Native and naturalised shrubs of the Bathurst Granites: past and present

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Semple, W.S. Department of Land and Water Conservation, PO Box 53, Orange 2800. Native and Naturalised shrubs of the Bathurst Granites: past and present. Cunninghamia *5(1): 803–827.* The Bathurst Granites (Kanimbla Batholith) occupy a large area to the west of the Blue Mountains in NSW. Trees and shrubs are infrequent but are relatively common on rocky granite hills and surrounding non-granite hills. Historical material suggests that shrubs were also infrequent at the time of european settlement in the early 1800s. A search of the literature on the flora of the Bathurst Granites and a roadside survey of the western part, resulted in a list of 107 taxa of shrubs and low trees. Diversity of native shrubs was generally higher on hilly sites, granite or non-granite. Exotic species comprised about 20 % of the total granite shrub flora. Landscapes with a long history of disturbance, *e.g.* more fertile areas, had a higher proportion of exotics. There is some evidence that the relatively low numbers and diversity of native shrubs on granite landscapes, compared to surrounding areas of similar topography, may apply to granite areas elsewhere. It is suggested that the abundance of native shrubs is related to the absence of a continuous sward of perennial grasses, which is, in turn, related to soil fertility.

Introduction

West of the Blue Mountains plateau is an extensive area of granite, which extends from the vicinity of Katoomba to west of Bathurst (Fig. 1). Apart from rocky hills such as Evans Crown (1104 m ASL), most of the area has sparse tree cover. This contrasts sharply with surrounding areas, which are underlain by metamorphic and sedimentary rocks, and commonly have moderate to dense tree cover (Fig. 2). This contrast was observed at the turn of the century by Clunies Ross (1898) and was probably evident at the time of european settlement.

The most obvious trees on many parts of the granite are exotics - particularly willows, poplars and pines. Belts of pine (mainly *Pinus radiata*) were planted here, as in other areas subject to cold, windy and/or wet winters (*e.g.* the basalt plains of western Victoria), as shelter for stock. In recent times however, a range of other tree values, including enhanced pasture/crop growth and control of some forms of land degradation, has been recognised (*e.g.* see review by Bird *et al*. 1992). Added to this is a renewed appreciation in the rural community of native vegetation and its role as habitat for native fauna, including those which may be predators of insect pests (*e.g.* Davidson 1995).

Largely due to the opportunities provided by the Landcare movement, trees are again being planted on a large scale. Shelter belts commonly consist of native rather than exotic species as was the practice in the past. However, to provide effective shelter, narrow belts of eucalypts require a shrub understorey. Further, there is evidence (P.R. Bird, pers. comm.) that the presence of shrubs enhances the growth and survival of young eucalypts.

A number of native (*e.g. Acacia*) and exotic (*e.g. Cotoneaster* and *Pyracantha*) shrub species are suitable for the granite soils of the Bathurst area but the choice of native

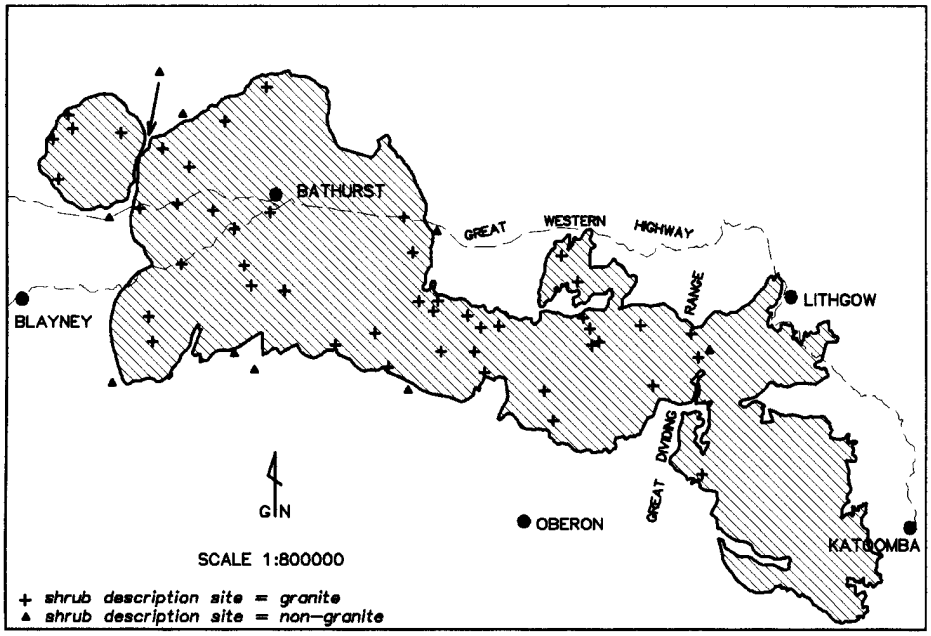

Fig 1. The extent of the Bathurst Granites. Adapted from Bryan (1966) and Packham (1968)

Fig 2. Metamorphosed sediments with timber cover (background) are in sharp contrast to the almost treeless granite country. South of Wimbledon

species is limited due to lack of published information; though vegetation surveys such as that of Keith & Benson (1988) will address this if extended to more westerly areas. This lack of information not only affects choice of shrub species for on-farm plantings, but also limits attempts at "recreating" original landscapes as occurs, to some extent, in rehabilitating roadsides (*e.g*. Wakefield 1994) or creating well-prepared wildlife corridors (*e.g.* Wilson & Lindenmeyer 1996).

