Effects of forest management practices on a localised Tasmanian endemic plant, the trailing riceflower *Pimelea filiformis* Hook.f. (Thymelaeaceae)

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Summary

Threatened plant species are a key component of forest ecosystems and are often justly considered sensitive to forestry practices. Management of threatened species is an important aspect of modern forest management. The trailing riceflower, *Pimelea filiformis* Hook.f. (Thymelaeaceae), is endemic to Tasmania and is confined to eucalypt forests of the central north of the State, an area important for production forestry activities. We determined the impact of forest practices on the abundance and health of *P. filiformis* by comparing sites that had and had not been logged. We examined four types of forestry activity: conversion of native forest to hardwood plantation; intensive native forest harvesting and regeneration undertaken prior to the introduction of the Tasmanian *Forest Practices Code*; intensive post-Code native forest harvesting and regeneration; and less-intensive post-Code native forest harvesting and regeneration. We also examined the environmental factors that were associated with *P. filiformis* in relatively undisturbed forest environments (control sites). *Pimelea filiformis* occurs most commonly on mid-slopes with relatively dense low shrub and ground layers (<1 m high) and low cover of both exposed soil and litter. *Pimelea filiformis* is least common on north-east-facing sites and most common on south-west-facing sites. There was a clear difference in both the cover and occurrence of *P. filiformis* between unlogged sites and those logged prior to adoption of the current *Forest Practices Code*. We found no evidence, however, for any impact on the cover, occurrence or health of *P. filiformis* between unlogged sites and those logged after the adoption of the Code, irrespective of the forestry treatment (including conversion of native forest to hardwood plantation).

Keywords: flora; endangered species; nature conservation; conservation areas; forest plantations; forest management; silvicultural systems; logging effects; *Pimelea filiformis*; Tasmania

Introduction

The management of threatened flora is recognised as an integral part of land-use planning. Tasmania supports about 1800 native vascular species, and about 460 of these are listed in the Tasmanian *Threatened Species Protection Act 1995*. About 150 species (or about 32% of listed species and 8% of the total vascular flora) are strongly associated with areas suitable for production forestry activities. In production forest areas in Tasmania, whether on private or public land, the management of threatened flora is underpinned by the Tasmanian *Forest Practices Code* (Forest Practices Board 2000), the Tasmanian *Regional Forest Agreement* (Anon. 1997) and the Tasmanian *Threatened Species Protection Act 1995*. Consultation between the forest industry (including both the private sector, represented by major companies and private landowners, and the public sector, represented by Forestry Tasmania, the government business enterprise responsible for management of State forest) and the government department administering the threatened species legislation (Department of Primary Industries, Water and Environment) is required to ensure that the management of threatened flora species is considered in forest management planning.

The threatened forest flora of Tasmania can be broadly categorised into those with widespread distributions that occur in a range of forest habitats, and those that have restricted distributions. The latter group of species includes those restricted to particular environments (such as forested riverine habitats) or substrates. Many of Tasmania's threatened flora are endemic to the state with many having very restricted distributions. The recognition of centres of local endemism in Tasmania has been used to design reserves (Kirkpatrick *et al*. 1991). However, as noted by Laffan and Crisp (2003), endemism, even when highly localised, does not always imply rarity or threat, because narrowly endemic species may be abundant within their range.

In Tasmania a high level of localised plant endemism is associated with particular rock types (Kirkpatrick and Brown 1984a; Hill and Orchard 1999). For example, endemism is strongly associated with granitic substrates on the east coast (Rozefelds 2001) and Cambrian serpentinite and associated ultramafic rock types in the central north and west (Brown *et al*. 1986; Orchard 1991). There is also a suite of endemic species associated with one of the more widespread rock types in the state, Jurassic dolerite (Kirkpatrick *et al*. 1980; Hill and Orchard 1999), which occurs extensively in eastern and northern Tasmania and the Central Highlands but is virtually absent from mainland Australia. The level of endemism associated with Jurassic dolerite is particularly high in the state's central east coast and Central Highlands (Kirkpatrick *et al*. 1980; Kirkpatrick and Brown 1984a; Hill and Orchard 1999), where the endemism may be explained at least in part by edaphic and climatic factors, and by past glacial events (Kirkpatrick and Brown 1984b).

Jurassic dolerite occurs extensively in the hinterland of Tasmania's central north coast. The association of the trailing riceflower *Pimelea filiformis* Hook.f. (Thymelaeaceae) with this landform unit has long been recognised (Kirkpatrick and Brown 1984b). At the time of the present study, *P. filiformis* was listed on Schedule 5 (Rare) of the Tasmanian *Threatened Species Protection Act 1995*, primarily due to its localised distribution. The species occurs in a region of Tasmania that has been, and continues to be, a focus for forestry activities. The area currently supports hardwood and softwood plantations, harvested forest and reserves. Native forest silviculture (mainly selective harvesting or clearfell, burn and sow) and conversion of native forest to plantation are the two main forestry activities undertaken in the range of *P. filiformis*. Consequently, there is on-going liaison about prescriptions to take account of the species in areas proposed for logging or other forestry operations. The focus of the current study was to develop better prescriptions and management strategies for *P. filiformis* by refining information on the distribution, habitat characteristics and conservation status of the species, with particular emphasis on the effects on the species of forest practices undertaken before and after the introduction of the *Forest Practices Code* (in 1987). Prior to the introduction of the Code, there was no requirement to manage threatened flora during forestry operations, and there were few restrictions on how forestry operations were conducted, particularly with respect to the management of soil and water values.

