A survey of 25 remnant vegetation sites in the South Western Slopes, New South Wales

G.E. Burrows

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A presence/absence survey of 25 remnant vegetation sites, principally Nature Reserves and State Forests, was carried out in the South Western Slopes (SWS) of New South Wales. A total of 658 taxa were recorded of which 188 (29%) were exotics. Eleven sites had an overstorey dominated by *Callitris glaucophylla* or *Eucalyptus camaldulensis* and 14 sites had an overstorey dominated by various eucalypt species such as *Eucalyptus blakelyi, Eucalyptus goniocalyx, Eucalyptus macrorhyncha, Eucalyptus polyanthemos, Eucalyptus rossii* and *Eucalyptus sideroxylon*. The *Callitris glaucophylla/Eucalyptus camaldulensis* dominated sites were in the western half of the region, were flatter and at lower elevation (average minimum and maximum elevations were 191 and 214 m, respectively), were smaller (average area 646 ha), were usually grazed more intensely, had a smaller average number of species per site (151) and a larger average percentage of introduced species (40%). In contrast, the sites dominated by various eucalypt species were usually in the eastern half of the region, had greater relief and were at higher elevation (average minimum and maximum elevations were 294 and 520 m, respectively), were larger (average area 1161 ha), were usually grazed less intensively, had a larger average number of species per site (179) and a smaller average percentage of introduced species (27%). This study provides the first published set of relatively comprehensive species lists for the SWS and has provided information relevant to species distribution, proportion of introduced species in the flora, threatened species, areas of conservation significance and directions for future research.

Introduction

Mainland NSW is divided into 13 botanical regions (Harden 1990). The South Western Slopes (SWS) botanical region is probably the most intensively and extensively disturbed region of NSW. A combination of mainly flat to undulating country, relatively fertile soils and reliable rainfall led to European settlement proceeding rapidly between 1829 and 1845 (Moore 1953a) and this led to large scale modification of the landscape for cropping and grazing of domestic stock over the next 100 years. Since 1945 the widespread adoption of pasture improvement involving the use of fertilisers and potentially invasive grasses and legumes has been responsible for a continued decline in native vegetation condition and diversity. The degree of disturbance is reflected in the small percentage of the SWS conserved in the reserve system and in the small number of botanical surveys.

In the 1980s the SWS had the second lowest percentage (0.2%) of reserved land (National Parks, Nature Reserves, State Recreation Areas) in NSW (Benson 1988). In the SWS there are no National Parks, six Nature Reserves (Hattons Corner 4 ha, Narrandera 71 ha, Table Top 103 ha, The Rock 341 ha, Burrinjuck 1300 ha, Ulandra 3930 ha) and two State Recreation Areas (Burrinjuck 173 ha, Bethungra 385 ha) with a total area of 6307 ha. In 1986 the total area of reserved land in NSW was 3 438 941 ha (4.2%), while in 1997 total reserved land in NSW had increased to 4 536 513 ha (5.7%) (Roger Good, pers. comm.), but there had been no additions to the reserve system in the SWS.

An indication of the limited research into the flora of the SWS is given by the compilations of floristic lists for NSW prepared by various authors at the National Herbarium of NSW. In total, only 26 of 813 lists recorded by Pickard (1972), Bryant & Benson (1981), Keith (1988) and Benson & Melrose (1993) are relevant to the SWS and several of these lists record only a limited number of species.

Given the small proportion of the SWS in the reserve system and the limited botanical research undertaken in the region it was considered useful to construct relatively comprehensive species lists for many of the larger areas of remnant vegetation. This broad scale approach aims to present information on: i) species occurrence and distribution in the SWS, ii) presence of threatened flora, iii) species and areas of conservation significance, iv) presence of introduced species and v) physical and botanical differences between the eastern and western parts of the SWS. This information should assist in conservation planning in the region while indicating future research areas.

Previous studies

General descriptions of the vegetation of the SWS are provided by Beadle (1981), Costermans (1981), Gillison & Walker (1994) and Sheahan (1998). Detailed studies of the native vegetation of the SWS or adjoining areas are, in chronological order, as follows:

Moore (1953a) described and mapped the pre-European extent of vegetation in the south-eastern Riverina which included the current study area but also extended further to the north and to the south west. He recorded 435 species (103 exotics) in seven alliances and provided separate species lists for the alliances, ranging from 48 to 287 species per alliance. Moore (1953b) described the disclimax communities (pastures) of the same region, particularly in its western half.

McBarron (1955) recorded observations on approximately 500 native, 260 exotic and 350 cultivated species in the Albury, Holbrook and Tumbarumba districts. He concentrated on disturbed areas rather than remnant vegetation in the mountains and arranged the information taxonomically rather than by site or community groupings.

Norris and Thomas (1991) studied 19 rocky outcrops and ranges to the west of the present study area. Each site was assessed with up to three 20 × 20 m quadrats or by traverses. A total of 338 species were recorded (16% exotic) with an average of 46 species per site.

Howard (1994), in an unpublished report, provided a summary of the condition of the vegetation in 72 State Forests in the SWS and the southern half of the Central Western Slopes. A listing of the main tree, shrub and groundcover species was provided for each State Forest. Fourteen of the 25 sites assessed in the present study were covered by Howard (1994). Twelve State Forests were listed as having a high biological diversity including five assessed in the present study (Benambra, Ellerslie, Livingstone, Pulletop and Tumblong).