In an attempt to add to the knowledge of the shrub flora of the granite soils of the Bathurst area, a search of the literature and field survey were carried out during 1992-95. The aims of the project were to:

1.compile a list of native and naturalised shurbs occurring in the area,

2.prepare, from (1), a list of native species, which were potentially useful for the shrub component of on-farm tree plantings, and

3.relate the occurrence of shrubs to particular substrates, including adjacent non-granite areas and to discuss changes which may have occurred since european settlement of the area in the early 1800s.

The primary aim of the project was (2), which was requested by the Bathurst office of the Soil Conservation Service. The list was prepared as an unpublished report in 1995.

Physical environment of the Bathurst Granites

The 'Bathurst (or Kanimbla) Batholith' was formed by intrusion of acid magma into Ordivician, Silurian and Devonian sediments during the Carboniferous. Recent geological mapping by Wyborn and Pogson (1994) has divided the area into a suite of granites: Bathurst, Dunkeld, Eusdah, *etc.*, which are collectively referred to here as the 'Bathurst Granites'. Uplift associated with the intrusion created a region of net erosion which still continues. The surrounding sediments, including the metamorphic aureole, were generally more resistant to erosion than the granite, resulting in a rim of elevated country around much of the exposed batholith (Somerville 1987). West of the Great Dividing Range (1100 - 1200 m ASL), where caps of Permian sediments overly the granite, the overall effect is a basin centred on Bathurst. The lowest point (620 m) is where the Macquarie River exits the exposed batholith.

The area is located within the Central Tablelands botanic subdivision of NSW. The relatively high altitude and its range are reflected by the climate. Median annual precipitation ranges from about 1000 mm on the Great Dividing Range to 750 mm west of Bathurst and is lowest (c.600 mm) in the Bathurst Basin. Occasional snowfalls occur throughout much of the area - particularly above 1000 m ASL. Although temperatures fall by about 6.4°C per 1000 m in summer and by 3.7°C per 1000 m in winter, cold air drainage can reverse this effect resulting in increased frequencies of fog and frost in low-lying areas (Bowie 1987). At Bathurst, for example, about 20 frosts per month occur in July and August (Anon. 1974).

Reconnaissance soil mapping west of the Great Dividing Range by Kovac *et al*. (1990) divided the erosional surfaces of the granite into four soil landscapes: 'Pine Mountain' and 'Rocks' - lands of high elevation and relief with siliceous sands and podzolic soils, 'Bathurst' - undulating lands with non-calcic brown soils and yellow solodics, 'Raglan' - slightly undulating plains with red and yellow solodics. Similar country to the 'Rocks' was subdivided into three landscapes in more detailed soil mapping to the east by King (1993, 1994). Alluvial landscapes include 'Macquarie'and 'Evans Plains', where siliceous sands, prairie soils, earthy loams, black earths and wiesenboden occur. The relative fertilities of the main soils are presented in Table 1.

Table 1. **Relative fertility attributes of the main soils of and adjacent to the Bathurst Granites - west of the Great Dividing Range (Adapted from Kovac *et al.*1990)**

Soils ocurring on granite	**Adjacent non-granite soil**								
Main soils	Siliceous sands, sandy earth, podzols	Yellow solodics	Red solodics	Non-calcic brown soils	Prairie soils	Yellow podzolics	Red podzolics	Yellow soloths	Shallow soils
Soil landscapes	Pine Mt. Rocks Evans Plains	Raglan lower slopes of: Rocks Bathurst	Raglan	Bathurst	Macquarie Evans Plains	Lambie Mayfield	Mookerawa Mullion Ck. Mayfield	Lower slopes of:Mookerawa Mullion Ck	Lambie
Fertility attributes:									
Drainage	well	poor	moderate	well	moderate	imperfect	moderate to well	imperfect	well
Water-holding capacity	low	high	high	moderate	high	low to moderate	low to moderate	high	low
Depth to bedrock (cm)	100+	300+	250	170	200+	60 to 150+	105 to200	150+	30
Topsoil pH	6.0	6.5	6.0 to 7.5	6.0	7.0	4.0 to 6.0	5.5 to 7.5	5.0 to 7.0	4.0
Chemical fertility	low	low	low	moderate	high	low	low to moderate	low	low

Relationships between relief, climate, soils and presumed original vegetation in the Central West of NSW (which includes most of the Bathurst Granites) have been summarised by Bowie (Goldney & Bowie 1987, Fig. 2, p.7).

Vegetation of the Bathurst Granites during the settlement period: evidence for the occurrence and frequency of shrubby plants.

The main sources of evidence for the nature of the original vegetation are from accounts of early visitors and from so-called "remnant stands" of vegetation. Both sources are considered but with emphasis on the historical.

Amongst the many problems in interpreting the work of early visitors (who were mainly interested in vegetation from the points of view of access, timber and/or grazing value) is the changing meaning of words; "forest" being a particular example:

• "FOREST … 1. A large space of ground - or wood-land, left uncultivated; or partly pasture, and partly wood, for breeding and hunting beasts of chase, etc. 2. [In law] a certain territory of woody grounds and fruitful pastures, privileged for wild beasts and fowls of forest, chace and warren, to rest and abide in, the safe protection of the king for his pleasure" (Bisley 1764).

