Invasion of indigenous vegetation in south-western Australia by *Leptospermum laevigatum* (Myrtaceae)

Anya Lam and Eddie van Etten
School of Natural Sciences, Edith Cowan University, 100 Joondalup Drive, Joondalup, Western Australia 6027, Australia

Summary This is the first detailed study of the environmental weed *Leptospermum laevigatum* (Gaertn.) F.Muell. in Western Australia. It is naturalised across the south-west of the State in a variety of soil and vegetation types, primarily in areas with at least 400 mm average annual rainfall. Although it proliferates following major disturbance (clearing, mining), it was found to be spreading into bushland in good condition. Successful control *via* chainsaw and/or herbicide has been demonstrated, although rapid, large-scale removal can be problematic.
Keywords Invasion, fire, *Leptospermum laevigatum*.

INTRODUCTION

Leptospermum laevigatum is a shrub to small tree indigenous to the coasts of south and central New South Wales, eastern Victoria, northern Tasmania and the Bass Strait Islands (Carr 1993, Bennett 1994). Its invasive tendencies are evident from its range expansions into adjacent coastal woodlands, heathlands and grasslands at sites within its natural distribution (Hazard and Parsons 1977, Burrell 1981, Molnar *et al.* 1989, Bennett 1994), and its expansions into non-coastal areas in Victoria (Carr 1993). Its prevalent translocation for use as an ornamental and for soil stabilisation within Australia and overseas has lead to invasions in Western Australia, South Australia, South Africa, New Zealand, Hawaii and the USA.

Upon invasion, *L. laevigatum* commonly forms monospecific stands, which may suppress growth and regeneration of indigenous plant species. Its wide geographic range, its presumed ability to invade bushland in good condition and its potential to change ecosystem structure and function have led to its rating as a High Priority environmental weed in Western Australia (CALM 1999). Despite this, until now there has been no formal research conducted on the species in Western Australia. This research addresses the current distribution of the species in Western Australia, with the objective of predicting the potential distribution of the species on a number of scales. Hypotheses explaining various invasion patterns of *L. laevigatum* into bushland are described, along with potential consequences for community composition. Chainsaw removal as a management option is discussed.

MATERIALS AND METHODS

Geographic and habitat distribution Details of naturalised populations of *L. laevigatum* were obtained from roadside surveys, casual observations, herbarium records and a comprehensive survey of land managers and community groups. For each occurrence life-form, location type, soil type, and vegetation structure were noted, and tallied. Habitat details were tallied to indicate the characteristics of sites most commonly invaded. The locations of populations were mapped using ArcView GIS.

Pattern of invasion Three bushland sites invaded by *L. laevigatum* were examined: 1) Leeuwin-Naturaliste National Park, approximately 400 m north-east of the Ellensbrook Homestead (north-west of Margaret River); 2) Shoalwater Foreshore Reserve, near Rockingham (Quindalup dune system); and 3) Yanchep National Park adjacent to Yanchep Beach Road (Spearwood dune system). At each site three parallel random transects were established (100 m × 2 m) running from the initial infestation (discerned by tree size and/or historical information) in the predominant direction of spread. The position and size (stem diameter) of each *L. laevigatum* along the transect was recorded, plus other factors such as proximity to other species and evidence of disturbance. Density and size distributions along transects were explored.

Impacts on community composition Floristic surveys were conducted in 5 × 5 m quadrats lying at 0 m, 50 m and 100 m along each transect. Quadrats with high cover of *L. laevigatum* (≥65%) were compared with those with low (≤15%) or no cover of *L. laevigatum.*

Management strategies Two sites where *L. laevigatum* has been removed using chainsaws (Little Grove near Albany, and Ellensbrook) were surveyed for regenerating plants, and compared with plots in adjacent intact thickets where possible.

RESULTS AND DISCUSSION

Geographic and habitat distribution *L. laevigatum* is largely restricted to areas with an average annual rainfall of more than 400 mm (Figure 1), and is reported not to be spreading where it occurs outside of this range (e.g. near Tammin). This suggests that the species is restricted by an annual rainfall of approximately 400 mm. Based on this assumption, the potential geographic range of the species is substantial, extending around the coastline some 1500 km between Kalbarri on the west coast and beyond Cape Arid on the south coast, and inland beyond Narrogin in the wheatbelt. This covers a substantial portion of the South-West Botanical Province (Figure 1).

