The invasion of *Pittosporum undulatum* in the Dandenong Ranges, Victoria: realising predictions about rates and impact

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Summary

Pittosporum undulatum Vent. was identified as an invader of forests and woodlands in southern Australia over 30 years ago (Gleadow and Ashton 1981). At the time it was predicted that its high reproductive potential, suppression of competitors, broad tolerance of environmental challenges, and changed management practices could result in serious infestations and threaten the regeneration of native eucalypt forests, unless steps were taken to control it. That prediction is becoming a reality. Seventy years ago, at Menzies Creek, in the Dandenong Ranges, east of Melbourne, there was only one female pittosporum tree in the entire village; now there are up to 6 000 saplings and mature trees per hectare. There are no eucalyptus seedlings under the coalescing canopy and plant diversity under that canopy is reduced.

In order to determine the rate and direction of invasion into neighbouring areas, a good approximation of tree age is required. A citizen science project, co-ordinated by one of us (JW), worked with the local primary school to estimate the age of trees from their circumference. Single stemmed trees (n=39) were felled 30 cm above ground level and their age determined using tree rings at two sites; at the edge of the invasion canopy, and within it. The correlation between age and circumference was highly significant at both sites; however the slopes differed between trees growing at the edge and those growing in a closed canopy. Incorporating plant growth parameters into an invasion model will determine the time it will take for *P. undulatum* to invade non-managed forests in the region. It was estimated that the invasion front is progressing southward from Menzies Creek at about 80 metres year^{-1}. The eastern and western invasion fronts now threatening the Dandenongs are about 4 km apart, so if the above rate applies to those fronts, and no treatment or control measures are put in place, all the forests and woodlands in the Dandenongs will be infested within 30 years.

The gender ratio of *P. undulatum* suggests that only about 30% of the population needs to be treated or controlled – the female trees carrying viable capsules – thereby reducing the cost of treatment greatly. While there are significant knowledge gaps in the area of population genetics, sex ratios and growth rates in different environments, it is important that coordinated action be taken soon to preserve the biodiversity of areas of significance to greater Melbourne and other areas of Victoria and Australia, wherever its invasions have become well established.

Introduction

Pittosporum undulatum Vent, is an Australian native tree species with a natural range from south east Queensland to eastern Victoria. The Australian Virtual Herbarium reports that it was first identified in 1803 in Port Jackson (Sydney) and later in 1854 at Brodribb River (Orbost), Victoria, and in 1884 at Studley Park in Victoria. It was inevitable that its sweet scented masses of white flowers in early spring and large orange capsules in autumn would attract the attention of nurserymen and gardeners, so it became a popular ornamental tree in gardens throughout eastern Australia – from where it has spread. It is now well established outside its natural range in New South Wales, Victoria, Tasmania, South and Western Australia (Australia's Virtual Herbarium 2014).

Internationally, it has invaded significant areas of the Blue Mountains of Jamaica (Goodland and Healey 1996), the Azores (Lourenço *et al.* 2011), is an emerging alien invader in South Africa (Mokotjomela *et al.* 2013) and has also been noted as invasive in Hawaii, New Zealand, and Norfolk and Lord Howe Islands (Gleadow and Ashton 1981, Saur 1988). Intensive management on Lord Howe Island has been successful in reducing its presence on the Island (New South Wales Department of Environment and Climate Change 2007). In Victoria, *P. undulatum* has invaded the cool moist environments south of the Great Dividing Range and is well established throughout East and West Gippsland, as well as the Shires of Bass, Mornington, Cardinia, Yarra Ranges and Knox. Its invasion has continued west of Port Phillip Bay throughout the coastal Shires to Glenelg in the far west, and then further west into South Australia (Victorian Department of Environment and Primary Industries 1996-2014).

In the Shire of Yarra Ranges, it is particularly prevalent along its peri-urban fringe, where there is a relatively high density of the introduced blackbird *Turdus merula* L. (Gleadow 1982) which is likely to be an important vector. After blackberry, (*Rubus fruticosus* L.), *P. undulatum* is the most common weed in the area; it is present in 50 per cent of reserves and roadsides and is now represented in forests along the entire perimeter of the Dandenong Ranges (Smitka, personal communication). Under current Victorian legislation, a native species cannot be declared noxious, however, its invasiveness has now been recognised and it is classified as an 'Environmental Weed' in the Shire of Yarra Ranges and 'Potentially Threatening' under the *Victorian Flora and Fauna Guarantee Act 1988*.