Prober and Thiele (1995) studied species diversity in *Eucalyptus albens* woodlands in the Central Western Slopes. By using a series of traverses they recorded 179 native species and 130 exotic species in 34 sites, all of which were less than 32 ha in area. Prober (1996) studied grassy *Eucalyptus albens* woodlands from southern Queensland to northern Victoria, although the survey work was largely restricted to NSW. Prober (1996) recorded 472 species (375 native) from 90 20 m × 50 m quadrats and noted that remnant quality declined significantly in southern NSW, indicating a need for a greater conservation effort in southern areas.

Bos and Lockwood (1996) studied the flora, fauna and recreation opportunities of 45 forest blocks in the SWS biogeographic region (see Thackway and Cresswell 1995 for borders), including 18 of the 25 sites studied in the present study. A total of 225 8 × 8 m or 20 × 20 m quadrats were surveyed (an average of five quadrats per forest block) and a total of 456 species were recorded and 16 communities recognised.

Benson et al. (1997) studied the native grasslands of the Riverine plain which is to the west of the current study area. They assessed 67 10 × 20 m quadrats and recorded 224 species (25% exotic) in six communities.

There has been a recent emphasis on the assessment of roadside vegetation in the SWS. Walker (1997b) listed c. 130 species for the roadside vegetation in Coolamon Shire, with numerous listings of 10–30 species for specific areas. Similar assessments have been carried out for the Olympic Way (Stelling 1996), Tumut Shire (Walker 1997a) and Lockhart Shire (Bull 1997).

Stelling (1998), in a revegetation guide for the SWS between the Murray and Murrumbidgee Rivers, provided approximately 75 cross sectional vegetation profiles with lists of the main tree, shrub and groundcover species.

Climate

Average annual rainfall ranges from approximately 450 mm at Matong and Brookong State Forests in the west of the study area to approximately 900 mm at Ellerslie, Murraguldrie and Tumblong State Forests in the east; an increase of 450 mm/year in 90 to 100 km (Table 1). See Moore (1953a) for a map of rainfall isohyets in the study region. February is the driest month for most of the region, while October is the wettest month for the drier and more westerly sites and the winter months are the wettest for the more easterly sites.

Table 1. Summary of meteorological data for selected weather stations in the study area (Bureau of Meteorology 1998) arranged by increasing average annual rainfall.

	highest mean maximum daily temperature (°C)	lowest mean minimum daily temperature (°C)	highest mean monthly rainfall (mm)	lowest mean monthly rainfall (mm)	average annual rainfall (mm)
Narrandera	32.2 Jan	2.5 Jul	46 Oct	31 Mar	451
Matong Forestry	32.9 Jan	2.3 Jul	51 Oct	24 Dec	462
Junee	32.4 Jan	2.3 Jul	53 Oct	36 Feb	533
Wagga Wagga	31.2 Jan	2.7 Jul	61 Oct	38 Feb	585
Cootamundra	31.5 Jan	1.9 Jul	61 Oct	39 Feb	626
Gundagai	31.6 Jan	2.1 Jul	79 Jul	41 Feb	714
Albury	30.1 Jan, Feb	2.8 Jul	102 Jul	36 Feb	785
Adelong	30.8 Jan	0.9 Jul	84 Jun	42 Feb	795
Murraguldrie	29.7 Jan	1.6 Jul	95 Aug	51 Feb	892
Carabost	28.9 Jan	0.7 Jul	112 Jul	58 Feb	1049

Methods

A total of 25 sites were surveyed in this study (Table 2, Fig. 1). Sites 1–10 were in the western half of the SWS, consisted of relatively flat country and had an overstorey dominated by *Callitris glaucophylla*. Berry Jerry and Currawananna State Forests (sites 10 and 11) differ from the other western sites as both adjoin the Murrumbidgee River and had a mix of *Callitris glaucophylla* and *Eucalyptus camaldulensis* communities. Currawananna SF was dominated by Cypress Pine and had a narrow ribbon of River Red Gum on its southern border, while Berry Jerry SF was dominated by River Red Gum and had a small area of Cypress Pine and Box eucalypts on its southern boundary. Sites 12–25 were mainly in the eastern half of the SWS and consisted mainly of rocky outcrops and the lower slopes of the Great Dividing Range, with an overstorey dominated by various eucalypt species such as *Eucalyptus blakelyi*, *Eucalyptus goniocalyx*, *Eucalyptus macrorhyncha*, *Eucalyptus polyanthemos*, *Eucalyptus rossii* and *Eucalyptus sideroxylon*. Sites 12–16, while mainly rocky outcrops, had a lower fringe of vegetation similar to the *Callitris glaucophylla* communities. A summary of attributes pertaining to the eastern and western sites is presented in Table 3.

At each site species were recorded as either present or absent (Appendix 1), there were no recordings of cover, abundance or distribution. Each site was surveyed by making a series of systematic traverses, at least three times in a year, usually starting in late winter or early September and finishing in early to mid December (Appendix 2). Each survey trip usually consisted of at least four hours in the field, usually by a pair of collectors. Additional species recordings for Matong and Lester State Forests and Ganmain and Coolamon Reserves were obtained from 60 semipermanent quadrats assessed at monthly intervals during spring 1996 for another project. All sites were on public land except for Malebo Range and Flowerpot Hill, although permission to cross private land must be obtained to access Pulletop, Ellerslie, Benambra and Tumblong State Forests and Tabletop Nature Reserve.

Table 2. Various characteristics of the 25 sites assessed (SF: State Forest, NR: Nature Reserve).