Leptospermum laevigatum was reported most commonly on sandy soils, but was not limited to them as previously thought. Other soils supporting *L. laevigatum* included sandy loam, sandy clay, laterite, clay, clay loam and peaty sand (Table 1). Soil type, therefore, does not appear to restrict the distribution of *L. laevigatum*.

Roadsides are commonly invaded by *L. laevigatum* (Table 1). Vehicles are probably a significant dispersal vector. Localised air currents created by passing vehicles could effect short distance dispersal by lifting and transporting the small (approx. 0.25 mg), winged seed. Long distance dispersal could be achieved by seed adhering to vehicles (Lam 2002). The transport of seed in soil moved during routine road verge and table drain maintenance is another potential source of spread along country roads (J. Moore pers. comm.).

Moderate shading (Lam 2002), loose topsoil and increases in soil nutrients (Burrell 1981) greatly enhance survival and growth of *L. laevigatum* seedlings. These factors are informative in assessing why roadsides, and certain vegetation types rather than others, commonly support invasions of *L. laevigatum*. Roadside habitats are probably conducive to survival and spread of *L. laevigatum* because they provide: 1) disturbed, bare soil; 2) increased soil moisture and nutrient loading, and; 3) seed supply from established roadside trees and a vector for their dispersal. Compared with forest or open forest, woodland and heathland have more open canopies, so they are more likely to provide the moderate levels of light that seem to be required for high rates of seedling survival. The canopy of densely wooded vegetation seems to confer some resistance to invasion by *L. laevigatum* (Lam 2002).

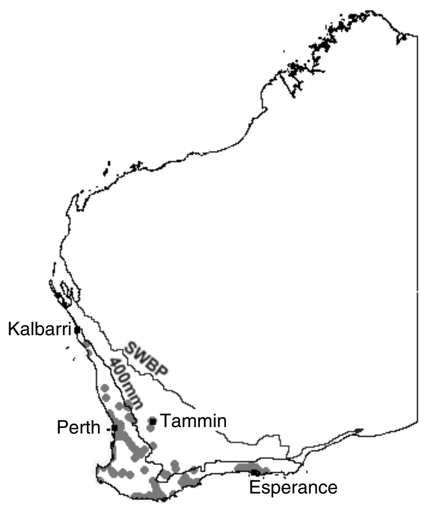

Figure 1. Distribution of *L. laevigatum* (grey dots) showing 400 mm average annual rainfall isohyet and the boundary of the South-West Botanical Province (SWBP).

Table 1. Number of reports of *L. laevigatum* showing the three most common habitat characteristics of invaded sites.

Substrate		Location		Vegetation	
Sand	39	Roadside	101	Heathland	49
Limestone	6	Railway	12	Woodland	37
Loam	4	Agriculture	7	Open forest	3

Pattern of invasion Spread into surrounding native vegetation was primarily in the direction of the prevailing summer sea breeze, consistent with wind dispersal. The density of *L. laevigatum* decreased with distance along the transect at all three study sites (Figure 2). This could reflect a habitat suitability gradient (e.g. soil disturbance, vegetation structure). Alternatively, density patterns may reflect a decline in seed rain density with distance from the initially established individuals. Knowledge of *L. laevigatum* introduction locations, prevailing wind direction and plant size comparisons support the latter. Density of plants in 20 m intervals was highly variable between transects (Figure 2). This partly reflects the clumping of individuals around larger *L. laevigatum* or underneath *Banksia* trees. Such locations provide moderate shelter from sunlight which apparently enhance seedling survival, and therefore form suitable establishment microsites (Lam 2002). Curve estimation regressions yielded complex relationships between plant size (stem diameter) and distance along transect (Lam 2002). Therefore, invasion is not sequential, with larger plants giving rise to smaller ones further into bushland. Conversely, larger, reproductively mature individuals are equally likely to be found far into bushland as are immature individuals. (The possibility of differential growth rates due to competition or habitat suitability was considered. Except in high density thickets at 0–12 m at Yanchep, there was no obvious reason to assume that stem diameter did not indicate plant age).

There is evidence that the initial infestation at each site established after severe physical disturbance (localised vegetation clearing and associated soil disturbance). However following initial post-disturbance recruitment, spread has occurred into relatively undisturbed bushland adjacent to the infestations at Ellensbrook and Yanchep. Notably, both of these sites support rabbits (*Oryctolagus cuniculus*), and *L. laevigatum* germinants were found in the disturbed soil of rabbit diggings at Yanchep. Yet walk trails and other evidence of human presence were absent from both sites, and bushland was structurally and floristically in good condition. Therefore, it appears that even small scale disturbance is adequate to allow invasion of indigenous vegetation by *L. laevigatum*.