The high invasability of *P. undulatum* is a result of its high competitive ability and early maturity, its dispersal into favourable sites (including undisturbed vegetation) by avian vectors and the high survival rate of seedlings in already invaded sites (Gleadow 1982, Gleadow and Narayan 2007). It is relatively sensitive to fire but traditional fuel reduction burns are not sufficiently hot to kill the basal buds or the seed held in the canopy. The suppression of fires in peri-urban areas has undoubtedly contributed to its success (Gleadow and Ashton 1981). Gleadow and Ashton (1981) predicted that the invasive characteristics of *P. undulatum,* together with its wide tolerance of environmental conditions (Gleadow and Rowan 1982), would likely result in it becoming a serious woody weed unless steps were taken to control it, such as by increasing the temperature of prescribed burns or, in areas too close to housing, physical removal and poisoning. Those measures were not taken, and that prediction has come to pass; it is a serious invader of remnant forests and now threatens State and National Forests in Victoria and elsewhere.

During the early 1940's, some 70 years ago, there was only one *P. undulatum* tree in the entire village of Menzies Creek, Victoria. It was a female tree planted as a garden ornamental, and judging from its circumference would have been planted around 1925, when that area of the Dandenong Ranges was being cleared for farming and residential development (J. Walker personal communication). In 2011, 200 metres from that original tree site, 1 209 seedlings were counted on a 1 924 m^2 block of remnant forest, which had not been cleared for two seasons, i.e. the seedling density was 6 280 ha^{-1}. On the two adjacent blocks of remnant forest, which have never been cleared, the density of saplings and young trees is approaching 6 000 ha^{-1} (Walker 2013).

This observation provided the motivation to involve Grade 6 students of the nearby Menzies Creek Primary School in a "citizen science" project. Now in its third year, a useful data set about the height, circumference and age of saplings and trees, the growth and development of seedlings, gender characteristics and biodiversity has been collected; the gender and fecundity of the flowers has been the subject of some discussion and may influence invasiveness (Mullett 1996). Incorporating these growth and morphological parameters into an invasion model should assist the estimation of the time it will take for *P. undulatum* to invade non-managed forests in the region, and help identify management strategies.

Materials and methods

Field sites and floristics

Three sites were established in a remnant moist forest of *Eucalyptus obliqua* L'Her., near the Menzies Creek Primary School, 50 km east of Melbourne. The elevation is 300 metres, annual rainfall 750 mm and the soil is a medium depth kraznozem. In order to characterise the plant diversity at the site, the number of species present in 5 m x 2 m quadrats along a 160 m x 2 m wide transect across one of the study blocks invaded by *P. undulatum* were recorded. The transect was orientated in an approximately north westerly direction from higher ground near the watershed of the Cardinia (Western Port) and Menzies Creek (Yarra – Port Philip) catchments to the head of the south western limb of Menzies Creek, (Walker 2013) and included both invaded and non-invaded areas.

Figure 1a. Low diversity along the transect of forest invaded by *Pittosporum undulatum* at Menzies Creek (remnant forest harvested for timber in 1948).

Figure 1b. Normal diversity under remnant eucalyptus forest (never been harvested) and not invaded by *P. undulatum* 800 m from site of Figure 1a.

Age-size determination

The relationships among plant height, circumference and age were determined on 39 saplings and young trees along transects at two sites, one within 5 m of the canopy boundary (i.e. an active invasion front) and the second set 5–15 m inside the canopy boundary. Only single-stemmed saplings and trees were used. Saplings and young trees were felled 30 cm above ground; the circumference of the stump and height of each tree (including the stump) was measured with a tape measure. Plant age was determined by counting tree rings. *Pittosporum undulatum* does not always form distinct seasonal growth rings so it is possible that the ages of a few trees may therefore be in error by one or two years. Regression analysis was performed and curves of best fit calculated using Microsoft Excel. The age data were then used to determine the direction of the invasion from the original planting at Menzies Creek, assuming that the youngest cohort of trees is furthest from the source; the rate of this invasion (m yr^{-1}) was determined by dividing that distance, in metres, by 89 (2014–1925).

