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Restoring *Lantana camara* Invaded Tropical Deciduous Forest:
The Response of Native Plant Regeneration to two Common *Lantana* Removal Practices

Lantana camara (hereafter, Lantana), a pantropical invasive species, has become widespread across India. Lantana forms dense thickets in the understory of deciduous forests, adversely affecting regeneration of native vegetation and habitat for wildlife. Lantana removal is now an integral part of protected area management in India. We tested the relative efficacy of two Lantana removal techniques—cutting and burning, and uprooting—commonly employed by forest managers. Our objectives were a) to see which technique resulted in better native plant recovery post-Lantana removal; and b) to evaluate the mechanisms underpinning Lantana's success in these forests. The two techniques did not differ greatly in post-removal recovery of native vegetation. However, there was a marked difference in the post-removal recovery of Lantana. Lantana in the uprooted plots was significantly denser than in the cut-and-burnt plots, making the latter the more effective of the removal techniques. Given the numerical dominance of Lantana seeds in the soil, and their wide dispersal, no Lantana removal is likely to be effective without post-removal monitoring and weeding. We also recommend post-removal planting of species that can pre-empt Lantana re-colonization, and respond positively to disturbances like fire and grazing, that are known to promote Lantana's spread.

Key words: Community composition, Restoration, India, Invasive species, Regeneration.

Lantana camara removal and restoration.

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Introduction

It is widely accepted that invasive species can alter community structure and composition (Hejda *et al.,* 2009; Vonshak *et al.*, 2010), transform ecosystem processes (Rossiter-Rachor *et al.*, 2009), and affect the supply of ecosystem services(Vila *et al.*, 2010). As a result, the development of effective techniques to remove or control invasive species is now a priority for scientists and managers worldwide (D'Antonio and Meyerson, 2002; D'Antonio *et al.*, 2004). So much so, that Hulme (2006) has suggested the application of ecological knowledge to invasive species management is possibly the best repayment for public investment in ecological research.

Invasive species removal does not always guarantee the restoration of native biological diversity. While in some cases removal has led to an increase in native species diversity, *e.g.*, *Mimosa pigra* management with a combination of herbicide, mechanical methods, fire, and biological control (Paynter and Flanagan, 2004), in other cases removal has resulted in a decrease in native species diversity, *e.g.*, the post-fire use of herbicides in the control of *Asparagus asparagoides* (Turner and Virtue, 2009). It is thus important to understand the site-specific response of native communities to different invasive species removal or control techniques (Flory and Clay, 2009).

The outcome of invasive species removal can also be a function of the method employed. For instance, a common technique—cutting and burning above-ground biomass—is a practical way of clearing invasive

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species but could kill seeds in the soil seed-bank, jeopardizing post-removal regeneration; burning could also kill mycorrhizal spores in the soil, rendering a site hostile for colonization by all but non-mycorrhizal graminoids (Holmes *et al.,* 2000). Uprooting is another common technique. Uprooting and removing invasive species biomass could lower the potential amount of phytotoxins in the soil, enabling post-removal colonization by species that would be inhibited by allelopathic invaders (Gentle and Duggin, 1997). Additionally, uprooting can bring buried seeds to the soil surface and accelerate colonization, assuming the seed-bank is not saturated with seeds of the invader, *e.g.*, in the case of *Mimosa pigra (*Lonsdale *et al*., 1988*)*.

Experimental tests of invasive species removal can yield two types of information. First, they can help identify optimal management interventions (a management goal). Second, they could provide insights into the mechanisms underlying invasive species success (a theoretical goal), whether direct competition for available resources (Funk and Vitousek, 2007), non-resource mediated interference such as allelopathy (Gentle and Duggin, 1997), altered nutrient cycling (Vitousek and Walker, 1989), or changed ecosystem dynamics (D'Antonio and Vitousek, 1992; Rossiter-Rachor *et al*., 2009). The direct effects of invasive species may be alleviated by invasive species removal; the indirect effects may require other post-removal interventions (Yelenik *et al*., 2004).

Lantana camara L. (Verbenaceae; hereafter *Lantana*), now a pan-tropical invasive species, is a large shrub native to Central and South America. It was first introduced to India in 1809 as an ornamental and hedge plant (Kannan *et al*., 2013). Today it is widespread, ranging from tropical deciduous forests in South India to subtropical forests of the Himalayas in the North (Hiremath and Sundaram, 2005). It occurs in a variety of habitats forming dense thickets, suppressing native regeneration, and altering understory structure and composition (Prasad, 2010; Sharma and Raghubanshi 2007; Sundaram and Hiremath, 2012). Furthermore, *Lantana* affects the cycling of soil nitrogen (Sharma and Raghubanshi, 2009), and alters fuel characteristics, affecting fire regimes (Berry *et al*., 2011; Tireman, 1916).

