Department of Sustainability and Environment

Spiny Rice-flower

Pimelea spinescens subsp. *spinescens* Rye.

Habitat condition and demographic structure of 16 selected populations from The Victorian Riverina and Volcanic Plains

Report No: 1
Spiny Rice-flower Recovery Plan Working Group
Department of Sustainability and Environment
September 2005

Author

Paul Foreman
Consultant Botanist
4 Karnak Road, Ashburton VIC 3147
paulforeman@hotkey.net.au

Acknowledgements

This research was undertaken as part of the Recovery Plan for Spiny Rice-flower and was funded by Natural Heritage Trust Funding and the Department of Sustainability and Environment.
I wish to thank:

- Andrew Prichard of DSE Warnambool and Deanna Marshall of DSE Bendigo project coordination.
- The following people for assistance with project planning and/or field work: Andrew Pritchard, Deanna Marshall, Andy Arnold, Sue Hadden, Cath Grant, Adrian Murphy and Jenni Thomas.
- Val Stajsic of the National Herbarium for assistance with voucher specimen lodgement.

For more information about this publication contact
Andrew Pritchard
Threatened Species Project Officer
Department of Sustainability and Environment
78 Henna St, Warrnambool VIC 3280
Email: andrew.prichard@dse.vic.gov.au

ISBN

www.dse.vic.gov.au

Table of Contents

Preface

This project has been funded under the Natural Heritage Trust (NHT) as part of the implementation of the Recovery Plan for Spiny Rice-flower (Carter and Walsh 2003) in Victoria - a collaboration between DSE Regions (North West, South West and Port Phillip) and the following Catchment Management Authorities (CMA): North Central, Corangamite, Glenelg Hopkins and Port Phillip and Westernport. The Recovery Plan aims "to minimize the probability of extinction of *Pimelea spinescens* subsp. *spinescens* in the wild and to increase the probability of important populations becoming self-sustaining in the long term." The project contributes to this objective by implementing all or part of selected actions recommended in the Recovery Plan. In particular the data collected herein contributes by acquiring more accurate information on: (1) the habitat and demographic structure of representative populations; (2) common habitat within both the Riverina and Volcanic Plains Bioregions, (3) site specific threats, (4) site specific conservation management strategies, and (5) critical biological functions.

Abbreviations

CMA	Catchment Management Authority
DSE	Department of Sustainability and Environment
EPBC	Environment Protection and Biodiversity Conservation Act
FFG	Flora and Fauna Guarantee Act
NHT	Natural Heritage Trust

Summary

Spiny Rice-flower is a Victorian endemic subshrub restricted to remnant grasslands and is listed as threatened under the EPBC Act and the FFG Act. Sixteen known Spiny Rice-flower populations, seven in the Riverina and nine in the Volcanic Plains were selected for assessing population structure and habitat condition in the winter and spring of 2004. The sites occurred across four CMAs: North Central, Port Phillip, Glenelg Hopkins and Corrangamite and was commissioned through the Spiny Rice-flower Recovery Plan Working Group.

Most populations were restricted to small, isolated grassland habitat on roadsides, railway lines and other miscelleaneous public land in highly fragmented landscapes. Only one population was located on freehold land. The grassland habitat was typically high quality with a relatively high indigenous species richness and low cover of weeds, and often supporting a range of other rare or threatened plants. Commonly associated indigenous species were identified that could be used to identify new populations. However, all sites remain unprotected and vulnerable to a wide range of threats associated with destructive land uses such as tree planting, ploughing for fire protection, vehicular use and inappropriate burning and stock grazing.

All populations were morphologically homogenous and readily attributable to subsp. spinescens, and found to be functionally dioecious. Due to limited information, all populations were thought to consist of mature plants with recruitment nonexistent or rare. Even though mature plants did represent the majority of the populations, all were found to support a significant complement of immature plants, including germinants on the Volcanic Plains. As expected, no vegetative regeneration (suckering) was observed.

Although variable, the density of male and female plants was strongly correlated and on average, a roughly equal proportion was present across all sites. As would be expected, the density of mature plants was also strongly correlated with the density immature plants. The relationship with female plants was so strong it could have utility in estimating the size of the immature population as part of a rapid census.

In the Volcanic Plains, the density of germination was strongly correlated with time since last fire which is thought to be linked to the amount of interstitial space. All sites with greater than four years since last fire supported no germination and long unburnt sites also supported the least mature plants and were clearly in decline. Although significant numbers of immature plants were recorded in the Riverina, no germination was observed during the survey work and recruitment is thought to be more episodic, linked to more variable climatic patterns. Biomass reduction, to create sufficient interstitial space, is probably necessary in the Riverina (especially to control weeds), but not at the same frequency as the southern sites.

Given the lack of knowledge, the first priority of any conservation strategy should be to search for new populations, especially in grassy woodlands. In parallel, all existing sites should protected with a range of tenure and physical security measures to minimise the risk of degradation and destruction from a range of threats. In all instances management must be assessed with stage-based demographic monitoring. In addition there maybe some role for translocation in the longer term and there is a need for ecological research into pollination biology, seed ecology and the applied biomass management.

1 Introduction

1.1 Plant description, Conservation Status, Distribution and Ecology

Spiny Rice-flower (*Pimelea spinescens* subsp. *spinescens* Rye) is a Victorian endemic stunted subshrub 5 to 30 cm high that grows in grassland or open shrubland in small, isolated populations scattered across the Volcanic Plains and Riverina bioregions. Stems are glabrous and distinctively spinescent. Leaves are shortly petiolate, opposite, narrowly elliptic to elliptic, green, concolourous, to 10 mm long and 3 mm wide. Inflorescence a terminal compact head of 6 to 12 unisexual, pale-yellow flowers. Subspecies spinescens and pubiflora are recognised and distinguished by the later having hairy pedicles and flowers (external). However, *Pimelea spinescens* subsp. *pubiflora* is apparently extinct having not been collected since 1901 (Walsh and Entwistle 1996).

Spiny Rice-flower is listed under the *Environment Protection and Biodiversity Conservation* Act 1999 (Commonwealth) and the *Flora and Fauna Guarantee* Act 1988 (Vic) (Mueck 2000; Carter and Walsh 2003). It is considered endangered in Victoria (Ross and Walsh 2003) and vulnerable nationally (Briggs and Leigh 1996).

According to the recovery plan Spiny Rice-flower remains in approximately 15 populations comprising between 2,000 and 12,000 individuals. However, a more recent census collated from the Flora Information System (FIS) and VROTpop curated by the Department of Sustainability and Environment (DSE), lists 24 sites comprising at least 5,860 individuals over the Volcanic Plains west of Melbourne and a further 16 sites in the Riverina west of Echuca (minimum population of 4,500 indivduals). The Volcanic Plains sites are almost exclusively roadside and rail remnants (one cemetery and two others on private land) spanning from Ararat to the western and northern suburbs of Melbourne. The Riverina sites are predominantly roadside remnants (one rail site and another three on private land) scattered from just west of Echuca to Dingee and Tandarra north of Bendigo (Andrew Pritchard and Deanna Marshall pers comm.). No sites are secured by reservation.

Spiny Rice-flower flowers in late autumn and winter from April to August and is apparently monoecious or dioecious. In the context of the Volcanic Plains populations plants "plants produce a large taproot which extends to a depth of 1m or more [and] are also thought to be slow growing and long lived, reaching ages of up to a century. No asexual reproduction has been observed… and female plants are thought to only produce relatively low numbers of seeds of unknown longevity. Germination and/or seedling survival also appears to be an irregular event." (Mueck 2000). It is unknown if these observations equally apply to the Riverina populations.

Spiny Rice-flower is known to be fire tolerant, observed readily resprouting following burns at many regularly burnt Volcanic Plains roadside and rail grassland remnants. However, most populations appear to be dominated by mature plants and recruitment is rare or non existent (Mueck 2000). Frequent burning conbined with appropriate climatic conditions probably provides germination and recruitment opportunities (Carter and Walsh 2003). As the Riverina populations are not burnt and apparently not or rarely disturbed in any other fashion (ie. stock grazing), it is unknown if the above observations about fire response and reproduction apply in the north.

As flowers are unisexual, Spiny Rice-flower is likely an obligate outcrosser. However, the pollination ecology and the details of the breeding system is unknown. The high mean pollen to ovule ratio of obligate outcrossers combined with deficients in pollinators due to massive habitat fragmentation could explain the low seed set observed. Recent attempts at seed germination at the Botanic Gardens have failed due to the difficulties in collecting viable seed (Deanna Marshall pers. comm.).

1.2 Recovery Plan and Strategic Background

Following this listing of Spiny Rice-flower under Victoria and Commonwealth biodiversity conservation legislation action plans have been prepared and published. An Action Statement was published under the FFG Act and a draft Recovery Plan has been prepared under the EPBC Act. Both documents recognise the severe level of threat to this species and aim to "minimise the probability of extinction of [Spiny Rice-flower] in the wild and to increase the probability of important populations becoming self-sustaining in the long term." (Carter and Walsh 2003). Because Spiny Rice-flower is endemic to Victoria, these two plans have been effectively merged into the Recovery Plan prepared under NHT funding.

The Recovery Plan will run for five years and will be implementated by a Threatened Flora Recovery Team managed under DSE. This team consists of scientists, land managers and field naturalists and will be responsible for preparing work plans and monitoring progress towards recovery (Carter and Walsh 2003).

1.3 Project Objectives

The objective of this project is to gather information relevant to the implementation of the Spiny Rice-flower Recovery Plan. More specifically this project will implement all or part of selected Recovery Plan objectives by sampling a representative selection of populations in the Volcanic Plains and Riverina bioregions to collect baseline data on: habitat condition; population demography (density, structure and reproduction); population health; morphological and taxonomic variation (esp. between the two bioregions); plant gender; conservation threats; pollination ecology; and general and site specific conservation management recommendations.

2 Methods

2.1 Site selection and description Data collection

A total of 16 populations representative of the known geographic range of wild populations across the Riverina and Volcanic Plains bioregions as well as the three Catchment Management Authorities (CMA – North Central, Corangamite, Glenelg Hopkins and Port Phillip and Westernport) were selected for sampling (Appendix 1). All were visited and assessed between July and September 2004 to coincide with peak flowering period. Assessments took approximately 2 to 3 hours and consisted of collecting the following three types of data: (1) general descriptive notes on site location and various miscellaneous attributes, (2) representative demographic structure (Quadrat), and (3) habitat/vegetation richness, structure and condition (Quadrat).