• *"Forest land is such as abounds with Grass and is the only Ground which is fit to Graze; according to the local distinction the Grass is the discriminating Character and not the Trees for by making use of the Former it is clearly understood as different from a Brush or Scrub"* (Governor King writing to Earl Camden, 1 Nov. 1805; cited by Ryan *et al*., undated).

• *"Forest … a wild uncultivated tract of ground with wood"* (Fulton & Knight 1831).

Clearly, the "forest" of the writings of the early to mid 1800s is not "forest" as is presently understood. It could, however, encompass lands which have dense trees; but it does not completely agree (as is implied by Ryan *et al*. 1996) with our present understanding of a "woodland".

"Plains" too was used differently in the 1800s. According to Rolls (1981, p.42) "*the colonists called any treeless area plains provided they were not steeply hilly*".

Extracts from the early literature which follow are selective in the sense that some reference to the presence and absence of shrubs was sought. It is hoped that they are not misleading, a criticism levelled by Croft *et al*. (1996) at Ryan *et al.*'s (undated) compendium of extracts from historical sources.

Early descriptions of the landscapes of the Bathurst Granites

The first europeans to view the granite landscapes were G. Blaxland, G. Lawson and W. Wentworth, who crossed the Blue Mountains plateau in mid 1813. The western extremity of their exploration was a 900 m hill (later named Mt. Blaxland) at the eastern end of the Bathurst Granites.

Following the explorers' return to Sydney, Governor Macquarie instructed Assistant Surveyor, G. Evans, to explore the new country. With five others, he departed in November 1813, crossed the Great Divide, named the "Bathurst Plains" and followed the Macquarie River (also named by him) almost to its junction with the Turon River. In July 1814, W. Cox, T. Hobby, R. Lewis and a gang of convicts began constructing a road from Emu Plains to Bathurst. It was completed in February 1815 and two months later, Macquarie and entourage travelled to Bathurst and proclaimed the settlement on 7 May 1815 (Barker 1992).

Other early visitors to the area included Cunningham and Oxley (1817), Darwin (1836) and considerably later, Maiden and Cambage (c.1909) retracing Cunningham's journey. These early visitors left written records of their journeys though their descriptions are often difficult to reconcile with the present landscape. All, however, noted the contrast between the sandstones of the Blue Mountains and the land below the escarpment where small areas of Permian sediments, as well as granite, occur (Bryan 1966). Examples include:

G. Blaxland 1813: *"On the 28th* [May 1813] *… they took up their station on the edge of a precipice* [Mt York]. *To their great satisfaction, they discovered that what they had supposed to be sandy barren land below the mountain was forest land, covered with good grass, and with timber of an inferior quality …* [the next day] *… They reached the foot at nine o'clock, AM., and proceeded two miles, north-north-west, mostly through open meadow land, clear of trees, the grass from two to three feet high … "* (Blaxland 1823, reprinted in Richards 1979, pp.73-74).

Describing the area between Mt. York and the Cox's River in the early 1900s, Maiden & Cambage reported that it was a: "*well defined botanical boundary, for we have hitherto been traversing the sandstone with its showy flora; we now (at Cox's River) get on to the granite with its larger trees (except in the sandstone gullies), and very much sparser flora. Let Allan Cunningham speak* [from his unpublished 1817 journal]: *'Here was observed the very remarkable change of country, differing from that on the mountains both in the vegetable production and nature of soil the* Banksia serrata *ceases to exist further westerly than the summit of Mount York, and …* B. marginata *succeeds, throughout the Vale (Clwydd)'"* (Maiden & Cambage 1909, p.129).

Darwin 1836: *"Soon after leaving Blackheath, we descended from the sandstone platform by the pass of Mount Victoria … We now entered upon a country less elevated by nearly a thousand feet, and consisting of granite. With the change of rock, the vegetation improved; the trees were both finer and stood farther apart; and the pasture between them was a little greener and more plentiful … "*(Darwin 1968 reprint, p.440).

Very few of the early accounts of the granite country itself refer to dense timber though clearly this existed, *e.g*. Lewin's 1815 painting of Evans Crown (Fig. 3A) and Antill's 1815 description of the same area: "*We appeared to be completely surrounded and hemmed in by a range of hills. The country from Cox's River abounds with red and black granite; … and the whole aspect of the country appeared as if it had undergone some great convulsion of nature, hills heaped upon hills and rocks upon rocks, with deep gullies between them, and all clothed with wood to their very summits … "* (Antill 1965 reprint, p.7).

Evans' account from the Great Dividing Range near the present Cheetham Trig. (1131 m ASL) (Weatherburn 1966) in November 1813 is somewhat ambiguous with respect to shrub and tree density: *" … I came to a very high mount where I was much pleased with the sight westward. I think I can see 40 miles which had the look of an open country. To the south and north there are large hills, much higher than the one I am on, with pasture to their tops. The range is rather over run with underwood and larger timber growing thereon, but the sides are as green as possible …* (Evans 1813 in Walker's 1913 facsimile).

