A pilot project testing the effectiveness of three weed control methods on the removal of *Lantana camara* in Forty Mile Scrub National Park, Queensland, Australia

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Summary

*Lantana (Lantana camara L.)* poses a serious risk to Australian ecosystems through its reduction in biodiversity (Humphries *et al.* 1991), loss of agricultural land (Sinden *et al.* 2004) and toxicity to native animals and livestock (Oosterhout 2004). Its high resilience following disturbance and tolerance of a variety of environmental conditions enables this weed to cover a variety of Australian habitats (Oosterhout 2004). Lantana has also been implicated with an increase in the intensity of forest fires by significantly increasing the biomass available to fuel fires (Fensham *et al.* 1994; Berry *et al.* 2011). These fires provide space for further lantana colonization, creating a fire-lantana-positive feedback cycle (Fensham *et al.* 1994). Australian dry rainforest ecosystems are particularly vulnerable to lantana invasion, which can inhibit native seedling growth, suppress native flora, negatively impact fauna (Gentle & Duggin 1997) and modify fuel loads (Fensham *et al.* 1994; Berry *et al.* 2011).

Weed control to manage existing infestations of lantana has varied considerably in form, function and success. Manual techniques, including pulling, grubbing and cutting, have been successful, but are extremely time and labour intensive (Tu *et al.* 2001). Herbicides have been used to treat large thickets, but depending on active constituents, application rates and methods, costs and climate conditions, these differ in their effectiveness (e.g. Somerville *et al.* 2011). We report a pilot project comparing effectiveness of three lantana control techniques (hand pulling, a foliar spray herbicide and a basal bark herbicide) in removing lantana and their success in reducing lantana fuel loads. The foliar spray herbicide was the most effective in killing lantana, while manual pulling resulted in the largest decrease in fuel height.

We suggest that foliar spraying will be most efficient for combating large infestations of lantana, while hand pulling techniques are recommended for creating firebreaks or when minimizing damage to native species is paramount.

Introduction

*Lantana (Lantana camara L.)* poses a serious threat to the biodiversity of the dry rainforest vegetation at Forty Mile Scrub National Park, Queensland, Australia, by outcompeting native species and increasing vulnerability to fire. This pilot study tests the effectiveness of three weed control methods (hand pulling, a glyphosate-based foliar spray herbicide and a picloram- and triclopyr-based basal bark herbicide) in removing lantana and their success in reducing lantana fuel loads. The foliar spray herbicide was the most effective in killing lantana, while manual pulling resulted in the largest decrease in fuel height.

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References


cide) on the heavily invaded dry rainforest vegetation at Forty Mile Scrub National Park, Queensland, Australia. We evaluated these techniques for their effectiveness in removing lantana and reducing fuel loads. We also propose a lantana control programme for Forty Mile Scrub NP by integrating these results with a detailed cost–benefit analysis.

Methods

Study area

The study was conducted at Forty Mile Scrub National Park (18° 08′ S 144° 50′ E), a 6300 ha park conserving extensive tracts of dry rainforest. In 1993, 73% of the dry rainforest in the park had densities of lantana greater than 5000 plants per ha (Fensham et al. 1994).

Treatment procedure

Queensland Parks and Wildlife Service (QPWS) applied all three treatments in March 2008 (wet season) on 50 × 50 m plots, with a fourth plot left untreated. Hand pulling (Treatment 1) was conducted by pulling every identifiable lantana plant in the designated plot. Foliar herbicide (Treatment 2), with the active constituent glyphosate at 9% concentration, was administered in the plot to the foliage of lantana with an effort to target only lantana. Basal bark spray (Treatment 3) was administered to the base of lantana plants from the ground to 30 cm up the stem (active ingredients: picloram and triclopyr, 17% in diesel; Clark et al. 2006).

One month later (April 2008), measurements were taken from four randomly selected 5 × 5 m subplots within each plot. The height of the highest lantana individual was recorded at 1-m intervals around the perimeter and along the diagonals of the subplot. Next, all twig biomass of lantana was collected from within 1 m³ frames constructed at two corners of the subplot. All live lantana plants within the plot were counted and placed into height categories: 5–30, 30–100 and 100 cm and above. Finally, the number of dead lantana plants in each herbicide plot was recorded and organized into the same size designations.

Analysis

One-way ANOVA was used to evaluate differences between treatments, and Tukey’s HSD pairwise post hoc tests were used to investigate significant relationships. All data were tested for normality and homogeneity of variances, and Kruskal–Wallis tests were used when data violated these assumptions (Table S1). Analyses were conducted using the computer program JMP 7.0 SAS Institute Inc., Cary, NC, USA.

It is important to acknowledge the existence of ‘pseudo-replication’ inherent in this study (Hurlbert 1984). The replicated treatment plots in the experimental design are, in fact, replicated samples of the same treatment plot and thus are pseudoreplicates. However, this study still provides useful insights on the effectiveness of these different lantana control measures and can inform future management within Forty Mile Scrub National Park.

Figure 1. Mean number of live lantana growing in each treatment plot organized into three size categories: 5–30, 30–100 and >100 cm; and total number of live lantana. Bars within the same size category that do not share the same letter are significantly different (Tukey’s pairwise HSD, \( P < 0.05 \), Error bars = +1 standard error of mean).
Results

There was a significantly higher total number of live lantana plants counted in the control plots compared to both the pulling and foliar spray plots (Fig. 1; Table S1). No difference was found between the number of lantana plants in the basal bark plots and any of the other plots. The foliar spray plots showed significantly more dead lantana plants than the basal bark plots (Fig. 1; Table S1).