Site no.	Site name	Abb-rev'n	Area (ha)	Elev'n range (m asl)	Total species recorded	No. native species recorded	% exotics
1	Brookong SF	bro	346	150–180	114	76	33
2	Milbrulong SF	mil	376	200–225	131	91	31
3	Kockibitoo SF	koc	244	160–170	117	75	36
4	Matong SF	mat	3176	160–170	221	135	39
5	Ganmain Reserve	gan	91	195–200	152	107	30
6	Lester SF	les	790	210–250	167	104	38
7	Kindra SF	kin	520	220–240	145	99	32
8	Coolamon Reserve	coo	58	250–260	163	102	37
9	Winery Hill	wh	c. 20	230–295	129	65	50
10	Currawananna SF	cur	286	165–190	184	95	48
11	Berry Jerry SF	bj	1198	165–170	135	66	51
12	Pomingalarna Park	pom	226	200–295	165	112	32
13	Malebo Range	mal	c. 400	260–388	164	103	37
14	Galore Hill Reserve	gh	c. 500	240–380	191	140	27
15	Flowerpot Hill	fp	c. 100	290–462	117	91	22
16	The Rock NR	tr	341	210–554	213	159	25
17	Pulletop SF	pul	809	360–450	119	91	24
18	Livingstone SF	liv	2183	320–470	190	146	23
19	Tabletop NR	tt	103	360–720	153	117	24
20	Benambra SF	ben	1445	300–640	191	136	29
21	Murraguldrie SF	mur	4485	350–701	221	160	28
22	Ellerslie SF	ell	909	280–545	199	135	32
23	Tumblong SF	tum	712	270–588	186	138	26
24	Mundarlo Road	mun	c. 100	270–325	132	94	29
25	Ulandra NR	ula	3930	400–761	258	190	26

Most of the main areas of remnant forest or woodland were surveyed in the western half of the study area, but in the east large areas of forest on private property were not assessed (Fig. 1).

The data in Appendix 1 were analysed using the PATN package. PATN analysis assumes that sites are of equal area and surveyed with uniform method and intensity. This is not the case in this study but allowing for these limitations broad trends in site relationships can still be investigated. Presence–absence data from each site were used to classify sites into groups of similar composition. The hierarchical, agglomerative, flexible unweighted paired group arithmetic average (UPGMA) procedure in the PATN package (Belbin 1994) was used, with the Czekanowski dissimilarity coefficient and default value, beta = -0.1. All species were included in the analysis.

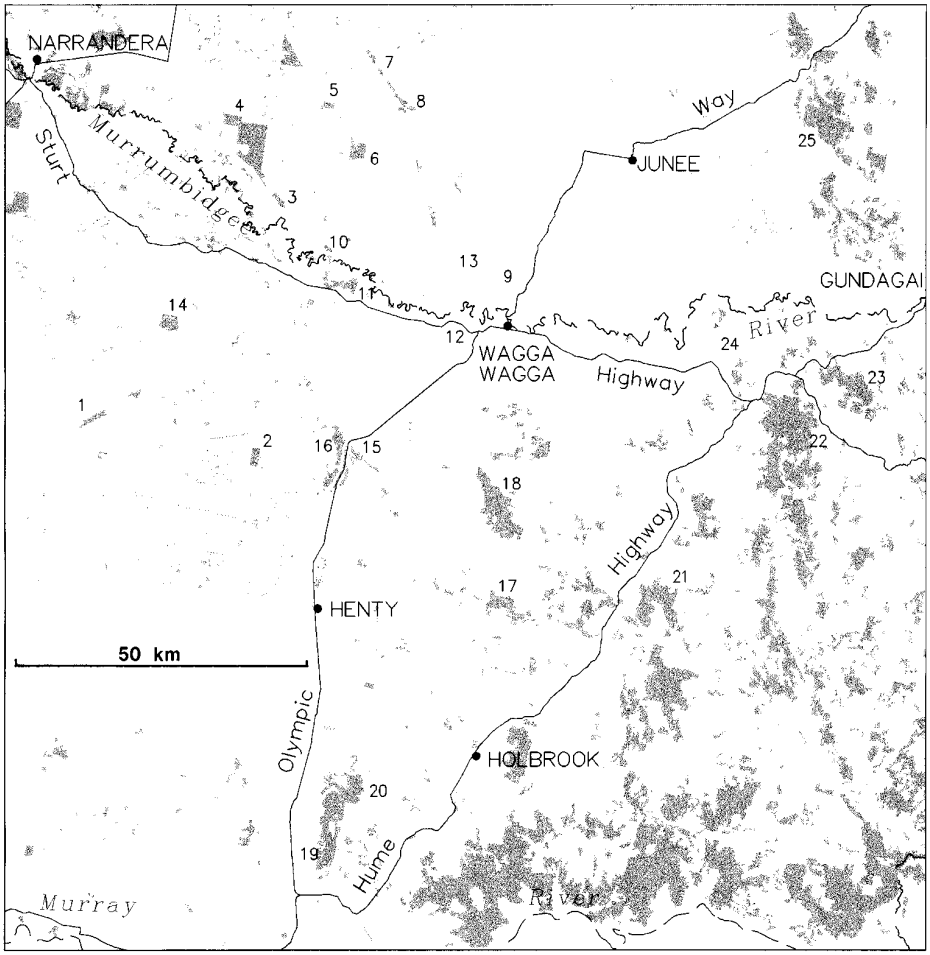

Fig. 1. Tree cover in the study area based on Department of Land and Water Conservation maps showing the approximate location of the 25 study areas. Site area numbers follow Table 2. The maps on which this figure are based were prepared during 1990–1993 from aerial photography carried out during 1985–1990. The minimum area of tree cover for inclusion was 100 ha. Note the increase in remnant tree cover to the east, especially east of the Hume Highway. Much of the south east corner of this figure is outside the SWS biogeographic region and to a lesser extent the SWS botanical region.