Methods

Study species

Pimelea filiformis Hook.f. (Thymelaeaceae) is a slender glabrous subshrub, characterised by its prostrate to ascending growth habit, often forming extensive patches over the ground and other low subshrubs, dark green opposite leaves, and small white–pink flowers in small terminal clusters (Curtis 1981) (Fig. 1).

The species was described by Hooker from specimens collected in 1844 from Distillery Creek east of Launceston, but this site is unlikely to be extant due to urban development (Whelan and Cave 1996). The species has subsequently been collected from over 200 sites in an area of about 1300 km^2, with two centres of distribution separated by the Tamar River system (Fig. 2). Adamczewski (2001), in a multivariate analysis of the association of various environmental factors with the distribution of several species of *Pimelea* in Tasmania, showed that *P. filiformis* is positively associated with eucalypt-dominated forests on a dolerite-derived substrate. We referred to existing threatened species databases (held by Forestry Tasmania and the Department of Primary Industry, Water and Environment) to define the area of the State occupied by *P. filiformis*. By overlaying these database records with geology maps we confirmed the exclusive association of *P. filiformis* with Jurassic dolerite and Quaternary dolerite talus slopes.

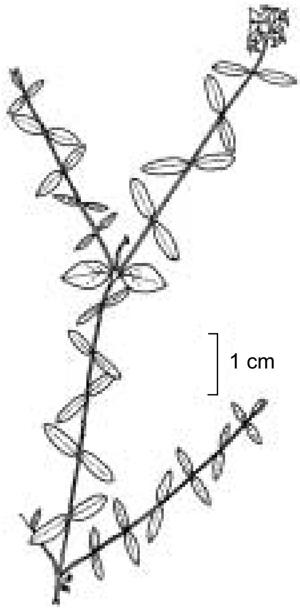

Figure 1. Growth habit, size and arrangement of leaves and inflorescence of *Pimelea filiformis*. Scale bar is 1 cm. Line drawing by Brian French.

The broad habitat variables (geology, climate, altitude, topography, forest type) affecting the distribution and abundance of the species are similar for both centres of distribution. The western population provided more opportunities for assessing the effects of a range of forestry treatments, and was chosen for more intensive survey.

Study area

The western area of *P. filiformis*, centred on the Reedy Marsh Forest Block (State forest managed by Forestry Tasmania), is characterised by undulating dolerite hills, with slopes varying from gentle to moderately steep, separated by small flats, drainage lines and gullies. The altitudinal range is about 40–450 m, and the area has a moist subhumid cool climate system (Gentilli 1972). The extensive flats surrounding the hills have been largely cleared for agriculture (or occasionally softwood or hardwood plantation). Most of the dolerite-based hills remain forested. The main forest types (wet and dry sclerophyll forest and intergrades between the two) are dominated by *Eucalyptus obliqua* (widespread), *E. delegatensis* (higher altitudes), *E. amygdalina* (drier sites) and *E. ovata* (poorly drained flats). Localised areas of mixed forest (eucalypt forest with a rainforest understorey) are confined to humid gullies protected from fire. The relationships between vegetation and environmental factors in this part of Tasmania were described by Brown and Buckney (1983).

Several forest management activities are practised in the area on both public and private land, including:

- management of existing eucalypt and softwood plantations, and establishment of new plantations (mainly *E. nitens*)