Leptospermum laevigatum is serotinous in Western Australia, with seed stored in capsules on the plant for usually two years (Lam 2002). Seed is released *en masse* upon plant damage including herbicide application, mechanical damage or fire. Adult plants are killed by fire. There has been discourse over the necessity of fire to promote invasion of adjacent vegetation by *L. laevigatum* in Victoria (e.g. Molnar *et al.* 1989, Bennett 1994), however all studies have indicated that high density recruitment of *L. laevigatum* occurs following fire. Burrell (1981) has nominated disturbed vegetation and topsoil, and a temporary increase in soil phosphorus, as post-fire factors which enhance *L. laevigatum* seedling establishment. Examination of plant densities for this study indicates that invasion of bushland by *L. laevigatum* may occur with or without fire. However, the combination of fire and an adjacent seed source leads to densities of *L. laevigatum* two orders of magnitude higher than does either feature separately (Table 2). Linear spread rates are also enhanced following fire (Lam 2002). Plants forming the high density thickets at burned sites were apparently even aged, supporting post-fire regeneration.

The invasion pattern of *L. laevigatum* (apparently controlled by the locations of suitable establishment microsites) makes the positions of established plants in bushland quite unpredictable. Therefore, thorough searching for individuals in areas away from the original infestation will be required to achieve eradication, rather than assuming that *L. laevigatum* invades as a ‘front’.

Invasion of bushland in good condition is likely to be slow and sparse in the absence of fire. However, fire is considered inevitable in south-western Australian vegetation, and could quickly transform a low-density, low impact invasion into a problematic one. Therefore, sites burned whilst in the vicinity of reproductively mature *L. laevigatum* require careful monitoring.

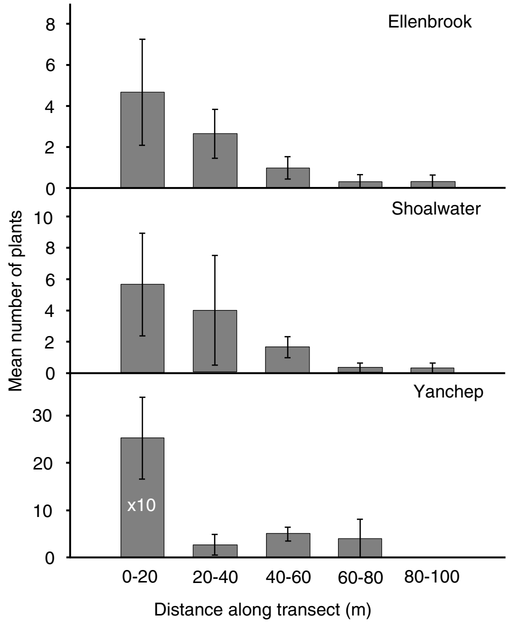

Figure 2. Mean density distribution (n=3) of *L. laevigatum* at 20 m intervals along transects, showing standard error. Value shown for 0–20 m at Yanchep is one tenth of the actual observed value.

Table 2. Comparison of seed source proximity, fire history and density of established *L. laevigatum*.

Site	Proximity of seed source	Fire?	Plants m^{-2}
Ellensbrook	350 m away	1970	0.045
Shoalwater	Adjacent	Suppressed	0.060
Yanchep	Adjacent	1991	1.320
Ellensbrook Homestead	Adjacent	1970	3.000

Potential impact on other species Invaded quadrats had significantly lower cover of indigenous species at Shoalwater and Yanchep (Mann-Whitney U test; U<0.001 for both sites; P=0.04 and 0.019 respectively). Significant differences in indigenous species richness were not detected. However, indigenous shrubs occurring in invaded quadrats showed signs of stress, which could affect their ability to produce seed for regeneration. This would affect species richness in future. Multi-dimensional scaling (MDS) to compare compositions of indigenous vegetation uncovered clear differences between invaded quadrats and uninvaded ones; *L. laevigatum* had a stronger negative effect on shrubs than on ground cover species (Lam 2002). Whilst the sampling method used can not strictly demonstrate that observed differences are the result of invasion by *L. laevigatum*, the observation that thickets of *L. laevigatum* support low cover of indigenous species is of concern.