Results and discussion

A total of 658 taxa were identified to the level of species or subspecies and of these 188 (29%) were introduced species (Appendix 1). Other studies west of the Great Dividing Range in NSW have recorded between 16 and 25% exotics (Moore 1953a, Cunningham et al. 1981, Norris & Thomas 1991, Sivertsen & Metcalfe 1995, Benson et al. 1997). Sivertsen and Metcalfe (1995) considered 20% exotics a high proportion and on this basis all sites surveyed in the present study had a high to very high percentage of weed species (Table 2, Appendix 1).

Ninety-nine families were recorded. The six most common families or subfamilies recorded were the Poaceae (88 species, 43% exotic), Asteraceae (86 species, 31% exotic), Fabaceae-Faboideae (48 species, 35% exotic), Orchidaceae (25 species, none exotic), Cyperaceae (24 species, 8% exotic) and Fabaceae-Mimosoideae (24 species, none exotic). These five families accounted for 45% of the species recorded. The Poaceae, Asteraceae and Fabaceae-Faboideae have also been the most species abundant families in other studies in this general region (Moore 1953a, Norris & Thomas 1991, Sivertsen & Metcalfe 1995, Benson et al. 1997).

As noted the sites were divided into two main groups (western and eastern) based on location, landform and dominant overstorey species and some of the main attributes of the two groups are presented in Table 3.

Table 3. Characteristics of sites in the western and eastern parts of the study area.

Attribute	**Western sites (1–11)**	**Eastern sites (12–25)**
dominant overstorey species	*Callitris glaucophylla*, *Eucalyptus camaldulensis*	various *Eucalyptus* species
usual grazing intensity	medium to high	nil to low
average area (ha)	646	1161
average elevation range (m asl)	191–214	294–520
average no. spp./site	151	179
average no. native spp./site	92	129
range: no. native species/site	65–135	91–190
average no. of introduced species/site	58	49
average % introduced species/site	39	27

Analysis of the data in Appendix 1 by the PATN package (Fig. 2) generally supported the division of the sites into western and eastern groups. The flat *Callitris glaucophylla* dominated areas (sites 1–8) were grouped together, along with site 10 (Currawananna SF) which had less than 5% of its area covered by *Eucalyptus camaldulensis* forest/woodland. Likewise, the easterly areas without a lower fringe of *Callitris glaucophylla* type vegetation (sites 17–25) were grouped together, with the subgroupings usually based on geographical proximity. Interestingly, Ulandra NR and Livingstone SF were grouped together although they are 80 km apart. Of the five rocky outcrops with a lower fringe of *Callitris glaucophylla* type vegetation (sites 12–16) three sites (Pomingalarna Park, Malebo Range and Galore Hill Reserve) were grouped with the flatter western sites, but distinct from them, and two sites (The Rock Nature Reserve and Flowerpot Hill) were grouped with the eastern sites, but again were distinct from them. Berry Jerry SF (site 11) which had over 90% *Eucalyptus camaldulensis* cover was indicated to be distinct from all other sites.

Most species were recorded at few sites and few species were found at more than 90% of sites (Fig. 3). Sivertsen and Metcalfe (1995) noted that 41% of the species recorded during their study occurred only once or twice. They also noted while this alone does

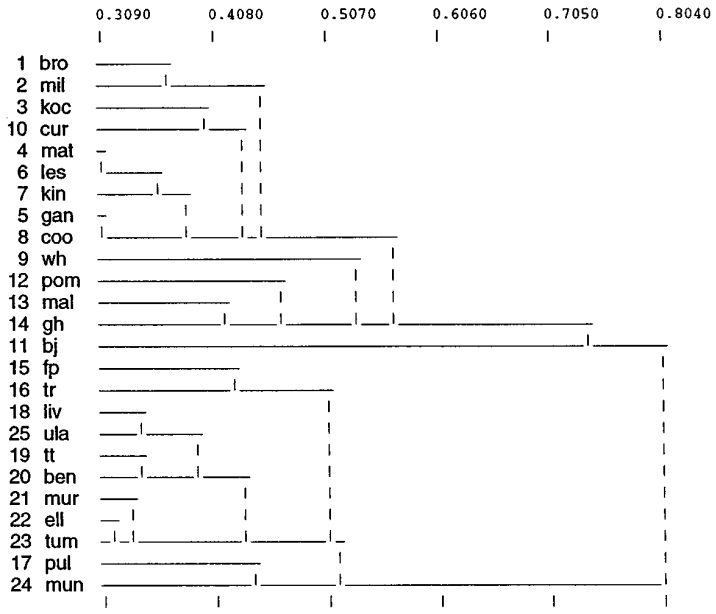

Fig. 2. Dendrogram showing the two main groups of sites and the relative isolation of site 11, Berry Jerry SF. Site name abbreviations follow Table 2.