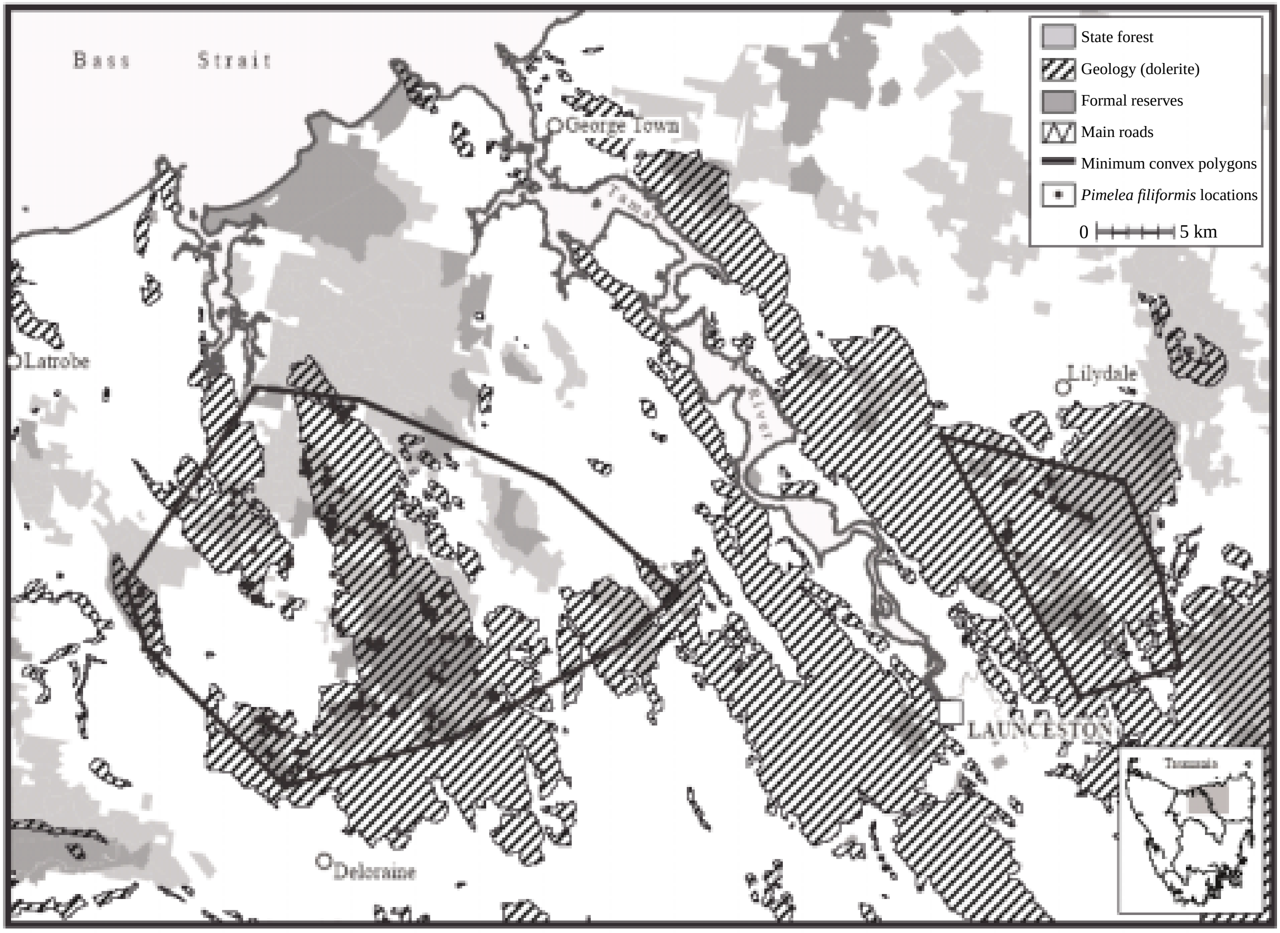

Figure 2. Distribution of *Pimelea filiformis* in Tasmania. The outlines enclose the 'populations' centered to the west and east of the Tamar River system.

- native forest silviculture, which varies from clearfell, burn and sow regimes in wetter forest types to less intensive practices (such as advanced growth retention, seed tree retention) in drier forest types
- formal and informal reservation of representative areas of forest, localised environments (e.g. riparian areas) and forest communities with a high priority for conservation.

Effects of forest practices

Treatments

Four forestry treatments were selected for detailed study. One treatment that was 'pre-Code' (i.e. logging undertaken before the introduction of the Tasmanian *Forest Practices Code* in 1987) was included. Coupes selected for the 'post-Code' era needed to be of suitable age to have allowed *P. filiformis* to have recovered, i.e. we did not want to measure a short-term (i.e. immediate post-harvest) effect on the species. The treatments were:

(1) *Pre-Code native forest silviculture coupes:* These coupes were 14–20 y old; timber harvesting plans indicated that most had been selectively logged but aerial photographs showed that the coupes had been effectively clearfelled and left to regenerate from retained seed trees (Fig. 3), i.e. seed tree retention silviculture, and/or relatively intensive advance growth retention as described by Wilkinson (1994). Most merchantable trees >40 cm diameter at breast height were removed. These coupes were burnt after harvesting, probably with a relatively intense top disposal/debris burn. By reference to numerous aerial photographs and ground truthing, sites considered representative of 'pre-Code' practices were selected.

(2) *Post-Code native forest silviculture coupes, 'lightly logged' coupes:* These coupes were 8–11 y old and categorised as 'lightly logged' on the basis of aerial photographs, which showed high retention of trees of diverse ages throughout the coupe (Fig. 3). The silvicultural regime applied to these coupes was a mixture of seed tree retention and advanced growth retention (Wilkinson 1994). These coupes received only relatively low-intensity top disposal/debris burning following harvesting. After the introduction of the *Forest Practices Code* in 1987, most coupes that were harvested and regenerated to native forest using seed tree retention silviculture also had clumps of retained habitat trees throughout, adding to the structural diversity retained.

(3) *Post-Code native forest silviculture coupes, 'heavily logged' coupes:* These coupes were of the same age as treatment (2), but aerial photographs showed them to have been much more intensively logged than the 'lightly logged' coupes, i.e. they