The general descriptive notes comprised the following attributes: landscape position, population health, conservation threats, tenure and management; habitat condition and variation; floral structure; geomorphology and soil type; and pollinator ecology.

One representative 10m by 10m quadrat was established to assess demographic structure and habitat condition. Sampling quadrats were all permanently marked with a wooden peg, with the location accurately recorded using a Global Positioning System (GPS) to facilitate relocation. Detailed diagrams were drawn to illustrate to position of the quadrats in the context of the broader populations.

Demographic structure assessment involved a detailed search of the sample quadrat for plants in the following categories: Dead, Senescent Adult, Mature Adult (Flowering), Immature Adult (Non-flowering), Sucker and Germinant. Both the Senescent and Mature Adult plants were further classed into: male, female/bisexual or unknown sex categories. Plants that had a mix of both male and female flowers were classified according to the dominant sex.

Habitat assessment consisted of a detailed search of the sample quadrat for all vascular plants (exotic and indigenous) and an estimate of the cover/abundance of each species as well as selected lifeform and aboitic substrate categories. Cover/abundance categories were based on the method recommended under the FIS:

+	<1% Projected Foliage Cover
1	1 to 5% PFC
2	>5 to 25% PFC
3	>25 to 50% PFC
4	>50 to 75% PFC
5	>75% PFC

Note: searching time ranged from 30 to 60 minutes in winter and early spring and the lists compiled should not be regarded as comprehensive.

In addition voucher specimens were collected from each site and pressed for lodgement at the National Herbarium at the Melbourne Botanic Gardens. These specimens served to improve the Herbarium collection and to assess taxonomic uniformity. Photographs of individual plants, flowers and general habitat were also taken at each site.

All plant taxonomy is based on Ross and Walsh (2003).

2.2 Data analysis

Selected data was entered into a MS EXCEL spread sheet in preparation for description and various analyses. The first analysis consisted of hierarchical agglomerative classification using the Sorensen coefficient for constructing the dissimilarity matrix and an iterative fusion procedure to produce a dendrogram (Kent and Coker 1992). The final number of vegetation 'groups' was determined subjectively based on knowledge of all sites.

The results are presented in a two-way vegetation table with the quadrats ranked along the horizontal axis by degree of similarlity and all species ranked along the vertical axis using homogeneity analysis. Homogeneity analysis ranks species in terms of representation in the groups identified by hierarchical agglomerative classification. Thus species are ordered from species exclusive to the left hand group down to those exclusive to the right hand group. Such group exclusive species are often referred to as indicator species.

Additional analyses were undertaken using the linear regression tool in MS EXCEL to assess for simple linear correlations between demographic attributes and relevant site attributes such as time since last burn. Results were summarized using graphs.

Total, indigenous and exotic/naturalized species density data was defined as the number in each category per quadrat (100 sq m).

3 Results

3.1 Habitat - Vegetation

A total of 156 taxa, comprising 46 exotic and two naturalised species were identified from the 16 quadrats. The flora consisted of 43 families with grasses (Poaceae), daisies (Asteraceae), saltbushes (Chenopodiaceae) and peas (Fabaceae) being most dominant (Appendix 2).

Total species densities ranged from 50 (Calder Rail) to 22 (Meins Lane) and are generally a reflection of habitat condition with the highest and lowest density of indigenous species recorded respectively (Table 1).

Table 1: Species density per quadrat

Riv = Riverina, Vol = Victorian Volcanic Plain

	Crossman Road	Jasper Road	McElwains Road	Hands Road	Durham Ox Road	Meins Lane	Mitiamo Rail	McSwain's Padd	Mt Mercer Road	Wingeel Rail	Poorneet Rail	Geggies Road	West HW, Dobie	Calder Rail	Western T'Plant	Truganina Cemetry
Bioregion	Riv	Riv	Riv	Riv	Riv	Vol	Riv	Riv	Vol	Vol	Vol	Vol	Vol	Vol	Vol	Vol
Quadrat	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
Exotics/Nat	12	12	11	12	11	11	10	14	6	3	9	5	19	17	6	7
Indigenous	21	27	27	22	21	11	22	26	27	28	18	20	14	33	18	25
Total	**33**	**39**	**38**	**34**	**32**	**22**	**32**	**40**	**33**	**31**	**27**	**25**	**33**	**50**	**24**	**32**

The hierarchical agglomerative classification resulted in splitting the 16 quadrats into two broad groups driven by geography and geology: Group 1 (seven quadrats) from the Riverina west of Echuca and Group 2: (nine quadrats) from the Volcanic Plains at three general locations – Castlemaine, Ararat and the Western Plains. Predictably the Riverina quadrats were all very similar, whilst the Volcanic Plains quadrats, with a greater geographic spread, was a more complex group consisting of one clear subgroup from the Western Plains (excluding the Calder Rail and Werribee Treatment Plant sites) (five quadrats) and four miscellaneous sites at Castlemaine, Ararat and Calder Rail and Werribee Treatment Plant (Appendix 3).

The Riverina quadrats were dominated by exotic graminioids (mainly annuals) and annual clover: **Romulea minutiflora*, **R. rosea*, **Avena spp.*, **Vulpia spp.* and **Trifolium angustifolium* var. *angustifolium*; and a range of indigenous perennial tussock-grasses, perennial forbs and small shrubs: *Austrodanthonia caespitosa, Austrostipa aristiglumis, A. gibbosa, A. nodosa, Enteropogon acicularis, Whalleya proluta, Chrysocephalum apiculatum* s.l., *Calocephalus citreus, Eryngium ovinum, Pimelea spinescens* subsp. *spinescens* and *Leiocarpa panaetioides*. Although saltbushes were common, they rarely dominated individual quadrats. Indigneous indicator species (ie. commonly associated with Spiny Rice-flower in the Riverina) include: *Enteropogon acicularis, Sida corrugata, Whalleya proluta, Maireana enchylaenoides* and *Atriplex semibaccata;* and to a lesser extent: *Lomandra effusa, Maireana decalvans, Vittadina cuneata* and *Austrostipa aristiglumis* (Appendix 2).

The Volcanic Plains quadrats were dominated by exotic graminioids (mainly perennials) and perennial forbs: **Romulea rosea*, **R. minutiflora*, **Briza maxima*, **Phalaris aquatica*, **Hypochoeris radicata* and **Plantago coronopus*; and a range of indigenous perennial tussock-grasses, perennial forbs and small shrubs: *Themeda triandra, Austrodanthonia caespitosa, Poa labillardierei, Austrostipa aristiglumis, Calocephalus citreus, Plantago varia, P. gaudichaudii, Velleia paradoxa, Chrysocephalum apiculatum* s.l., *Asperula conferta, Drosera whittakeri* ssp. *aberrans, Goodenia pinnatifida, Haloragis heterophylla, Leptorhynchos squamatus, Podolepis* sp. 1, *Pimelea spinescens* subsp. *spinescens* and *Eutaxia microphylla* var. *microphylla*. Indicator species (ie. commonly associated with Spiny Rice-flower in the Volcanic Plains) included: *Plantago varia, Acaena ovina, Geranium* spp. and *Themeda triandra* (Appendix 2).

In terms of dominance the two broad groups share the two common onion-grasses: **Romulea rosea* and **R. minutiflora* plus the indigenous species: *Pimelea spinescens* subsp. *spinescens*, *Calocephalus citreus, Austrodanthonia caespitosa, Chrysocephalum apiculatum* s.l., *Austrostipa aristiglumis*. Whilst exclusive indicator species for Spiny Rice-flower habitat in general cannot be determined here because non-habitat sites were not sampled, many species were recorded at all or most sites across both bioregions that maybe useful for identifying new populations. These include: *Austrostipa gibbosa, Chrysocephalum apiculatum* s.l., *Oxalis perennans Austrodanthonia setacea, A. caespitosa, Calocephalus citreus, Convolvulus erubescens* spp. agg., *Asperula conferta, Eryngium ovinum* and *Leptorhynchos squamatus* (Appendix 2).

As would be expected for threatened vegetation such as lowland temperate grasslands, Spiny Rice-flower is not the only threatened species occurring at the 16 sampled quadrats. In fact, 12 Victorian Rare or Threatened (VROT) species were recorded in total, including four listed under the FFG Act and five under the EPBC Act (Table 2). It is very likely this list would be extended with more thorough survey, especially during spring.

It is relevant to note that since the field work for this project was undertaken in 2004, at least one new population has been located on a roadside in a Grassy Woodland dominated by Yellow Gum (*Eucalyptus leucoxylon*) near Marong, just east of Bendigo. This vegetation is intermediary between Grassy Woodlands found in the Riverina and those found in the Goldfields (dominated by Box Ironbark Forests) and further survey could reveal an entirely new habitat niche for the species and potentially a whole range of possible new populations.

Table 2: Threatened species recorded from sample quadrats

Riv = Riverina, Vol = Volcanic Plains, FFG = Flora and fauna Guarantee Act (L = Listed), EPBC = Environment Protection and Biodiversity Conservation Act (V = Vulnerbale, E = Endnagered), VROT = Victoria, rare or threatened status (r = rare, k = unknown but likely rare or threatened).

