Impacts of trail networks on rare and threatened plant communities in Australia

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Nature-based tourism and outdoor recreation are increasing worldwide as is the environmental damage associated with these types of use. Trails are one of the most common types of infrastructure provided for tourists by park agencies or created by tourists as they access destinations. These formal and informal visitor trail networks have a range of negative impacts on flora, fauna and ecosystem functioning (Monz et al., 2010a). Where such trails traverse plant communities that are already rare and threatened such impacts are of even greater concern.

Although by definition rare and threatened plant communities have limited distributions, perversely, they can also be particularly attractive tourism and recreational destinations. Firstly, topography contributes to the rarity of some plant communities such as those on mountain summits and headlands or in dune systems, coastal heaths and riparian zones. These topographic attributes also make such sites attractive destinations for enjoying views, rock-climbing, hiking, biking, horse-riding and boating (Monz et al., 2010b). They often become 'honey pot' sites subject to crowding, unregulated use and the creation of informal trails (Wimpey and Marion, 2011). Secondly, urbanization, like topography, may contribute to rarity and high visitation rates. In urban areas there are plant communities that are threatened due to clearing for housing and other urban infrastructure. These remnant communities can receive high visitation both as 'green spaces' for recreational purposes and because they are easy to access by a diverse range of users (Pickering et al., 2010). This means that these communities, already curtailed by external fragmentation, may continue to decline in ecological quality through internal fragmentation resulting from the proliferation and use of formal and informal trails (Newsome and Davies, 2009). Thirdly, in some cases, threatened plant communities can be inherently attractive to tourists, in part due to their rarity, but also due to other qualities such as unusual growth forms (Succulent Karoo, South Africa), mass flowering (Ephemeral herb-rich grasslands, Australia) and age (Ancient Oak woodland, UK). Such qualities can also lead to large visitor loads and the generation of informal trails by users in order to get closer to the unusual plants in these communities, which in turn further degrade their quality and extent.

The damage caused by trail networks to rare and threatened plant communities varies with timing of use (social, seasonal and biological), user behavior, activity type and intensity and the resistance/resilience of the ecosystem. Impacts include the direct effects of trail construction, maintenance and use as well as indirect or spatial effects resulting from the internal fragmentation caused by these trails. Firstly, the formation and use of trails for a wide range of activities directly damages vegetation and these on-trail impacts have been widely studied. Impacts may include reduced vegetation cover, biomass and height as well as a range of abiotic changes including the removal of soil surface cover and alterations to soil biochemistry, light penetration, wind speed, temperature and water flow. Secondly, trails have a range of spatial fragmentation effects such as edge effects that extend various distances from the trail. For example reductions in canopy cover along a trail can increase light, temperature and wind penetration into the adjacent vegetation and hence alter biomass, cover and composition. Trail fragmentation also generates barrier effects, resulting in reduced species and genetic movement across the trail. This can include inhibiting seed dispersal with obvious effects on gene flow and community composition. In contrast, these linear networks can also facilitate dispersal along the trail. This may involve the dispersal of weed seed attached to tourist clothing, bike tires and vehicles, and on the coats of feral animals such as cats, foxes and dogs who also utilize trail networks when hunting. As a result, networks of trails fragment rare and threatened plant communities into both smaller and more degraded patches, altering a range of biotic and abiotic processes and ultimately reducing their capacity to recover from disturbances such as fire, weed invasion and deliberate damage.

Despite the increase in recreation ecology research, the fragmentation effects of trails and trail networks on rare and threatened plant communities have received limited attention in comparison to on-trail trampling and campsite condition studies. The majority of fragmentation research on plants has looked at the effects of external fragmentation imposed by urbanization and agricultural land-use change on forest remnants. This research has concentrated on a range of issues including the effects external fragmentation has on gene flow, microclimate and edge-core gradients. Specifically, research on fragmentation due to tourism and recreation has focused on assessing the effects of infrastructure development and weed invasions, primarily in coastal and montane environments. There is limited work on assessing the internal fragmentation caused by trail networks save for a handful of very recent studies examining fragmentation by trail networks on sub-alpine meadows in Yosemite National Park, USA (Leung and Louie, 2008) and on alpine meadows and steppe vegetation in the Argentinian Andes (Barros and Pickering, proceedings of this conference).

The impacts of trail networks on different Australian threatened plant communities from a variety habitat types will be assessed as part of Ballantyne's postgraduate thesis. This research will assess trail network impacts using patch size and geometry, extent of internal fragmentation (number of sub-patches) and linearity (the ratio of perimeter to area) variables in relation to edge effect gradients. This

includes assessing changes in community composition and soil variables from track center to patch core. Micro-climatic data and trail age along with qualitative information regarding trail condition and use will also be recorded. This research will aim to highlight the importance of fine-scale fragmentation in affecting the composition and long-term quality of plant communities that are already threatened with extinction in Australia.

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