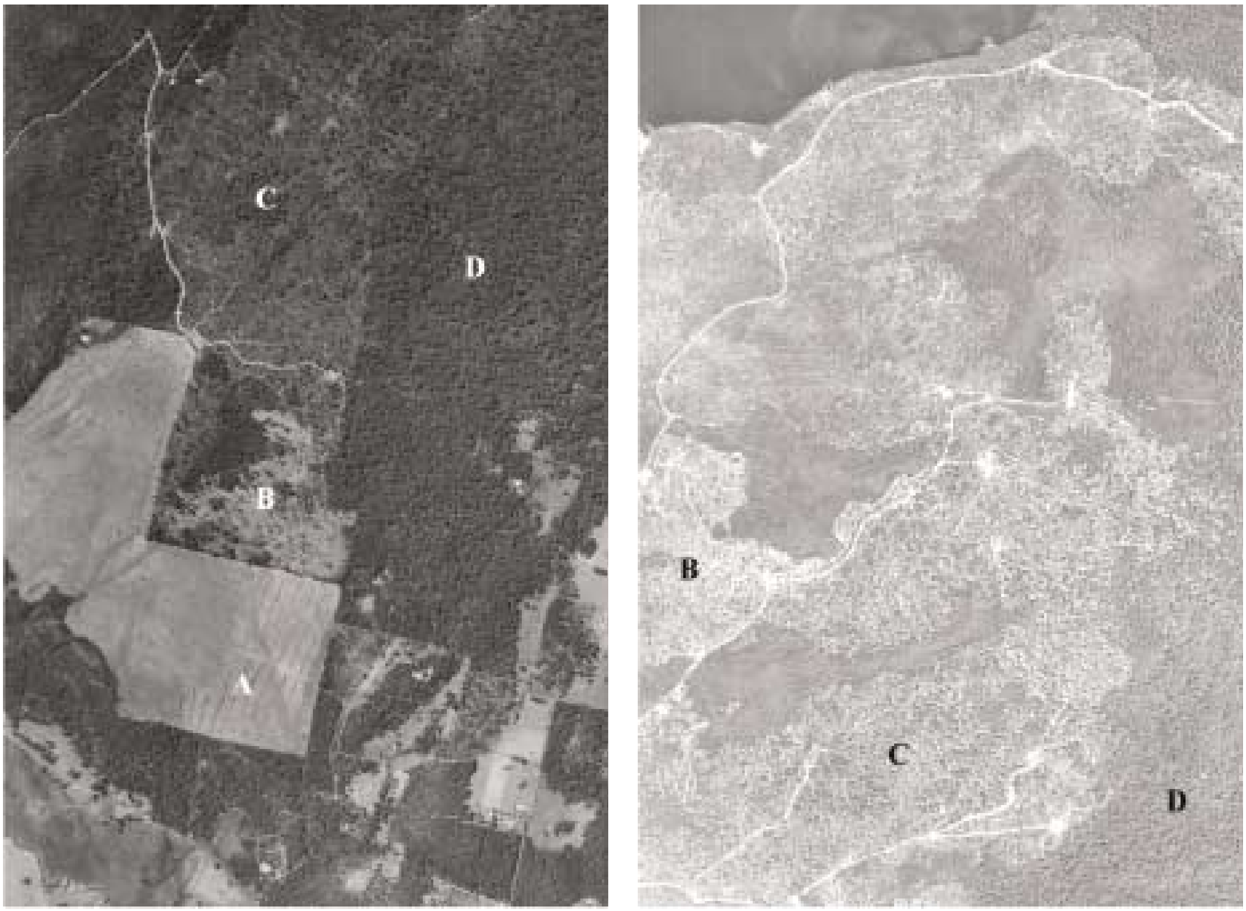

Figure 3. Aerial photographs of parts of the western range of *Pimelea filiformis*. The figure on the left shows the mosaic of agricultural development, plantation establishment, native forest silviculture and reserved native forest typical of much of the range of the species at its periphery. The figure on the right shows the typical mosaic of native forest regrowth of different ages interspersed with formal and informal reserves. A = hardwood plantation establishment on ex-native forest site; B = post-Code native forest silviculture coupes, 'heavily logged' using seed tree retention silviculture; C = post-Code native forest silviculture coupes, 'lightly logged' using seed tree retention and advanced growth retention; D = reserved native forest. The figure does not show a pre-Code coupe.

approached the classic seed tree retention silviculture (Wilkinson 1994) seen in the pre-Code treatment coupes (Fig. 3). These coupes received relatively low-intensity top disposal/debris burning following harvesting. These coupes did not have specific prescriptions for habitat tree retention applied (as discussed above for the 'lightly logged' coupes).

(4) *Hardwood plantations, i.e. monoculture plantations of either* Eucalyptus globulus *(Tasmanian blue gum) or* E. nitens *(shining gum):* These coupes were established after the clearfelling of native forest sites, followed by windrowing and burning of woody debris. The age of the plantations sampled was 14–20 y. While the exact history of all sites was not known (particularly with respect to use of chemicals such as fertilisers and herbicides), we believe that the sites selected were broadly similar, in terms of original vegetation, to sites selected for other treatments, and that the manner of plantation establishment and maintenance applied to our sites are similar to those currently used.

Control sites were selected in relatively undisturbed native forest with topography similar to that in treatment areas, most of which were adjacent to the treatment sites, i.e. habitat-matched sites. The term 'relatively undisturbed native forest' has been used because most of the habitat occupied by *P. filiformis* has been disturbed to some degree by forestry activities, although the control sites showed only minor evidence of previous activities (e.g. low-intensity firewood or post-wood cutting).

We also assessed the presence of *P. filiformis* in softwood plantations established on Jurassic dolerite sites previously supporting native forest. These sites were not included in the formal analyses because of problems in finding suitable controls. Plantations from three forest blocks (Virginstow, Branches Creek, Long Hill) representing the range of ages and the geographic range of the plantations within the western distribution of *P. filiformis* were examined. The age of the softwood plantations sampled was 5–28 y. Most sites had been thinned and had had fertiliser applied during their history. Sites were surveyed informally using a random search method: the presence and abundance of *P. filiformis* was noted at each site.

Sampling regime

For each treatment (excluding the softwood plantation sites), three coupes were selected by reference to photo-interpretation (forest type) maps, aerial photographs of logged coupes, information from timber harvesting plans and digital data of coupe ages. Sites were ground-truthed to confirm the age of regeneration and the nature of logging practices, and the presence of potential habitat of *P. filiformis*.

Three transects were randomly placed within each coupe. Each transect ran from the lowest to the highest point on a slope within a coupe, perpendicular to the contour. Minimum and maximum transect length was 100 m and 480 m, respectively, and mean transect length was 260 m. Each transect was stratified into 20-m sections and each section was sampled by the random placement of a 1 m × 1 m quadrat. This allowed regular sampling along the transect but avoided confounding with regular patterns in the environment.