The earliest records of systematic *Lantana* management in South and Central India date from the end of the 19th century (Anon. 1895). There are other later references to *Lantana* removal in Central India (Sawarkar, 1984). More recently Babu *et al*. (2009) and Love *et al*. (2009) reported a successful new *Lantana* removal technique, the cut-rootstock method, from Corbett National Park, North India.

In many protected areas, however, uprooting, or cutting-and-burning, are still the most prevalent *Lantana* control methods in use. We tested the relative efficacy of these two *Lantana* removal methods employed by forest managers. (In recent years the cut-rootstock technique has also been attempted at our study site, but our experiment preceded this). We compared post-removal regeneration in plots subjected to the two removal techniques with control plots that were *Lantana*-invaded, and control plots where *Lantana* was absent. Our objectives were to (a) evaluate the relative efficacy of the two *Lantana*-removal methods in terms of recovery of native understory plants (or the less desirable alternative: re-colonization by *Lantana*), and (b) evaluate the mechanisms underlying *Lantana's* success.

Material and Methods

Study area

We conducted this study in the Biligiri Rangaswamy Temple Wildlife Sanctuary, now Tiger Reserve (hereafter, BRT), in Karnataka, South India. The sanctuary is part of the Western Ghats biodiversity hotspot. The 540 km^2 sanctuary is located between 11º47' - 12º09' N latitude and 77º-77º16' E longitude. The terrain is hilly, and elevation ranges from 600-1800 m. Annual rainfall is spatially variable, ranging from ca 900-1750 mm along an altitudinal gradient. Most of this rain is received during June-September, with a second brief rainy period between October-December; January-April is a pronounced dry season. The mean annual temperature is 25.3ºC and ranges from 11ºC in winter to 42ºC in summer (Murali *et al.,*1998). Soils are well-drained gravelly clays classified as typic ustropepts (Anon., 1996).

The area is rich in plant biodiversity, with at least 1400 species of angiosperms (Kammathy *et al*., 1967). Plant nomenclature used here follows Kammathy *et al*. (1967). Several forest types occur within BRT: dry scrub-savannah, dry-deciduous and moist-deciduous forests, and evergreen and shola (montane) forests. The scrub savannah and deciduous forests constitute approximately 90% of the study area (Ganesan and Setty, 2004) and are extensively invaded by *Lantana (*Sundaram and Hiremath, 2012*)*.

Management plans first mention the presence of *Lantana* in BRT in 1934 (Ranganathan, 1934). Elders of the indigenous *Soliga* community recall it from the 1970s, suggesting that it probably started to become abundant then. The early 1970s coincide with BRT's notification as a wildlife sanctuary. The *Soligas*, who had been shifting cultivators, were moved out of the sanctuary and given permanent settlements. The abandoned village clearings were planted with *Eucalyptus* spp. (eucalyptus) and *Grevillea robusta* (silver oak). It is possible that these clearings provided *Lantana* a suitable habitat to colonize. In just the past decade, the extent of *Lantana* has practically doubled (Sundaram and Hiremath, 2012), making removal and restoration a management priority.

Lantana removal and native species regeneration

On a vegetation map of BRT (Ramesh and Menon, 1997), we randomly selected 5 replicate sites within *Lantana*-invaded moist deciduous forest ensuring that sites were at least 1 km apart. The sites were similar in terms of extent of *Lantana* in the understory (mean [sd] aboveground biomass of *Lantana* across sites was 19.7 [3.8] kg/m^2, more than triple the aboveground *Lantana* biomass of 5.5 kg/m^2 reported from neighbouring Bandipur Tiger Reserve (Prasad, 2012); figures denote dry weight).

At each site we established four plots (25×25 m), three in *Lantana*-invaded vegetation and one in understory that was not invaded. In one of the three invaded plots we cut all *Lantana*, left it to dry for 6 weeks, and burnt it ('Burnt'). Within another of the invaded plots we uprooted and removed all *Lantana* ('Uprooted'). The third *Lantana*-invaded plot served as a *Lantana* control ('Invaded'); the plot with no *Lantana* served as a *Lantana*-free control ('Uninvaded'). All measurements were made from within the 20x20 m core of each plot, leaving an outer 2.5 m buffer. *Lantana* removal was performed only once at the beginning of the study in January 2006.