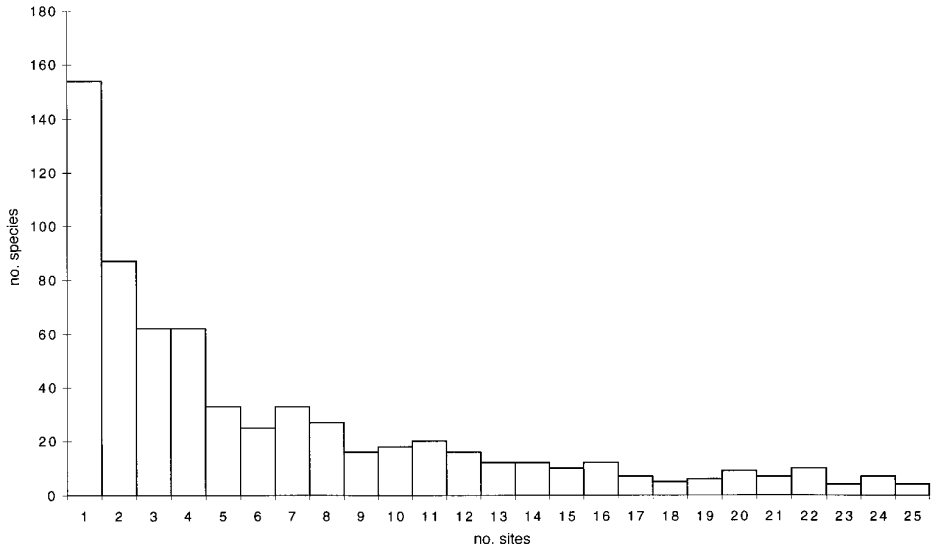

Fig. 3. Histogram indicating that a large number of taxa were recorded at only a few sites, while few taxa were found at most sites.

not confer rare or threatened status, it does indicate that further investigation of these populations is warranted. The study of Sivertsen & Metcalfe (1995) was quadrat based while the present study was based on wide ranging traverses at different times of the year. Thus most species recorded at only one site (e.g. shrub species such as *Cassinia laevis, Astroloma humifusum, Beyeria viscosa, Dampiera lanceolata, Goodenia ovata, Prostanthera ovalifolia, Zieria cytisoides* and *Cyphanthera albicans* recorded only at The Rock NR) can be reliably considered to be locally rare. In the present study 37% of taxa were recorded at only one or two sites and this finding is discussed below in relation to areas of possible conservation significance.

The fives sites with the lowest native species diversity were all in the west of the study area (Brookong, Milbrulong, Kockibitoo and Berry Jerry State Forests and Winery Hill). The five sites with greatest native species diversity were eastern-type sites and three were reserves (Galore Hill Reserve and The Rock and Ulandra Nature Reserves) and two were State Forests (Livingstone and Murraguldrie).

At November 1997, 7555 plant taxa had been recorded for NSW in the census database (National Herbarium of NSW) with 1463 taxa recorded for the SWS and of these 471 (32%) were introduced. Thus the present study recorded approximately 45% of all SWS taxa, 47% of native species and 40% of introduced species. The area of the 25 study sites was 23 354 ha which is less than 1% of the SWS. Thus a relatively large percentage of species were recorded in a relatively small area. Further survey work in the *Acacia pendula–Atriplex nummularia* alliance (Moore 1953a), the flood plains of the Murrumbidgee and Murray Rivers, swamps and clay pans, areas bordering on the Southern Tablelands and in intensively disturbed areas would result in a significant increase in the number of species recorded.

The study added numerous species to the census database (National Herbarium of NSW) of species recorded for the SWS. Of the 658 taxa recorded 107 (16%) had not been previously recorded for the SWS (Harden 1990–1993). As might be expected most of these species were recorded from a small number of sites (72 or 67% were recorded at only one or two sites), but several (eg. *Bursaria spinosa, Stachys arvensis, Pterostylis mutica, Urtica urens, Cotula australis, Goodenia hederacea* and *Anagallis arvensis*) were found at 9 or more sites. While not recorded for the SWS on the NSW Herbarium's census database many of the 107 species have been recorded for the region in other studies, eg. the seven species listed above were all recorded by McBarron (1955). Only two species were found that had not been previously recorded for NSW and one of these was *Pultenaea humilis*. This species is known from Victoria and Tasmania and was found at Murraguldrie SF, c. 50 km north of the NSW/Victorian border. Herbarium specimens of the majority of these 107 taxa have been sent to the NSW National Herbarium.

Rare or Threatened Australian Plants

In the 1995 update of *Rare or threatened Australian plants* (Briggs & Leigh 1996) 19 ROTAPs are listed for the SWS and in a 1997 update obtained from Environment Australia 21 ROTAPs were listed (Burrows 1998). Of these 21 species six are listed as

presumed extinct in the SWS and one species (*Aphanes pumila*) is known from only a single collection and is not described in the Flora of NSW. The remaining 14 species are classified as Endangered (1 species), Vulnerable (8 species), Rare (2 species) or Poorly Known (3 species) (Burrows 1998). Of these 14 species three (*Ammobium craspedioides*, *Senecio garlandii* and *Diuris tricolor)* were recorded during this study. The first two species are listed as 'Vulnerable' and the last as 'Poorly Known'.

Ammobium craspedioides is recorded in the *Flora of NSW* as 'rare, confined to the Yass district' (Harden 1992) but a small population was found in Livingstone State Forest (c. 30 km south of Wagga) and presumably there may be further populations in the intervening distance of over 100 km.

Senecio garlandii (Woolly Ragwort) is probably the most easily observed ROTAP in the SWS as it is a conspicuous part of the flora of the upper part of The Rock NR and is sometimes mistakenly considered a weed. Previously *Senecio garlandii* was known from only six or seven sites and only one of these, The Rock NR, was a conservation area. *Senecio garlandii* was recorded from a further three sites of which two are conservation areas (Ulandra and Table Top Nature Reserves) and this study has confirmed its apparent habitat preference for the upper scree slopes of steep sided hills and rocky outcrops in the SWS (Burrows 1995).

Diuris tricolor was recorded at several sites (sites 1, 3, 4, 6, 8 and 10) in the *Callitris glaucophylla* communities to the west of Wagga Wagga and while never abundant the 'Poorly Known' listing may not be appropriate.

Brachycome papillosa was recorded from one site in the western part of the SWS. This species is listed as Vulnerable but is not recorded for region 52, the SWS (Briggs & Leigh 1996).

