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Vegetation structure and floristics of granite landforms in the South-west Slopes of New South Wales

Damian R. Michael and David B. Lindenmayer*

Fenner School of Environment and Society, The Australian National University, Canberra, ACT. 0200 AUSTRALIA.

*Corresponding author: damian.michael@anu.edu.au

Abstract: We describe the natural vegetation structure and floristics of 44 small-sized granite outcrops (inselbergs) in agricultural landscapes in the South-west Slopes (SWS) bioregion of New South Wales (35° 26' S, 147° 23' E to 35° 58' S, 146° 59' E) and their relationships with geomorphology. We provide a list of 196 species (117 natives and 79 exotics). We found that structurally complex outcrops supported a greater diversity of native ground cover species and fewer exotic species than structurally simple outcrops. Tor landforms lacked vegetation structural complexity and were deficient in native shrubs, mid-storey and over-storey species but typically supported exotic grasses and broad-leaved exotic weeds. Floristic composition differed among landforms and cluster analysis revealed highly dissimilar native plant communities among outcrops. Our study highlights the need to rehabilitate tor landforms and manage a broad spectrum of outcrops to conserve floristic diversity in agricultural landscapes. Selecting genetically diverse species for replanting, considering the density and spatial arrangement of plantings, and controlling invasive plants and feral herbivorous animals are fundamental issues in restoring granite outcrop vegetation in the SWS bioregion.

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Introduction

Inselbergs are granite outcrops that rise abruptly from flat landscapes (Twidale 1982) providing a broad range of micro-climatic conditions that contrast with surrounding landscapes (Campbell 1997) and supporting biologically diverse communities (Porembski & Barthlott 2000). For these reasons, the biota of inselbergs have fascinated scientists from around the world for over 200 years (Walters 1982), not least because these environs are rich in endemic taxa (Porembski & Barthlott 2000), but also because they provide a model framework for examining patterns of floristic diversity and species composition in the context of island biogeography theory (Burke 2003, Butler & Fensham

2008, Michael et al. 2008). However, in many parts of the world, agricultural development and the associated impacts of habitat fragmentation is threatening the natural insularity of inselbergs by creating smaller habitat isolates, and increasing isolation by reduced vegetation connectivity. This process has serious implications for the long-term viability of plant populations in modified landscapes (Broadhurst & Young 2006, Broadhurst *et al.* 2008).

An important aspect of inselberg ecology is their role in providing refugia for endemic and fire sensitive flora. Fires on granite outcrops are generally rare due to the buffering effect of rock (Burke 2003), and in the absence of fire, fire-sensitive and mesic-adapted plants such as ferns grow in sheltered locations (Hopper et al. 1997). Many outcrops

support obligate seeders (Hopper 2000, Hunter 2003) such as *Callitris* spp., *Acacia* spp., *Pultenaea* spp. and *Dodonaea* spp. which germinate following fire, in contrast to sprouters which regenerate primarily from epicormic buds or underground rhizomes, such as many *Eucalyptus* species (Clarke 2002). In sclerophyllous vegetation, frequent high-intensity fires promote sprouters whereas intermediate low-intensity fires promote obligate seeders (Keith 1996). Frequent fires can therefore alter plant species composition, a process which can threaten the integrity and long-term persistence of outcrop flora (Bradstock et al. 2002).

The grassy box woodlands of temperate south-eastern Australia represent a broad bio-climatic region that has been extensively modified (Beadle 1981) and continues to be threatened by agricultural intensification and urban development (Yates & Hobbs 1997, Lindenmayer et al. 2010). It is estimated that less than 5% of the original grassy box woodland remains intact (Prober 1996), with much of the remaining vegetation occurring on skeletal soils and rocky outcrops. The South-west Slopes (SWS) botanical region of New South Wales is one of the most heavily cleared bioregions in New South Wales (Benson 2008). Grassy box woodlands are significantly fragmented; improvements to the condition and extent of remnant vegetation are a priority conservation action of natural resource management agencies (Murray Catchment Management Authority 2007). If it were not for an archipelago of rocky outcrops in the SWS, the majority of which are granite, grassy box woodland may have been more extensively cleared than current vegetation patterns suggest.

In Western Australia, inselberg vegetation has been the subject of considerable research (Smith 1962, Burgman 1987, Ornduff 1987, Hopper et al. 1997, Ohlemuller 1997, Porembski et al. 1997, Pigott 2000, Porembski 2000), whereas inselbergs in eastern Australia have received far less attention (Ashton & Webb 1977, Norris & Thomas 1991, Hunter & Clarke 1998). The value of granite outcrops in supporting rock-dwelling reptiles in agricultural landscapes has been reported recently in the SWS (Michael et al. 2008, Michael et al. 2010a), and specific management actions have been proposed to enhance habitat for this group (Michael et al. 2010b). Given the paucity of vegetation studies in the SWS (Burrows 1999), additional studies are required which may help inform restoration activities in the region. The main aim of this study was to examine vegetation patterns and floristic composition of relatively small granite outcrops in relation to different landforms. It is widely recognized that vegetation communities change in response to lithology (Norris & Thomas 1991, Burrows 1999). However, the influence of geological landform on patterns of vegetation is less well understood (Kruckenburg 2002). We frame our study by proposing three main questions. 1) Do current patterns of vegetation structure differ among landforms of the same geology? 2) Is floristic composition influenced by granite landform? 3) Can these findings help guide conservation and restoration activities in the SWS bioregion?

Methods

Study area

This study area was in the southern half of the South-west Slopes (SWS) bioregion of New South Wales, bordered by Big Springs in the north (35° 19' S, 147° 25' E), Albury in the south (36° 00' S, 146° 53' E), Kyeamba in the east (35° 26' S, 147° 37' E) and Goombargana in the west (35° 44' S, 146° 34' E). Annual average rainfall in the region ranges from approximately 450 mm at Walbundrie to 550 mm near Tarcutta (Bureau of Meteorology 2012). Due to drought conditions the average monthly precipitation during the study period, Oct 2006 – Feb 2007, was generally below average for each month (2006 Oct– 2.4 mm, Nov– 46.2 mm, Dec– 1.6 mm; 2007 Jan– 36.5 mm, Feb– 40.8 mm, Bureau of Meteorology 2012). The vegetation type is temperate woodland (*sensu* Hobbs & Yates 2000), dominated by the endangered ecological vegetation community – White box (*Eucalyptus albens*), Yellow box (*Eucalyptus melliodora*), Blakely's red gum (*Eucalyptus blakelyi*) woodland (www.environment.gov.au 2012).