Within the 20x20 m core of each plot we established three subplots (3×3 m) to monitor vegetation regeneration. The first census of regenerating vegetation was immediately after *Lantana* removal in February 2006; subsequent censuses were in April and June 2006, April 2007, and April 2008. June marks a pulse of new regeneration immediately following the onset of rain, while April marks the end of the dry season, when the soil is at its driest and the greatest die-back and mortality of young desiccation-prone vegetation probably occurs (Lieberman and Mingguang, 1992). We were unable to repeat censuses in June owing to restriction of entry into BRT during June-July in subsequent years.

At each census, we counted and identified all individuals emerging and classified them as resprouts or seedlings. If we could not identify a species we assigned it a lifeform label, *i.e.,* shrub, herb, climber (vines and lianas) or tree. By the last census (April 2008) it became difficult to distinguish resprouts from seedlings, and we recorded only total numbers of individuals regenerating.

Analyses

We pooled vegetation data from the sub-plots to obtain plot-level data for each treatment. To test whether *Lantana* removal treatment had an effect on mean regeneration we conducted a two-way Analysis of Variance (ANOVA) on the abundance of regenerating individuals of different lifeforms of native species, and of *Lantana,* across the different treatments. Data analyzed were from June 2006 and April 2008. The June 2006 census followed a pulse of regeneration in the cleared sites during the first rains; April 2008 was the last census >2 years after *Lantana* removal. April is peak dry season, so regeneration recorded may underestimate actual regeneration, given drought-induced die back. We conducted this analysis in R version 2.15.2 (R Development Core Team, 2012).

We used species rarefaction curves to compare total species richness among the four treatments by the end of the experiment (*i.e.*, in April 2008). Species richness can be an artefact of the number of individuals encountered. The use of species rarefaction curves helps to overcome this potential difficulty and enables meaningful comparisons across treatments varying in overall sample size (Gotelli and Colwell, 2001).

To determine whether *Lantana* removal technique affects native community composition we used nonmetric Multi-Dimensional Scaling (nMDS) and Analyses of Similarity (ANOSIM). We plotted nMDS ordinations on Bray-Curtis dissimilarity matrices. We also used these matrices in ANOSIM to determine whether native community dissimilarity between plots was related to *Lantana* removal. The higher the Global-R value of a pair-wise ANOSIM test, the greater the dissimilarity between the plots in the pair. We used PRIMER (Primer E-Ltd) for nMDS and ANOSIM.

Results and Discussion

Altogether, we counted seedlings and resprouts of 237 native species across the four treatments, over the 2 years following *Lantana* removal. These comprised 53 trees, 69 shrubs, 52 herbs, and 54 climbers (vines and lianas); we also encountered a bamboo, a palm, 2 orchids and 5 ferns. Ninety-nine species could only be identified by local name, and 18 could not be identified. The latter were mainly shrubs and climbers.

Of the total only four species were non-native. Apart from *Lantana*, these comprised *Ageratina adenophora*, *Chromolaena odorata*, and *Parthenium hysterophorus.*

Abundance

Following the onset of rains (June 2006), we observed a pulse of regeneration. Overall, there was a significant treatment effect ($p < 0.001$; Fig. 1a) with regenerating individuals in the *Lantana*-removal treatments being more abundant than in the controls. There was also a significant effect of lifeform ($p < 0.01$), and a significant lifeform-treatment interaction ($p < 0.001$). Within treatments, the abundance of regenerating individuals of different lifeforms varied widely, but these differences were not all significant. The only exception to this overall pattern was in the Uninvaded plots, where trees, followed closely by shrubs, dominated regenerating vegetation, with very few herb and *Lantana* individuals.