Further study arising from the present investigation

Keith (1988) noted that 'Floristic lists are often the only source of botanical information for a particular area and may serve as a useful starting point for more detailed study.' Likewise this study has provided the impetus for more detailed quadrat based studies of various aspects of the remnant vegetation in the SWS. Seven of the eight areas of reserved land in the SWS are located in the eastern half of the region and the other area (Narrandera NR) is a small area of *Eucalyptus camaldulensis* forest. Thus no dryland vegetation in the western half of the SWS is included in the reserve system. Essentially the only remnant vegetation in this western area were several *Callitris glaucophylla* dominated State Forests. These forests superficially appeared to be of low conservation value as the overstorey was a *Callitris* monoculture through eucalypt ringbarking, no shrub layer was present and the ground layer was dominated by introduced species. This study showed that many of these forests had a relatively high diversity of native species (average 95 native species/site), but did not provide information on distribution or abundance. To provide this information a study funded by the National Estates Program (NEP 96 422) assessed 105 10 × 10 m quadrats in several *Callitris glaucophylla* dominated woodlands and forests (including sites 4, 5, 6 and 8 of the present study) at monthly intervals over a four month period. This study revealed

that some quadrats had a high diversity of native species per quadrat (up to 46) and indicated that some of these areas had a high conservation value (Burrows, unpublished data).

In addition, there is an urgent need for research into areas such as detailed vegetation mapping, reserve selection, off-reserve remnant vegetation management, weed management and regeneration techniques (Yates & Hobbs 1997).

Areas of possible conservation significance

This study provides information which may be useful in identifying areas that might be of conservation significance.

a) In the west of the SWS Matong SF had a much larger area than the other *Callitris glaucophylla* sites surveyed and had the highest number of total species and native species recorded, 221 and 135, respectively (Table 2). Morgan and Terrey (1992) considered that Matong SF was one of two 'key areas' for conservation within the lower slopes of the SWS, based mainly on its size. It appears that this is a valid assessment based on the results of this study and on unpublished quadrat based surveys.

b) Coolamon Reserve is the southern extension of Kindra SF. With assistance from State Forests of NSW this area is now managed by a local landcare group for its conservation value and is a de facto nature reserve. On the basis of the present results it would be beneficial if similar arrangements could be organised for Ganmain Common as this site had a high diversity of native species and relatively few exotic species were recorded.

c) Of the State Forests in the eastern half of the SWS Livingstone SF and Murraguldrie SF require further assessment as they had the highest number of native species, combined with relatively low percentages of exotic species. Howard (1994) listed Livingstone SF, along with Benambra, Ellerslie, Tumblong, Pulletop and eight other State Forests not covered in the present study, as priority areas for future evaluation due to their high biological interest. Murraguldrie SF was assessed as having only restricted biological interest by Howard (1994).

The results were also assessed for sites that possessed a large number of taxa that were recorded only once or twice during the study. It was considered that these sites may be of conservation significance given the number of locally rare species they held. Matong SF and Ganmain Common had relatively large numbers of locally rare species for sites 1–11, while The Rock NR, Ulandra NR and Murraguldrie SF had relatively large numbers of locally rare species for sites 12–25. For the non-reserve areas these results again indicate the potential conservation significance of Ganmain Common and Matong and Murraguldrie State Forests. Currawananna SF and Berry Jerry SF also had large numbers of infrequently recorded species as they had the only regularly flooded *Eucalyptus camaldulensis* communities studied.

Indicator species of eastern and western areas

While the overstorey species that defined the various sites were readily ascertained the results indicated that there were various shrub and groundlayer species that had distinct distribution patterns and were part of defining sites 1–11 and sites 12–25. Species that were recorded from at least 5 sites and up to 16 sites were useful as potential indicator species, a total of 234 species. Species that were recorded at less than five sites were too infrequent to give an accurate indication of distribution, while species recorded at more than 16 sites were usually widespread in the SWS.
Indicator species were defined as follows:

a) in the western sites:
   i) 5 to 6 recordings in sites 1–11, 0 to 5 recordings at sites 12–16, and 0 recordings for sites 17–25, or
   ii) 7 to 11 recordings in sites 1–11, 0 to 5 recordings at sites 12–16, and 0–1 recordings for sites 17–25.

b) in the eastern sites:
   i) 5 to 6 recordings in sites 12–25 and 0 recordings for sites 1–11, or
   ii) 7 to 14 recordings in sites 12–25 and 0–1 recordings for sites 1–11.

This is similar to the criteria used by Benson et al. (1997) that indicator species were those species that occurred in more than 40% of the sites in a community and were rarely or never found in another community.

Of the 234 species considered, 176 were native and 58 were introduced. Ninety-nine native species (44% reduction) and 15 introduced species (74% reduction) met the above selection criteria. Sivertsen and Metcalfe (1995) noted in their PATN analysis that exotic herbaceous species were not considered as they have a tendency to grow in a wide range of environments and native communities and this is also shown in the present study. A listing of the 20 most frequently recorded native indicator species for sites 1–11 and 12–25 is given in Table 4.

A similar analysis of the data was performed but using the site groupings indicated by the PATN analysis (Fig. 2, Table 5). The site groupings used were sites 1–14 but excluding site 11 and sites 15–25. Indicator species were defined as those having a minimum of 7 recordings in one of the site groupings and:

i) if there were 7 recordings in one group a maximum of one recording was permitted in the other group,

ii) if there were 8–11 recordings in one group a maximum of two recordings was permitted in the other group, and

iii) if there were 12–13 recordings in one group a maximum of three recordings was permitted in the other group.