Gender and fecundity

The gender of 153 trees was determined during July 2013, at three locations in Boronia and Ferntree Gully, in the foothills of the Dandenong Ranges, from the apparent sex of their flowers, as indicated by the presence or absence of stamens and styles. The gender and fecundity of 328 trees was determined by the presence or absence of capsules in November 2013 at four sites in Menzies Creek and again in February 2014 at two of the above sites in Menzies Creek and Ferntree Gully; these measurements were made before the capsules ripened and became susceptible to predation. Capsule density was scored as follows: Heavy (profuse bunches of 8–20 capsules on most branchlets); Medium (smaller bunches of 4–10 capsules on many branchlets); Few (1–5 capsules on a few branchlets); and None (no capsules, male). Efforts were made to keep scoring consistent by following these scoring criteria. Measurements were repeated at the Aura Vale Road site in Menzies Creek with the same 132 trees in February 2014; they were found to be concordant with earlier measurements.

Results

Floristics

In the 160 m x 2 m transect running from the Menzies Creek Primary School study site to the head of the south west limb of Menzies Creek, there were 10 *Eucalyptus obliqua* trees along the transect (312 ha^{-1}) and 116 (3 635 ha^{-1}) *P. undulatum* seedlings, saplings and young trees. There were no *Eucalyptus* seedlings under the combined *Eucalyptus – P. undulatum* canopies. Except for saw sedge (*Gahnia radula* (R.Br.) Benth.), which was present at many locations, and occasional seedlings of other bird distributed woody weeds (e.g. *Arbutus unedo* L., *Ilex aquifolium* L., *Rubus fruticosus* L. agg., *Cotoneaster* sp. and *Coprosma quadrifida* (Labill.) B.L.Rob.), the ground was open or covered in litter (Figure 1a).

Age-size relationship

A strong positive correlation was detected between plant height and age, as determined by tree rings (Figure 2) for trees from both transects; the correlation coefficients (r^2) were 0.935 and 0.829 for plants growing near the edge and under the canopy, respectively. The relationship was not linear, plateauing when trees approached approximately 8 m tall. The Circumference x Age relationship, by contrast, was linear (Figure 3) with correlation coefficients for the edge and canopy curves being 0.933 and 0.624, respectively. Together, the height, circumference and age relationships presented in Figures 2 and 3 indicate that in the Menzies Creek environment, *P. undulatum* saplings and trees growing within the canopy were about 5% taller, with circumferences substantially greater (by 30%), than those growing at the edge of the canopy. While more data are necessary to refine this relationship before it can be applied more generally, the relationship here is strong. In practice, it is generally sufficient to age a number of trees growing near the edge of an invasion front, so the relationship shown in Figure 3 for the 'edge' data is sufficiently predictive for use in an invasion model; in the Menzies Creek environment the circumference of *P. undulatum* trees are expanding at about 2.6 cm per year ($r^2 = 0.933$).

Direction and rate of invasion at Menzies Creek

The Age data presented (Figure 2) were used to determine the direction of the *P. undulatum* invasion in the vicinity of Menzies Creek. The invasion front has progressed in a generally southern direction, through remnant forests with good habitat for avian vectors. The youngest cohort of seedlings and younger trees has now reached beyond the southern end of the Cardinia Reservoir wall, along Wellington Road, about 7 km from the original tree, in about 89 years. The rate of invasion has therefore been about 80 m year^{-1}.

Gender and fecundity

At flowering time in late winter the male:female gender ratio of trees, as determined by the gender of the flowers on the trees, was about 60:40 (Table 1). However, in late spring and midsummer, when the presence of capsules was used to assess gender, the proportion of viable females had fallen to around 30 percent (Table 2). Thus, it appears that not all female trees (as determined by the gender of their flowers), went on to produce fruit. Of those female trees that did carry capsules, the load varied between individuals with approximately one third having a Heavy capsule load (8–20 capsules on most branchlets), another third having a Medium capsule load (4–10 capsules on many branchlets), and the remainder with comparatively Few capsules (1–5 capsules on a few branchlets) (Table 2).

