



Too much of a good thing; successful reintroduction leads to overpopulation in a threatened mammal

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ABSTRACT

The failure of broadscale management to protect some threatened species has led to an increase in the use of islands and fenced reserves as translocation sites or foci for intensive threat mitigation. Although highly successful at excluding some threats, these sites may be prone to ecosystem imbalance due to the absence or removal of predators and competitors. We documented population trends and environmental impacts of the burrowing bettong, (*Bettongia lesueur*), a threatened herbivorous macropod reintroduced to a 1400 ha fenced reserve in arid Australia for 17 years after release. The population increased from 30 individuals to an estimated 1532 individuals (1.09 per ha), a density up to ten times higher than wild populations. There was little evidence that population growth was density dependent, the average intrinsic rate of increase (r) was 0.125 and population size was unrelated to rainfall, body condition or reproductive output.

Browse damage on palatable plant species increased, and cover of palatable shrub species decreased, with increased abundance of bettongs. Activity of another reintroduced herbivore, the greater stick-nest rat, (*Leporillus conditor*), declined as bettong abundance increased while a reintroduced species not reliant on herbage was unaffected.

The burrowing bettong has been successfully reintroduced to the Arid Recovery fenced reserve but the positive average intrinsic rate of increase, inflated population density and impacts to resident plant and animal species suggests the population is now overabundant. This is the first documented case of overpopulation of a reintroduced species at a restricted site in Australia, highlighting the importance of preparing overpopulation management plans and considering reintroductions of species from all trophic levels including native predators.

1. Introduction

The number of threatened species continues to rise globally (IUCN, 2017) despite significant advances in conservation management. Methods used to protect threatened species and their habitat include invasive species management, habitat augmentation and population supplementation. In recent years, in situ broadscale management of threatened species has been supplemented by the reintroduction of threatened species to islands or fenced reserves (Long and Robley, 2004; Moseby and Read, 2006; Hayward and Kerley, 2009). Many government and private conservation organisations now rely on these relatively small and bounded areas for successful in situ protection or reintroduction of threatened species. Australia has > 32 fenced reserves larger than 10 ha (Dickman, 2012). Reserves usually protect populations from predation by cats (*Felis catus*) and foxes (*Vulpes vulpes*) and harbour threatened species such as the greater stick-nest rat (*Leporillus*

conditor) (Moseby and Bice, 2004), the eastern barred bandicoot (*Perameles gunnii*) (Arnold et al., 1990), western barred bandicoot (*Perameles bougainville*) (Richards and Short, 2003), burrowing bettong (*Bettongia lesueur*) (Short and Turner, 2000; Moseby et al., 2011) and bridled nail-tailed wallaby (*Onychogalea fraenata*, Hayward et al., 2014). In South Africa, fenced reserves play an important role in the preservation and reintroduction of the African elephant (*Loxodonta africana*) (Slotow et al., 2005) and black rhinoceros (*Diceros bicornis*) (Linklater and Swaisgood, 2008). New Zealand also has a network of fenced reserves protecting native species such as the little spotted kiwi (*Apteryx owenii*) from introduced predators including the stoat and weasel (Burns et al., 2011).

Islands and fenced reserves are often extremely effective at conserving specific fauna species due to their ability to exclude threats (Moseby et al., 2011). However, fenced reserves are costly to erect and maintain (Moseby and Read, 2006; Scofield et al., 2011). Furthermore,

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these sites may also be prone to ecosystem imbalance due to the removal of predators and/or competitors and the physical barriers to dispersal. These restricted sites are essentially closed systems that prevent the natural dispersion of enclosed animals (Slotow et al., 2005) and animals can increase in abundance relative to areas outside fences. In Africa, fenced reserves can lead to over-browsing of vegetation including *Acacias* by elephants (Hoare, 1992; Wiseman et al., 2004; Slotow et al., 2005) and vegetation damage has also been recorded in Australian fenced reserves by introduced native herbivores (Linley et al., 2016; Verdon et al., 2016). Unlike Africa where the carrying capacity of species within fenced reserves can be estimated by comparisons with unfenced populations (Hayward et al., 2007), in Australia there are very few areas where threatened mammal species remain in their natural state, thus rendering it difficult to ascertain natural population densities (Hayward et al., 2014). The absence of prior information on carrying capacity has led to informal debates over whether overpopulation actually exists in fenced reserves in Australia and when a population is considered overabundant.

Overpopulation of herbivores can be defined using a range of criteria including overgrazing. The definition of overgrazing varies according to the aims and outlook of the practitioner (Mysterud, 2006) but from a nature conservationist's perspective overgrazing can be defined as a time when grazing impacts are above a level at which other aspects of biodiversity are threatened (Mysterud, 2006). Overgrazing can lead to significant changes to vegetation (e.g. deer, Cote et al., 2004), causing major shifts in vegetation composition and ultimately stabilising at a level where there is a significant loss of productivity (Van de Koppel and Rietkerk, 2000). In addition to vegetation impacts, overgrazing can also negatively impact the abundance and community composition of a range of other fauna (for review see Foster et al., 2014). Sound conservation management suggests that herbivore abundance within fenced reserves should be managed to avoid impacts to other resident fauna and flora and to maintain ecosystem productivity.