MANAGEMENT

Chainsaw removal of *L. laevigatum* Total indigenous species richness and mean cover were higher in plots from which *L. laevigatum* had been removed compared with invaded plots (Table 3). Alien species richness and cover were also higher in chainsawed plots. At Little Grove, some chainsawed areas have been overrun by *Avena barbata*, whilst others have a 'wheat field' regeneration of *L. laevigatum* seedlings.

The results show that at some sites, there can be high potential for regeneration of indigenous species from soil seed banks upon removal of *L. laevigatum*. Because of the associated high potential for regeneration of alien species, including high densities of *L. laevigatum* seedlings, removal of stands should be restricted to areas where adequate resources are available for follow up monitoring and weed control. Otherwise, reinvasion could pose threats to regenerating indigenous seedlings. The possibility of erosion must also be considered. Gradual removal of stands may be most practical (i.e. the Bradley method) since it creates smaller areas for maintenance, allowing indigenous plants to establish and prevent further invasions. Additionally, etiolated plants that have survived in thickets are able to acclimatise to exposed conditions more slowly (with protection from the remaining portion of the thicket), and their chance of survival is increased (K. Ninyett pers. comm.).

Chainsaw removal is the most commonly used method for control of *L. laevigatum* in Western Australia. Plants sometimes coppice unless herbicide is immediately applied to the cut stump (J. Moore pers. comm.). Reports of coppicing have been predominantly from Albany populations; it has been suggested that these may form a distinct subspecies of *L. laevigatum*. However, coppicing plants have been observed at Woodman Point and in the Serpentine-Jarrahdale region, both immediately south of Perth (S. King and B. Dunn pers. comm.). Therefore, resprouting probably depends on the level and age at which the plant is cut rather than genetic differences between populations (S. King and J. Moore pers. comm.).

Other management strategies include bulldozing, herbicide sprays (foliar or basal bark), herbicide wicks and potentially, biological control (development not recommended: Lam 2002). For bushland situations, the least invasive method (which is also relatively quick, effective and inexpensive) is tree injection of herbicide. The advantage of this method is that non-target damage of surrounding indigenous plants from herbicides can be avoided, and the *L. laevigatum* skeleton is left in place, marking the site for follow up work to remove *L. laevigatum* seedlings (C. Turley pers. comm.).

Table 3. Species richness and cover in invaded and chainsawed plots. Standard error shown in brackets.

Site	Area sampled (m^2)	Indigenous species		Alien species	
		No.	% cover	No.	% cover
Ellensbrook invaded	75.0	3	21.833 (20.335)	2	0.500 (0.289)
Ellensbrook chainsawed	79.6	10	37.5 (22.250)	8	4.667 (2.682)
Little Grove chainsawed	100.0	18	21.125 (5.854)	22	15.750 (7.273)

ACKNOWLEDGEMENTS

We are grateful for the input of all those who responded to requests for information about the species. Also, Greg Keighery gave initial guidance; Greg, Jenny Stevens and Anne Bellman assisted with plant identification; and John Moore initiated weed mapping. This research was funded by Edith Cowan University (ECU), ECU's Centre for Ecosystem Management and the Western Australian Department of Conservation and Land Management (CALM).

REFERENCES

Bennett, L.T. (1994). The expansion of *Leptospermum laevigatum* on the Yanakie Isthmus, Wilson's Promontory, under changes in the burning and grazing regimes. *Australian Journal of Botany* 42, 555-564.

Burrell, J.P. (1981). Invasion of coastal heaths of Victoria by *Leptospermum laevigatum* (J.Gaertn.) F.Muell. *Australian Journal of Botany* 29, 747-764.

CALM (1999). 'Environmental weed strategy for Western Australia'. (Department of Conservation and Land Management, Como).

Carr, G.W. (1993). Exotic flora of Victoria and its impact on indigenous biota. *In* 'Flora of Victoria', eds D.B. Foreman and N.G. Walsh, 256-289. (Inkata Press, Melbourne).

Hazard, J. and Parsons, R.F. (1977). Size-class analysis of coastal scrub and woodland, Western Port, southern Australia. *Australian Journal of Ecology* 2, 187-197.

Lam, A. (2002). 'Invasion of indigenous vegetation in south-western Australia by *Leptospermum laevigatum* (Myrtaceae)'. (Edith Cowan University, Joondalup).

Molnar, C.D. *et al.* (1989). Relationships between heath and *Leptospermum laevigatum* scrub at Sandringham, Victoria. *Proceedings of the Royal Society of Victoria* 101, 77-87.