Capsule maturity and leaf form

There was a range in the maturity of capsules among the population, mainly between trees, but also, to a minor extent, within trees; some capsules remained green and immature at the same time that most capsules had already ripened and split. There were at least five variants among the Menzies Creek population as reflected by leaf length, undulation frequency and colour. Leaf length was either between 10 and 12 cm (predominant), or between 7 and 9 cm; leaf undulation frequency varied between 3 and 8 per side; while the predominant colour of leaves was a matte mid-green and about 10% were a bright shiny green (also short) while a few were a mottled lime green without undulations.

Discussion

Verification of age class determination

Height is frequently used to determine age classes for *P. undulatum* (e.g. Gleadow and Ashton 1981, Mullet 1996), based on the assumption that it is indicative of age. Data presented here confirm that both height and circumference are good proxies for plant age. For plants between 5 and 10 years of age, height increased at approximately 0.5 m year^{-1}, but it increased by only about 0.1 m year^{-1} over the following 10 years. While the relationship between age and circumference is linear and therefore relatively easily applied over a greater range of ages and sizes, it varies with environment. This is not surprising, given the difference in available light. While *P. undulatum* is very shade-tolerant, it cannot maintain high growth rates under dense shade (Gleadow *et al.* 1983). The circumference of *P. undulatum* trees growing near the edge of invasion fronts expands by about 2.6 cm per year so this can be used to assess the ages of similar trees and, in turn, their ages can be used to determine the direction and rate of such invasions.

General descriptions of *P. undulatum* describe mature trees as over 8 m tall with longevity of 40 years. One tree at Menzies Creek, outside the data sets reported here is 56 years old (C. Nitschke personal communication 2012) with a height of 8 metres, a circumference of 180 cm and a canopy that is 17 m wide. This large tree carries a very heavy load of capsules and is described here as a 'matriarch'. There are only two such trees among the thousands in Menzies Creek, both being daughters of the original 'matriarchal' tree (planted in about 1925). While this invites genetic speculation, it may be that they are simply the only survivors of their original cohort; the remainder may have been destroyed by periodic bushfires or removed from nearby farmland.

Invasion rates and estimates of extent of invasions

The rate of invasion in this study was estimated to be approximately 80 metres year^{-1}. This rate is much faster than the 30 metres year^{-1} in the semi-tropical environment of the Blue Ranges of Jamaica (Goodland and Healey 1996), to our knowledge the only other place where the rate of invasion has been documented. Even then, it may be an underestimate, the original tree may have been planted later than 1925 and the route of the invasion may have been longer than 7 km. More estimates of the invasion rates in different environments are indicated.

The oldest tree in the Menzies Creek cohort is 56 years old, while the next oldest are 40, 28 and 22 years; a continuum to new seedlings then follows. Gleadow and Narayan (2007) emphasized the role of fire in the survival of *P. undulatum*, and these apparent gaps in the age spectrum may

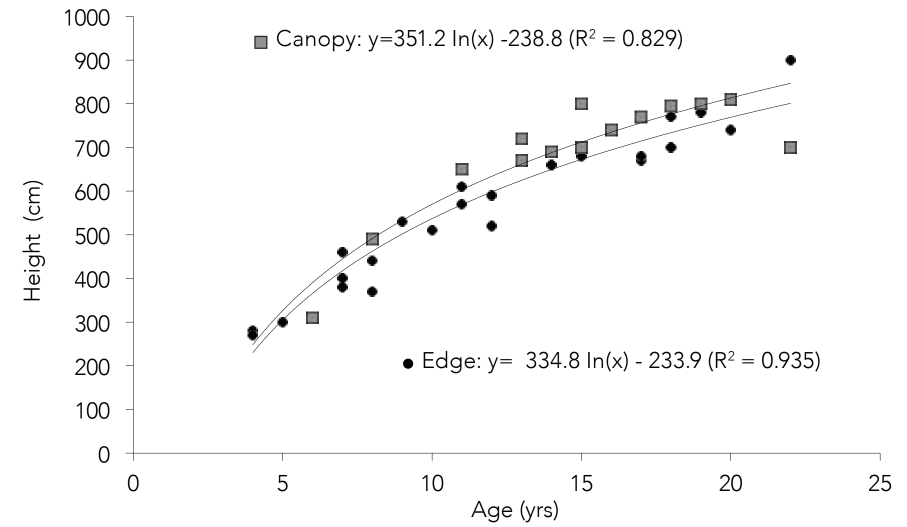

Figure 2: Relationship between height and age (as determined by tree rings) of *P. undulatum* saplings and young trees (n=39) recorded along two transects at Menzies Creek.