In another of the few references which note the presence of a shrubby understorey, W. Cox, the road builder, in describing the Fish River country south of Evans Crown noted: *"The land got hilly, and falls more into gullies than lower down. It is also shrubby in places and more timber on it."* (Cox's 1814-15 journal in Anon. 1979, p.110). A year earlier, G. Evans referred to the Fish River - possibly in the same area - as: *"I now find the mimosa in clusters on the banks of the river … The country continues good particularly for grazing. Yet it has not been altogether so pleasing to the eye as before, being in some places over run with a shrub among the grass, somewhat the same as on the Cow Pastures near Stone*

Fig 3A. Evans Crown as depicted by J.W. Lewin in 1815 (Breckwoldt (1988) presents a coloured reproduction of this scene together with an 1815 view of the "Bathurst Plains").

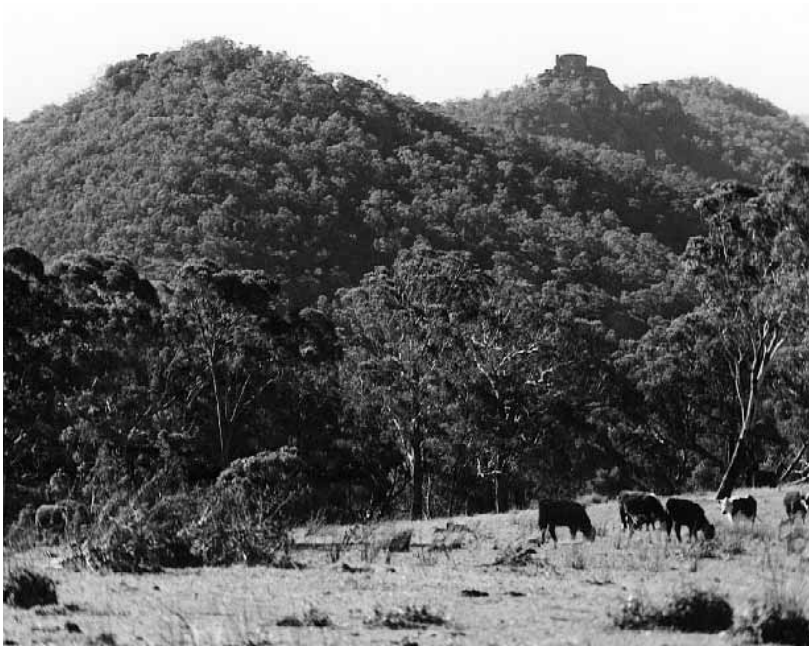

Fig 3B. Evans Crown from near Mt. Olive in 1996.

Quarry Creek. The land is still of a light sandy nature, thinly wooded with small gums" (Evans 1813 in Walker's 1913 facsimile).

Perhaps the best known of the early descriptions of the Bathurst area are extracts from Governor Macquarie's journal of his first visit in 1815. For example: "*After riding about 9 miles* [from the Campbell River crossing] *through a pretty wooded country we arrived on a height which commanded a very extensive, grand, and noble view of the Bathurst Plains extending on both sides of the Macquarie River for 11 miles and for nearly 3 miles on each side of it, being almost entirely clear of timber for that extent"* (Macquarie 1956, p.97).

The country in the vicinity of Bathurst was clearly lightly timbered: *"Within a distance of ten miles from the site of Bathurst, there is not less than 50,000 acres of land clear of timber, and fully one half of that may be considered excellent soil, well calculated for cultivation. It is a matter of regret, that, in proportion as the soil improves, the timber degenerates; and it is to be remarked, that every where to the westward of the Mountains, it is much inferior both in size and quality to that within the present colony; there is, however, a sufficiency of timber of tolerable quality , within the district around Bathurst, for the purpose of housebuilding and husbandry."* (Government and General Orders 10 June 1815, reprinted in Richards 1979, p.127). As it turned out, there was insufficient timber for fuel in the early period of settlement (Templeton 1976) and, no doubt, the removal of what timber there was had a significant effect on the early landscape.

From these descriptions, it seems that Macquarie was describing alluvial plains such as the "Macquarie" and "Evans Plains" soil landscapes. However, Darwin's 1836 description clearly indicates that the treeless country also extended to non level country - probably the "Raglan" soil landscape east of Bathurst: *"In the afternoon we came in view of the downs of Bathurst. These undulating but nearly smooth plains are very remarkable in this country, from being absolutely destitute of trees … "* (Darwin 1968 reprint, p.442).

Many of the early descriptions refer to lightly timbered country; *e.g.* Blaxland's 1813 report from Mt. Blaxland: *"In the afternoon, they ascended the summit, from whence they descried all around, forest or grassland, sufficient in extent, in their opinion, to support the stock of the Colony for the next thirty years"* (Blaxland 1823, reprinted in Richards 1979, p.75).