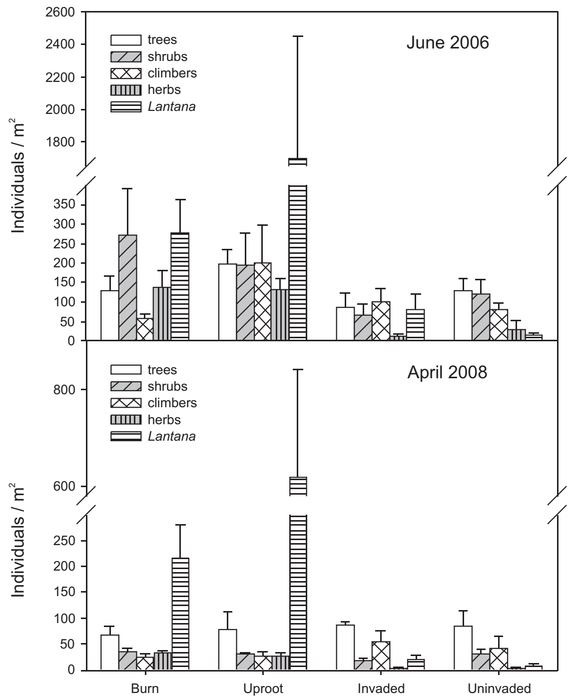

Fig. 1: Density of regenerating individuals (seedlings + resprouts) in *Lantana* removal plots (Burnt, Uprooted) and from controls (Invaded, Uninvaded) at two different times since removal (a) in June 2006 and (b) in April 2008.

Table 1: Analyses of Similarity conducted on Bray-Curtis dissimilarity indices between pairs of plots across 4 treatments: Burnt, Uprooted, Invaded, and Uninvaded. Dissimilarities were calculated for numbers of individuals in each native genus for (a) all lifeforms, (b) trees, (c) shrubs and (d) climbers for April 2008.

Vegetation	Effect	Groups	Global R	P	Similarity
(a) All native	Overall		0.13	0.001	
	Pairwise	Burn-Uproot	-0.008	0.553	Greatest
		Burn-Invaded	0.246	0.001	
		Burn-Uninvaded	0.253	0.001	Least
		Uproot-Invaded	0.13	0.001	
		Uproot-Uninvaded	0.174	0.001	
		Invaded-Uninvaded	0.005	0.34	
(b) Trees	Overall		0.058	0.005	
	Pairwise	Burn-Uproot	-0.035	0.894	Greatest
		Burn-Invaded	0.121	0.005	Least
		Burn-Uninvaded	0.117	0.008	
		Uproot-Invaded	0.082	0.008	
		Uproot-Uninvaded	0.076	0.012	
		Invaded-Uninvaded	-0.016	0.676	
(c) Shrubs	Overall		0.179	0.001	
	Pairwise	Burn-Uproot	0.027	0.178	
		Burn-Invaded	0.431	0.001	Least
		Burn-Uninvaded	0.351	0.001	
		Uproot-Invaded	0.172	0.001	
		Uproot-Uninvaded	0.149	0.001	
		Invaded-Uninvaded	0.01	0.319	Greatest
(d) Climbers	Overall		1.06	0.001	
	Pairwise	Burn-Uproot	0.075	0.035	
		Burn-Invaded	0.031	0.161	
		Burn-Uninvaded	0.173	0.001	
		Uproot-Invaded	0.062	0.023	
		Uproot-Uninvaded	0.265	0.001	Least
		Invaded-Uninvaded	0.03	0.109	Greatest

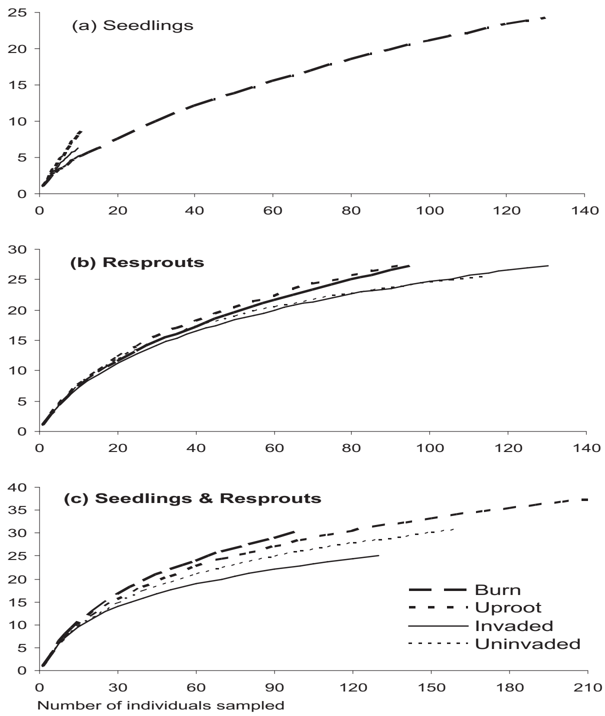

Fig. 2: Species rarefaction curves for (a) seedlings, (b) resprouts, and (c) both seedlings and resprouts, of all native trees, shrubs and climbers in April 2008 in *Lantana*-removal plots (Burnt, Uprooted) and the controls (Invaded, Uninvaded).