Crossman Rd Q1 Riv	Jasper Rd Q2 Riv	McElwains Rd Q3 Riv	Hands Rd Q4 Riv	Durham Ox Rd Q5 Riv	Mitiamo Rail Q7 Riv	McSwain's Padd Q8 Riv	Meins Lane Q6 Vol	Mt Mercer Rd Q9 Vol	Wingeel Rail Q10 Vol	Poorneet Rail Q11 Vol	Geggies Rd Q12 Vol	West HW, Dobie Q13 Vol	Calder Rail Q14 Vol	Western T'Plant Q15 Vol	Truganina Cem Q16 Vol	NAME	COMMONNAME	FFG	ESP	VROTS
+	1															Panicum laevinode	Pepper Grass			v
							+		+	+	+					Comesperma polygaloides	Small Milkwort	L		v
2	+				3											Leiocarpa panaetioides	Woolly Buttons			r
	1	1		+		2							+	1		Austrostipa gibbosa	Spurred Spear-grass			r
					+											Panicum decompositum	Australian Millet			k
					+	+										Chenopodium desertorum ssp. virosum	Frosted Goosefoot			k
	+															Swainsona plagiotropis	Red Swainson-pea	L	V	e
2	2	2	1	1	1	1	+	1	2	2	2	1	1	1	1	Pimelea spinescens ssp. spinescens	Spiny Rice-flower		V	e
							+								+	Dianella amoena	Matted Flax-lily		E	e
													2			Podolepis sp. 1	Basalt Podolepis			e
															+	Rutidosis leptorhynchoides	Button Wrinklewort	L	E	e
													1			Senecio macrocarpus	Large-fruit Fireweed	L	V	e

3.2 Population Structure (demography)

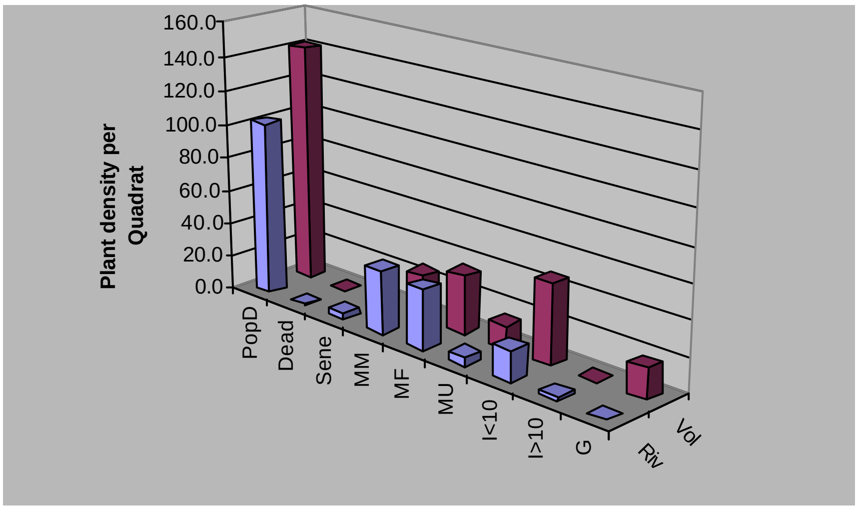
Population densities of Spiny Rice-flower (numbers of living plants per quadrat) varied from 23 at Meins Lane to 322 at Poorneet Station. On average densities were higher in the Volcanic Plains compared to the Riverina quadrats (142 cf. 102) (Fig. 1; Appendix 3). Populations were primarily composed of mature (flowering) plants, split into male, female and unknown sex categories, immature (non-flowering) plants less than 10 cm high and germinants. None or very low numbers of dead, senescent and immature (non-flowering) plants greater than 10 cm high were observed throughout. Despite active searching no evidence of asexual vegetative reproduction (suckering) was observed anywhere as is consistent with Mueck (2000).

Amongst the mature plants the sex ratio was broadly 1:1 (see later results/discussion on plant gender and dioecy) and densities on average were remarkably consistent between both bioregions (78 in the Riverina cf. 74 in the Volcanic Plains), although variation was far greater in the Volcanic Plains due to differences in disturbance regimes. Thus the higher total population densities in the Volcanic Plains is attributable to higher denities of immature plants. Immature plants less than 10 cm as well as germination were both much higher in the south. In fact, no germination was observed at all in the Riverina during the field assessment. However, this is not to say that germination was widespread and consistent in the Volcanic Plains. As would be expected, it was highly variable and patchy, being observed at six of the nine sites and ranging in density from 3 to 120 per quadrat (see later discussion on burning and disturbance regime).

Lowest mature plant densities were observed at Meins Lane (20) and Western Treatment Plant (15) on the Volcanic Plains and Mitiamo Rail (28) and Durham Ox Road (31) in the Riverina. These populations also had the lowest total plant densities as germination and recruitment was absent or sparse. Both the Volcanic Plains sites are long unburnt, although the Western Treatment Plant population was burnt for the first time in many years in May 2003 when weed control commenced to "kick off" a conservation management program after Spiny Rice-flower was recently rediscovered there.

Meins Lane is representative of the "worst" sites, characterized by high weed cover and only destructive disturbances such as tree planting and the complete absence of burning. Without germination and recruitment, the adult population has dwindled to very low levels. Except for recent conservation focused intervention, the Western Treatment Plant site would be in a similar situation. Here, recent weed control and burning has served to not only reinvigourate the grassland vegetation generally, but has stimulated Spiny Rice-flower germination that should result in recruitment that will increase population density. The Western Treatment Plant experience indicates that even very degraded populations can be rescued with simple management techniques and is exactly what is required for sites like Meins Lane.

Figure 1: Average population structure of Riverina and Volcanic Plains quadrats.
See Appendix 3 for demographic categories on x-axis.



3.3 Tenure, Disturbance and Threats

Five of the seven Riverina sites are roadsides. The two non-roadsides are Mitiamo Rail, a narrow railway easement just north of the Mitiamo siding, and McSwains, a large apparently uncultivated freehold paddock just west of Echuca that is grazed by cattle. These represent the majority of the known sites in the Riverina and most occur within the Shires of Campaspe and Loddon. None are adequately protected in conservation reserves.

McSwains notwithstanding, Spiny Rice-flower rarely persists under frequent grazing and is virtually unknown from freehold land. Although further searching would be warranted, the Loddon and Campaspe regions have been reasonably thoroughly surveyed for threatened species and habitat (Diez and Foreman 1997; Diez *et al.* 2000) and it is unlikely large new populations would be found on freehold land.

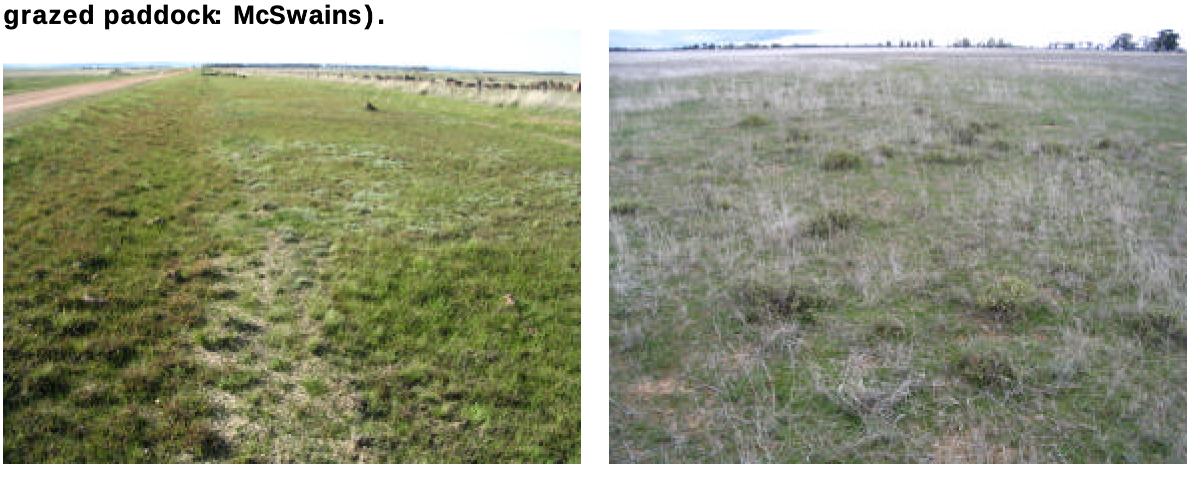
The roadsides are small, narrow, isolated corridors of generally uncultivated remnant riverine grassland that is not or occasionally grazed or usually unburnt. They are surrounded by cropland, fallow, tree plantations, exotic pasture that are virtually devoid of indigenous habitat. Only occasionally do sites adjoin degraded native pasture. Vegetation quality is highly variable and reflects the spatial complexity of past disturbance. For instance remnants maybe bisected by discrete bands of high weed cover that reflect past disturbance such as ploughing, soil dumping or infrastructure construction. They continue to be vulnerable to wide range of threats. These include: roadside ploughing; roadside grading and associated road maintenance; inappropriate stock grazing; flooding; fence construction or maintenance; weed control related disturbance; weed invasion; tree planting; soil dumping; spray and fertilizer drift; rabbit and hare browsing; and vehicular use. The small size and isolation continues to represent an enormous on-going threat in its own right. Not only does this increase the probability of extinction because of exposure to chance distructive events, but it also increases the chance of inbreeding depression than can reduce genetic diversity and population fitness.

An additional possible threat is insect browsing. The Jasper Road population was apparently completely defolitated by plague locusts observed in the region as intense swarms moving into the region from the north during the 2004/05 summer. Although some plants have subsequently resprouted (July 2005), many have apparently died and population fecundity is certain to be significantly diminished. (Note: most plants subsequently resprouted and chemical testing has revealed a level of glyphosate that may implicate drift as an alternative cause – Ben Thomas pers. comm. Further investigation is required to establish the cause of the dieback.)

The situation on the Volcanic Plains is almost identical. Four sites are roadsides, three are on similarly narrow, linear rail reserves (typically the broader nodes associated with station sidings) and the remaining two on puiblic land – a cemetery and a reserve on the margins of a wetland at the Werribee Wastewater Treatment Plant. The key threats here are the same as in the Riverina, with the possible exception of inappropriate burning. The exclusion of burning (especially in the absence of some alternative disturbance) will quickly degrade grassland vegetation, reducing species richness and inciting weed invasion.

Limited attempt was made to investigate the management history of individual sites nor to thoroughly document the details of current management and threats. Additional information was only sought on time since last burn.

Figure 2: Examples of Spiny Rice-flower habitat on the (a) Volcanic Plains (frequently burnt roadside: Geggies Road) and (b) Riverine Plains (frequently grazed paddock: McSwains).



3.4 Floral Structure, Plant Gender and Pollination Ecology

All populations were found to have unisexual flowers: the males with prominent exerted anthers, no ovary and no style; and the females with a prominent exerted style (simple stigma) with either no anthers or anthers that are apparently neuter. Flowers were readily sexed in the field using a hand lens. In general individual plants were dominanted by one or the other and all populations were considered dioecious. Whilst male plants tended to almost entirely consist of male flowers, the females were often found to have number of male flowers, apparently randomly scattered throughout (ie. monecious). Unknown sex was attributed to those plants visited late in the season that had finished flowering and could not be attributed to either sex.