Identifying overpopulation can be difficult in reintroduced populations as many translocated populations go through predictable post-release population changes including an initial establishment and high growth phase followed by a regulation phase where the population declines to carrying capacity and fluctuates in response to environmental conditions (e.g. Griffiths et al., 2017). Furthermore, any damage to vegetation needs to be considered in light of the ecosystem services that reintroduced species provide, including the provision of burrows for other fauna (Read et al., 2008), increased soil carbon and germination levels (James et al., 2010) and control of woody weeds (Noble et al., 2007). However, impacts of reintroduced species on in situ fauna and flora during the high post-release growth phase have the potential to reduce future carrying capacity and cause a legacy of impact that continues into the regulation phase. Despite the potential magnitude of impact, and calls for focussed research on the impacts of reintroduced species on their ecosystems (Armstrong and Seddon, 2008), very little attention has been given to the issue of overpopulation in the context of reintroductions.

Arid Recovery is an ecosystem restoration program located in northern South Australia and is based around a 123 km² feral-proof fenced reserve, the largest on mainland Australia. Feral cats, European rabbits (*Oryctolagus cuniculus*) and red foxes have been eradicated and excluded from 60 km² of this Reserve by a 1.8 m high feral-proof fence (Moseby and Read, 2006). Four locally extinct threatened mammal species have since been successfully reintroduced; the greater stick-nest rat, the burrowing bettong, the greater bilby (*Macrotis lagotis*) and the western barred bandicoot (*Perameles bougainville*). The burrowing bettong is a macropod and, due to the high population growth rates observed in related macropod species (Caughley et al., 1984), our study aimed to determine if the burrowing bettong has become overpopulated inside the Arid Recovery Reserve. In our study, we defined overpopulation as a population density higher than natural wild

populations, high population growth that was not strongly density dependent and induced measurable impacts on the survival, abundance or health of bettongs, flora or other resident fauna species. A previous study by Linley et al. (2017) recorded browsing on a range of plant species within the Arid Recovery Reserve close to bettong warrens but low sample size, an absence of data on long term trends in vegetation cover and relative abundance of bettongs meant that overpopulation could not be confirmed. We monitored long-term abundance, population growth, reproductive output and survival of bettongs as well as changes to the abundance of preferred dietary plant species, general vegetation cover and reintroduced native mammalian competitors. As the Arid Recovery Reserve is located in an arid environment where rainfall is low and erratic, we conducted our study over a long time period to avoid short term rainfall-induced changes in vegetation condition. The potential ecosystem benefits of the burrowing bettong reintroduction on soil, invertebrates or resident in situ fauna were not measured in this study but previous studies have found some ecosystem benefits do exist (Read et al., 2008; James et al., 2010). Long term management options for threatened species within fenced reserves are discussed.

2. Methods

2.1. Study area

The Arid Recovery Reserve is located 20 km north of Roxby Downs (30° 29'S, 136° 53'E) in the arid zone of northern South Australia (Fig. 1). The reserve is surrounded by a wire netting fence which

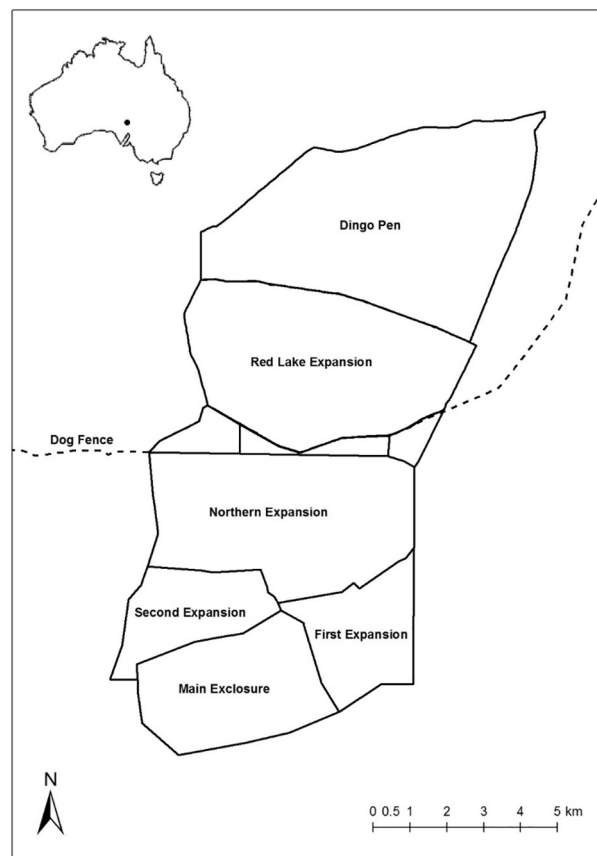


Fig. 1. Map of the Arid Recovery Reserve showing each paddock and the Dog Fence – an exclusion fence that keeps dingoes out of the area to the south of the fence. Burrowing bettongs were first reintroduced into the Main Enclosure and then into the First, Northern and Red Lake expansions. Bettongs naturally dispersed into the Second Expansion from the Northern Expansion by climbing over the short 900 mm high fence that separated the two areas. No bettongs are present in the Dingo Pen.

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