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Does the removal of *Lantana camara* influence eucalypt canopy health, soil nutrients and site occupancy of a despotic species?

Kathryn T.A. Lambert [a,*], Nick Reid [b], Paul G. McDonald [a]

[a] Centre for Behavioural and Physiological Ecology, Zoology, University of New England, Armidale, NSW 2351, Australia
[b] Ecosystem Management, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia

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ABSTRACT

Weed removal experiments provide strong evidence for weed impacts, validating management techniques and demonstrating the means by which biodiversity can be maintained. We examined the effects of removing Lantana (*Lantana camara*) through herbicide application in eucalypt-dominated sclerophyll forest and, then measured the response of soil carbon and nitrogen levels, tree canopy health and the density of Bell Miners (*Manorina melanophrys)* a bird species thought to amplify the negative impacts of Lantana on tree health. Four sites in northern New South Wales were monitored for 2.5 years. We measured Lantana health, (index of height, number of stems and leaves present), soil nutrients (nitrogen and carbon at two depths: 0–10 cm and 20–30 cm), Bell Miner density (using acoustic methods) and eucalypt canopy health (5 trees/quadrat) in six 50 × 50 m quadrats per site ($n = 24$; 12 treated, 12 untreated). Lantana foliage in treated quadrats was sprayed with glyphosate. Lantana showed significant reductions in health within 6 months of treatment and remained in a debilitated state compared to control quadrats for the duration of the project. Despite this, soil nutrients, Bell Miner density and canopy health did not differ between intact and treated quadrats for up to 2 years after treatment. The lack of impact on soil nutrient level or tree canopy health despite large changes in Lantana abundance in treatment sites was unexpected, and may indicate that Lantana is unimportant in shaping these measures. However, a more likely explanation is that longer term monitoring is required before the full impact of Lantana removal can be detected. The level of habitat modification following herbicide application was insufficient to stimulate relocation of Bell Miner colonies. Further investigation is required into how Lantana removal affects Bell Miner density, soil nutrient levels and canopy health in the medium to long term.

1. Introduction

Invasive plants threaten the integrity and function of numerous native ecosystems around the world. Competition for resources by invasive plants can directly affect ecosystem composition and structure (Wiser et al., 1998) and can also alter soil quality, water availability and fire regimes (Brooks et al., 2004). Invasive plants may adversely affect native plant species diversity by displacing mature vegetation or limiting juvenile recruitment (Yurkonis et al., 2005). Gooden et al. (2009) showed that invasion by Lantana (*Lantana camara*) reduced the establishment of *Eucalyptus* and native understorey species in wet schlerophyll forests. The mechanisms by which Lantana limits native species recruitment include allelopathy (Duggin and Gentle, 1998), and competition for light, nutrients and space (Sharma et al., 2003; Totland et al., 2005; Sharma and Raghubanshi, 2009; Carrion-Tacuri et al., 2011; Osunkoya and Perrett, 2011). Recruitment limitation may result in fewer resident juvenile plants in weed-invaded vegetation relative to non-invaded areas (Gooden et al., 2009; Sundaram and Hiremath, 2012).

Invasive plant removal studies provide strong evidence for invasive plant impacts on native species, since changes in species diversity and abundance following invasive plant removal can be directly measured (Turner and Virtue, 2006). Invasive plant impact mechanisms such as recruitment limitation can also be indicated by invasive plant removal studies by monitoring demographic changes in native species populations following weed control (D'Antonio et al., 1998). However, residual invader effects, such as altered soil nutrient concentrations, can influence the response of native species to weed removal (Mason et al., 2007).

Invasive plant control for biodiversity conservation aims to improve diversity by mitigating the adverse effects of invading plants, reducing their competitive effects and facilitating the

* Corresponding author.
E-mail address: kathryn.ta.lambert@gmail.com (K.T.A. Lambert).

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rehabilitation of native vegetation (Mason and French, 2007). The removal of invasive plants has led to practical increases in species diversity in some areas, such as removal of the exotic perennial grass Coolatai grass (*Hyparrhenia hirta)* (Chejara, 2006). Positive outcomes following invasive plant removal are not guaranteed, however. Removal of Bridal Creeper (*Asparagus asparagoides)* led to plant biodiversity decline, due possibly to the influence of dead tubers below the surface on seedling establishment, the growth of a secondary invasive plant after removal and lack of suitable environmental conditions (Turner and Virtue, 2006). Additionally, invasive plant control can significantly disturb native communities, influencing the composition of regenerating native plants and potentially facilitating secondary plant invasion (Mason and French, 2007). Therefore, it is necessary to investigate the effects of the plant invader and the effects of its control on the factors that influence native vegetation growth such as soil nutrient pools, competition with canopy species and invasive plant influences on biodiversity where invasive plant removal has been advocated to promote community recovery.

We investigated the effects of Lantana invasion and treatment on wet sclerophyll forest where eucalypt dieback was present. Lantana is an exotic thicket-forming shrub that invades wet sclerophyll forest and rainforest margins in mainland eastern Australia (Swarbrick et al., 1998). Dense monospecific thickets often dominate the understorey, suggesting that the species reduces native vascular plant diversity (Duggin and Gentle, 1998). A positive feedback loop can occur where an invasive plant creates habitat favourable for its own regeneration (Buckley et al., 2007). Plants that prefer highly disturbed habitats with high light availability often generate positive feedback loops, including Lantana (Hiremath and Sundaram, 2005). The larger the canopy gap, the more persistent long-term invasions become (Totland et al., 2005). Originally from Central and South America, Lantana was introduced into Australia as an ornamental plant in the 1840s (DNRME 2004). Since then, Lantana has invaded 4 million hectares of forest and private land in eastern Australia (Parsons and Cuthbertson, 2001), and is listed as a Weed of National Significance (ARMCANZ, 2000).