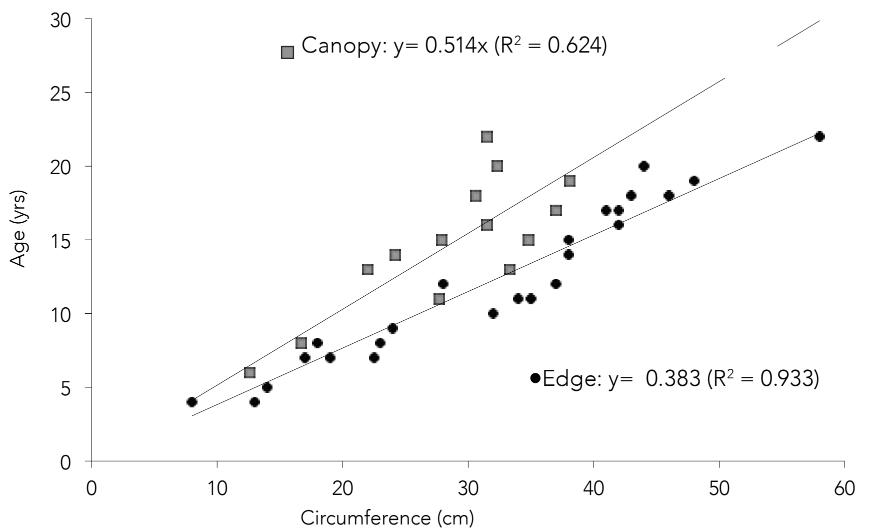

Figure 3: Relationship between age (as determined by tree rings) and circumference (at 30 cm) of *P. undulatum* saplings and young trees (n=39) growing along two transects at Menzies Creek.

possibly be due to periodic bushfires such as occurred in 1939, 1943 and 1962. The locality is a former vegetable and flower farming district and while farmers would most likely have removed any woody plants on their properties, including weeds, this is not sufficient to explain the absence of *P. undulatum* within the nearby remnant forests. While the causal factor is consistent with episodic fires, it may also be possible that the behaviour of the main vector, blackbird (Gleadow 1981) also plays a role in possible invasion surges: blackbirds are strongly territorial reinforcing the physical clumping nature of the invasion of new sites (Gleadow 1982). Furthermore, they tend to nest low in the canopy so they are vulnerable to predators such as foxes and cats, possibly leading to fluctuations in density over time (J. Walker personal observations).

Once a beachhead has been established, *P. undulatum* can be a vigorous invader (Gleadow and Naryan 2007). A recent study in the Azores estimated, using aerial mapping, that *P. undulatum* was present in 62% of sites (Costa *et al.* 2012) and is now the most widespread invasive weed in the Islands (Costa *et al.* 2013). Areas to the west of the present study site, in the Monbulk and Ferny Creek valleys, are also being heavily invaded (Smitka, personal communication). It is unlikely that the Cardinia Creek invasion originated from the west as there are only seven isolated older trees, in domestic gardens, between it and South Belgrave (3 km), while there are thousands of seedlings, saplings and young trees in the northward continuum between the Cardinia Reservoir and Menzies Creek.

Numerous studies have shown that there is reduced abundance and floristic diversity in sites with high density of *P. undulatum*. (e.g. Gleadow and Ashton 1981, Mullet 1995, Rose and Fairweather 1997, Gleadow and Narayan 2007). The absence of *Eucalyptus* seedlings and poor diversity under the *P. undulatum* canopy at Menzies Creek confirms these earlier studies and indicates that the eucalyptus ecosystem will be replaced progressively, by a virtually monocultural *P. undulatum* ecosystem as mature eucalyptus trees die. Moreover, the process accelerates as the invading trees overtop smaller trees and shrubs (Gleadow and Ashton 1981). Similar impacts on diversity have been observed in invaded forests in the Azores (Hortal *et al.* 2010). For example, on Graciosa Island, it has taken over the very last remains of *Morella faya*-dominated forest, causing a serious decline in the rare Azores bullfinch (*Phyrrula murina* Godman) (Ramos 1996). The ability of *P. undulatum* to outcompete the Azorean native forest species makes it one of the biggest, if not the biggest threat for the species inhabiting the very last remnants of the original low-altitude native forests that are now under protection in the entire Azores archipelago (Hortal *et al.* 2010).