Being unisexual and largely dioecious, Spiny Rice-flower is an obligate outcrosser – a process totally or partly facilitated by invertebrates. Although no specific pollinating behaviour was observed at any site during the field visits, many female plants were observed with swollen flowers at most sites that presumably went on to set amounts of viable seed. Only a "small hairy beetle" was noted on flowers at the Lake Borrie population, but it was unclear whether this beetle is the primary pollinator (Cropper 2004, pg 5). Elsewhere blue butterflies have been observed visiting flowers (Deanna Marshall pers. comm.)

Viable seed has been collected from populations both in the Riverina and Volcanic Plains (Deanna Marshall pers. comm.). Further research would help determine the pollination ecology of Spiny Rice-flower, in particular the primary pollinator species and mechanisms and relationship to viable seed production.

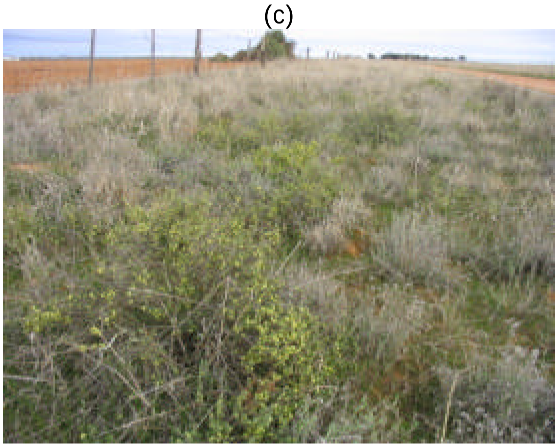
Investigations at the Werribee Wastewater Treatment Plant population support these general comments. Here direct observation of floral structure and assumptions based on general generic characteristics suggested further specific behaviour: each female flower has the potential of producing only one seed; the hard seed matures within the ovary to form a nut and falls to the ground enclosed in a husk-like spent flower; and the seed/ovary wall is not ornamented and would fall close to the female plant" (Cropper 2004, pg 3-4). Although no data was collected on the spatial patterning of germinants and juvenile plants for the current study, they tended to be found close to female plants. These small dispersal distances are consistent with the lack of ornamentation observed at the Lake Borrie population.

Figure 3: Floral structure: (a) male flower; (b) female flower; (c) male plant; (d) female plant

(a)

(b)

(c)



(d)

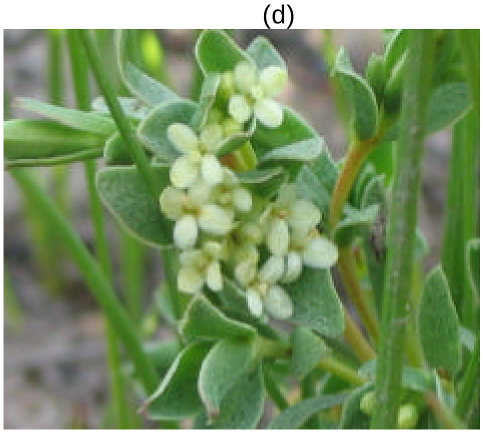


Figure 4: Relationship between the density of female and male plants;
(n = 16; senescent plants excluded).

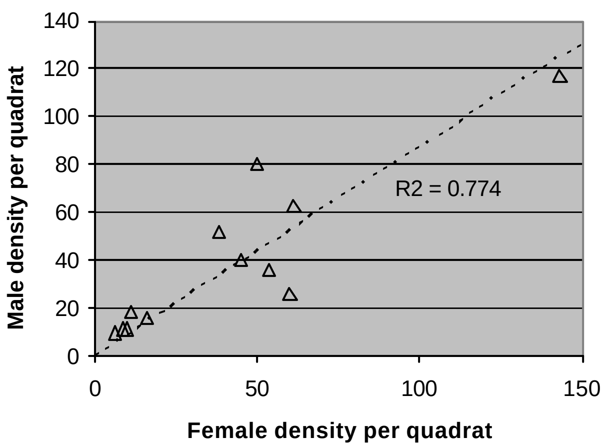
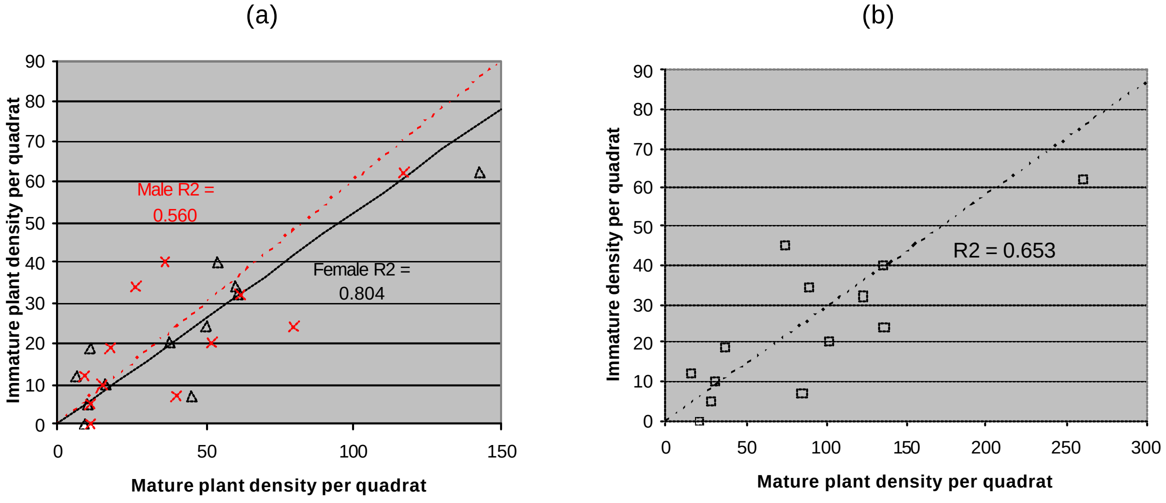


Figure 5: Relationship between the density of mature plants and immature plants (a) male and female plants separated, n = 12; (b) male and female plants pooled n= 13; Note: three recently burnt sites on the Volcanic Plain excluded as plant sex could not be determined and because it was visited at the end of the flowering phase.

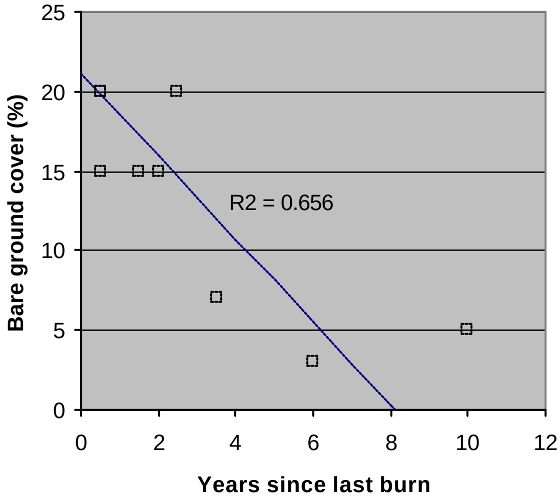


In general there is clear correlation between the density of female, male and immature (germinants and recruits combined). The mean density ratio respectively across all sites is 1.00: 0.90:0.90. Between all mature (including unclassified mature and excluding non-senescent individuals) and immature plants the mean density ratio is 1.00:0.44. These data can be used to predict the numbers of immature plants from the number of fowering or non-flowering mature plants which are quicker and easier to count. In other words if a population has 100 female plants it is likely to have about 90 immature individuals or if the census is undertaken outside the flowering period, a population of 100 mature plants is likely to have about 44 immature plants. These ratios are slightly different in the two Bioregions with proportionately less females and immature individuals in the Riverina (female:male:immature 1.00:1.07:0.59) compared to the Volcanic Plains (1.00:0.77:1.12).

As would be expected, the regression analysis showed that the correlation was strongest between mature female plants and immature plants (R-squared = 0.802; $P < 0.01$) and would produce the most reliable predictions of immature plant densities (Fig. 5). Given there is an equal probability a seed will produce a male or female plant, their densities at each site are highly correlated (R-squared = 0.774; $P < 0.01$) (Fig 4.).

The proportion of bare ground in each quadrat is inversely correlated with time since last burn (R-squared = 0.656; $P < 0.01$) on the Volcanic Plains with upto 20% of the quadrat "available" for germination immediately following a burn. This proportion drops suddenly to about 5%, 3 to 4 years later (Fig. 6).

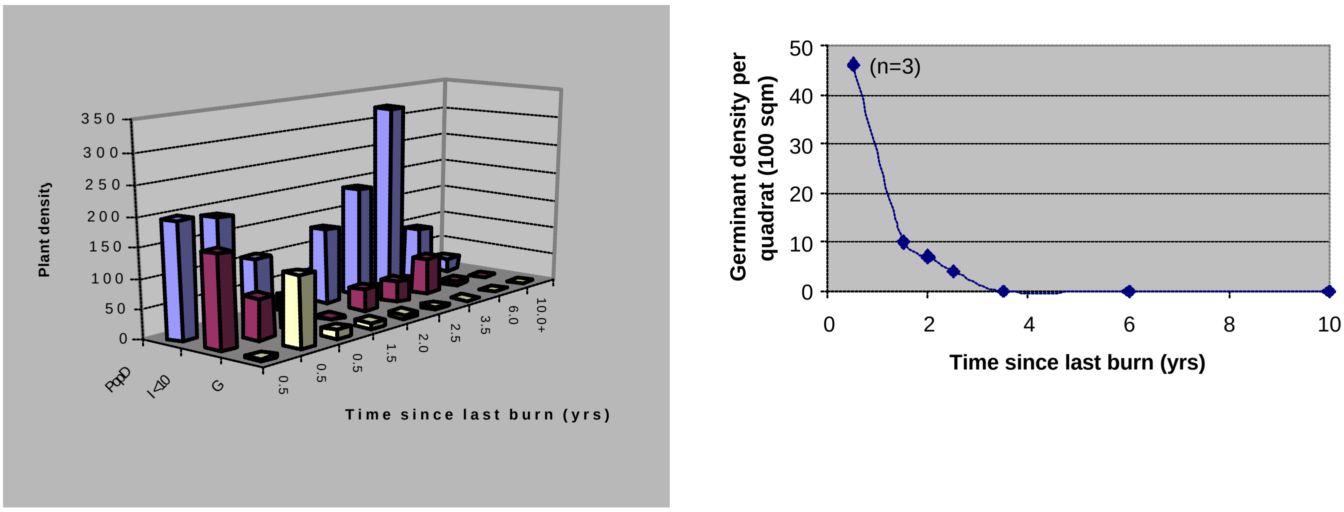
Figure 6: Relationship between the proportion of bare ground in quadrats with time since last burn; n= 9.