Transects were established in a similar manner in control sites, most of which were adjacent to the treatment sites (i.e. three transects perpendicular to the contour, arranged as described above).

The following (mainly qualitative) data were collected for each quadrat: topography (lower slope, midslope, upper slope, ridge, gully, flat); slope (in degrees); aspect (compass bearing); drainage (poor, medium, good); percentage cover exposed rocks; percentage cover litter (<10 cm diameter); percentage bare ground; percentage cover coarse woody debris (>10 cm diameter); percentage cover vegetation (<1 m high); percentage cover of single dominant species (<2 m high); vegetation cover (>1 m high) — recorded as none, sparse, moderate or dense. Vascular species, identified to species level, were recorded for each plot. For each quadrat, the following details about *P. filiformis* were recorded: abundance (low, medium or high); condition (dead, poor, good or healthy); and life stages present (seedling, young shoot, trailing plant or erect plant). Note that abundance was divided into broad categories because the growth habit of the species (trailing between and over leaf litter, debris and subshrubs) makes calculation of absolute abundance difficult in field conditions. For each quadrat, disturbance associated with logging was also recorded (e.g. presence of snig tracks, landings, logging debris, outrows or stumps).

Statistical analyses

Microhabitat associations

Data from the control sites were used to determine microhabitat factors affecting the presence and abundance of *P. filiformis* in forest environments that had not been recently disturbed by forestry operations. Exclusion of data from operational areas allowed distribution patterns in the treatment sites to be compared with those in relatively undisturbed environments. Reducing data for analysis to include only quadrats from control sites created a sample size of 369 quadrats.

The relationship between *P. filiformis* and recorded environmental factors was assessed for the control sites using *t*-tests on the difference in each environmental factor between sites where *P. filiformis* was present and those where it was absent. Because of the large number of *t*-tests involved, a sequential Bonferroni adjustment was made to the level of significance to reduce the possibility of family-wise Type I error (Quinn and Keough 2002).

The relationship between topography (slope site) and aspect was tested via χ^2 analysis.

The effects of forestry treatments on the cover, frequency and health of *P. filiformis* were tested for each different forestry treatment by a single-factor ANOVA using general linear model procedures with the SAS statistical software program, version 8 (SAS Institute Inc.). Because of the multiple tests, the statistical significance was reduced with a sequential Bonferroni adjustment. Significant effects were investigated with a Ryan-Einot-Gabriel-Welsch *post hoc* comparison following Day and Quinn (1989).

The effect of forestry treatments on microhabitat factors significantly associated with the presence of *P. filiformis* was tested via a Student's *t*-test, with significance reduced by a sequential Bonferroni adjustment.

Reservation and conservation status

Site records for *P. filiformis* collected during the present study were added to the threatened species databases maintained by the State government and the Tasmanian Herbarium. The potential range of the species was determined by two minimum convex polygons defined by the 'populations' centred on each side of the Tamar River system. For each polygon the following variables, based on broad tenure categories, were calculated for areas occupied by Jurassic dolerite and dolerite talus (i.e. potentially suitable habitat for *P. filiformis*):

- area reserved in gazetted reserves and informal reserves (including streamside reserves, wildlife habitat strips and other forest protected from logging)
- area of softwood and hardwood plantation, and
- area of land managed for agricultural activities.

Results

Microhabitat associations

The presence of *P. filiformis* was associated significantly with a greater cover of vegetation <1 m tall, less litter cover and less bare ground (Table 1). Other measured variables (drainage, vegetation cover >1 m, cover of woody debris, and cover of surface rocks) were not significantly correlated with the presence of *P. filiformis*.

Pimelea filiformis occurrence was non-randomly distributed along slopes (χ^2 = 13.5, df = 4, P < 0.01; Fig. 4), tending to be less common on flats and upper slopes and more common on lower slopes, midslopes and ridges. The actual inclination of the slope, however, was not significantly correlated with the presence of *P. filiformis* (t = –0.29, df = 728, P = 0.77).

Pimelea filiformis was found in 31% of quadrats in unlogged forest. It was found on a full range of aspects (Fig. 5) but was less common on sites with north-easterly aspects (18.6%) and

Table 1. Microhabitat variables significantly associated with presence of *Pimelea filiformis* (control sites only). Data presented are means ± SE. The *t* statistics were calculated with 368 degrees of freedom.

Variable	Absent	Present	Statistic
Vegetation cover <1 m	30.6 ± 1.6	42.2 ± 3.0	$t = -5.26$, $P < 0.0001$
Litter cover	46.7 ± 1.7	36.8 ± 2.93	$t = 4.57$, $P < 0.0001$
Bare ground	5.2 ± 0.3	1.6 ± 0.05	$t = 6.12$, $P < 0.0001$

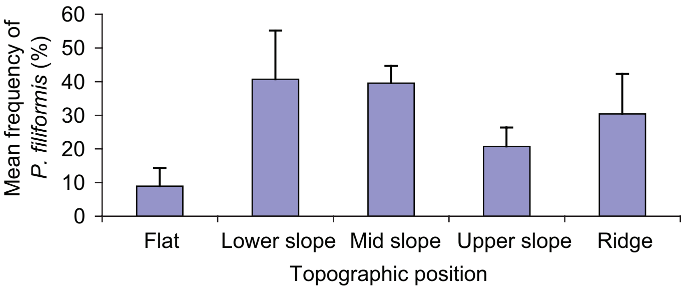

Figure 4. Mean percentage frequency (±SE) of occurrence of *Pimelea filiformis* as a function of topographic position