It is likely that the early visitors tended to highlight the lightly timbered country because of its perceived value for grazing and farming. Also, the route of Cox's Road (see maps in Maiden & Cambage 1909 and Carey 1976), by which the early visitors travelled, would have followed the open country wherever possible. Writing from the vicinity of this road in May 1815 Antill noted: *We proceeded up the bank of the Campbell River for about three miles, upon the banks of which we were to encamp near a bridge made over it … the face of the country we rode over this day*

after quitting the road, was beautiful and open, large tracts of land without timber or underwood, and in the spring when grass is green must be delightful … " (Antill 1965 reprint, pp.8-9). The Campbell River crossing at that time is shown as a woodland in one of Lewin's 1815 paintings (Fig. 4). Another scene (Sidmouth Valley, Fig. 5A) shows an alluvial flat with grassland, lower slopes with woodland and hills with woodland and/or forest; the scene today (Fig. 5B) is similar to that depicted in 1815.

Evidence from the present vegetation

Before considering the present vegetation, it is pertinent to note some of the major events that have occurred since settlement. Some examples from Barker (1992):

Fig 4. Governor Macquarie's camp at the Campbell River crossing as depicted by J.W. Lewin in 1815

• decline in numbers of aboriginals and an increase in the numbers of europeans - particularly since the discovery of gold in the district in the 1850s

• introduction of domestic livestock in 1815

• construction of roads, *e.g.* Cox's in 1815 and Mitchell's in the 1830s, and the railway in the 1860s and 70s

• arrival of rabbits in the late 1850s (Stacy 1976) and other exotics such as blackberry

• introduction of subterranean clover and superphosphate for "pasture improvement" in the 1950s (Smith, undated). This was apparently partly responsible for the reduction in the area of sheet erosion recorded between 1943 and 1967 (Anon. 1974)

Cultivation was initially restricted to the treeless flats. In one such area, the Fitzgerald Valley, south-west of Bathurst, chaff, hay, wheat, maize, cream and pigs were being produced by the late 1880s (Smith, undated). The commencement of large-scale clearing of timber from the Bathurst Granites is unknown though Smith (undated, p.17) reported that "*when the clearing of the undulating country … began in earnest about the early 1930s it was found to be suited to the growing of wheat and oats. This country … was described … in 1899 as being "rough and hilly"* ".

Also uncertain is the time of formation of the large gullies for which the Bathurst district is well-known (Semple *et al.* 1995). The gullies are still active (Crouch & Blong 1989) and are common sites of invasion by exotic shrubs such as blackberries (*Rubus* spp.), sweet briar (*Rosa rubiginosa*) and african boxthorn (*Lycium ferocissimum*) (Fig. 6).

What interpretation can be made from existing stands of timber such as occurs on Evans Crown? The vegetation is not dissimilar to that sketched in 1815 (Figs. 3A and 3B). It could be argued that the structure of the vegetation is much as it was, though

Fig 5A. Sidmouth Valley from the vicinity of Cox's Road as depicted by J.W. Lewin in 1815.

Fig 5B. The same scene from the Carlwood Road (presumed to closely follow Cox's Road) at Black Soil Flat in 1996. The trees in the mid ground are willows, introduced since Lewin's time.

the understorey, at least, would have been affected by the introduction of other plants and animals, reduced fire frequency, *etc.*

In the case of small areas of timber in apparently cleared paddocks (*e.g.* Fig. 7), the interpretation is less clear. Are they remnants of the original vegetation and if so, are they representative of adjacent areas that appear to have been cleared? As areas are left uncleared for a reason (*e.g.* too rocky, poorly drained, potential use as timber, or for stock shelter), it is unlikely that they can be considered representative of the surrounding areas. In some cases the supposed "remnants" appear to be denser than originally described, *e.g.* the country below Mt. York (Fig. 8). It is unlikely that Blaxland (cited earlier) would have described it as he did, if the area was completely covered with timber as dense as in the "remnants".

A further explanation of the apparent discrepancy between early and current descriptions of the vegetation is that considerable woody plant regeneration may have occurred following settlement. This has been reported from other areas, *e.g.* Gippsland (Howitt cited by Anderson 1941), the semi-arid woodlands of western NSW (*e.g.* Anon. 1969), the Pilliga area (Rolls 1981) and the Gulgong area (Nicholson & Seis 1993). A possible explanation for this is that lignotuberous eucalypt seedlings were present in the original woodlands but suppressed by grass competition and regular burning. Following increased grazing by domestic stock and the reduced frequency of fires this growth, previously un-noticed, would have been released. According to Florence (1996), this mechanism was probably responsible for the rapid regrowth of forests following logging in the early days of settlement.

A Survey of Shrubs Occurring on the Bathurst Granites

The primary aim of the survey described below was to compile a list of shrubs that may be suitable for the understorey of on-farm tree plantations. As a consequence, a somewhat broader view of "shrub" than that used by Harden (1990-92) was adopted. Low non-eucalypt trees, which commonly branch near ground level, *e.g.* many *Acacia* spp., were included. Though naturalised* shrubs and those <2 m mature height were considered unsuitable for habitat/shelter plantations, opportunity was taken to record them in the survey.

The literature, including compilations of species lists by Pickard (1972), Bryant & Benson (1981), Keith (1988) and Benson & Melrose (1993), was searched for previous records of shrubs. Accounts of the vegetation by Chisholm (1923), Cambage (1902) were of little use due to the lack of distinction between granite and non-granite substrates. The main sources were Maiden & Cambage (1909), National Parks and Wildlife Service (undated), Wakefield (1994) and Clunies Ross (1898).