The relative differences among treatments persisted 2 years after *Lantana* removals. In April 2008 the *Lantana* removal treatments still differed significantly from the control treatments ($p < 0.001$; Fig. 1b). Likewise, the effect of lifeform ($p << 0.00001$) and the lifeform-treatment interaction ($p < 0.001$) remained significant in April 2008. Noticeable differences that emerged over the 2-year period were the relative abundances of lifeforms within the *Lantana*-removal treatments: Statistically, trees and *Lantana* were significantly more abundant than the other lifeforms by this time; however, *in situ*, *Lantana* dominated all other regenerating vegetation, particularly in plots from which *Lantana* had been uprooted.

Community structure

When seedlings and resprouts were examined separately, *Lantana*-removal plots had higher seedling species richness than either of the control plots. Seedling species richness was highest in plots that were burned and lowest in plots where *Lantana* was absent to begin with (Fig. 2a). Surprisingly, although the abundance of native plant resprouts was similar across treatments, species richness of resprouts was higher in the *Lantana*-removal plots compared to the controls (Fig. 2b). Consequently, the combined species richness of seedlings and resprouts was higher in the *Lantana* removal plots than in the control plots (Fig. 2c).

Overall, community composition at the level of genus of all lifeforms combined (Table 1a), as well as of individual lifeforms (Table 1b-e), differed significantly across treatments. Pairwise comparisons between treatments

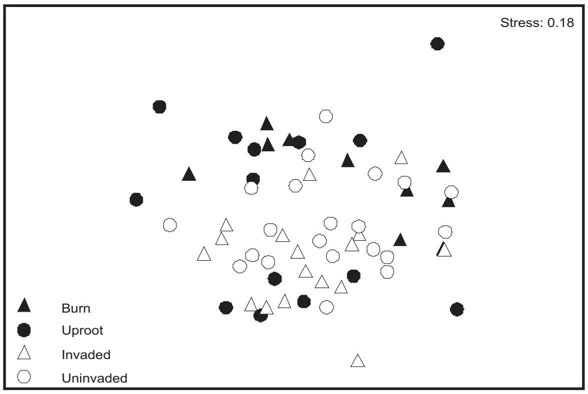

Fig. 3: Nonmetric multidimensional scaling comparing shrub community composition across the Lantana-removal treatments (Burnt, Uprooted) and controls (Invaded, Uninvaded). Data are from 5 censuses: February 06, April 06, June 06, April 07, April 08.

showed that for all native genera, as well as for trees separately, composition in Burnt plots was most similar to that in Uprooted plots (R = -0.008, and R = -0.035 respectively). However, for both shrubs and climbers Invaded and Uninvaded plots were most similar (R = 0.01, and R = 0.03 respectively). Conversely, the greatest compositional difference between treatments for all native genera was between Burnt and Uninvaded plots (R = 0.253). The greatest compositional difference between treatments a) for trees and shrubs, was between Burnt and Invaded plots (R = 0.121, and R = 0.431 respectively), and b) for climbers was between Uprooted and Uninvaded plots (R = 0.265). The native shrub community showed the strongest response to burning with the largest differences between Burnt and Invaded as well as Burnt and Uninvaded plots (R = 0.431 and R = 0.351 respectively; Fig. 3). The dissimilarity between Uprooted and Invaded, and Uprooted and Uninvaded treatments was also high (R = 0.172 and R = 0.149 respectively) suggesting that while individual treatments result in significant differences in composition, the greatest difference results from *Lantana* removal by either means.

The differences in community composition among treatment plots may be largely attributed to differences in the relative abundance of a few common genera. For trees, the genus *Randia* appeared to be more abundant in the *Lantana*-removal plots than the control plots, although of the 10 most abundant genera, *Randia* was the most abundant genus across treatments. The similarity between Uprooted and Invaded plots is likely due to *Anogeissus,* which was virtually absent in the Burnt and Uninvaded plots (Fig. 4a).

When all native lifeforms were viewed together, again *Randia* comprised a greater proportion of the native community in Burnt plots compared to all other treatments (Fig 4b). Further, *Solanum* spp. appear to be absent from Burnt plots but present in all others, although their proportion in the Uprooted plots was higher than in the control plots. Similarly, *Jasminum* and *Acacia* appeared to be present as a much larger proportion of the total in the Burnt plots cf all other treatments (Fig. 4b).