Despite its negative effect on plant biodiversity, Lantana is thought to increase nesting habitat for the Bell Miner (*Manorina melanophrys*) which is suggested to be one of the causes of eucalypt dieback in wet sclerophyll forest in eastern Australia (Loyn et al., 1983). Lantana is part of a positive feedback loop, as it provides nesting habitat for the Bell Miner and is thought to increase soil nitrogen levels and *Eucalyptus* leaf nitrogen levels, which in turn make leaves more attractive to psyllids, herbivorous insects that produce a lerp, a waxy carbohydrate-rich covering that Bell Miners utilise as food (Haythorpe and McDonald, 2010). Bell Miners appear to require nesting habitat and lerp to inhabit an area (Dare et al., 2008a). Once Bell Miners colonise an area, an infestation of psyllids is thought to follow, as Bell Miners aggressively exclude all other avian species that prey on psyllids and lerp (Clarke and Schedvin, 1999; Dare et al., 2008b; Leseberg et al., 2014). Previous studies have shown that the regeneration and revegetation of native plant communities is possible through Lantana control (Macleay, 2004; Cummings et al., 2007; Gooden et al., 2009). However, field-based evidence linking Lantana, reduced understorey diversity, changes in soil nutrients, reduced canopy health and high Bell Miner density is scarce, discouraging effective Lantana and dieback management (Wardell-Johnson et al., 2005).

We assessed the responses of Lantana, canopy health, Bell Miner density, soil total carbon, soil total nitrogen and soil carbon–nitrogen ratio after the treatment of Lantana – infested wet sclerophyll forest in northern New South Wales. The effects of Lantana treatment on eucalypt dieback were determined by comparing the growth rate of Lantana, changes in soil chemistry, Bell Miner density and tree canopy health over a 2.5 – year period. Specifically, we asked, does Lantana treatment: (1) reduce Lantana health and if so over what time-scale; (2) affect soil chemistry properties (total nitrogen, total carbon and carbon–nitrogen ratio) and (3) influence Bell Miner density? We used an information theoretic approach to establish whether (4) ecological factors that appeared to be the primary influences on eucalypt canopy health.

2. Methods

2.1. Study area and habitat

The study was conducted in four sites in northern NSW, from May 2012 to October 2014: (1) Oxley Wild Rivers National Park (30°48.730′S; 152°04.052′E), near Armidale; (2) Kippara State Forest (31°10.918′S; 152°34.913′E), near Port Macquarie; (3) Toonumbar National Park (28°31.030′S; 152°46.129′E), and (4) Creek's Bend (28°34.012′S; 152°45.329′E), a private property, both near Kyogle. Creek's Bend and Toonumbar National Park have subtropical climates; Oxley Wild Rivers National Park has a temperate climate and Kippara State Forest is intermediate. The sites near Kyogle and Kippara State Forest have average temperatures ranging from 6.5 °C and 5.4 °C in winter, respectively to 29.9 °C and 27.8 °C in summer respectively. The corresponding temperatures in Oxley Wild Rivers National Park were −0.4 °C and 26.7 °C (Bureau of Meteorology, 2013). All sites experienced rainfall deficits in comparison to mean historical rainfall between October 2012 and January 2015 (Bureau of Meteorology, 2015).

Native vegetation in all sites was wet or dry sclerophyll forest, categorised by a tall open eucalypt canopy with an understorey of Lantana and various rainforest and sclerophyll shrub species and grasses. Sclerophyll forest in each study area had been extensively thinned or cleared by logging or for farming but had since been managed for restoration (Somerville et al., 2011). During periods of disturbance, Lantana had invaded the sites and had since became dominant in forest openings with an incomplete canopy cover.

Lantana treatment occurred at Creek's Bend in May 2012, followed by Toonumbar National Park in August 2012. The two other sites were treated in 2013: Oxley Wild Rivers National Park in February and Kippara State Forest in September. Monitoring was undertaken seasonally (i.e. at 3-monthly intervals) prior to and after treatment at each site. Treatments always occurred when plants were healthy with high numbers of leaves. Lantana responded in all sites with leaves dropping and plants dying.

2.2. Field methods

Before treatment, six 50 × 50 m quadrats (three treated with herbicide and three untreated) were measured at each site. As Bell Miner 'tink' calls can be monitored over 50 m, this distance was used to measure Bell Miner density (Lambert and McDonald, 2014). Quadrats contained Bell Miners, an understorey of Lantana and evidence of dieback in the canopy, such as reduction in leaf cover along with epicormic growth and branch death (Stone et al., 1995; Fig. 1). Control quadrats remained untreated throughout the study while treated quadrats were sprayed with glyphosate (Somerville et al., 2011). Quadrats were randomly placed throughout each site, at least 30 m apart in the forest interior and away from cleared land. All quadrats had a 30 m buffer zone of similar vegetation.

Within each quadrat, five points, each 25 m apart, were assessed, one in each of the four cardinal directions and another in the centre of the quadrat. As branch and foliage density are indicators of healthy Lantana growth (Totland et al., 2005), the occurrence of Lantana was recorded by noting the number of stems or