Gleadow and Ashton (1981) foreshadowed the situation we see now where the Dandenong Ranges are essentially encircled by invaded forest. Yarra Ranges Council has mapped the weed distribution in all of its reserves and roadsides, and substantial populations of *P. undulatum* surround the Dandenong Ranges at Mount Evelyn, Silvan, Monbulk, The Patch, Menzies Creek, Selby, South Belgrave, Belgrave, Tecoma, Upwey, Ferntree Gully, Boronia, The Basin, Kilsyth, Mooroolbark and Montrose (Smitka, personal communication). The eastern and western boundaries of this encirclement are 4 km apart, so if the rate of the invasion in the Menzies Creek environment, of about 80 metres $year^{-1}$, prevails throughout the Dandenong Ranges, then the existing invasion fronts will meet in about 25–30 years.

There have been some successes in controlling P. *undulatum* in other areas. Whitehorse Council, for example, has removed it completely from some of its reserves (e.g. Antonio Park, Nunawading, Victoria) using a combination of cutting, treating the stumps with herbicides and follow up weeding, but this has been very time intensive and relied on volunteers to do a lot of the work. Similarly, Yarra Ranges Council and an active volunteer group, has removed 8 ha of a 12 ha invasion of the Glenfern Valley Bushlands, in Upwey, Victoria, by chipping the trees, treating the stumps and leaving the chips *in situ*, which was then followed by a revegetation programme. Parks Victoria has also worked with volunteer groups to remove it from the southern fringe of the Dandenong Ranges National Park near Ferntree Gully. However, these control measures are somewhat *ad hoc* and represent 'first steps' in what could evolve into a Statewide strategy to protect existing ecosystems from *P. undulatum* invasion. Additionally, funding will need to be made available to encourage private landholders to address the issue.

Gender and fecundity

Invasive species often have a higher proportion of males to females (e.g. Wang *et al*. 2012). The proportion of male to female trees at flowering was around 60:40 but between flowering and fruit/capsule development the female proportion appeared to decline to around 30%. No explanation for this attrition can be offered but the Menzies Creek grade 6 students did observe that some of the capsules in the 'Few' category were rotting in November, perhaps reflecting self-incompatability, as has been observed in the Indian medicinal trees *Pittsporum dasycaulon* Miq. (Gopalakrishnan and Thomas 2014), or inbreeding depression. Further studies on floral biology are required before this question can be answered.

The fruit or capsule load on female trees also varied considerably and this may influence the overall reproduction rate of *P. undulatum* in this environment, particularly as the vectors are probably more likely to visit those trees with heavy berry loads rather than 'waste time' hunting for sustenance on trees carrying lesser berry loads. These gender ratios suggest that only about 30% of the population would need to be controlled - those carrying capsules - as distinct from the 40% that bear female flowers, thereby reducing the cost of control; target trees in any given location could be marked during the fruiting season and the labour to treat or remove them mobilised in spring and early summer when the trees would be more susceptible to herbicides. Mullet (1996) also reported a higher proportion of male trees in her study areas in the nearby Mornington Peninsula, although she noted that some apparently male trees did sometimes have a few capsules. The viability of the different categories of capsules will be resolved in a forthcoming study; any differences would influence control considerations.

Habitat

Anecdotally, there is a belief in the community that *P. undulatum* is an important habitat for the powerful owl (*Ninox strenua* Latham) and therefore that it should not be controlled. While it may well provide such a habitat, particularly for its fledglings, the question should be asked as to what species provided its habitat before this invasion. It seems likely that it was blackwood (*Acacia melanoxylon* R.Br.) (Loyn *et al.* 2002) and since many blackwood trees are extant in and near these remnant forests, *P. undulatum* is superfluous for this role. If *P. undulatum* is to be controlled then only the female trees (to a maximum of about 30% of the population) need to be treated or removed; the remaining male trees would still provide habitat for a long period of time while the powerful owl adapts to the gradual decline of the male *P. undulatum* population and re-establishes its habitat amongst the blackwood.