Granitoid formations associated with the Southern Highlands Fold Belt (Wagga Metamorphic Belt) are one of the main lithologies in the SWS (Packham & Day 1969). Soils derived from surface weathering of granite produces a shallow layer of sandy loam that overlays sandy clay (Norris & Thomas 1991). Four geomorphologically distinct granite landforms (*sensu* Campbell 1997; see Michael et al. 2008 for images) occur in the region. These are:

- (1) Bornhardt / Dome (6 outcrops) – large, steep-sided dome-shaped hills arising abruptly from the surrounding landscape characterized by large expanses of bare rock. Shallow and elliptical bornhardts are called 'whalebacks' or 'turtlebacks'.
- (2) Nubbin (13 outcrops) – small, conical hills rising gently from the surrounding landscape, characterized by small boulder-strewn rock piles.
- (3) Castle koppie (8 outcrops) – small, steep-sided hills arising abruptly from the surrounding landscape characterized by large orthogonally fractured boulder stacks.
- (4) Tors (17 outcrops) – sparsely aggregated rocks in flat or gently undulating landscapes characterized by individual, block-shaped pillars of various sizes.

Sampling protocol

Between October 2006 and February 2007, one of the authors (DM) assessed vegetation on 44 privately owned granite outcrops located within agricultural landscapes. Subsets of all four landforms were surveyed each month over the assessment period. With the exception of three outcrops where livestock had been excluded prior to the study, grazing pressure included set stocking rates (N = 25 outcrops) or rotational grazing regimes (N = 16 outcrops). On each outcrop, we established a 1 hectare (100 m x 100

Table 1. Summary of geological and floristic attributes for each granite landform in the SWS bioregion (Bold numbers indicate relatively high or low attribute values).

	Nubbin	Koppie	Tor	Bornhardt
Geomorphological attributes				
Number surveyed	13	8	17	6
Mean outcrop size (ha)	4.9	4.2	3.2	57.1
Median outcrop size (ha)	4	5	1.5	17.5
Exposed rock cover (%)	45	55	31	50
Vegetation structural attributes				
Total stem density (stems/ha)	54.4	42.5	10.4	60.3
Density of regrowth (DBH < 20 cm)	28.1	24.6	2.3	30.5
Density of oldgrowth (DBH > 60 cm)	2.4	3.4	3.5	2.4
Native overstorey cover (%)	19	17	5	28
Native shrub cover (%)	31	13	1	0.8
Total grass cover (%)	28	23	48	28
Floristics				
Mean native species richness	18	18	12	14
Mean exotic species richness	9	12	11	8

m) grid and recorded plant species richness over a two hour period by assessing areas with soil, rock crevices and ledges. The average amount of exposed rock within each quadrat ranged from 30% on tors to 60% on koppies. In addition, we recorded structural attributes such as overstorey density (live and dead), overstorey stem diameter size class (0 – 20 cm, 21 – 40 cm, 41 – 60 cm and > 60 cm), midstorey height class (0 – 0.5 m, 0.51 – 1.0 m, 1.1 – 2.0 m and > 2 m), percent cover estimates for individual species (overstorey, midstorey and understorey shrubs), percent cover estimates for native and exotic grass cover, native and exotic forbs, woody weeds, rock cover, leaf litter and bare ground. We also recorded the number of logs, stumps and fallen trees in our 1 ha plots. We identified species using Harden (1990 –2002) and followed the nomenclature of PlantNET (www.Plantnet.com.au).

For the outcrops in this study the median patch size was 4 ha (mode = 5 ha, mean = 11 ha, range 0.5 – 201 ha) which meant in many cases our sampling area covered a large proportion of the outcrop. We assigned each outcrop a structural complexity score ranging from 1 – 5 based on the tally of rocks in six volumetric categories (flat expanses of rock, rocks < 0.5 m³; boulders between 0.5 m³ – 2 m³, pillars between 2 m³ – 5 m³, blocks between 5 m³ – 10 m³; and domes > 10 m³, see Michael et al. 2008).

Statistical analysis

We completed non-parametric data analysis using options available in Excel, SPSS v7 and Primer v6 (Clarke & Gorley 2006). We standardized our data to site level and compared species richness, structural attributes and cover

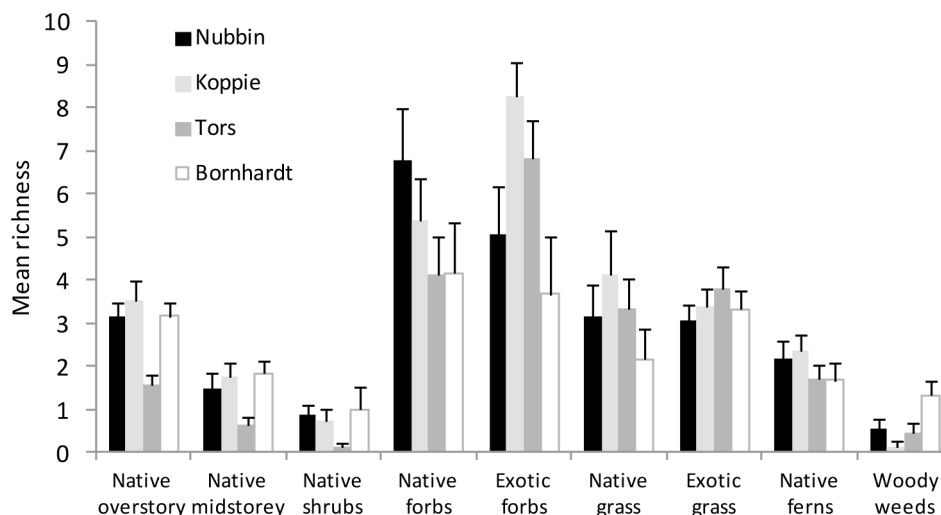


Fig. 1. Variation in mean species richness (±1 SE) for nine floristic groups on four granite landforms in the NSW South-west Slopes.

abundance estimates among landforms using ANOVA. We used presence/absence data to construct a similarity matrix for all species, native and exotic taxa, and compared floristic composition among landforms (ANOSIM), with 9999 random permutations of the data. We used the Jaccard coefficient of similarity to perform hierarchical cluster analysis (Clarke & Gorley 2006).