The latter was particularly useful as a clear distinction between the granite and non-granite flora was made. However, Harden's (1990-1992) flora and Jacobs & Pickard's (1981) census were necessary to interpret obsolete nomenclature* and some mistakes may have occurred. A number of taxa were also obtained from Keith & Benson's (1988) description of communities which occur both on and off the Bathurst Granites east of the Great Divide; their presence on granite soils was assumed.

The field survey was mainly limited to roadsides on and to the west of the Great Dividing Range. Most of the roads were travelled, as opportunity arose, during 1992-95. Stops were made where native shrubs were observed. On many roads, particularly on the "Raglan" and alluvial soil landscapes, shrubs were absent or represented by exotics only and hence, were not sampled. Sample sites were either a small defined area or a stretch of a few kilometres of road. Where access was readily available,

*As recorded for the Central Tablelands botanic subdivision by Harden (1990-92). This flora is also the authority for species nomenclature.

Fig 6. Erosion gullies are common sites of exotic shrub invasion.

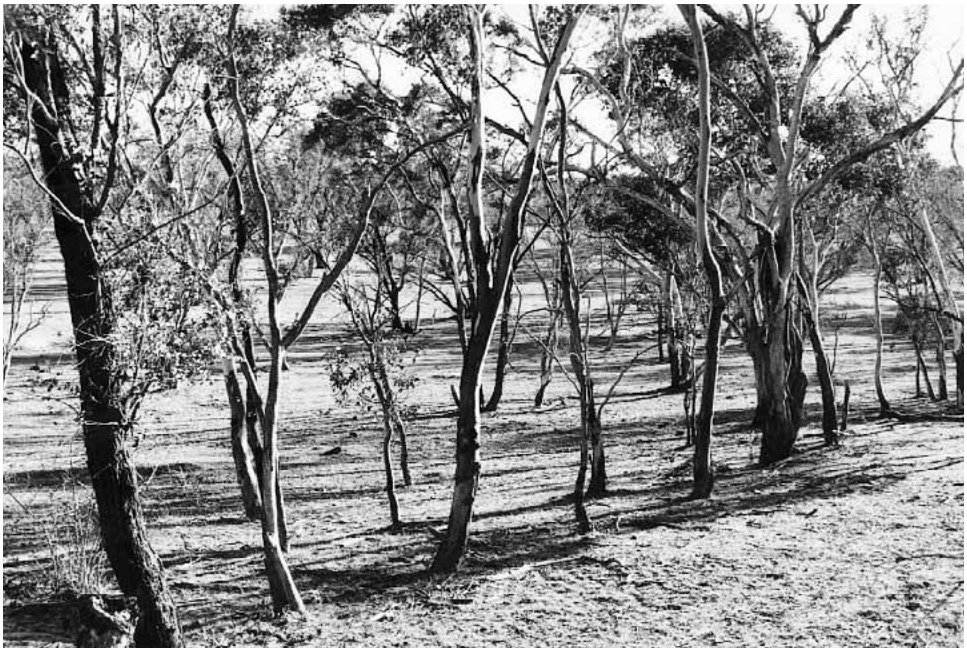

Fig 7. An *Eucalyptus melliodora - E. blakelyi* woodland south-east of Bathurst. It is uncertain (though unlikely) that this is representative of the original vegetation.

e.g. Evans Crown Nature Reserve, off-road sites were also examined. For purposes of comparison, shrubs were also recorded on non-granite sites adjacent to the granite.

Shrubs were recorded from 47 granite sites and nine non-granite sites. Their locations are shown in Fig. 1.

Results

The literature search resulted in a list of 67 native and naturalised shrub taxa, which occurred or were very likely to occur on the Bathurst Granites. Eighty taxa were recorded in the field survey, resulting in a total of 107 taxa for the area (Table 2). In the field survey, an additional 17 taxa were recorded only on non-granite soils adjacent to the granite (though three of these, *Allocasuarina littoralis, Acacia genistifolia* and *Daviesia genistifolia*, had been recorded on granite soils in earlier surveys). Taxa are listed in Appendix I.

Table 2. Numbers of shrub taxa recorded for the Bathurst Granites

	Previous surveys	Roadside surveys	All surveys
Native	61	60	87
Naturalised	6	20	20
Total	67	80	107

A number of shrubs previously recorded in the granite were not observed in the roadside survey. However, most of the uncommon shrubs, *i.e.* recorded at only one site, had not been previously recorded on the granite, *e.g. Polyscias sambucifolia, Acacia gladiiformis, Dillwynia cinerascens, Baeckea utilis*, *Pomaderris betulina* and *Pimelea stricta*. The most common shrubs, *i.e.* those occurring at many of the roadside sites, were exotics. *Rubus* spp. (blackberries) occurred at 77% of granite sites, *Crataegus monogyna* (53%), *Malus* sp. (53%) and *Rosa rubiginosa* (70%). These figures probably underestimate exotic frequencies as sites with exotics only were not sampled. The most commonly recorded natives were *Acacia dealbata* (77% of granite sites) and *Cassinia arcuata* (68%).