Lantana removal and native species regeneration

Other recent studies have reported an increase in both abundance and richness of native species regeneration following *Lantana* removal (Cummings *et al*., 2007; Gooden *et al*., 2009), and we too found this. Trees,

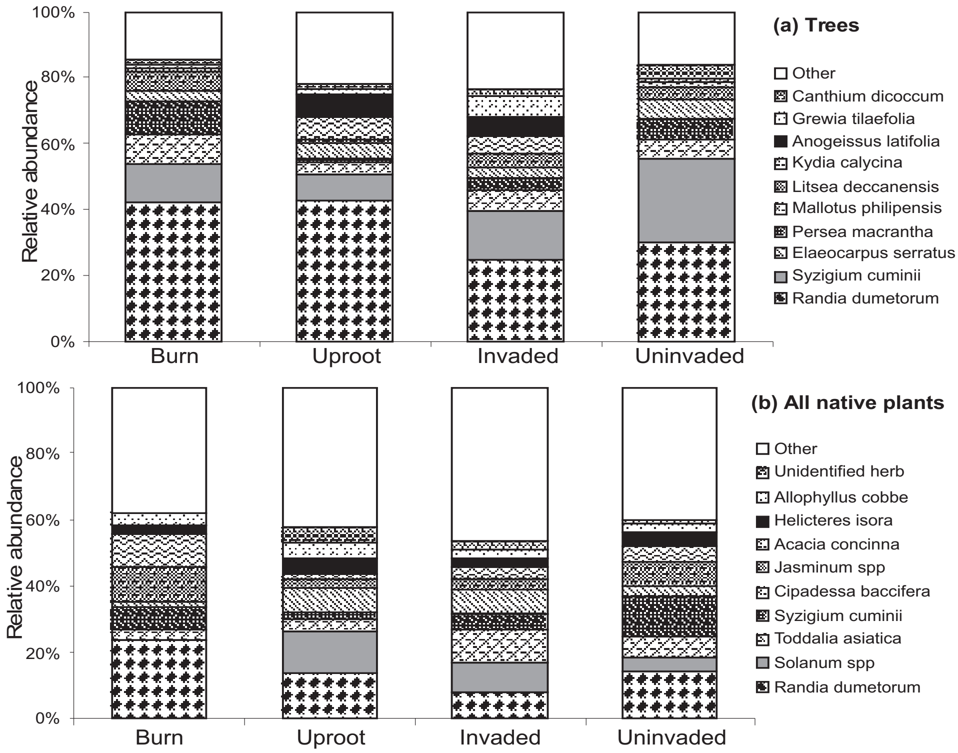

Fig. 4: Relative abundances of the 10 most abundant genera, and all other genera of (a) trees, and (b) all native trees, shrubs, herbs, and climbers, in April 2008, in the *Lantana*-removal treatments (Burnt, Uprooted) and the controls (Invaded, Uninvaded).

relative to the other lifeforms, largely drove the increase in abundance of native regeneration we observed. This corresponds with others' findings of differences amongst lifeforms in response to *Lantana* removal, though they reported a significant increase in herbs and shrubs, relative to trees and vines (Gooden *et al*., 2009).

Gooden *et al*. (2009) sampled vegetation regeneration following two types of *Lantana* management – manual hand-pulling, and cutting and poisoning of stem bases with glyphosate. They did not, however, distinguish between the two *Lantana* removal treatments in reporting their results, presumably because *Lantana*-removal method affected subsequent regeneration of native vegetation less than *Lantana* removal *per se*. This was similar to our findings also—the method of *Lantana* removal had little effect on the overall regeneration of native species. However, we found larger numbers of native seedlings in the burnt treatments, compared with larger numbers of native resprouts in the uprooted treatments. It is possible that burning killed rootstock of native vegetation.

There was a marked difference in post-removal regeneration of *Lantana* between the two removal methods. By the end of our study *Lantana* was about three times more numerous in the uprooted treatment relative to the burnt treatment. *Lantana* tends to be dominant in the soil seed bank (Sundaram, 2011), and uprooting may have brought buried seeds to the soil surface. There is also some evidence that burning kills *Lantana* seeds in the soil seed bank (Hiremath and Sundaram, 2013); this may account for lower *Lantana* regeneration observed in the burnt treatment. Alternatively, uprooting and removing *Lantana* may have inadvertently helped to disperse *Lantana* fruits, which are present almost year-round (Day *et al*., 2003).