Results

We recorded a total of 196 vascular plant species (117 native and 79 exotic species) including eight *Eucalyptus* species, six *Acacia* species, 45 native forbs, 20 native grasses, 21 exotic grasses, 47 exotic forbs / broad-leaved weeds, and 11 woody weeds (Appendix 1). The dominant families Poaceae and Asteraceae accounted for 36% of all species. Common overstorey species included *Eucalyptus albens* (55% of

sites), *Acacia implexa* (57%), *Eucalyptus blakelyi* (50%) and *Brachychiton populneus* (48%). *Indigofera australis* was the most common shrub (16%). The most common ground cover species included *Isotoma axillaris* (75%), **Acetosella vulgaris* (62%), **Hordeum leporinum* (61%), *Cheilanthes austrotenuifolia* (61%), **Bromus diandrus* (55%), *Oxalis perennans* (55%), **Echium plantagineum* (52%), *Pleurosorus rutifolius* (48%), *Austrodanthonia caespitosa* (48%), **Avena fatua* (46%), **Hypochaeris radicata* (43%), **Vulpia myuros* (39%) and *Bothriochloa macra* (39%). One threatened species, *Senecio garlandii* was recorded on two sites. (* above indicates exotic species).

Species richness

We found that plant species richness did not differ significantly among landforms ($F_{3, 40} = 0.8, P = 0.49$) and ranged from 22 species on bornhardts to 30 species on

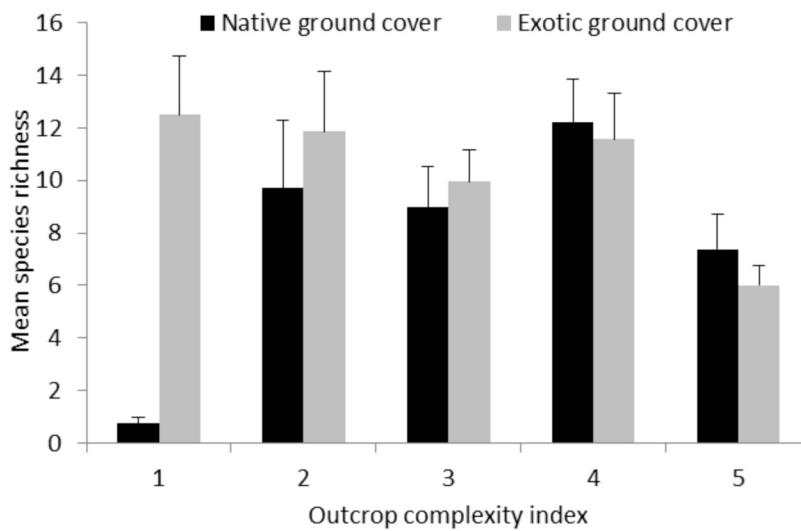


Fig. 2. Variation in mean richness of native and exotic ground cover species (± 1 SE) among granite outcrops of varying structural complexity in the NSW South-west Slopes.

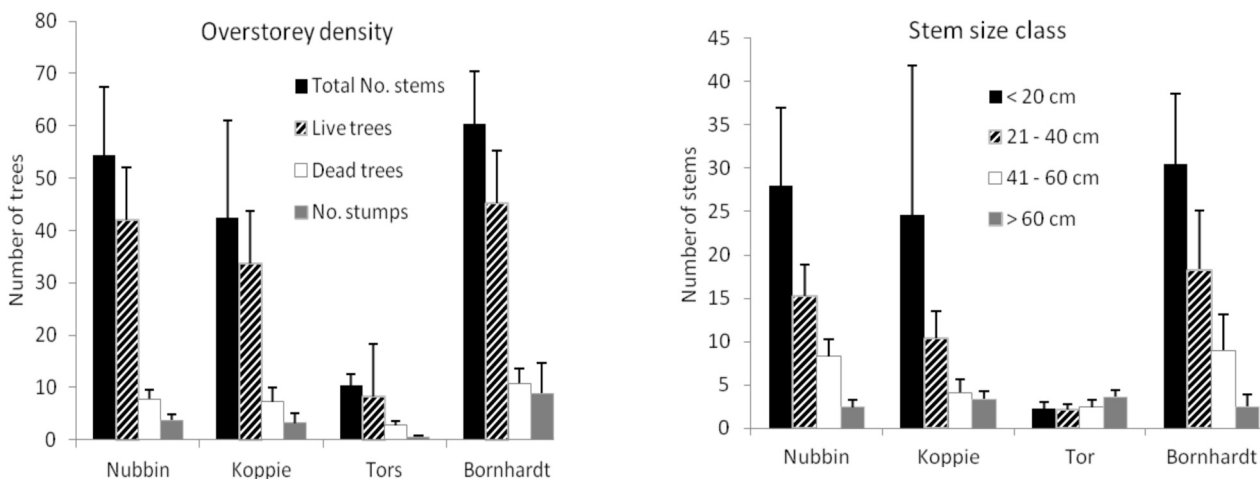


Fig. 3. Variation in the mean density (± 1 SE) of overstorey attributes among granite landforms in the NSW South-west Slopes.

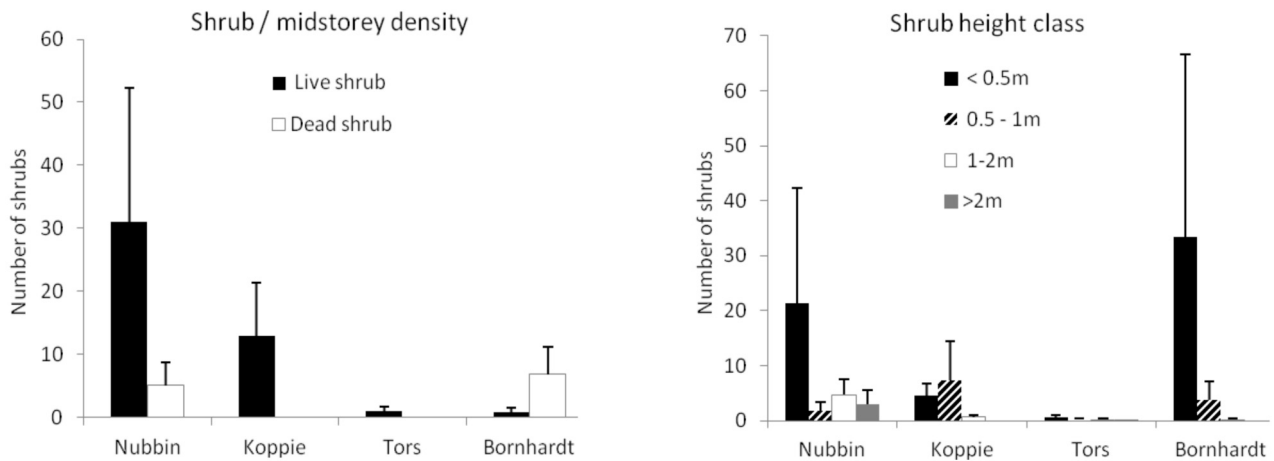


Fig. 4. Variation in the mean density (± 1 SE) of midstorey attributes among granite landforms in the NSW South-west Slopes.

koppies (Table 1). Of floristic groups, native overstorey ($F_{3, 40} = 8.89, P < 0.001$), midstorey ($F_{3, 40} = 3.47, P = 0.02$) and native shrub species richness ($F_{3, 40} = 3.11, P = 0.03$) differed significantly among landforms, with tors supporting the least number of species in all three groups (Figure 1). The number of exotic forbs and woody weeds also varied among landforms (Figure 1), although these differences were not significant (exotic forbs $F_{3, 40} = 2.5, P = 0.07$, woody weeds $F_{3, 40} = 2.71, P = 0.057$).