• Current nomenclature for *"Acacia crassiuscula"* and *"Leptospermum stelligerum"* could not be found. *Dodonaea lobulata* is not recorded for the Central Tablelands (Harden 1990-1992) and was presumed to be a misidentification

The proportion of exotics was higher in the field survey than was suggested by the results of earlier surveys (though this was probably a consequence of lesser interest in exotic species in the earlier works, rather than an increase in recent times). Exotics comprised almost 20 % of the total granite shrub flora (Table 2) and 25 % of the shrubs recorded in the field survey (Table 3), a higher proportion than on non-granite sites. Table 3 also shows that almost half of the naturalised taxa was restricted to the granite, whereas none was restricted to adjacent non-granite sites.

Native species were more likely to be recorded from more rugged terrain, *viz.* "Rocks", "Pine Mountain" (*e.g.* Evans Crown, Fig. 3B) and adjacent non-granite soil landscapes. These areas were usually the least disturbed by agricultural activities and trees were often present. Native species were not observed on the alluvial landscapes though

Table 3. Numbers* of shrub taxa rcorded on different substrates in the roadside survey

	On granite only	On both granite and non-granite	On non-granite only	Total granite	Total non-granite	Total all substrata
Native	22	36	17	58	53	75
Naturalised	11	9	0	20	9	20
Total	33	45	17	78	62	95

*The apparent discrepancy between numbers in this and the previous table is due to *Bursaria* spp. being recorded here as one taxon (It was not possible to identify beyond genus level at all sites in the field survey)

exotics were present (Table 4). Mean numbers of native taxa per site appeared to be inversely proportional, and naturalised taxa proportional, to the degree of disturbance: alluvial > "Raglan" > "Bathurst" > "Rocks" > "Pine Mountain" and non-granite landscapes (Table 4A). When total numbers of taxa recorded on each landscape are considered (Table 4B), the relationships are less clear with a tendency for the more intensively sampled landscapes to have a higher number of taxa.

Fig 9. Shrubs are common on this rocky outcrop on Pine Ridge road, c.15 km west of Bathurst. This area is presumed to be the same one, which - due to the presence of *Callitris endicheri* - attracted Governor L. Macquarie in 1815 and botanist/explorer, A. Cunningham, in 1822 (McMinn 1970). Macquarie recorded his visit as follows: *"The rest of the party accompanied me on horseback as far as Pine Hill about 7 miles to the westward of Mt. Pleasant* [Stewart]. *Our ride to this place was a very rough one over a succession of steep hills and deep valleys alternately. On reaching Pine Hill we saw the pine-tree of this country in great numbers and of a considerable height, but of no great circumference, none of them being above one foot in diameter....."* (p.103, 1956 reprint

Table 4. Occurrence of shrub taxa[1] on non-granite and granite soil landscapes

	Non-granite landscapes	Pine Mountain	Rocks[2]	Bathurst	Raglan	Evans Plains & Macquarie[3]
No. of sites	9	3	24	18	2	0
(a) Mean number of taxa per site:						
Native	13.3	12.7	8.3	6.3	1.0	-
Naturalised	2.2	2.3	4.0	4.8	5.5	-
Total	15.5	15.0	12.3	11.1	6.5	-
(b) Number of taxa recorded for each landscape:						
Native	53	30	44	33	2 -	
Naturalised	9	5	15	17	8 -	
Total	62	35	59	50	10	-

1. Bursaria spp. counted as one taxon
2. Includes Marrangaroo and Round Mount soil landscapes in the vicinity of the Great Dividing Range
3 .No native shrubs were observed on these landscapes; hence, no sites were sampled

Discussion

Despite the passing of 180 years, the present landscape still has some affinities with descriptions of it at the time of settlement. Evans Crown (Figs. 3A and 3B) retains its tree cover as do a number of other rocky hills such as Pine Ridge, where *Callitris endlicheri* still occurs (Fig. 9). Scenes with scattered eucalypts, such as those shown in Figs. 4 and 5, can still be seen. The native grasslands of the Bathurst area are long gone, having been replaced by naturalised species, horticultural crops and/or trees. According to Barker (1992 p.34), " … 0*when one also considers the introduction of exotic species - orchard, poplars, willows and elms, amongst others - it becomes certain that there are more trees on the local plains now than there were when Bathurst was founded*".

The written and pictorial historical records cited appear to satisfy most of Forman & Russell's (1983) criteria for evaluating historical data in ecology. However, some exaggeration is possible; *e.g.* Blaxland's description of the granite country from Mt. Blaxland (p.6). Even allowing for some exaggeration and selective reporting, the records suggest that the granite landscape had timbered hills (particularly in the vicinity of the Great Dividing Range), slopes with grassy wood-

*1. First- or second-hand observation

2. Purpose, or possible bias, of the statement

3. Author's knowledge of the subject

4. Context of the statement

lands, and flats (and near Bathurst, the adjacent slightly undulating country) with grasslands. Shrubs were apparently infrequent except on the more rugged country. Apart from the presence of exotic shrubs, this is in accordance with their distribution today as recorded in the roadside shrub survey (Table 4).

As far as the occurrence of shrubs and trees on the adjacent non-granite country is concerned, Clunies Ross' (1898 p.470) observations are still valid: *"On approaching the boundaries of the granite in certain directions one finds some new plants, but the variety is still limited until one reaches the Silurian rocks. Then a change is at once noted. Instead of open land, with scattered trees and well grassed, one finds numerous shrubs and stunted gum-trees, with detached tussocks of coarse grass."* These observations are supported by the roadside shrub survey (Table 4).