3.5 Ecological relationships

Germination was only observed on the Volcanic Plains and then only at sites that had been recently burnt – within the previous two-and-a-half years. In fact, there appears to be a strong inverse relationship, with maximum germination happening within the first year following burning and none occurring after about 3 years (Fig. 7). As for many grassland plants, the burning opens up the sward, creating (briefly) perfect conditions for germination – exposed mineral earth and negligible water, light and nutrient competition (Lunt 1994). Provided seed is available and climatic conditions suit, germination is apparently guaranteed. It is likely the same mechanisms apply for Spiny Rice-flower, however, further research is required and other possibilities investigated.

Figure 7: Relationship of time since last burn and germination density on Volcanic Plains.
Note that the three most recently burnt sites have been averaged.

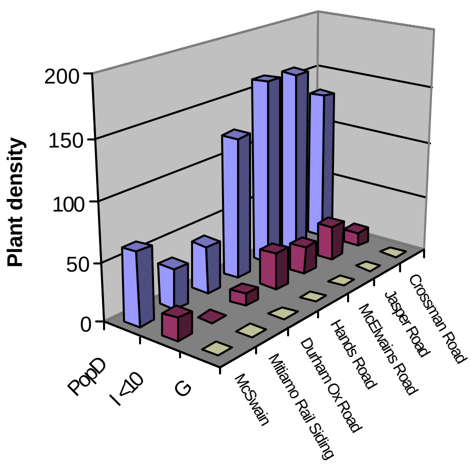


As the germination phase, by definition, only lasts for a year, individuals either die or are recruited into the immature phase at the beginning of the second year. How long they remain in this immature phase (ie. before they flower and move into the adult phase) is unknown.

Assuming that germination mainly occurs with the first three years following burning, plants could remain immature for three or more years (ie. Wingeel Siding). A large immature phase population suggests either substantial regular (ie. annual) germination rate or large, less frequent episodic events and is indicative of active recruitment. This behaviour was observed at all but the least frequently burnt sites (ie. Meins Lane and Wingeel Siding). The only exception was at the Western Wastewater Treatment Plant where burning has only just been reintroduced after possibly decades of absence. Here germination has apparently occurred in successive years following weed control and the resumption of burning with the only immature plants likely dating from the spring of 2003. If not for the recent management, this population would look very similar to that Meins Lane – a low density of large mature plants with no germination or recruitment.

In contrast, no germinants were observed at any of the Riverina sites (Fig. 8). However, the presence of a significant immature phase population at each suggests some germination has occurred in recent years. This suggests that Spiny Rice-flower doesn't require smoke to break dormancy and adds credience to the hypothesis that germination relies on the coincidence of other conditions. As the Riverina is drier and supports different vegetation, burning is not required to maintain a suitably open sward (or at least less frequent disturbance of a different type) and that successful germination is limited by climate whereby suitable conditions are more episodic than down south. This would account for the lower overall densities of immature plants and the absence of germination in 2004. The absence of immature plants at the Mitiamo Siding where disturbance has been completely excluded now for many years (although historically rail lines were regularly burnt), suggests disturbance in the Riverina is a factor in the regeneration equation and the absence of germination across the board in 2004 suggests the epidsodic influence of climate. Both interact to contribute to the total population densities and structures observed, the best of which are observed at Jasper, McElwains and Hands Roads.

Figure 8: Lack of germination in Riverina in 2004.



4 Discussion

4.1 Critical Habitat

Spiny Rice-flower is apparently exclusively restricted to the better quality grassland remnants of the Riverina and Victorian Volcanic Plains. Such refugia include roadsides, railway easements, public reserves and occasionally freehold land. They are typically small, isolated, unprotected and continue to be vulnerable to a wide range of threats such as tree planting, ploughing and other forms of soil disturbance and in the case of the Volcanic Plains the lack of frequent burning. Whilst originally Spiny Rice-flower have had a somewhat patchy distribution spanning from Echuca and Mitiamo in the north, through to the Ararat, Ballarat, Geelong and Keilor Plains districts of the Volcanic Plains, it was likely widespread and abundant throughout its range prior to European arrival. It has therefore only become rare and threatened (as per its grassland habitat and other affiliated species) with the widespread distruction of lowland grassland habitat for intensive agricultural land use over the last 150 years. This characteristic of land use induced rareness is typical of many threatened species in Victoria, especially those associated with highly depleted ecosystems (Leigh *et al.* 1984).

The clear bidivision of the distribution of Spiny Rice-flower has always puzzled taxonomists. Given the significant differences in habitat north and south of the divide, the lack of some morphological, genetic or ecological differentiation seems counter intuitive. And the lack of good voucher specimens in the herbarium has always hindered any ready demystification. Some have speculated that some or all of the northern poulations could be more affiliated with the now apparently extinct pubscent sub-species (not collected since 1901; Walsh and Entwistle 1996) *Pimelea spinescens* subsp. *pubiflora*, which was apparently endemic to the Northern Plains. This study has confirmed that on the bases of morphology, all populations are correctly labeled subsp. spinescens. However, genetic study and further ecological research (such as pollination biology) could reveal more subtle differentiation between the two broad groups.

A number of indigenous plants were found exclusively with Spiny Rice flower in the Riverina and another group exclusively in the Volcanic Plains, whilst another tended to frequently occur with Spiny Rice-flower in both bioregions. The later group comprised: *Austrostipa gibbosa, Chrysocephalum apiculatum* s.l., *Oxalis perennans Austrodanthonia setacea, A. caespitosa, Calocephalus citreus, Convolvulus erubescens* spp. agg., *Asperula conferta, Eryngium ovinum* and *Leptorhynchos squamatus*. Any or all of these groups could be used to help identify sites supporting suitable habitat for Spiny Rice-flower and provide a focus for future strategic search effort. The recent location of a new population in Grassy Woodland habitat near Bendigo suggests there could be merit in extending the range of likely refugia into at least parts of the Goldlfields and possibly other adjacent bioregions.

4.2 Population ecology

There have been very few studies on the biogeography, habitat and ecology of Spiny Rice-flower. This lack of field research and knowledge has resulted in the perception that populations are not or rarely recruiting and are likely to be in demographic decline with high extinction pprobabilities. “Most populations observed appear to consist of relatively mature plants and there is little evidence of recruitment (J. Morgan *et al.* pers comm.1998)” from Mueck (2000) is an example. Previously only crude censuses have been undertaken. For example data collected under the Department of Sustainability and Environment’s VROTpop database have been based on rapid assessments were only mature plants are actively counted and then often in different seasons, by different people, in different sections of the sites and using variable methods. This inconsistent process has resulted in little useful information except perhaps verification of the presence or absence of populations. In particular these data are not useful for charting population dynamics and therefore computing extinction probabilities (although this in a sense this is likely to remain high because of the high threat of incidental destruction due to population size, location and the lack of adequate reservation).

In this context it can be concluded from this study that population numbers have been significantly underestimated and population structure misrepresented in the past. There is clearly a far higher number of plants at each site than was previously understood, each with a relatively complex population structure that includes active germination and recruitment. On the basis of the population censuses conducted for VROTpop, the entire Victorian (therefore global) population of the subsp. was less than 8,000 (7,911). Insufficient data was recorded to calculate densities. On the basis of this study, using density data from the quadrats combined with crude estimates of the area occupied by each site, the total population number could be as high as 292,000. Even if the actual numbers are a tenth of this due to errors and lack of replication, the estimate of 29,200 is still three times higher than what has been previously estimated. This result seems reasonable given that on the basis of the mature to immature plant ratios calculated, there'd be at least another 50% more plants that picked up with the VROTpop censuses that focused on mature plants alone.

Spiny Rice-flower flowers have long been recognized as being unisexual (Walsh and Entwistle 1996). However it has not always been clear that the species is functionally dioecious. Presumably this was always suspected on the basis of the collected material, but never confirmed due to the lack of specimens and field-based studies. As part of his work for the Western Wastewater Treatment plant, Simon Cropper observed that "it appears that the species is dioecious with different plants having male and female flowers" (Cropper 2003; page 3). Although, as Cropper also observed, further study is required to clarify the exact status as some plants were not exclusively of one sex. In particular, some predominantly female plants occasionally had the odd male flower.

Although clearly germination was observed, signifying that some outcrossing was successfully occurring, no pollinators were observed at any sites during this study. Whilst beetles and moths have been observed by others visiting flowers, no one has apparently observed pollination. Consequently it is unclear which insect or insects are the primary pollinators and whether this process is in any way limiting Spiny Rice-flower reproduction. The consistent presence of germination, especially in the Volcanic plants where seedling density is strongly correlated with available space, suggests outcrossing is unlikely to be seriously limited if at all. Given the highly disturbed nature of most sites, perhaps this suggests outcrossing is facilitated by a range of species and/or very common species.

As would be expected for grassland habitats, it is not surprising that Spiny Rice-flower germination and recruitment is linked to episodic biomass reduction. In the case of the Volcanic Plains this is periodically achieved by control burning and in the Riverina, apparently, by climatic fluctuation or stock grazing. In the Volcanic Plains burning is either carried out for fire protection purposes or directly as a management tool for biodiversity conservation. Either way the frequent burning has the effect of removing all or most if the above ground biomass, "opening up" the often thick Kangaroo Grass dominated sward and providing space that is, for a short period, resource rich and available for plant regeneration. This mechanism is well understood, particularly for grassland forbs. In this study, the highest density of germinants was observed immediately following burns and the least or none were recorded from sites that hadn't been burnt for four or more years. These data imply that as the time since fire increases, interstial space decreases in direct proportion with germination density. Not only were long unburnt sites not producing germinants, they also supported the lowest densities of mature plants and the grassland habitat was often in poorer condition (weedy and less species rich). These sites were simply dying out because recruitment was being prevented by lack of space. Once these last individuals die off the population would likely not recover without intervention because there appears to be no lasting seed bank. Much of this requires further research to test, but collectively represents a reasonable reproductive model for the species on the Volcanic Plains.