Table 1. Gender of *P. undulatum* flowers. Flowers were collected from trees growing at three sites along the south-western perimeter of the Dandenong Ranges and their sex determined.

Location	n	Male	Female	M:F Ratio
Burwood Road, Boronia	47	27	20	57:43
Walbundry Avenue, Ferntree Gully	44	26	18	59:41
Forest Road, Fern Tree Gully	62	39	23	63:37
TOTALS	153	92	61	
Gender Ratio by Flowers		60.1	39.9	60:40

Table 2: Fecundity of *P. undulatum*. The amount of fruit (capsule load) on trees was scored at five sites in Novemeber 2013 or January 2014; one of these sites (Aura Vale Road) was reassessed in January 2014.

Location	Capsule Load[A]				
Late Spring, November 2013					
	n	None (%)	Few	Medium	Heavy
Study Site, Menzies Creek	74	50 (67.6)	16	5	3
Aura Vale Road, Menzies Creek	132	90 (68.2)	16	11	15
Railway Line, Menzies Creek	61	47 (77.0)	2	6	6
Selby Aura Road, Menzies Creek	61	46 (75.4)	6	5	4
TOTALS	328	233	40	27	28
Percentages		71	12.2	8.2	8.5
Gender Ratio by Capsules		M:71	F:29		
Mid-Summer, January 2014					
Aura Vale Road, Menzies Creek	132	93 (70.5)	10	16	13
Walbundry Avenue, Fern Tree Gully	70	45 (64.3)	4	10	11
TOTALS	202	138	14	26	24
Percentages		68.3	6.9	12.9	11.9
Gender Ratio by Capsules		M: 68.3		F: 31.7	

[A] Capsule load: Heavy 8–20 capsules on most branchlets; Medium 4–10 capsules on many branchlets; Few 1–5 capsules on a few branchlets; None with no capsules (Male).

Conclusions

The current distribution of *P. undulatum* in eastern Australia raises questions about what constitutes a "natural distribution". In the Sydney basin, for example, there are records of *P. undulatum* dating to first settlement by Europeans, yet its increase in density, particularly in wet gullies in remnant urban forests is reducing biodiversity (Rose and Fairweather 1997). Implicit in this discussion is that "native" is taken to be synonymous with pre-European distribution, even though this time-based definition says nothing about its ecological requirements in space and time (Head and Muir 2004). This distinction will only become more difficult as the climate changes and historical locations are no longer suitable, and/or new areas become available for colonization (Gleadow and Ashton 1981, Webber and Scott 2012). In the case of *P. undulatum*, there is no doubt that the reduction in relatively hot forest fires and the introduction of avian vectors, have aided its spread. If the rate of the *P. undulatum* invasion from Menzies Creek during the past 90 years is relevant for the entire Dandenong Ranges, then they will be covered with *P. undulatum* in about 25 to 30 years and biodiversity will likely be lost, unless the issue is recognised and appropriate control measures put in place. As a first step, female trees with high fecundity should be identified and removed. Areas that can be safely burnt should be managed in that way, although it is not completely effective and follow-up weeding would be required (Gleadow and Narayan 2007). In Victoria, the only legislative support for its control is that it is listed as 'Potentially Threatening' under the *Flora and Fauna Guarantee Act 1988*, and even then, ambiguity arises as to the interpretation of its 'natural distribution' or 'endemic range'. The implications of this study indicate that stronger legislation along the lines of that suggested for New South Wales (Johnson 2014) will be required.

The participation of pupils from the Menzies Creek Primary School in this citizen science project demonstrates that simple measurements can be made that add substantially to the body of knowledge and can also act to engage students in science, and help them understand the need for environmental management in order to maintain biodiversity in their region.

Gleadow and Ashton concluded in 1981, that "*the invasion of forest remnants by* P. undulatum *and other weeds is threatening the survival of the eucalypt forests in urban areas*". In hind-sight, that conclusion appears to have been an understatement; it has now escaped from suburbia and is progressing through peri-urban areas into adjacent forests and national parks.