As with total numbers of regenerating individuals, so also community composition of regenerating vegetation was more similar between the two *Lantana* removal treatments than between *Lantana* removal treatments compared with the controls. Overall 82 species occurred only in *Lantana*-removal treatments (burnt and uprooted), and not in either of the control treatments: 18 climbers (*Asparagus* sp., *Hemidesmus indicus*, *Pterolobium hexapetalum*, *Zizyphus xylopyrus* and 12 species identified by local name only), 27 herbs (*Achyranthes aspera*, *Phyllanthus reticulatus* and 25 species identified by local name only), 25 shrubs (*Argyreia cuneata*, *Asclepias curassavica*, *Crotolaria calycina*, *Datura splendens*, *Lantana indica*, *Solanum* sp., *Vernonia* sp. and 18 species identified by local name only), and 12 trees (*Bridelia retusa*, *Cedrella toona*, *Chuckrassia tabularis*, *Cordia obliqua*, *Diospyros melanoxylon*, *Eriolaena quinquilocularis*, *Mallotus* sp., *Melia dubia*, *Premna orientalis*, *Radermachera xylocarpa*, *Schrebera swietenoides*, and *Sterculia villosa*).

Conversely, there were about 9 species that were unique to the Invaded control plots: 6 trees (*Artocarpus heterophyllus*, *Atalantia monophylla*, *Aphanamixis polystachya*, *Cinnamomum malabatrum*, *Premna tomentosa*, and *Sterculia guttata*) a fern, 2 climbers and a herb. Furthermore, a shrub, *Ardisia solanaceae,* and the palm, were found only in the Uninvaded control plots. Finally, there were some species that were more abundant in the control plots though they also occurred in the cleared plots (*e.g.*, *Syzigium cuminii, Eleaocarpus* sp.*, Litsea* sp.*, Sapindus laurifolius*). Amongst species that were either unique to the control plots or more abundant in the control plots (*e.g.*, *A. heterophyllus, S. laurifolius, and S. cuminii*) several are typically large-seeded evergreens whose seedlings can persist in the shaded understory (Troup, 1921).

Mechanisms underlying Lantana's success

As expected, there was very little *Lantana* regeneration in the two undisturbed control plots. *Lantana* is a weedy pioneer in its native habitat (Croat, 1978) and is known to benefit from disturbances such as fire and grazing (Duggin and Gentle, 1998). However, the presence of some *Lantana* regeneration in the uninvaded controls is indication that the seedbank may be accruing *Lantana* seeds and these areas may not remain uninvaded for long.

Our findings suggest the primary mechanism underlying *Lantana's* success in these environments is its numerical advantage in regenerating following disturbance-amply illustrated in the two *Lantana* removal treatments. This is likely due to its dominance in the soil seed bank (Sundaram, 2011), in turn a function of its prolific fruiting and its wide dispersal aided by common generalist species of birds (Bhatt and Kumar, 2001). We know little, yet, about the dynamics of the *Lantana* seed bank (Day *et al*., 2003).

A secondary mechanism underlying *Lantana's* success may be its greater survival relative to regenerating native vegetation-*Lantana* was more abundant than all other vegetation at the end of 2 years. *Lantana* is unpalatable and toxic to herbivores (Day *et al*., 2003) and this could be to its advantage relative to native species. In India, *Lantana* toxicity has been reported in livestock (Sharma *et al*., 1981), though we are not aware of investigations on *Lantana* palatability or toxicity to wild herbivores.

Finally, there is some empirical evidence that *Lantana* can allelopathically inhibit native species recruitment (Gentle and Duggin, 1998), but there is no real quantitative evidence for this from field observations (Gooden *et al*., 2009), including our study. We observed a number of species regenerating in the *Lantana*-invaded controls. The fact that these species differed from those in the *Lantana*-removal plots is more likely a function of their shade tolerance than a function of allelopathic interference.

Conclusions

The two *Lantana* removal treatments that we investigated differed little in their post-removal recovery of native vegetation though they differed markedly in the post-removal return of *Lantana*, with a high density of *Lantana* in the uprooted plots compared with the burnt plots. This, together with its higher monetary and labour costs, would argue against uprooting as a recommended *Lantana* removal method.

Cutting and burning, on the other hand, is comparatively feasible and practical from a management perspective, and is widely used where land is of low value, as also in open pastures (Day *et al*., 2003). There is also evidence that burning reduces the number of *Lantana* seeds in the soil seed bank (Hiremath and Sundaram, 2013). In fact, a recent study from Australia has recommended the use of frequent fires for *Lantana* control in fire tolerant ecosystems (Debuse and Lewis. 2014). In high value conservation areas such as BRT there are potential drawbacks to the use of this method, especially where *Lantana* is dense. Intense fires resulting from the high fuel biomass of *Lantana*, could damage the overstory (Tireman, 1916), pers observation). In such cases, some *Lantana* biomass removal may need to precede burning.