In general there was a good correlation between the two approaches especially for the more westerly sites where there was a 80% correlation between the left hand side columns of Tables 4 and 5.

Table 4. Native indicator species for sites 1–11 (western *Callitris*) and 12–25 (eastern *Eucalyptus*), arranged within columns by decreasing recording frequency.

Sites 1–11 (western *Callitris*)	**Sites 12–25 (eastern *Eucalyptus*)**
Einadia nutans	*Stipa densiflora*
Calandrinia eremaea	*Hardenbergia violacea*
Callitris glaucophylla	*Poa sieberiana*
Sida corrugata	*Luzula densiflora/meridionalis*
Goodenia pinnatifida	*Exocarpos cupressiformis*
Acacia deanei subsp. *paucijuga*	*Gonocarpus tetragynus*
Eucalyptus microcarpa	*Indigofera australis*
Acacia decora	*Poranthera microphylla*
Chamaesyce drummondii	*Stypandra glauca*
Allocasuarina luehmannii	*Eucalyptus polyanthemos*
Lepidium pseudohyssopifolium	*Eucalyptus macrorhyncha*
Enteropogon acicularis	*Hibbertia obustifolia*
Acacia montana	*Allocasuarina verticillata*
Chenopodium desertorum	*Cheilanthes austrotenuifolia*
Atriplex semibaccata	*Parietaria debilis*
Actinobole uliginosum	*Brunonia australis*
Myriocephalus rhizocephalus	*Acacia doratoxylon*
Pimelea curviflora	*Lepidosperma laterale*
Acacia hakeoides	*Bursaria spinosa*
Rhodanthe pygmaea	*Eucalyptus goniocalyx/nortonii*

Table 5. Native indicator species for sites 1–14 (excluding site 11) and sites 15–25, arranged within columns by decreasing recording frequency.

Sites 1–14 (excluding 11)	**Sites 15–25**
Einadia nutans	*Gonocarpus tetragynus*
Calotis cuneifolia	*Indigofera australis*
Callitris glaucophylla	*Poranthera microphylla*
Sida corrugata	*Eucalyptus polyanthemos*
Eucalyptus melliodora	*Eucalyptus macrorhyncha*
Goodenia pinnatifida	*Hibbertia obtusifolia*
Eucalyptus microcarpa	*Cheilanthes austrotenuifolia*
Acacia decora	*Brunonia australis*
Chamaesyce drummondii	*Acacia doratoxylon*
Allocasuarina luehmannii	*Lomandra filiformis*
Lepidium pseudohyssopifolium	*Lepidosperma laterale*
Enteropogon acicularis	*Carex appressa*
Acacia montana	*Eucalyptus goniocalyx/nortonii*
Chenopodium desertorum	*Lissanthe strigosa*
Atriplex semibaccata	*Microseris lanceolata*
Vittadinia cuneata	*Calytrix tetragona*
Actinobole uliginosum	*Brachyloma daphnoides*
Pimelea curviflora	*Xanthorrhoea glauca*
Acacia hakeoides	*Pterostylis nutans*
Calotis hispidula	*Galium gaudichaudii*

Moore (1953a) also briefly discussed some species which were indicative of rainfall levels. He noted that species of *Stipa* and *Danthonia* are found over a wide range of rainfall conditions, that several genera of the Chenopodiaceae are restricted to the drier areas, as is also shown in the present study (Tables 4 and 5, Appendix 1). He also noted a third less well-defined group which only occurred in areas of relatively high rainfall. Of the five species given by Moore (1953a) as examples of this group two (*Acacia pycnantha* and *Sebaea ovata*) were frequently found in the drier sites in the present study, two species (*Acacia acinacea* and *Acacia rubida*) were restricted to the wetter sites in the present study but were found at relatively few sites and only one species (*Brunonia australis*) occurs in Tables 4 and 5.

Influence of grazing intensity

The results show a correlation between degree of disturbance through grazing by domestic stock and the percentage of introduced species at a site. All the *Callitris glaucophylla* and *Eucalyptus camaldulensis* dominated sites have been routinely grazed by stock except for Ganmain Common and Coolamon Reserve. Ganmain Common was fenced on only two sides and thus stock were not kept in the area for long periods and it had the lowest percentage of weeds (30%) for the western sites. The easterly sites were mostly ungrazed and had, on average, a lower percentage of weed species (Table 3).

Sivertsen and Metcalfe (1995) noted that about 40% of plant species recorded for their Riparian/Floodplain remnants were exotics, an average 22% of species recorded in the Box and Cypress Pine remnants were exotics, and in the Mallee and Hills remnants an average of 14% of species were exotics. A similar trend was found in the present study with 49, 36 and 27% of species were exotics in sites 11 and 12 (floodplain), sites 1 to 10 (Cypress Pine) and sites 13–25 (Rocky Outcrops, Hills), respectively.

Given that grazing by domestic stock is detrimental to native vegetation it is unacceptable that most areas of public land, including Crown Land, in the SWS continue to be grazed without a Grazing Management Plan having been prepared and implemented. State Forests of NSW (Narrandera District) are now preparing Grazing Management Plans that seek to maintain or enhance biodiversity whilst reducing fuel loads (Wilson et al. 1997). The Albury Rural Lands Protection Board is implementing a similar approach for the management of their Stock Routes and Reserves. Such an approach should be adopted by managers of other public lands.

Additional species lists

An additional 23 species lists from a variety of sources were found for 16 of the 25 surveyed sites. The majority of these lists were not referred to in the floristic lists published by the National Herbarium of NSW. On average, four times more species were recorded in the present study than in previous surveys, thus it would appear that the species lists of the present study are relatively complete. However intensive, quadrat-based assessment of four of the *Callitris* dominated sites (sites 4, 5, 6 and 8) produced, on average, a 17% increase in the number of species recorded. Thus while the species lists of the present study are more comprehensive than those previously available they are not definitive.