Relationship between outcrop complexity and species richness

We found a significant positive linear relationship between native ground cover species richness and outcrop structural complexity ($R^2 = 0.3$), where native species richness increased as a function of complexity. On average, structurally simple outcrops supported one or less native

species, whereas complex outcrops supported more than 12 native species (Figure 2). In contrast, we found a strong negative linear relationship between exotic ground cover species richness and outcrop structural complexity ($R^2 = 0.6$), where exotic species richness decreased as a function of outcrop complexity. On average, structurally simple outcrops supported more than 12 exotic species, whereas, complex outcrops supported half that number (Figure 2).

Vegetation structure

We found a significant difference in several overstorey attributes among landforms, including total number of stems ($F_{test 3, 40} = 5.19, P = 0.004$), number of live trees ($F_{test 3, 40} = 4.26, P = 0.01$), number of dead trees ($F_{test 3, 40} = 3.70, P = 0.02$), and number of tree stumps ($F_{3, 40} = 2.92, P = 0.04$). These results were influenced by tor landforms supporting the lowest value for all four variables mentioned

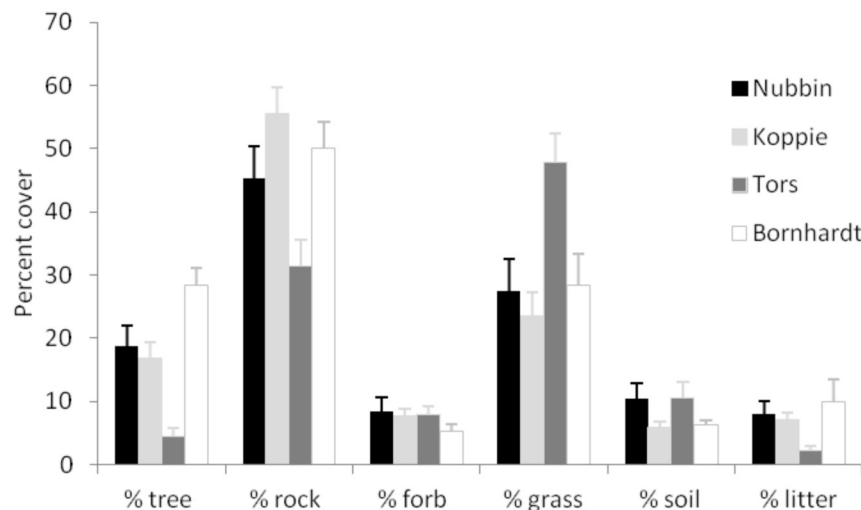


Fig. 5. Variation in percent cover abundance estimates (± 1 SE) for biotic and abiotic variables among granite landforms in the South-west Slopes of New South Wales.

above (Figure 3). The mean number of stems in several diameter size classes also differed significantly among landforms, particularly for number of stems less than 20 cm ($F_{3, 40} = 2.88, P = 0.04$), between 21 and 40 cm ($F_{3, 40} = 6.24, P < 0.001$) and between 41 and 60 cm ($F_{3, 40} = 3.27, P = 0.003$). These differences were attributed to the low number of stems in all size classes on tor landforms (Figure 3).

We found the mean total number of shrub and midstorey plants did not differ significantly among landforms, although both nubbins and koppies supported an average density of 31 and 13 midstorey plants respectively (nubbin range = 0 – 271 plants / ha, koppie range = 0 – 69 plants / ha) (Figure 4). In addition, the number of shrub and midstorey plants in four height classes did not differ significantly among landforms (Figure 4).

We found a significant difference in mean percent cover abundance estimates between landforms (Figure 5). These included overstorey tree cover ($F_{3, 40} = 13.72, P < 0.001$) which was highest on bornhardts and lowest on tors, grass

cover ($F_{3, 40} = 5.67, P = 0.002$) which was highest on tors, and leaf litter cover ($F_{3, 40} = 3.25, P = 0.03$) which was lowest on tors.

Floristic composition

Analysis of similarity (ANOSIM) revealed floristic composition varied significantly among landforms when all species were included (Global R statistic = 0.13, $P = 1\%$), and for exotic species (Global R statistic = 0.14, $P = 3\%$), but not for native species (Global R statistic = 0.04, $P = 21\%$) or just native perennials (Global R statistic = 0.02, $P = 33\%$). When all species were included, hierarchical cluster analysis revealed high levels of floristic dissimilarity among outcrops, with the majority of outcrops sharing less than 30% of total species. When exotic species were excluded, cluster analysis showed the majority of outcrops shared less than 40% of species, and when only native perennials were included, cluster analysis showed the majority of outcrops shared less than 45% of species (Figure 6).