Given the numerical dominance (and widespread dispersal) of *Lantana*, no *Lantana*-removal, alone, would be sufficient to restore native vegetation. For one, follow-up monitoring and management would be an essential part of any *Lantana* removal intervention (Ramaswami *et al*., 2014). In addition, removal may need to be followed by planting of other vegetation to pre-empt *Lantana* re-colonization. For example, Cummings *et al*. (2007), in a recent study comparing *Lantana* removal (with and without post-removal weeding) under different conditions of overstory canopy cover found that there was a marked increase in native species regeneration where the overstory canopy was removed. However, by the end of their 2-year study the highest diversity and density of native vegetation remained where the overstory canopy cover was highest. They attributed this to greater increase in the relative cover of *Lantana* where the overstory was missing, regardless of post-removal weeding. Thus, post-removal weeding, alone, is likely to be insufficient. Weeding may need to be accompanied by post-removal planting of species that can rapidly capture removal sites, pre-empting *Lantana* reestablishment. Such species should also be selected based on their ability to withstand disturbances-for example, grazing and fire-that *Lantana* is known to take advantage of.

In the BRT context, anecdotal accounts of Soliga elders, and historical accounts of travelers (Sanderson, 1882) suggest that the forest was historically more open, resembling a savanna woodland with a grassy understory, and subject to annual dry season burning. It is possible that an attempt to reintroduce native grasses (*e.g.*, *Themeda cymbaria*, *Themeda triandra*, *Cymbopogon nardus*) would make this and similar forests more resilient to the types of disturbances that help to promote *Lantana*, and thus more resistant to invasion by *Lantana*.

_लैण्टाना कमारा_ से आक्रान्त उष्णकटिबंधीय पर्णपाती वन का पुनरूद्धार : दो सामान्य _लैण्टाना_ निष्कासन पद्धतियों के प्रति देशज पादप पुनर्जनन की अनुक्रिया

अंकिला जे. हिरीमथ, आयशा प्रसाद एवं भरथ सुन्दरम

सारांश

लैण्टाना कमारा (जिसे इसके आगे लैण्टाना कहा जाएगा) एक सर्व-उषणकटिबंधीय आक्रामक प्रजाति है, जो भारत में चारों और व्यापक रूप से फैल गयी है। लैण्टाना पर्णपाती वनों के अधोवितान में घनी झाड़ियां बना देता है, जो वन्यजीव के आवास और देशज वनस्पति के पुनर्जनन को प्रभावित करता है। लैण्टाना का निष्कासन भारत में संरक्षित क्षेत्र प्रबंधन का एक अभिन्न भाग है हमने लैण्टाना निष्कासन की दो तकनीकों, यथा-काटना और जलाना एवं उखाड़ना जिसे आमतौर पर वन प्रबंधकों द्वारा नियोजित किया जाता है, की सापेक्ष क्षमता का परीक्षण किया। हमारे उद्देश्य थे (क) यह देखना कि किस तकनीक के फलस्वरूप लैण्टाना निष्कासन के उपरान्त बेहतर देशज पादप पुनर्लाभ हुआ और (ख) इन वनों में लैण्टाना की सफलता को आधार मानकर क्रियाविधियों का मूल्यांकन करना है। दोनों तकनीकों देशज वनस्पति के निष्कासन उपरान्त पुनर्लाभ में अत्यधिक भिन्न नहीं हैं। तथापि, लैण्टाना के निष्कासन पश्चात पुनर्लाभ में खासी भिन्नता थी। उखाड़े गए भूखण्डों में लैण्टाना काटे एवं जलाए गए भूखण्डों की अपेक्षा महत्वपूर्ण रूप से घना था, जो बाद वाली तकनीक को निष्कासन तकनीकों में ज्यादा प्रभावी बनाता है। मृदा में लैण्टाना बीजों की संख्यात्मक प्रधानता और इनके व्यापक फैलाव को देखते हुए निष्कासन उपरान्त अनुवीक्षण एवं निराई के बिना किसी भी तरह का लैण्टाना निष्कासन प्रभावी नही होगा। हमने निष्कासन उपरान्त उन प्रजातियों के रोपण की संस्तुति भी की है, जो लैण्टाना के पुनर उपनिवेशन को पूर्व-रिक्त कर सकें और आग एवं चराई जैसे विक्षोमों, जो लैण्टाना के फैलाव को प्रोत्साहित करने के लिए जाने जाते हैं, के प्रति सकारात्मक अनुक्रिया कर सकें।

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