trails, the combined area of trail tread and edge effect may even exceed that of undisturbed habitat (Barros et al., 2013). In urban areas where natural land is already limited by development, recreational trails may exacerbate this problem if their condition and spatial spread is not actively controlled and managed (Pickering et al., 2012). Although formal planned trails do often concentrate damage to limited areas (Marion & Leung, 2001), it is the proliferation of unauthorised, informal trails that is often more responsible for trail-based fragmentation (Leung, Newburger, et al., 2011; Wimpey & Marion, 2011).

This research assesses how recreational trails can contribute to the fragmentation of an endangered remnant forest type in urban areas. Specifically, we assessed trail networks using geographic information systems (GIS) in 17 remnants of an endangered urban forest across 937 km^2 of some of the most highly developed lowland regions of Australia. The aims of the study were to: (1) assess the lineal extent and diversity of recreational trails in these remnants, (2) quantify the degree of trail-based fragmentation across remnants, (3) determine possible human and environmental factors influencing fragmentation in these remnants, and (4) explore possible relationships between these factors.

2. Methods

As a result of land clearing for agriculture and urbanisation along the east coast of Australia, many ecosystems are at high risk of extinction, and now consist of small isolated remnants of once much larger, contiguous ecosystems (Lindenmayer & Fischer, 2006). In the southeast of the state of Queensland, expansion and urban infilling around the two largest cities, Brisbane and the Gold Coast, have resulted in extensive clearing of coastal lowland habitats (Bradshaw, 2012; McAlpine, Spies, Norma, & Peterson, 2007; Wilson, Neldner, & Accad, 2002). Over 100 (64%) of the 156 regional ecosystems in southeast Queensland are threatened (Queensland Government, 2013). Many of these urban remnants are now popular destinations for recreational use (Queensland Government, 2007; Rossi, Pickering, & Byrne, 2012) including the endangered Tall Open Blackbutt Forest ecosystem (Pickering et al., 2012).

This open dry forest is dominated by the tall hardwood *Eucalyptus pilularis* with a sparse shrubby mid-storey and under-storey of graminoids and forbs (Queensland Government, 2013). It is state-listed as 'Endangered' once covering over 10,000 ha prior to urbanisation, but by 2006 only around 20% (2024 ha) remained (State of Queensland, 2013). It is now restricted to a series of around 226 small (circ. 8 ha) scattered remnants within urban areas. Only 14 of these remnants are greater than 20 ha, some of which are protected under national park or conservation area status while the rest are very small with many having been sold to developers.

The forest provides habitat for a number of threatened fauna including the International Union for the Conservation of Nature (IUCN) Red-listed Green-thighed Frog (*Litoria brevipalmata*) and the Queensland state-listed Wallum Froglet (*Crinia tinnula*) and Glossy Black Cockatoo (*Calyptorhynchus lathami*). It also forms a popular destination for recreational use at least in part because most remnants are close to urban populations. The forest has a mixed terrain and generally open structure facilitating trail creation and many of the smaller remnants are unprotected.

2.1. Study region

The study took place within a 937 km^2 region between the Brisbane River and the New South Wales border in southeast Queensland where the majority of extant Tall Open Blackbutt Forest ecosystem remains (Fig. 1). Soils in this region are characterised by coastal Palaeozoic sediments that have been strongly metamorphosed and interbedded with igneous strata (Queensland Government, 2013). The climate is sub-tropical with a mean annual temperature of 21.3 °C and mean annual rainfall of just over 1000 mm (Australian Bureau of Meteorology, 2013). Local topography is largely low-lying, under 100 m a.s.l., interspersed with sedimentary foothills that rise to igneous hinterland ranges in the west of about 1000 m a.s.l. Within this region there are around 226 isolated remnants of Tall Open Blackbutt Forest covering 2024 ha.

2.2. Sampling the lineal extent and diversity of recreational trails

First we identified all suitable remnants for sampling: e.g. all those that were >5 ha and accessible to the public. Of the 226