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Understanding the biology and ecology of poverty weed (*Iva axillaris* Pursh) – A guide towards eradication and control programs in Victoria

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Abstract

Poverty weed (*Iva axillaris* Pursh) is a State Prohibited Weed in Victoria. State Prohibited Weeds do not occur in Victoria, or there is a reasonable expectation that they can be eradicated from the state. Understanding the ecology and biology of the weed is paramount in any eradication or control programs. It may be possible to eradicate poverty weed in Victoria by using an integrated weed control approach, and also through education and legislation enforcement. This paper aims to review the literature on the general weed control/management of the weed, legislation, biology and ecology of poverty weed thereby providing eradication and control guidelines and recommendations that may be used in integrated weed management programs for poverty weed.

Keywords: eradicate, education, integrated, invasive, legislation, State Prohibited Weed.

Introduction

Poverty weed (*Iva axillaris* Pursh) is a herbaceous perennial that belongs to the Asteraceae family and is native to North America. It is a highly invasive weed that aggressively competes with native species and reduces crop yields (Parsons and Cuthbertson 2001). Poverty weed is also allelopathic, and is often the only species present in dense infestations (California Department of Food and Agriculture 2013). Pasture areas in western Canada that are densely populated with poverty weed have been reported to have become of little or no value for grazing (Best 1975). Poverty weed is a selenium accumulator and may be toxic to livestock when ingested (California Department of Food and Agriculture 2013). Fortunately, the plant is not very palatable (Hanson and Ball 1928), hence, the poisoning risk to livestock is minimal. Poverty weed pollen is highly allergenic and plants may cause contact dermatitis to sensitive individuals (Bassett *et al.* 1962).

In Victoria, recorded poverty weed infestations are restricted to a few small patches in Quambatook and Dingwall, with a total infested area of less than 50 ha (Munakamwe 2013). These Victoria infestations rarely produce viable seed (Pritchard 1987) and date back to 1926 (Parsons and Cuthbertson 2001). The only other infestations ever recorded in Australia were in South Australia in 1933, at Riverton and Sevenhill. These were successfully eradicated; there have been no further reports of poverty weed again on those sites.

Poverty weed is declared a State Prohibited Weed in Victoria under the *Catchment and Land Protection Act 1994*. Eradication is the management goal for all State Prohibited Weeds in Victoria. Dodd (1990) reported that although eradication is often prescribed as a management goal, in general it is seldom achieved. Hester *et al.* (2004) suggested that eradication is technically feasible for both large and small infestations, but only economically feasible for small infestations. Therefore, poverty weed eradication may be both technically and economically feasible in Victoria, as the known and recorded infestation size is less than 50 ha. This can be achieved by using weed control legislation (Hester *et al.* 2004), knowledge of the biology and ecology of the weeds, and using an integrated weed management approach.

This paper reviews poverty weed literature in relation to integrated weed management tools, thereby providing eradication and control guidelines, and recommendations that may be used in current and future management programs. Emphasis is mostly directed at understanding the biology and ecology of the weed, as this knowledge provides fundamental principles for effective invasive weed management protocols.

Eradication and weed management tools

Legislation

States and Territories Responsibility for the use and management of land rest primarily with the States and Territories under the Australian Constitution. Each State and Territory has legislation covering the control of weeds declared noxious and the movement of weeds and weed seeds, including crop seeds and stock feed. The legislation empowers these governments to compel landholders and occupiers to control certain weeds and to prevent their movement and spread.

Victorian legislation Under the *Catchment and Land Protection Act 1994*, noxious plants are classified under four categories: State Prohibited Weeds, Regionally Prohibited Weeds, Regionally Controlled Weeds and Restricted Weeds. Poverty weed is classed as a State Prohibited Weed. This is the highest category of noxious weeds under this act. The Victorian Government, through the Department of Environment and Primary Industries, has the sole responsibility for treatment and management of State Prohibited Weeds, but may direct land owners to prevent their growth and spread. Details of the other categories can be found in the *Catchment and Land Protection Act 1994*.

Understanding the biology of poverty weed

Knowledge and in-depth understanding of the ecology and biology of poverty weed is of paramount importance to the success of eradication programs as this relates to early detection, proper identification and effective timing of treatment operations. However, there is currently limited literature worldwide