There was a significant difference in the average fuel load height between the control and each of the treatment methods, as well as between the herbicide treatments and the pulling plots (Table S1; Fig. S1). Regression analyses found a significant positive correlation between the mean corner fuel height of the plots and the corresponding total corner biomass (Fig. S2).

Discussion

Effectiveness of lantana removal

While all three treatments reduced the counts of lantana, only the foliar spray and pulling plots had significantly fewer lantana than the control, perhaps due to the delayed response of the basal bark spray. This treatment requires an estimated 9–12 weeks for the death of the plant following application (Clark et al. 2006), and thus, plants counted as live during data collection may have died in subsequent weeks.

The significantly higher number of smaller lantana plants in the pulling plot compared to the foliar spray plot may reflect the difficulty of correctly locating, identifying and removing very small lantana seedlings. Alternatively, the weed control treatments applied in this study may have differential effects on regrowth, potentially affecting plant counts in our post-treatment survey. A foliar spray herbicide leaves targeted plants rooted and maintains canopy cover and enters the seed bank inhibiting the growth of seedlings (Tu et al. 2001). In the pulling treatment, however, plants are removed completely and the dense subcanopy of lantana is entirely eliminated. This leaves behind a patch of soil that has ample sunlight, an abundant lantana seed bank and few other competing species, potentially stimulating fast regrowth of newly germinated seedlings and thereby increasing the small lantana counts in the pulling plot.

Effect on the fuel load

All three treatments resulted in significantly decreased fuel height, with the pulling method the most effective. The two herbicide treatments showed no significant differences to each other, as these treatments do not include any mechanical means to remove the dead plants from the ground.

Regression analyses found a significant positive correlation between the mean fuel height of lantana and nearby lantana biomass, justifying fuel height as an appropriate surrogate measure of lantana biomass in the plots. Therefore, we suggest that all three treatments considerably decrease the biomass of lantana, with the largest of such decreases coming with the pulling method. This is an important effect in an ecosystem where, in the absence of lantana, fires are rare due to a lack of fuel at the ground level (Fensham et al. 1994) and effective fire risk management involves the reduction in the fuel load in this stratum.

Forty mile scrub NP Lantana camara management plan

A principle limiting factor in the control of harmful weeds in ecosystems is the financial investment that land managers are willing to make; inadequate funding is often the primary contributing factor to the rapid dispersal of weeds (Sinden et al. 2004). The estimated material cost of the basal bark herbicide treatment used here was $0.67/L, while the foliar spray herbicide was $0.08/L. Costs of manual weed removal were calculated using pulling rates and 2008 wages of the QPWS staff; it is estimated to cost $1,920 for one person to remove a hectare of heavily infested lantana. To clear the same amount of lantana, it would cost QPWS $128 to use the foliar spray and $840 to use the basal bark method. In addition to financial considerations, preserving biological diversity is vital at Forty Mile Scrub NP due to the magnitude and intensity of the invasion in the park. QPWS employees counted over 10,200 plants pulled in the hand pulling plot (Simon Thompson, QPWS, personal communication), which corresponds with a density of over 40,000 plants per hectare. As such, large amounts of lantana need to be removed at an affordable cost to minimize its impact on the environment while minimizing the financial burden on park managers.

Our preliminary results suggest that the foliar spray is the most effective and economical, saving QPWS $712 per ha compared to basal barking. If all of the approximately 1,990 ha infested were treated, this would save QPWS up to $1,416,880 in operating costs compared to basal barking.

The pulling technique was very effective at removing lantana and reducing fuel loads. However, the large amount of time required for this process (≈64 person hours per ha of heavily infested terrain) significantly inflates the financial cost for large-scale projects. We propose that hand pulling methods be focused primarily along scenic paths and edge areas vulnerable to fire invasion to create a fire buffer zone from surrounding ecosystems (Fensham et al. 1994). Follow-up control must include the close monitoring of the treated areas to ensure native species re-establishment instead of lantana re-colonization. Our proposal mirrors the guidelines laid out by the Lantana Best Practice Manual and Decision Support Tool (Stock et al. 2009), which calls for prioritization of
management areas and an integration of multiple control methods and follow-up monitoring.

Lantana poses a threat to the biodiversity of a range of Australian ecosystems, and appropriate action must be taken to ensure that this threat is reduced. We suggest that foliar spray herbicides most effectively remove lantana and thus may be most efficient in combating large-scale invasions in dry rainforests, while hand pulling techniques may be most beneficial in ecologically sensitive areas or to establish firebreaks around areas threatened by changed fire regimes. Following effective weed removal, cost-effective management of dry rainforest will depend on close monitoring of susceptible areas and quick treatment responses to lantana along park borders to minimize the magnitude of invasions. Ultimately, frequent monitoring and quick treatment will be more cost-effective than allowing areas to become infested at the densities of our study area.

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References

Supporting Information
Additional Supporting Information may be found in the online version of this article:
Figure S1. Mean lantana fuel height found in each treatment plot.
Figure S2. Regression analysis of mean total lantana biomass taken from cubic meter corner sections in each treatment plot against mean corner fuel height ($y = 3.1355x + 159.37, r^2 = 0.3218, P < 0.001$).
Table S1. Results of one-way analysis of variance comparing Lantana camara treatment methods to a range of variables.