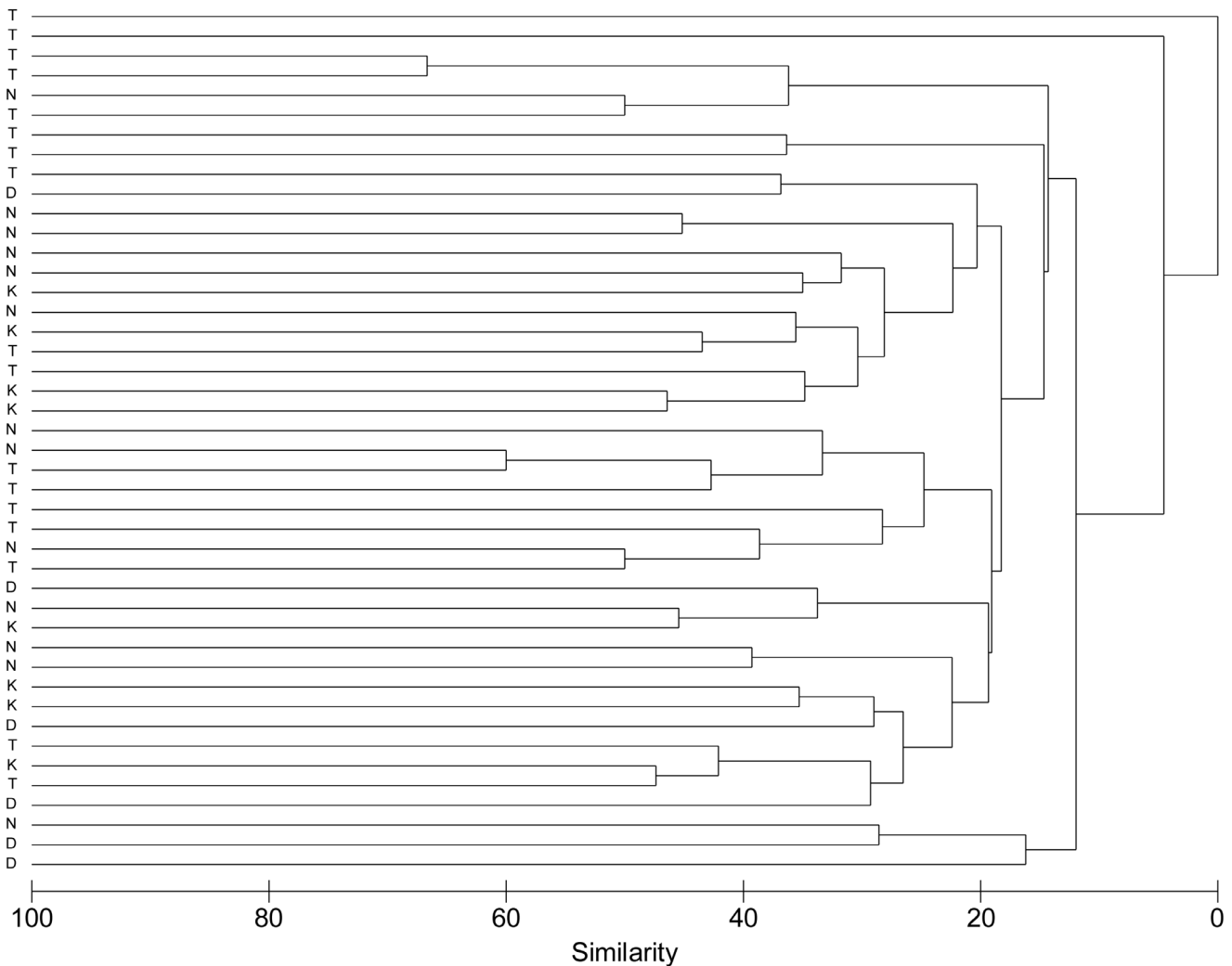


Fig. 6. Heirarchical cluster analysis showing community similarity for native perennial species (Jaccard similarity co-efficient) among outcrops classified by geomorphology in the South-west Slopes of New South Wales (N = nubbin, K = koppie, T = tor, and D = Dome / bornhardt).

Discussion

Granite inselbergs represent unique environments for plant survival and are typically rich in floristic diversity and endemic taxa (Hopper et al. 1997, Hunter & Clarke 1998), but there are few studies on small granite outcrops in south-eastern Australia (see Norris & Thomas 1991). This study was conducted during the spring and summer months of a prolonged period of drought, thereby spanning a non-optimal survey period for detecting native annual plant species (Burrows 2004). Nevertheless, we recorded 197 species (Appendix 1), including a new record with approximately 50 individuals of the daisy *Senecio garlandii* (Asteraceae family), a threatened species listed as Vulnerable under the *NSW Threatened Species Conservation Act 1995*. *Senecio garlandii* is currently known from nine locations in the SWS (Burrows 2001). *Senecio garlandii* (Asteraceae) was recorded growing near the base of outcrops 6.8 km west of Gerogery and near Big Springs (19 km south of Wagga Wagga). Several regionally significant species were recorded. *Correa glabra* (Rutaceae) was recorded from the summit of Mount Budginni near the locality of Tabletop, 8 km north of Albury CBD. *Pultenaea platyphylla* (Fabaceae) was recorded from rock crevices on two outcrops 13 km west of Gerogery. *Acacia penninervis* (Mimosaceae) was recorded growing on the summit of Mount Mullemba (8.4 km north of Walbundrie) and an outcrop near Big Springs (27 km south of Wagga Wagga) and *Santalum apiculatum* (Santalaceae) was recorded on an outcrop 10 km east of Henty and 9.4 km south of Walla Walla.

Additional key findings include: 1) marked differences in mid and overstorey species richness, vegetation structure and floristic composition among granite landforms; 2) multi-directional relationships between the ratio of native and exotic groundcover species and outcrop structural complexity, and 3) high levels of floristic dissimilarity among outcrops. However, because some of our surveys

were conducted during less optimal periods of the year for detecting annual forb and grass species in the SWS (Burrows 2004), our results should be interpreted with caution. We discuss the management implications of our findings below and conclude with recommendations to help guide future restoration programs in the SWS bioregion.

Species richness and vegetation structure

Inherent differences in physical complexity among landforms mean outcrops are differentially affected by agricultural practices. The majority of outcrops in the study region supported remnants of the endangered ecological vegetation community; white box *Eucalyptus albens*, yellow box *Eucalyptus melliodora*, Blakely's red gum *Eucalyptus blakelyi* woodland, although species richness, vegetation cover and condition varied among landforms. In general, tor landforms were dominated by exotic grasses and forbs (Figure 1), lacked shrubs (Figure 4) and supported less than 5% tree cover (Figure 5). By contrast, complex outcrops supported greater plant diversity (Figure 2), multiple strata, and more vegetation cover (Figure 5). Tor landforms are the highly eroded remnants of bornhardts and consequently occur in relatively flat, productive landscapes (Twidale 1982). Historically, native vegetation growing on the most productive soils has been extensively cleared for agriculture, whereas native vegetation growing on poorer soils has often survived relatively intact, but exposed to disturbances such as fire, logging and livestock grazing (Prober & Thiele 2004). Fire can cause *Eucalyptus* species to resprout from basal lignotubers (Gill 1981, Noble 2001), whereas logging activities often leave behind cut stumps which resprout above the ground (Figure 7) (Wildy et al. 2000). Both regeneration pathways can produce cohorts of multi-stemmed trees. The high density of small-sized overstorey stems (less than 20 cm) and tree stumps on nubbins and koppies (Table 1) is indicative of previous fire and logging activities.



a)



b)

Fig. 7. Images showing a) basal regeneration of *Eucalyptus blakelyi* following a wildfire on a granite outcrop near Gerogery in 2008, and b) tree stump as evidence of past logging activities (Photos DM).