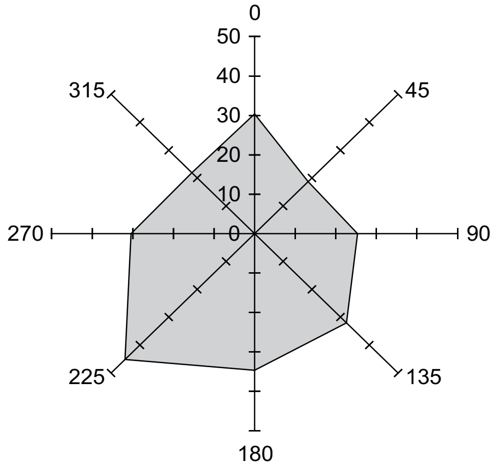

Figure 5. Percentage frequency of *Pimelea filiformis* as a function of aspect

Table 2. *Pimelea filiformis* status in four categories of logged and control coupes in northern Tasmania. Those means in the same row with the same superscript are not significantly different at $P = 0.05$. ANOVA results are the *F* ratios and associated probabilities; ns = non-significant at $P < 0.05$ with sequential Bonferroni adjustment.

Coupe status and variable	Mean values		Results of statistical analysis					
			Treatment		Site		Treatment × site	
	Coupe	Control	*F*	*P* > *F*	*F*	*P* > *F*	*F*	*P* > *F*
Post-Code lightly logged coupes								
Cover	0.54[a]	0.46[a]	0.10	ns	0.03	ns	0.07	ns
Frequency	0.39[a]	0.31[a]	0.23	ns	0.13	ns	0.15	ns
Health	1.63[a]	2.01[a]	0.91	ns	2.48	ns	0.47	ns
Post-Code heavily logged coupes								
Cover	0.77[a]	0.46[a]	1.35	ns	0.09	ns	0.01	ns
Frequency	0.45[a]	0.31[a]	0.53	ns	0.79	ns	0.01	ns
Health	1.89[a]	2.01[a]	0.35	ns	0.16	ns	4.87	ns
Pre-Code coupes								
Cover	0.29[b]	0.46[a]	6.45	0.03	21.9	0.001	0.01	ns
Frequency	0.18[b]	0.29[a]	9.91	0.01	12.0	0.006	0.68	ns
Health	1.83[a]	2.30[a]	1.96	ns	0.14	ns	0.98	ns
Plantations								
Cover	0.32[a]	0.42[a]	2.24	ns	11.3	0.001	1.66	ns
Frequency	0.24[a]	0.26[a]	0.09	ns	2.46	ns	0.53	ns
Health	1.82[a]	1.96[a]	0.33	ns	1.90	ns	0.42	ns

more common on those with south-westerly aspects (45.2%). This variation was statistically significant ($\chi^2 = 16.6$, df = 7, $P < 0.025$).

There were no significant associations of *P. filiformis* with the presence of other understorey species in the forest types assessed.

Effects of forest practices

There was no significant difference between logged and control sites in the cover, frequency or health of *P. filiformis* in either the heavily or lightly-logged post-Code coupes or the plantations (Table 2). There was, however, a significant effect of logging on both the frequency and cover of *P. filiformis* in pre-Code coupes (Table 2). There was also evidence of variation among the plantation sites and among the pre-Code sites, but there was no site × logging interaction (Table 2). The pre-Code coupes had the lowest mean cover (0.29) and frequency (0.18) of *P. filiformis*, while the post-Code heavily logged coupes had the highest cover (0.77) and the highest frequency (0.45) (Table 2).

Microhabitat associations within forestry treatments

Table 3 shows the three significant microhabitat variables that were found to correlate with the distribution of *P. filiformis*. There was a significantly greater amount of bare ground in plantations and pre-Code coupes. However, it is noteworthy that the amount of bare ground in the post-Code coupes was greater than in the older treatment, which is probably simply a reflection of the time since ground disturbance occurred. Vegetation cover <1 m high was significantly greater in the pre-Code coupes and post-Code heavily-logged coupes. Litter cover was significantly less in the plantations, pre-Code coupes and post-Code heavily-logged coupes.

Softwood plantations

The abundance of *P. filiformis* appeared to be correlated with the degree of canopy openness (most abundant where canopy was sparser) and density of native understorey (most abundant where there was a well-developed understorey of native species). The species was very sparse in the youngest plantation, which had a very open canopy and moderately dense understorey. *Pimelea filiformis* was sparse to moderately dense in plantations 16–19 y old, all of which had relatively open canopies and moderately dense understories. The species was very sparse in 27–28-y-old plantations, which all had dense canopies and very little native understorey with dense mats of pine needles. Within plantation areas, *P. filiformis* appeared to be most common in canopy openings (whether created by production thinning, windthrow or linear features such as roads and firebreaks), and where there is native forest immediately adjacent to or within the plantation (either as remnant native forest patches or as larger contiguous patches).