The situation in the Riverina is fundamentally the same, but with two major differences: firstly that biomass reduction is not achieved by fire and is required less frequently and secondly climatic suitability for germination is more episodic. Germination did not occur in the Riverina in 2004, but the presence of established immature plants demonstrates that it has happened in recent years. Whilst in the Volcanic Plains, germination is probably equally likely in any year (provided there has been recent burning), in the Riverina it is highly variable, with the chance of it happening dependent on the coincidence of suitable rainfall. On top of this sufficient space must also be available for germination to proceed. Given in this semi-arid climate biomass accumulation rates are considerably lower than that in the south, sufficient space may be available for a much longer period following a significant disturbance or, on some soil types, may always be present and allow some germination whenever the climate allows. For a variety of reasons, burning isn't frequently used for fire protection in the Riverina and often biomass reduction, especially on roadsides, stock routes and in paddocks, is achieved by stock grazing. The post European arrival modification of grassland composition and structure, as well as the invasion of weeds (especially annual grasses), means biomass reduction is usually required to maintain remnant grasslands today (Foreman 1996). Under this model, switching to burning is certainly a management option that is not ecologically inconsistent, but would need to be thoroughly trialled beforehand and could end up being more expensive.

4.3 Conservation Management (Recommendations)

As Spiny Rice-flower has been rendered threatened by habitat destruction (land clearing), the best strategy for conservation must be two-fold: (a) protect existing habitat; and (b) find or create new habitat. The first of these involves protecting sites from the range of threatening processes identified as part of this study and ensuring that natural reproductive processes are working such that the probability of extinction is minimized. The recent discovery of a new population near Bendigo and our general lack of information about remant biodiversity in general suggest finding new habitat is likely to be highly successful. Creating new habitat, especially on land that has been entirely replaced by exotic vegetation is not just difficult to do, but also prohibitively expensive.

Protecting existing habitat

Many of the most significant and and serious short term threats can only be off-set by securing the remnant populations. This includes a combination of tenure security and physical security. Tenure security would be framed by existing tenure: cemeteries, roadsides, railway lines and other miscellaneous forms of public land could be declared conservation reserves under Public Management Authority Agreements (examples: Western Wastewater Treatment Plant, and Porneet and Wingeel Station Sidings); some larger sites could be acquired and established as formal parks; and private land could also be aquired for conservation parks (example: McSwains). These measures would have the affect of addressing threats relating to the primary objectives of management. Where tenure change or conservation agreements are not possible, establishing a range of physical security measures would help to minimize the types of disturbance possible. Even where these conservation agreements are in place, such measures would equally guard against inadvertent catastrophic disturbance.

Additional actions maybe required over and above these measures to mitigate against other site specific threats. For instance if spray drift is problematic because a narrow roadside strip adjoins a cereal cropping paddock, it might be necessary to negotiate a management change with the land owner.

Successful conservation depends not just on mitigating against threats that shouldn't happen, but also implementing appropriate *in situ* conservation management. In essence this means keeping the populations and habitat heathly and vigourous. To do this, two actions are required: biomass reduction and weed management required, and both will need to be approached differently between and even within the two bioregions. In the Volanic Plains biomass reduction should be achieved by maintaining frequent burning. Every two to three years would be ideal to maintaining a healthy grassland by stimulating regerenation. Annual burning and longer than every three years would be tolerable provided recruitment is monitored and management modified as necessary. Annual burning could be negative as populations visited that were burnt in the previous autumn didn't flower (Spring burning). A variable frequency within these limits is also likely to be acceptable. Weed control in the Volcanic Plains would focus on aggressive invaders that cannot be control by burning. Large perennial tussock grasses such as **Phalaris acquatica* is perhaps one of the priority species.

It will be important to assess the potential impact of these tenure and physical security measures on the disturbance regimes currently occurring at sites. For instance it may not be appropriate to establish a fence around a narrow roadside in the Riverina to provent roadside ploughing if this will exclude stock and prevent episodic biomass reduction.

In the Riverina the conservation strategy is not as clear. Further monitoring and research is required to determine the role and mechanisms for biomass reduction. Until this work is complete, it would be difficult to justify anything too different from the status quo. In general biomass reduction should be maintained by stock grazing unless this regime is difficult to define or maintain. Grazing along narrow roadsides is often difficult to control and is possibly a situation where burning could be trialled and/or fences erected to exclude other disturbances. Strategic burning could have the affect of increasing recruitment and expand the population area. Given such roads support none or few indigenous annuals, burning is unlikely to be detrimental if applied correctly. In fact, burning could be an enormously beneficial management tool by reducing the adundance of a range of exotic annual grasses that act to “choke up” the grassland vegetation reducing interstitial space and therefore recruitment opportunities (Foreman 1996).

Critical to management at all sites is monitoring as it is one of the primary means of obtaining iterative feedback on the success of implement management. Monitoring is fundamental to the principle of adaptive management and flexibility in the light of new information is the reality of managing grasslands. This study assumes current management is appropriate for long term management because germination and recruitment was actively observed at most sites. Only where this wasn’t observed in 2004, (or in the former few years) was it assumed current disturbance management is likely to be appropriate and should be changed. Meins Lane near Castlemaine is an example. There is little doubt the Meins Lane situation is unhealthy and management change is essential, but the situation is less clear elsewhere. Even were the highest levels of germination and recruitment were observed, it is still possible these populations are in trouble when you consider mortality and recruitment patterns over time. A temperal sequence is necessary to assess other dynamic demographic characteristics. Spatially replicated, stage-based dynamics monitoring which can be used to determine extinction probabilities and finite rate of increase is recommended. In addition, population-wide data such as population area, weed cover, interstial space and species-richness should be collected.

Find or create new habitat

The two-way vegetation analysis based on hierarchical agglomerative classification identified a range of indigenous species that consistently occur in association with Spiny Rice-flower in the Riverina, the Volcanic Plains and in both bioregions. By screening databases such as Flora Information System (FIS) for sites that support these species but not Spiny Rice-flower, it will be possible to strategically identify sites that could be targets for further searching. These data could also be used to identify regions of interest that could be targeted for more general searching, including on private land. This work would be a very efficient investment of resources, with relatively little effort potentially identifying dozens of new sites and massively increasing the known population size and habitat area, and vastly improving both our knowledge of the species as well as the conservation options available.

Another conservation management tool is translocation: “the deliberate transfer of plants or regenerative plant material from an ex situ collection or natural population to a location in the wild, including existing or new sites or those where the taxon is locally extinct.” (Vallee *et al.* 2004). Although the strategic searching for new sites should be a higher priority because it has the potential to significantly shift our understanding of the biogeography and ecology of the species, translocation has been demonstrated to work for Spiny Rice-flower and could play a role in the species’ recovery (Mueck 2000). As with the Laverton example on the western margin of Melbourne, translocation could be utilized if sites are planned for destruction as a result of unavoidable development. This experience has resulted in a range of recommendations that should maximize the chances of success including site selection, use of specialized equipment and follow up management and monitoring (Mueck 2000). Translocation could also be considered to effectively expand the area of habitat at or near some of the more vulnerable populations where the adjacent land supports suitable vegetation or vegetation that could be readily restored, and can be secured for conservation. This strategy would need to be thoroughly planned using the Australian Network for Plant Conservation (ANPC) translocation guidelines (Vallee *et al.* 2004) and shouldn't occur until after higher priority actions are implemented. This strategy would be most useful in the Riverina where most sites occur on narrow roadsides over small areas.

4.4 Knowledge Gaps and Further study

Two of the critical knowledge gaps have been addressed with the recommendations above: searching for new habitat and populations, and monitoring to determine the finite rate of increase. The current assumption is that populations where recruitment was observed have a high finite rate of increase and those that don't are spiraling towards extinction. Somewhere inbetween there will be a threshold based on recruitment levels as driven by biomass reduction (ie. burning frequency on the Volcanic Plains). These assumptions will be tested through the recommended stage-based demographic monitoring. However, there are a number of other aspects of Spiny Rice-flower ecology that could be investiagated that would be useful for applied conservation management. These include: pollination biology, seed germination biology (including seed bank dynamics) and biomass reduction ecology.

As Spiny Rice-flower is dioecious, outcrossing between plants is essential. Because there is germination we know that some level of outcrossing is happening. However, the primary pollinator has not yet been identified. The colour and structure of the flowers suggest an insect of some kind and beetles and moths have been observed visiting flowers. The primary objectives of a pollination biology study would be to identify the primary pollinators, determine the level of viable seed set and whether this is being limited in any way (ie. such as via the number and behaviour of the pollinators).

A second area of interest is the process from the setting of viable seed to germination. Is the seed bank on the adult plants or on the ground? and how long does it last? As soil seed banks in grasslands are generally short lived (Lunt 1994), it is likely germination in any one year is resulting from seed set from the previous season (spring). Seed persistence and laboratory seed bank composition studies would help test this mechanism. At a practical level, development of methods for germinating seed would also be useful. To date, propagation has been exclusively achieved by cuttings and division and attempts to germinate apparently viable seed have been largely unsuccessful (Deanna Marshall pers. comm.).

Currently biomass reduction is based on burning in the Volcanic Plains and grazing in the Riverina. In the Volcanic plains it is unclear what burning regime would be optimal in terms of Spiny Rice-flower conservation. A range of burning frequencies (eg. one to five years) could be trialled and success compared using finite rate of increase. And in the Riverina the merit of replacing grazing with burning could be assessed with burning trials at selected roadsides. Given the very small area of most populations here, this work would necessarily occur on an experimental scale. At the same time this study could assess the efficacy of using burning as a means of reducing the cover of exotic annual grasses.