Environmental and agricultural weeds

Exotic plants have become naturalized on granite outcrops around the world and are considered a major problem in preserving the integrity of inselberg flora (Porembski 2000). Exotic species can alter vegetation structure and fire regimes (Benwell 2007) and cause the extinction of endemic taxa (Pigott 2000). In this study 40% of the plants recorded were exotic, mostly agricultural species from the Poaceae and Asteraceae families (Appendix 1). However, had we conducted multiple surveys during different times of the year, the actual number of exotic species is predicted to be higher (Burrows 1999).

An interesting outcome of this study was the relationship between outcrop physical complexity, and a high number of native species but low number of exotic species (Figure 2). Structurally complex outcrops may support more native species because of the greater breadth of microhabitats available serving as refugia from livestock grazing. However, other factors such as fire history and the distance to roads, homesteads and towns, may also influence which invasive plants are likely to be present. Several 'woody weed' species recorded in this study have the potential to cause serious concern because they are long-lived, able to survive harsh conditions, and spread prolifically when mature (Low 1999). These species which include **Ailanthus altissima*, **Celtis australis*, **Lycium ferocissimum*, **Opuntia stricta*, **Prunus* spp., **Robinia pseudoacacia* and **Schinus areira* can be controlled and should be managed before they become a costly environmental problem. Several native species not local to the SWS including *Melia azedarach* were also recorded.

Floristic composition

A key finding of this study was that floristic composition between outcrops was significantly dissimilar, with the majority of outcrops sharing less than 30% of total species, and less than 40% of native species (Figure 6). This result appears to be characteristic of granite outcrops in general. For example, Norris & Thomas (1991) found several granite outcrops in the SWS were floristically dissimilar. Furthermore, patterns of floristic diversity on granite outcrops in Western Australia are characterized by high diversity within homogenous habitats (α -diversity), high species turnover along environmental gradients (β -diversity) and high species turnover among similar habitats across geographical gradients (γ -diversity) (Hopper 1992, Hopper et al. 1996). Our findings suggests that small granite outcrops in modified landscapes also conform to general patterns of floristic diversity, and highlights the need to protect a broad range of outcrops to maintain floristic diversity on a regional scale, by fencing out livestock and controlling feral animals such as goats, deer and rabbits.

Management Implications

Traditional revegetation programs focus on stabilizing creek banks, mitigating dry land salinity by planting hill tops,

creating wind breaks for livestock, and establishing wildlife corridors (Munroe & Lindenmayer 2011). In most cases, these efforts fail to incorporate rocky outcrops and consequently, many outcrops remain devoid of overstorey vegetation. In the SWS, many outcrops are less than 10 ha in size and occur as habitat isolates embedded within highly modified, cleared landscapes. This enhanced insularity has implications for the long-term persistence of saxicolous plant populations, especially for species with few individuals and which do not occur on the intervening parts of the landscape (Broadhurst & Young 2006). Our study has identified tor landforms to be severely degraded and in immediate need of restoration. Broadhurst et al. (2008) suggest introducing germplasm from genetically diverse source populations is required to increase the long-term viability of small plant populations in fragmented landscapes. This principle is applicable to outcrops in the SWS as they support small populations of several shrub species and small trees (Appendix 1). However ecological constraints such as grazing may be limiting some species, and landforms which support moderate amounts of remnant vegetation, such as koppies and nubbins, may benefit most from fencing to keep out livestock and feral herbivores, and to encourage natural regeneration.

Two findings of this study relevant to the design of restoration programs were the presence of shrubs and small trees, and the low density of large mature trees on structurally complex outcrops. The composition and structure of woodland vegetation may have important implications for the survival of rock-dwelling taxa. A recent study in the SWS bioregion for example found high densities of overstorey regrowth vegetation produced high shade levels and supported lower reptile diversity than structurally open outcrops (Michael et al. 2008). Dense vegetative regrowth may also affect growing conditions for saxicolous plants by competing for light and space, and altering micro-climatic conditions (Benwell 2007). Choosing appropriate plant species and carefully considering the density and spatial arrangement of plantings are fundamental issues in the design of future restoration programs involving outcrops.

Conclusion

We examined vegetation structure and floristic composition of relatively small (< 11 ha) granite outcrops in modified landscapes. Tor landforms were most degraded and were characterized by a significant absence of canopy cover, midstorey species, shrubs and native ground cover. Tor landforms could therefore provide nodal points in the design of future restoration activities, which will need to consider appropriate plant species, the spatial arrangement of plantings and genetic diversity of seed stock. Overall, the high percentage of floristic dissimilarity among outcrops in this study highlights the need to manage a broad spectrum of outcrops to maintain floristic diversity in the SWS bioregion. In many cases, this may only require fencing out livestock, controlling invasive plants, monitoring outcomes and adjusting management according to site-specific objectives.

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Appendix 1. Native and exotic plant species recorded on four granite landforms in the South-west Slopes of NSW between October 2006 and February 2007 showing percentage frequency on each landform.

* = introduced species, # = noxious species, + = species listed in the NSW Threatened Species Conservation Act 1995).

	Nubbin	Koppie	Tors	Bornhardt
No of sites	13	8	17	6
PTERIDOPHYTES				
Adiantaceae				
<i>Adiantum aethiopicum</i>	23	0	0	0
<i>Cheilanthes austrotenuifolia</i>	62	75	59	50
<i>Cheilanthes distans</i>	8	0	24	0
<i>Cheilanthes sieberi</i>	23	25	29	33
Aspleniaceae				
<i>Asplenium flabellifolium</i>	23	38	0	0
<i>Pleurosorus rutifolius</i>	31	75	41	67
GYMNOSPERMS				
Cupressaceae				
<i>Callitris endlicheri</i>	8	0	0	17
<i>Callitris glaucophylla</i>	31	0	6	33
ANGIOSPERMS				
Amygdalaceae				
<i>Prunus dulcis</i> *	0	0	0	17
<i>Prunus cerasifera</i> *	0	0	6	0
Anacardiaceae				
<i>Schinus areira</i> *	23	0	6	67
Anthericaceae				
<i>Arthropodium minus</i>	15	0	6	0
<i>Dichopogon fimbriatus</i>	0	0	0	17
<i>Tricoryne elatior</i>	8	13	12	0
Apiaceae				
<i>Daucus glochidiatus</i>	8	0	0	0
<i>Hydrocotyle laxiflora</i>	0	0	6	0