Growth form analysis

As shown in the 'Growth Form' column of Appendix 1, of the 653 taxa identified to species or subspecies 194 (30%) were annuals, 7 (1%) were biennials, 295 (45%) were perennial herbs, 120 (18%) were shrubs and 37 (6%) were trees. Likewise Moore (1953a) found that for most of the seven alliances that he identified the life-form spectrum was dominated by hemicryptophytes (herbaceous perennials) and therophytes (annuals). These figures show that much of the plant biodiversity of this region was associated with the groundlayer and in the west where there were usually only one or two tree species in the overstorey and the shrub layer was almost non-existent the groundlayer can encompass over 95% of the plant species diversity. The perennial herbs were the dominant growth form and were comprised of species with various subterranean organs. During summer most of these species, except for some grasses and species such *Sida corrugata* and *Boerhavia dominii*, were dormant below ground level. Thus surveys conducted in the SWS during mid to late summer, autumn and much of winter for either scientific, commercial or legal reasons will produce a major underestimate of botanical diversity and could miss species for which there are specific responsibilities.

Of the annuals and biennials 65% were exotics, while only 12% of the perennials (perennial herbs, shrubs, trees) were exotics. Prober and Thiele (1995) found similar proportions in their study of the understorey of grassy *Eucalyptus albens* woodlands in the Central Western Slopes and noted this difference could be exploited when rehabilitating degraded remnants.

Conclusion

While the SWS is an area that has been extensively and intensively altered in the past 200 years, some areas of remnant vegetation still exist. Their relative rarity, particularly in the western half of the region, makes the protection of these areas all the more critical, and emphasises the need to identify and map them while investigating suitable conservation-based management strategies.

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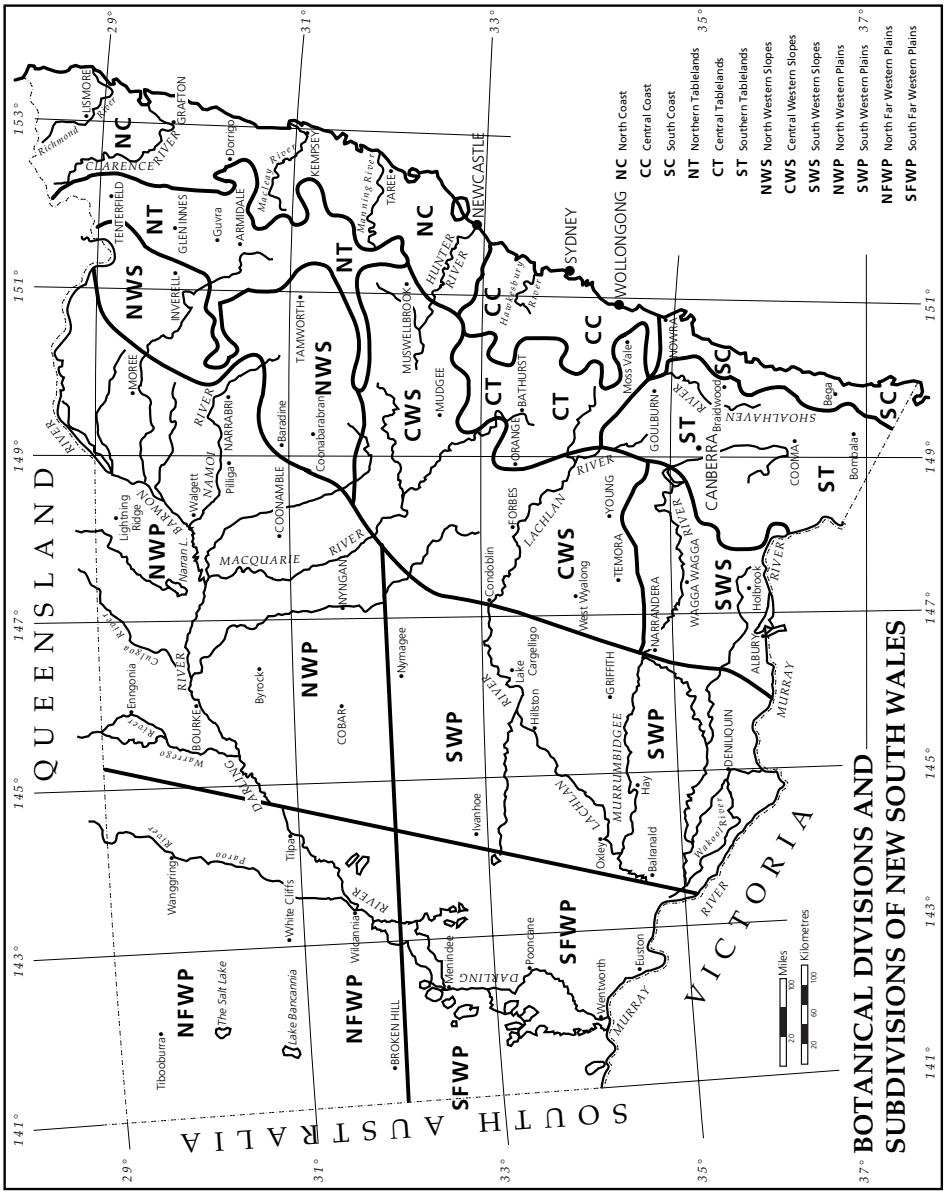

For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R.H. (1961). Introduction, in *Contributions from the NSW National Herbarium*, Flora Series Nos 1–18.