5 Conclusions

- *Spiny Rice-flower is apparently restricted to small, isolated grassland refugia in the Riverina north of Bendigo, and the Volcanic Plains west of Melbourne and spanning across to the Ballarat District.*
- *Surprisingly little is known of the species biogeography and ecology and further searching is likely to identify new populations and habitat types (including in grassy woodlands).*
- *The structured demographic data collected in this study not only identified that populations are recruiting when previously it was thought they weren't, but also total population numbers are significantly higher than previous estimates, which were derived from rapid censuses.*
- *Although variable, the densities of male and female plants are roughly similar across all sites and are strongly correlated to the density of immature plants (pre-flowering plants including germinants).*
- *As would be expected, the density of female plants can be used to predict that of the immature plants as part of a more accurate rapid census.*
- *Germination was observed at most Volcanic Plains sites and a strong inverse correlation was observed between the density of germinates and time since last fire which controls the amount of bareground or interstitial space.*
- *Long unburnt sites supported no germinants or recruits and had the lowest densities of mature plants indicating an advanced state of decline that can only be reversed by reintroducting biomass reduction (burning).*
- *In the Riverina the situation is not as clear with germination more episodic as controlled by rainfall and stock-grazing-based biomass reduction.*
- *As Spiny Rice-flower has been rendered threatened by habitat destruction, the best strategy for conservation is: (a) protect existing habitat; and (b) finding or creating new habitat.*
- *The first of these involves protecting sites from the range of threatening processes and ensuring that natural reproductive processes are working throught strategic stage-based demographic monitoring.*
- *The recent discovery of a new population and our general lack of information on this species, suggests seeking out new habitat is likely to be highly successful.*
- *Creating new habitat is likely to be prohibitively expensive, although there maybe some role for carefully planned translocation.*

References

DNRE. (2001). Victorian Flora Species Index. Parks, Flora and Fauna Division. Department of Natural Resources and Environment, Melbourne.

DNRE. (2002). Flora Information System. Parks, Flora and Fauna Division. Department of Natural Resources and Environment, Melbourne.

Diez, S. and Foreman, P.W. (1997). Remnant vegetation survey and botanical inventory of the Loddon Shire. Unpublished report, Natural Resources and Environment, Bendigo.

Diez, S., O'Brien, E., and Alexander, J. (2000). Remnant vegetation survey and botanical inventory of the Shire of Campaspe. Unpublished report, Natural Resources and Environment, Bendigo.

Briggs, J.D., and Leigh, J.H. (1995). Rare or threatened Australian plants. 1995 Revised Edition. Centre for Plant Biodiversity Research, CSIRO Division of Plant Industry, Canberra, Australia.

Cropper, S. (2003). The distribution of *Pimelea spinescens* ssp. *spinescens* (Spiny Rice-flower) on Lake Borrie Spit and a discussion on the appropriate management of the population. Technical document 2003-130, Botanicus Australia P/L, Sunshine.

Cropper, S. (2004). Monitoring of *Pimelea spinescens* ssp. *spinescens* (Spiny Rice-flower) on Lake Borrie Spit in December 2003 and a discussion on the appropriate management of the population. Technical document 2003-133, Botanicus Australia P/L, Sunshine.

Foreman, P.W. (1996). Ecology of native grasslands on Victoria's northern Riverine plain. Masters Thesis, School of Botany, La Trobe University.

Gullan, P.K., Cheal, D.C., and Walsh, N.G. (1990). Rare or threatened plants in Victoria. Department of Conservation and Environment.

Harden, G.J. (1990). Flora of New South Wales, Volume 1. Royal Botanic Gardens, New South Wales University Press, Sydney.

Kent, M., and Coker, P. (1995). Vegetation Description and analysis: A practical approach. John Wiley and Sons, England.

Lunt, I.D. (1994). Variation in flower production of nine grassland species with time since fire, and implications for grassland management and restoration. **Pacific Conservation Biology** 1, 359-366.

Walsh, N.G., and Entwistle, T.J. (eds). (1996). Flora of Victoria, Volume 3: Dicotyledons, Winteraceae to Myrtaceae. National Herbarium of Victoria. Inkata Press, Melbourne.

Vallee, L., Hogbin, T., Monks, L., Makinson, B., Matthes, M., and Rossetto, M. (2004). Guidelines for the translocation of threatened plants in Australia, Second Edition. Australian Network for Plant Conservation, Canberra.

Appendices

Appendix 1: Quadrat locations

Quad = Quadrat; CMA = Catchment Management Area (NC = North Central, Cor = Corrangamite, PP = Port Phillip); Bio = Bioregion (Riv = Riverina, Vol = Victorian Volcanic Plain); Elev = Elevation ASL in metres

Quad	Site Name	Type	CMA	Bio	Date	Zone	East	North	ASL	PopD	Area -ha	Total -est
1	Crossman Road	Rd	NC	Riv	20/07/04	55H	262453	5982995	100	132	0.1	1,320
2	Jasper Road	Rd	NC	Riv	21/07/04	55H	263267	5980858	102	160	0.1	1,200
3	McElwains Road	Rd	NC	Riv	21/07/04	55H	254646	5970529	105	162	0.1	810
4	Hands Road	Rd	NC	Riv	21/07/04	55H	256769	5969709	107	123	0.3	3,690
5	Durham Ox Road	Rd	NC	Riv	19/07/04	55H	242848	5965540	115	41	1.0	4,100
6	Meins Lane	Rd	NC	Vol	22/07/04	55H	247733	5886679	292	23	0.3	690
7	Mitiamo Rail Siding	Rail	NC	Riv	20/07/04	55H	250459	5989608	90	35	0.0	53
8	McSwain	Padd	NC	Riv	29/07/04	55H	289541	5995948	103	63	1.0	6,300
9	Mt Mercer Road	Rd	Cor	Vol	25/08/04	54H	757070	5796842	202	107	1.0	10,700
10	Wingeel Rail	Rail	Cor	Vol	24/08/04	54H	750024	5780836	121	92	4.0	36,800
11	Poorneet West Rail	Rail	Cor	Vol	24/08/04	54H	740936	5783542	148	322	5.0	161,000
12	Geggies Road	Rd	Cor	Vol	24/08/04	54H	740882	5792453	157	196	1.0	19,600
13	Dobie, Western HW	Rd	Cor	Vol	25/08/04	54H	677518	5869007	N/A	189	1.0	18,900
14	Calder Rail	Rail	PP	Vol	28/09/04	N/A	N/A	N/A	N/A	131	0.5	5,895
15	Western Treatment	Pub	PP	Vol	17/08/04	55H	286124	5790287	10	191	1.0	19,100
16	Truganina Cemetery	Pub	PP	Vol	19/08/04	55H	299215	5810899	38	27	0.7	1,890
												292,048

Appendix 2: Two-way vegetation table based on hierarchical agglomerative classification

Q1 to Q16 = quadrat samples; OR = origin (* - exotic and # - naturalized); see methods for definition of cover/abundance codes.

Crossman Road Riv Q1	Jasper Road Riv Q2	McElwains Road Riv Q3	Hands Road Riv Q4	Durham Ox Road Riv Q5	Mitiamo Rail Riv Q7	McSwain's Padd Riv Q8	West HW, Dobie Vol Q13	Western T'Plant Vol Q15	Meins Lane Vol Q6	Calder Rail Vol Q14	Truganina Cem Vol Q16	Mt Mercer Road Vol Q9	Poorneet Rail Vol Q11	Geggies Road Vol Q12	Wingeel Rail Vol Q10	OR	NAME	COMMONNAME
1	2	1	1	+	1	+											Enteropogon acicularis	Spider Grass
+	+	1	+	+	+	1											Sida corrugata	Variable Sida
+	+	+	+	+	+	+		+									Maireana enchylaenoides	Wingless Bluebush
4	2	+	2	2	3	1	1			+						*	Avena spp.	Oat
2	1	2	2	1	1	1	+			1						*	Trifolium angustifolium var. angustifolium	Narrow-leaf Clover
+	+	1	+	+	+	1				1			+			*	Trifolium campestre var. campestre	Hop Clover
+	1	+	1	1		1	+									*	Arctotheca calendula	Cape Weed
+	+	1	+	+	+			+									Atriplex semibaccata	Berry Saltbush
1	+	1	+			1										*	Trifolium arvense var. arvense	Hare's-foot Clover
+		+	+	+													Lomandra effusa	Scented Mat-rush
1	+	+			+												Maireana decalvans	Black Cotton-bush
+	+		1			+											Vittadinia cuneata	Fuzzy New Holland Daisy
2	1		+	+	1				1						+		Whalleya proluta	Rigid Panic
1	2		2	1				2									Austrostipa aristiglumis	Plump Spear-grass
	+	+				1											Arthropodium minus	Small Vanilla-lily
	1	2				1											Austrostipa nodosa	Knotty Spear-grass
	+			+		+										#	Chamaesyce drummondii	Flat Spurge
2	+				3												Leiocarpa panaetioides	Woolly Buttons
+																	Arthropodium spp. (s.s.)	Vanilla Lily
						+										*	Carthamus lanatus	Saffron Thistle
1																*	Critesion marinum	Sea Barley-grass
						1											Goodenia pusilliflora	Small-flower Goodenia
						+											Linum marginale	Native Flax
				+												*	Lophopyrum ponticum	Tall Wheat-grass
					+												Panicum decompositum	Australian Millet
		+															Ptilotus erubescens	Hairy Tails
						1											Rhodanthe pygmaea	Pygmy Sunray
					1												Sclerolaena diacantha	Grey Copperburr
	+																Swainsona plagiotropis	Red Swainson-pea
						+											Swainsona procumbens	Broughton Pea
		1															Teucrium racemosum s.l.	Grey Germander
						1										*	Trifolium tomentosum var. tomentosum	Woolly Clover
			+														Vittadinia gracilis	Woolly New Holland Daisy
				+													Vittadinia spp.	New Holland Daisy
		+															Wurmbea latifolia ssp. vanessae	Broad-leaf Early Nancy