Reservation and conservation status

Table 4 shows the proportion of reserves, plantations and cleared land within the range of *P. filiformis* (Fig. 2 shows the location of the two 'populations' of the species). The species occupies a

Table 3. Mean values of microhabitat factors associated with occurrence of *Pimelea filiformis* in logged and control sites of four forestry treatments. ns = non-significant at $P < 0.05$ with sequential Bonferroni adjustment

Coupe status and variable	Logged	Control	*t*	d.f.	Probability
Post-Code lightly logged coupes					
Bare ground	5.07	4.48	0.39	171	ns
Veg. <1 m	1.16	1.89	–7.77	179	<0.0001
Litter	50.7	44.7	1.96	223	ns
Post-Code heavily logged coupes					
Bare ground	4.55	4.48	0.05	222	ns
Veg. <1 m	0.95	1.89	–9.51	209	<0.0001
Litter	28.6	44.7	–4.57	223	<0.0001
Pre-Code coupes					
Bare ground	2.5	1.10	1.94	165	ns
Veg. <1 m	1.10	1.50	–4.38	210	<0.0001
Litter	41.5	49.3	–1.93	213	ns
Plantations					
Bare ground	6.69	4.11	1.42	155	ns
Veg. <1 m	1.38	1.24	1.62	185	ns
Litter	62.1	53.5	2.13	185	ns

Table 4. Range and potential area of occupancy (in hectares) for *Pimelea filiformis* categorised by tenure, geology and land use

Category of land	East polygon[6]		West polygon[6]		Total[5]	
Whole area	13 240		54 916		68 156	
Reserved area[1]	2 114	(3%)	9 192	(14%)	11 306	(16%)
Other public land[2]	2 922	(4%)	13 344	(20%)	14 730	(22%)
Private land	8 204	(12%)	32 379	(48%)	42 962	(63%)
Area on dolerite[4]	10 995	(16%)	25 177	(37%)	36 172	(53%)
Cleared land (all geologies)[3]	962	(1%)	11 900	(18%)	12 862	(19%)
Cleared land (on dolerite)[4]	301	(0.5%)	971	(1%)	1 272	(2%)
Plantation (dolerite)[4]	168	(0.2%)	995	(1.5%)	1 163	(2%)

[1]This figure includes formal reserves (i.e. gazetted reserves) and informal reserves (e.g. informal set-asides under the *Forest Practices Code*)
[2]This figure includes State forest and other public land (e.g. Crown land)
[3]This figure was calculated using vegetation type codes from the TASVEG mapping
[4]The total area of dolerite was calculated as the sum of the area dolerite bedrock (mapped as Jdl — Jurassic dolerite) and dolerite talus (mapped as Qpt — talus derived from Jurassic dolerite)
[5]The 'total' figure is the sum of the area of the east and west minimum convex polygon. Percentage figures represent the percentage of the total of each category shown in the rows of the total area.
[6]Percentage figures represent the percentage of the total of each category shown in the rows of the total area (i.e. 68 156 ha)

potential range of 68 156 ha (13 240 ha in the eastern 'population' and 54 916 ha in the western 'population'). Of this total area, 37% is on public land (of which 11 306 ha (or 16% of the total area) is reserved) and 63% is on private land. While 19% of the total area has been cleared for agricultural activities, only 2% of the total area and 2% of the total area that occurs on potentially suitable substrates (i.e. Jurassic dolerite or dolerite talus) has been cleared or developed as plantation, respectively.

Discussion

Habitat associations

The distinct habitat requirements of *P. filiformis* — its strong association with one rock type — means predicting the presence of the species is relatively simple. This is important in the management of any species potentially affected by disturbance within its range (in the case of *P. filiformis*, this disturbance is most likely to be forestry activities). It is interesting to note that Jurassic dolerite is a relatively common rock type throughout eastern, central and northern Tasmania and yet *P. filiformis* is restricted to a limited area in the central north of the State. The reason for its absence from other parts of the State with dolerite is not known (and was not investigated as part of this study) but is probably related to past climatic conditions.

At a finer scale, the distribution and abundance of *P. filiformis* appear to be correlated with a number of site characteristics. The results indicate that the overstorey vegetation characteristics (i.e. the cover of taller shrubs and overstorey trees) are not significantly associated with the presence of *P. filiformis*; rather, the understorey characteristics are more important. We found that a dense understorey was significantly associated with the presence of *P. filiformis*, as was less litter cover and less bare ground. This apparent incongruity between the density of the understorey (which might create a dense litter layer) and the cover of litter and amount of bare ground is probably explained by the composition of the vegetation, i.e. sclerophyllous species (such as leguminous shrubs, *Pteridium esculentum* and *Lomandra longifolia*) that do not shed copious quantities of litter. In addition, the presence of rocks within plots might explain the apparent discrepancy.

Forestry effects

Forest-dependent threatened flora are often perceived to be at risk from various forestry activities (mainly from replacement of native forest with monoculture plantations — see Briggs and Leigh 1996 and Burgman 2002), but in Tasmania there is an increasing literature to suggest that some threatened forest flora may not be at risk from many of the routinely practised native forest silvicultural techniques (e.g. Wapstra *et al*. 2002; C. Hawkins, Forest Practices Authority 2005, unpublished data), and that their threatened status may simply be due to a restricted range, or lack of detailed ecological information (e.g. Roberts *et al*. 2003). Studies that identify habitat requirements and key management issues allow management prescriptions for individual species to be incorporated into broad-scale and coupe-level planning.

Our study has provided evidence for the beneficial impacts of some provisions of the Tasmanian *Forest Practices Code*, particularly those concerned with minimising the degree of soil disturbance and compaction. We found no significant difference in the occurrence or health of *P. filiformis* between logged and control sites in post-Code native silviculture sites, but the occurrence and cover of *P. filiformis* in pre-Code native silviculture coupes were significantly less than in post-Code treatments and controls (although plants were equally healthy in pre- and post-Code coupes).