	Nubbin	Koppie	Tors	Bornhardt
No of sites	13	8	17	6
Asteraceae				
<i>Arctotheca calendula</i> *	23	25	47	50
<i>Bidens pilosa</i> *	0	0	6	0
<i>Carduus tenuiflorus</i> *	8	25	6	17
<i>Carthamus lanatus</i> *	23	25	24	17
<i>Cassinia aculeata</i>	8	0	0	0
<i>Cassinia laevis</i>	8	0	0	0
<i>Cassinia longifolia</i>	15	0	0	0
<i>Centaurea calcitrapa</i> *	8	0	0	0
<i>Cichorium intybus</i> *	8	0	0	0
<i>Cirsium vulgare</i> *	38	25	35	0
<i>Conyza sumatrensis</i> *	0	0	0	17
<i>Conyza bonariensis</i> *	0	0	6	0
<i>Cynara cardunculus</i> *#	0	13	0	0
<i>Helichrysum rutidolepis</i>	0	0	6	0
<i>Hypochaeris glabra</i> *	31	25	35	17
<i>Hypochaeris radicata</i> *	38	25	59	33
<i>Lactuca serriola</i> *	0	0	12	0
<i>Onopordum acanthium</i> *	8	0	6	0
<i>Silybum marianum</i> *	8	13	0	0
<i>Senecio garlandii</i> +	0	13	0	17
<i>Senecio hispidulus</i>	8	0	0	33
<i>Senecio quadritentatus</i>	8	13	0	17
<i>Sonchus asper</i> *	0	0	24	0
<i>Sonchus oleraceus</i> *	0	0	12	0
<i>Taraxacum officinale</i> *	15	13	12	0
<i>Vittadinia cuneata</i>	15	0	0	0
<i>Xanthium spinosum</i> *#	8	13	6	0
<i>Xerochrysum viscosum</i>	15	0	0	17
Boraginaceae				
<i>Echium plantagineum</i> *	23	88	65	33
<i>Heliotropium europaeum</i> *	0	0	6	0
Cactaceae				
<i>Opuntia stricta</i> *#	0	0	0	17
Campanulaceae				
<i>Wahlenbergia communis</i>	0	0	6	0
<i>Wahlenbergia stricta</i>	0	0	6	0
<i>Wahlenbergia gracilentata</i>	23	13	24	17
Caryophyllaceae				
<i>Cerastium glomeratum</i> *	0	13	6	17
<i>Moenchia erecta</i> *	8	0	0	0
<i>Spergularia rubra</i> *	8	0	0	0
<i>Stellaria media</i> *	15	13	0	0
Casuarinaceae				
<i>Allocasuarina verticillata</i>	23	25	6	33
Chenopodiaceae				
<i>Dysphania pumilio</i>	46	0	18	0
<i>Einadia nutans</i>	0	13	6	0
Convolvulaceae				
<i>Convolvulus erubescens</i>	8	13	12	0
<i>Dichondra repens</i>	0	13	18	0
Crassulaceae				
<i>Crassula decumbens</i>	15	13	0	0
Cucurbitaceae				
<i>Citrullus colocynthis</i> *	23	38	0	0
<i>Cucumis myriocarpus</i> *	15	13	24	0

	Nubbin	Koppie	Tors	Bornhardt
No of sites	13	8	17	6
Cyperaceae				
<i>Carex appressa</i>	0	13	18	0
<i>Lepidosperma laterale</i>	0	0	12	0
Dilleniaceae				
<i>Hibbertia obtusifolia</i>	23	25	12	0
Ericaceae				
<i>Brachyloma daphnoides</i>	8	0	0	0
<i>Lissanthe strigosa</i>	23	0	0	0
<i>Melichrus urceolatus</i>	0	0	6	0
Fabaceae				
<i>Acacia buxifolia</i>	8	13	0	0
<i>Acacia rubida</i>	8	38	12	17
<i>Acacia implexa</i>	54	100	41	50
<i>Acacia genistifolia</i>	8	0	0	0
<i>Acacia penninervis</i>	0	13	6	17
<i>Acacia doratoxylon</i>	15	0	0	33
<i>Desmodium varians</i>	8	0	6	0
<i>Glycine clandestina</i>	8	25	12	0
<i>Glycine tabacina</i>	15	13	6	0
<i>Hardenbergia violacea</i>	15	0	0	0
<i>Indigofera adesmifolia</i>	0	13	0	0
<i>Indigofera australis</i>	23	25	6	17
<i>Pultenaea cunninghamii</i>	0	13	0	17
<i>Pultenaea platyphylla</i>	0	13	6	0
<i>Pultenaea foliolosa</i>	8	0	0	0
<i>Robinia pseudoacacia*</i>	8	0	0	0
<i>Trifolium sp*</i>	8	38	18	0
Gentianaceae				
<i>Centaurium erythraea*</i>	8	0	0	0
Geraniaceae				
<i>Erodium cicutarium*</i>	0	0	24	17
<i>Geranium retrorsum</i>	0	13	0	0
<i>Geranium solanderi</i>	15	13	24	17
<i>Pelagonium australe</i>	15	13	12	0
Goodeniaceae				
<i>Goodenia pinnatifida</i>	8	0	0	0
Haloragaceae				
<i>Gonocarpus elatus</i>	54	0	0	0
<i>Gonocarpus tetragynus</i>	31	13	0	50
Hypericaceae				
<i>Hypericum perforatum*</i>	31	50	0	33
Iridaceae				
<i>Romulea rosea*</i>	8	0	18	0
Juncaceae				
<i>Juncus filicaulis</i>	0	25	0	0
Lamiaceae				
<i>Ajuga australis</i>	8	13	0	17
<i>Marrubium vulgare*</i>	38	25	35	0
<i>Salvia verbenaca*</i>	0	13	6	0
Lobeliaceae				
<i>Isotoma axillaris</i>	62	100	71	83
Loranthaceae				
<i>Amyema miquelii</i>	8	13	0	0
<i>Amyema miraculosum</i>	8	25	0	0
<i>Amyema pendulum</i>	8	13	6	0