		+	+														Arthropodium fimbriatum	Nodding Chocolate-lily
		1	1														Austrostipa blackii	Crested Spear-grass
		+			+												Bulbine bulbosa	Bulbine Lily
					1	+											Calotis scabiosifolia	Rough Burr-daisy
					+	+											Chenopodium desertorum ssp. virosum	Frosted Goosefoot
		+				+											Crassula sieberiana	Sieber Crassula
	+			+													Maireana excavata	Bottle Bluebush
			+			1											Maireana humillima	Dwarf Bluebush
+						+											Maireana pentagona	Hairy Bluebush
+	1																Panicum laevinode	Pepper Grass
	+				+												Ptilotus exaltatus	Mulla Mulla
+					+											#	Pycnosorus globosus	Drumsticks
				+	1											*	Trifolium striatum	Knotted Clover
1	1				+						+						Austrodanthonia fulva	Copper-awned Wallaby-grass
		+	1	+								+					Chloris truncata	Windmill Grass
	+	+				+	+									*	Erodium botrys	Big Heron's-bill
1	+				+		1									*	Lolium rigidum	Wimmera Rye-grass
	+		1						+							*	Bromus hordeaceus ssp. hordeaceus	Soft Brome
			+			1	+									*	Hypochoeris glabra	Smooth Cat's-ear
+	+								+								Rumex dumosus	Wiry Dock
		2	2							1						*	Vulpia spp.	Fescue
		+	+			+			+				+			*	Aira spp.	Hair Grass
				+						+							Austrostipa scabra	Rough Spear-grass
	+										1						Einadia hastata	Saloop
					+								+			*	Helminthotheca echioides	Wiry Glasswort
						1				1						*	Lolium perenne	Perennial Rye-grass
					1					+						*	Medicago spp.	Medic
				+						+						*	Rumex spp. (naturalised)	Dock (naturalised)
+				+								+	+				Juncus spp.	Rush
	1	1		+		2		1		+							Austrostipa gibbosa	Spurred Spear-grass
	2	3	2	+	1					1	+			3	+		Chrysocephalum apiculatum s.l.	Common Everlasting
+	+	1	+	+	+	+				+	+		+				Oxalis perennans	Grassland Wood-sorrel
	1	1	1	1	+	1	1	+		1		1	1				Austrodanthonia setacea	Bristly Wallaby-grass
+	+	+	+	1	+		1			1	+	+	+	+		*	Trifolium spp.	Clover
2	2	2	1	3	2	2				1	1	1	2	2	+	*	Romulea minutiflora	Small-flower Onion-grass
1	1	2	2	2	2	2	1	2		1	1	2	1	1			Austrodanthonia caespitosa	Common Wallaby-grass
2	2	2	1	1	1	1	1	1	+	1	1	1	2	2	2		Pimelea spinescens subsp. spinescens	Spiny Rice-flower
+	1	1	1	2	1	1	+		+	+	2	2	+	1	2		Calocephalus citreus	Lemon Beauty-heads
+	+	1	2	2			2	3	2	+	1	2	1	1	1	*	Romulea rosea	Onion Grass
		+	+	+			+	1	+	+	+	1	+	+	+		Convolvulus erubescens spp. agg.	Pink Bindweed
		+		+	+	+		1		+		1	+	1	2		Asperula conferta	Common Woodruff
+	+	+	1			2		1	+		+	1		1	1		Eryngium ovinum	Blue Devil
		1				+				1		1		2	1		Leptorhynchos squamatus	Scaly Buttons
						+	+					+					Crassula decumbens var. decumbens	Spreading Crassula
+							+			+						*	Sonchus oleraceus	Common Sow-thistle
						+	1	2						+		*	Plantago coronopus	Buck's-horn Plantain
								1	+								Austrodanthonia duttoniana	Brown-back Wallaby-grass
										+	+						Cheilanthes spp.	Rock Fern
												+			+		Craspedia variabilis	Variable Billy-buttons
									+		+						Dianella amoena	Matted Flax-lily
										1	1						Dianella revoluta s.l.	Black-anther Flax-lily
								1		2							Eutaxia microphylla var. microphylla	Common Eutaxia
												2		+			Goodenia pinnatifida	Cut-leaf Goodenia
							+				+						Oxalis corniculata s.l.	Yellow Wood-sorrel
										+	1						Pimelea curviflora s.l.	Curved Rice-flower
													3		2		Poa labillardierei	Common Tussock-grass
										+		+					Ptilotus macrocephalus	Feather Heads
							+		+							*	Sonchus asper s.l.	Rough Sow-thistle
								+				+					Thelymitra spp.	Sun Orchid
							1									*	Acetosella vulgaris	Sheep Sorrel
									1							*	Agrostis capillaris s.l.	Brown-top Bent
								+									Agrostis s.l. spp.	Bent/Blown Grass
							1									*	Anagallis arvensis	Pimpernel
							+										Austrodanthonia geniculata	Kneed Wallaby-grass
										+							Caesia calliantha	Blue Grass-lily
												+					Carex breviculmis	Common Grass-sedge
															+		Cassytha glabella	Slender Dodder-laurel
							+									*	Centaurium tenuiflorum	Slender Centaury
										+						*	Cynara cardunculus	Spanish Artichoke
										1						*	Dactylis glomerata	Cocksfoot
										+							Daucus glochidiatus	Australian Carrot
											1						Dichelachne spp.	Plume Grass
															+		Drosera glanduligera	Scarlet Sundew
											+					*	Eucalyptus cladocalyx	Sugar Gum
										1							Geranium sp. 2	Variable Cranesbill
												2					Haloragis heterophylla	Varied Raspwort

								+								*	Leontodon taraxacoides ssp. taraxacoides	Hairy Hawkbit
											+					*	Lepidium africanum	Common Peppercress
								+									Lobelia pratioides	Poison Lobelia
							1										Lomandra filiformis	Wattle Mat-rush
															1		Microseris scapigera spp. agg.	Yam Daisy
											1					*	Oxalis debilis var. corymbosa	Pink Shamrock
							+										Pimelea linifolia	Slender Rice-flower
							+									*	Poa annua	Annual Meadow-grass
															1		Poa morrisii	Soft Tussock-grass
										1							Poa sieberiana var. sieberiana	Grey Tussock-grass
										2							Podolepis sp. 1	Basalt Podolepis
															+		Prasophyllum spp.	Leek Orchid
										+							Ptilotus spathulatus f. spathulatus	Pussy Tails
									+							*	Romulea spp.	Onion Grass
											+						Rutidosis leptorhynchoides	Button Wrinklewort
										+						*	Salvia verbenaca	Wild Sage
										1							Senecio macrocarpus	Large-fruit Fireweed
											+						Solenogyne gunnii	Hairy Solenogyne
											+					*	Spergularia rubra s.l.	Red Sand-spurrey
											+						Stackhousia monogyna	Creamy Stackhousia
							+										Tricoryne elatior	Yellow Rush-lily
															1		Veronica gracilis	Slender Speedwell
										+						*	Vicia spp.	Vetch
										1							Wahlenbergia communis s.l.	Tufted Bluebell
			+							+		+	+	+			Elymus scaber var. scaber	Common Wheat-grass
					+					2		+		+	1		Plantago gaudichaudii	Narrow Plantain
						+				2	1			2	1		Velleia paradoxa	Spur Velleia
							1			1		1					Acaena echinata	Sheep's Burr
								+		+					1		Austrodanthonia spp.	Wallaby Grass
											1	1		1			Austrostipa spp.	Spear Grass
											1		1	1			Poa sieberiana	Grey Tussock-grass
											+	1			+		Wahlenbergia stricta	Tall Bluebell
	+										1	2	2	1	+		Plantago varia	Variable Plantain
							+	+	+				+			*	Cirsium vulgare	Spear Thistle
									+				+	+	+		Comesperma polygaloides	Small Milkwort
										+			1	1	2		Drosera whittakeri ssp. aberrans	Scented Sundew
										+		+	+		+		Hypoxis spp.	Wiry Glasswort
							3		2			1	1			*	Phalaris aquatica	Toowoomba Canary-grass
							1		1	+		1				*	Plantago lanceolata	Ribwort
										+		+		+	1		Solenogyne dominii	Smooth Solenogy ne
								+	1				+	+	+		Acaena ovina	Australian Sheep's Burr
								+	2				2	+	+	*	Briza maxima	Large Quaking-grass
							+				+	+	+		+		Geranium spp.	Crane's Bill
							1	2	1	+		+				*	Hypochoeris radicata	Wiry Glasswort
							3	+	2	3	4	3	4	3	4		Themeda triandra	Kangaroo Grass

Appendix 3: Demographic structure

Bio = Bioregion; Dist = Disturbance type; Lburn = Last burnt (years); PopD = Population density (per quadrat); Sene = Senescent; MM = Mature Male; MF = Mature Female; MU = Mature Unknown sex; MT – Mature Total; I<10 = Immature <10 cm high; I>10cm Immature (non-flowering) > 10 cm high; IT = Immature total; G = Germinants

No	Site Name	Type	CMA	Bio	Date	Dist	Lburn	PopD	Dead	Sene	MM	MF	MU	MT	I<10	I>10	IT	G
1	Crossman Road	Rd	NC	Riv	20/07/04	None	N/A	132	0	11	52	38	11	101	12	8	20	0
2	Jasper Road	Rd	NC	Riv	21/07/04	None	N/A	160	0	5	62	61	0	123	30	2	32	0
3	McElwains Road	Rd	NC	Riv	21/07/04	Graz	??	162	2	2	80	50	6	136	24	0	24	0
4	Hands Road	Rd	NC	Riv	21/07/04	Graz	??	123	0	0	26	60	3	89	32	2	34	0
5	Durham Ox Road	Rd	NC	Riv	19/07/04	Graz	??	41	0	0	15	16	0	31	10	0	10	0
6	Meins Lane	Rd	NC	Vol	22/07/04	None	10.0	23	0	3	11	9	0	20	0	0	0	0
7	Mitiamo Rail Siding	Rail	NC	Riv	20/07/04	None	N/A	35	0	2	11	10	7	28	0	5	5	0
8	McSwain	Padd	NC	Riv	29/07/04	Graz	N/A	63	1	7	18	11	8	37	19	0	19	0
9	Mt Mercer Road	Rd	Cor	Vol	25/08/04	Burnt	0.5	107	0	0	9	30	1	40	52	0	52	15
10	Wingeel Rail	Rail	Cor	Vol	24/08/04	Burnt	6.0	92	0	0	40	45	0	85	7	0	7	0
11	Poorneet West Rail	Rail	Cor	Vol	24/08/04	Burnt	3.5	322	1	0	117	143	0	260	62	0	62	0
12	Geggies Road	Rd	Cor	Vol	24/08/04	Burnt	0.5	196	0	0	15	22	0	37	156	0	156	3
13	Dobie, Western HW	Rd	Cor	Vol	25/08/04	Burnt	0.5	189	0	0	0	0	0	0	69	0	69	120
14	Calder Rail	Rail	PP	Vol	28/09/04	Burnt	2.0	131	0	11	0	0	75	75	38	0	38	7
15	Truganina Cemetery	Pub	PP	Vol	19/08/04	Burnt	2.5	191	0	16	36	54	45	135	36	0	36	4
16	Western Treatment	Pub	PP	Vol	17/08/04	Burnt	1.5	27	0	0	9	6	0	15	2	0	2	10