Coupes harvested before the introduction of the *Forest Practices Code* (in 1987) are likely to have been subject to more intensive ground disturbance than coupes harvested under the provisions of the Code. Disturbance of the soil profile, compaction of soil and changes to the hydrological conditions of the ground (e.g. puddling) have been highlighted as major problems associated with decreased productivity of harvested forests (e.g. Wronski 1984; Williamson 1990). Snig tracks and landings have been identified as sites of greatest soil disturbance (Rab 1994, 1996) and they are often the site of reduced plant growth in the long term (e.g. Loyn *et al*. 1983; Williamson 1990). Evidence of snig tracks and landings was still present at sites we examined in this study, which had been harvested before the introduction of the Code. The Tasmanian *Forest Practices Code* and its revisions restrict the amount of snig track and the size of log landings in a coupe, and operations in wet weather (Forest Practices Board 2000). Reducing the amount of bare ground created by snig tracks and landings is likely to have been beneficial to species such as *P. filiformis*, which are negatively correlated with the presence of large areas of bare ground.

The replacement of native vegetation with crops, sown pasture and plantations has been identified as one of the key threats to vascular species in Australia (Table 6 in Burgman 2002). Our study has demonstrated that for *P. filiformis*, at least, plantations need not be deleterious. The species does not appear to be adversely affected by the development of hardwood plantations on native forest sites. While we did not examine the persistence of *P. filiformis* through successive rotations of hardwood or softwood plantation sites (due to lack of available sites) we suggest that its abundance may be reduced in the long term by the development and successive rotation of plantations. Hardwood plantations within the range of *P. filiformis* tend to have relatively well-developed understoreys of native shrubs and there is often a relatively dense litter layer resulting in little exposure of bare ground. In contrast, softwood plantations are often depauperate in the diversity of native shrubs and the ground is often bare or covered in dense mats of pine needles, features negatively associated with occurrence of *P. filiformis*. Pine needles contain phenolic compounds that can be toxic to some species (Souto *et al*. 1994). It is important to emphasise that the response of *P. filiformis* to more intensive plantation management practices, such as fertiliser application, is not known. However, given the observed correlations between *P. filiformis* abundance and habitat features, we suggest that plantation sites can be managed to enhance the conditions for survival and persistence of understorey species such as *P. filiformis*. Maintenance of remnant patches of native forest within plantations, or as a network of linked strips through plantation aggregates, may be beneficial in locally conserving understorey species. Harvesting and establishment techniques that minimise the degree of disturbance to the soil are also likely to benefit species such as *P. filiformis*. *Pimelea filiformis* produces moderately heavy seeds with hard coats, and is a low, almost ground-hugging plant, so is unlikely to readily be dispersed over large distances by vectors such as birds or mammals. Rather, it is likely to persist on disturbed areas through survival of the vegetative rootstock, and through regeneration from soil-stored seed (hence the presence of the species along edges of plantations and within canopy gaps where competition with other species or the amount of leaf litter may be less).

While we did not directly measure the effect of fire on the distribution and abundance of *P. filiformis*, we are confident that fire does not deleteriously impact on the species. High-intensity fires (wildfires and regeneration establishment burns) and lower-intensity prescribed burns (e.g. for fuel reduction) have been a regular component of the environment of *P. filiformis* and such events are likely to maintain the understorey in a condition suitable for the species. Other species of *Pimelea* have been shown to be tolerant of fire (Mueck 2000; Willis *et al*. 2003).

Reservation and conservation status

Pimelea filiformis occurs in eight gazetted reserves (forest reserves): Brushy Rivulet, Christmas Hills, Hollybank, Pipers River, Prossers Forest, Reedy Marsh, Roaring Magg Hill and Virginstow. Importantly, these reserves are distributed throughout the known range of the species, containing populations both east and west of the Tamar River divide. In addition, the species is known from numerous, less formal reserves in both private and public forests not subject to forestry (or other clearing) activities: such 'reserves' include the network of wildlife habitat strips in State forest, streamside reserves required by the Tasmanian *Forest Practices Code* (Forest Practices Board 2000), and numerous other areas excluded from harvesting for operational reasons (such as steepness, soil conditions), or because of other natural or cultural values requiring protection.

At the time of the present study, *P. filiformis* was listed on Schedule 5 ('Rare') of the Tasmanian *Threatened Species Protection Act 1995*. A reanalysis of the conservation status of *P. filiformis* indicates that it may qualify as 'Rare' due to its restricted distribution (682 km^2, of which about half is considered potentially suitable habitat, i.e. Jurassic dolerite or dolerite talus). However, this criterion indicates that a species may qualify for listing due to a potential 'stochastic risk' (DPIWE 2002). It is our opinion that no realistic stochastic risk exists within the range of *P. filiformis*. It should be noted that the species is almost wholly forest-dependent (with only negligible parts of the population occurring in non-forest situations such as agricultural land or rural-residential sites). This study has demonstrated no deleterious effect of forestry practices to the species, and virtually all areas suitable for clearing (which is likely to be detrimental to the species in the longer term) occur on substrates other than Jurassic dolerite (with which the species is exclusively associated). High-intensity fires (wildfires and regeneration establishment burns) and lower-intensity prescribed burns (e.g. for fuel reduction) have been a regular component of the environment of *P. filiformis*, indicating that such events are not likely to adversely affect the species in the long term. We suggest that *P. filiformis* is simply a species with a naturally limited range and area of occupancy. While species with limited ranges are often those at greatest risk of extinction, we argue that *P. filiformis* is not 'at risk' from predictable or stochastic events, and as such its formal conservation status should be reassessed by State authorities.

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