	Nubbin	Koppie	Tors	Bornhardt
No of sites	13	8	17	6
<i>Muellerina eucalyptoides</i>	0	0	6	0
Malvaceae				
<i>Malva parviflora</i> *	8	13	0	0
Martyniaceae				
<i>Ibicella lutea</i> *	0	0	6	0
Meliaceae				
<i>Melia azedarach</i>	8	0	0	0
Mimosaceae				
<i>Acacia buxifolia</i>	8	13	0	0
<i>Acacia rubida</i>	8	38	12	17
<i>Acacia implexa</i>	54	100	41	50
<i>Acacia genistifolia</i>	8	0	0	0
<i>Acacia penninervis</i>	0	13	6	17
<i>Acacia doratoxylon</i>	15	0	0	33
Myoporaceae				
<i>Myoporum montanum</i>	0	0	0	17
Myrtaceae				
<i>Eucalyptus albens</i>	38	75	59	50
<i>Eucalyptus blakelyi</i>	54	63	29	83
<i>Eucalyptus dealbata</i>	62	25	0	33
<i>Eucalyptus goniacalyx</i>	23	38	12	17
<i>Eucalyptus macrorhyncha</i>	23	50	6	33
<i>Eucalyptus melliodora</i>	0	0	0	17
<i>Eucalyptus nortonii</i>	15	38	6	0
<i>Eucalyptus polyanthemus</i>	0	0	0	17
<i>Syzygium australe</i> *	0	0	6	0
Orobanchaceae				
<i>Orobanche minor</i> *	0	13	24	0
Oxalidaceae				
<i>Oxalis perennans</i>	85	38	47	33
Papaveraceae				
<i>Papaver somniferum</i> *	0	13	0	0
Phormiaceae				
<i>Dianella longifolia</i>	8	0	0	0
<i>Dianella revoluta</i>	8	25	6	33
Phytolaccaceae				
<i>Phytolacca octandra</i> *	8	38	18	17
Poaceae				
<i>Aira cupaniana</i> *	8	0	6	17
<i>Anthoxanthum odoratum</i> *	0	0	6	0
<i>Aristida behriana</i>	8	38	18	17
<i>Aristida ramosa</i>	31	38	18	17
<i>Austrodanthonia eriantha</i>	31	13	18	17
<i>Austrodanthonia caespitosa</i>	31	63	59	33
<i>Austrodanthonia setacea</i>	0	0	0	17
<i>Austrostipa aristiglumis</i>	15	13	0	0
<i>Austrostipa scabra ssp. scabra</i>	31	50	24	33
<i>Austrostipa scabra ssp. falcata</i>	15	13	18	33
<i>Austrostipa densiflora</i>	8	0	6	33
<i>Avena fatua</i> *	31	50	47	67
<i>Bothriochloa macra</i>	46	63	35	0
<i>Briza maxima</i> *	46	38	12	33
<i>Bromus diandrus</i> *	46	50	59	67
<i>Bromus hordeaceus</i> *	23	38	35	17
<i>Bromus rubens</i> *	8	0	0	0
<i>Bromus unioloides</i> *	0	25	6	0

	Nubbin	Koppie	Tors	Bornhardt
No of sites	13	8	17	6
<i>Chloris truncata</i>	8	13	6	0
<i>Cymbopogon refractus</i>	8	0	6	0
<i>Cynosurus echinatus</i> *	8	0	0	0
<i>Cynodon dactylon</i>	0	0	6	0
<i>Dichelachne crinata</i>	38	38	35	0
<i>Eleusine tristachya</i> *	8	0	0	0
<i>Elymus scaber</i>	15	50	35	17
<i>Holcus lanatus</i> *	0	0	6	0
<i>Hordeum leporinum</i> *	62	38	82	33
<i>Hyparrhenia hirta</i> *#	0	13	6	0
<i>Joycea pallida</i>	0	0	6	0
<i>Lamarckia aurea</i> *	15	0	0	0
<i>Lolium perenne</i> *	15	25	24	33
<i>Microlaena stipoides</i>	8	0	24	0
<i>Panicum effusum</i>	8	13	12	0
<i>Paspalum dialatum</i> *	8	0	6	17
<i>Phalaris aquatica</i> *	0	13	18	0
<i>Phalaris paradoxa</i> *	0	0	6	0
<i>Poa sieberi</i>	15	13	6	0
<i>Poa annua</i> *	0	0	6	0
<i>Setaria verticillata</i> *	0	0	6	0
<i>Themeda australis</i>	0	0	6	0
<i>Vulpia bromoides</i> *	0	13	18	0
<i>Vulpia myuros</i> *	38	38	35	50
Polygonaceae				
<i>Acetosella vulgaris</i> *	46	100	71	17
<i>Rumex brownii</i>	38	38	47	0
Portulacaceae				
<i>Portulaca oleracea</i>	0	0	6	0
Proteaceae				
<i>Grevillea floribunda</i>	0	0	0	17
Rosaceae				
<i>Rosa rubiginosa</i> *	0	0	12	0
<i>Rubus fruticosus</i> *	0	38	12	17
Rubiaceae				
<i>Galium aparine</i> *	0	0	0	17
<i>Galium gaudichaudii</i>	8	0	0	0
Rutaceae				
<i>Correa glabra</i>	8	0	0	0
<i>Correa reflexa</i>	0	13	0	0
Santalaceae				
<i>Exocarpus cupressiformis</i>	23	63	0	33
<i>Santalum apiculatum</i>	8	13	0	0
Sapindaceae				
<i>Dodonea viscosa</i>	8	13	0	17
Scrophulariaceae				
<i>Verbascum virgatum</i> *	8	75	29	17
Simaroubaceae				
<i>Ailanthus altissima</i> *	0	0	18	17
Solanaceae				
<i>Lycium ferocissimum</i> *	8	0	0	17
<i>Solanum cinereum</i>	0	13	6	0
<i>Solanum elaeagnifolium</i> *	15	0	0	0
<i>Solanum nigra</i> *	8	38	53	33
<i>Solanum simile</i>	0	0	0	17

	Nubbin	Koppie	Tors	Bornhardt
No of sites	13	8	17	6
Sterculiaceae				
<i>Brachychiton populneus</i>	62	63	41	17
Thymelaeaceae				
<i>Pimelea linifolia</i>	15	13	0	0
Ulmaceae				
<i>Celtis australis*</i>	8	13	0	0
Urticaceae				
<i>Urtica urens*</i>	0	13	6	0
Viscaceae				
<i>Notothixos cornifolius</i>	0	25	6	0
Xanthorrhoeaceae				
<i>Lomandra filiformis</i>	23	25	35	0
<i>Lomandra longifolia</i>	0	25	6	0
<i>Lomandra multiflora</i>	15	13	0	17
Zygophyllaceae				
<i>Tribulus occidentalis</i>	8	0	6	0