On Hayden's (1971) map of the supposed pre-settlement vegetation of NSW, most of the Bathurst Granites west of the Great Dividing range was shown as having supported an *Eucalyptus melliodora - E. blakelyi* (presumably grassy) woodland. Forests of *E. fastigata - E. viminalis* and *E. macrorhyncha - E. rossii* were shown on and to the east of the Great Dividing Range. The scale of the map was too small to show most of the forested hills (which are present today [*e.g.* see National Trust of Australia 1987] and presumably occurred previously) within and at the margins of the granite. These, together with the supposed locatation of the original grasslands, are shown on a larger-scale map (Anon. 1974) of the western part of the granite.

On the western section of the Bathurst Granites, historical sources and the shrub survey suggest that the frequency and diversity of native shrubs were (and are) relatively:

1. low over much of the granite - particularly on lower-lying country
2. high on rocky granite hills, and
3. higher on the adjacent non-granite hilly country.

Keith & Benson's (1988) descriptions of current vegetation on the eastern part of the Bathurst Granites - including an outlier east of Jenolan Caves - also supports (1) and (2).

A survey of rocky outcrops (6 granite and 13 non-granite) in the central southern part of NSW by Norris & Thomas (1991) suggest that these observations may be of general applicability. Only 4 shrub species were recorded on the granite outcrops compared to 49 on sandstone. Slate and rhyolite substrates also had low numbers of shrub species but only one site of each was sampled. Unlike many rocky outcrops of the Bathurst Granites, most of the outcrops in that survey were of low relief.

Further evidence for the reduced frequency of shrubs on granite soils comes from the bimble box-pine (*Eucalyptus populnea - Callitris glaucophylla)* woodlands of western NSW. The frequency of species of *Dodonaea, Senna* and *Eremophila*, as well as *Callitris*, has been increasing since the late 1800s such that most of this originally grassy woodland is now a shrub woodland (Anon. 1969). Small areas of granite soil - mainly "Penshurst" and "Warrowie" land systems (Johnston & Milthorpe 1984) - have been largely unaffected by these species, though in recent years *Acacia* spp. have been increasing (R. Harland, pers. comm.)

The increased frequency of shrubs on the non-granite soils near Bathurst is probably a consequence of the shallow, low fertility soils. These factors are associated with dry sclerophyll forests with moderately to well-developed shrub layers in other areas (*e.g.* Moore 1953, Biddiscombe 1963). As many of the shrub species - particularly those restricted to non-granite sites (Appendix 1B) - are xeromorphic, the limiting factor may be phosphorus as proposed by Beadle (1981). However, in a review of shrub increase on rangelands, Archer (1994) noted that, compared to grasses, shrubs are better able to use the resources of sites with shallow and/or rocky soils by exploiting fissures in the underlying barriers.

Soils of the more rugged granite country ("Pine Mountain" and "Rocks" soil landscapes) are not of markedly higher fertility than adjacent non-granite areas. Waterholding capacity and chemical fertility, for example, are low in both groups, though the non-granite soils tend to have lower pH (Table 1). As 36 native shrub taxa were common to both granite and non-granite soils (Table 3), it is likely that low fertility is at least partly responsible. However, as 11 native shrub taxa were restricted (at least in the roadside survey, Table 3) to granite soils suggests other factors were operating. As many shrubs only occurred on drainage lines or near rock outcrops, enhanced moisture availability may explain the presence of some species on the more rugged granite sites. Drainage lines, including gullies, were also sites of exotic (non-xeromorphic) shrub increase on these granite soil landscapes.

On the lower slopes and alluvial flats where soils are deeper and generally more fertile (Table 1), native shrubs were uncommon. Only two species, *Cassinia arcuata* and *Acacia dealbata*, were recorded on the "Raglan" soil landscape and none on "Macquarie" or "Evans Plains". Exotic shrubs, however, did occur on roadsides, gullies and along watercourses and have been present on the granite country for a considerable time; *e.g.* Maiden & Cambage's (1909, p.132) report of "sweet briar" (presumably *Rosa rubiginosa*) "in the greatest profusion" at the junction of Hobby's Creek and the Fish River.

Some native shrubs can be established - at least from tubestock (*e.g.* Semple *et al.*1995) - on these areas. Whether all those recorded (Appendix 1A) can be established in this way is unknown - particularly in view of the changes that have occurred since settlement: *e.g.* applications of superphosphate, changed drainage, grazing and introduction of exotic forbs and grasses. Direct seeding of trees and shrubs has not been very successful on the Bathurst Granite. In trials reported by Semple & Koen (in

press), low seedling survival was partly attributed to the abundance of wingless grasshoppers, *Phaulacridium vittatum* (Sjöstedt), which is thought to be due to changed conditions since settlement (Semple *et al.* 1995, Davidson 1995). Competition from herbaceous species was the main reason for low survival of seedlings.

The absence of native shrubs in the original grasslands and lower slope woodlands is often attributed to burning by aboriginals. Examples of this general practice from the early literature have been provided by Ryan *et al.* (undated) and for this area, in the reports of Antill (1965) and Darwin (1968). However, to prevent suppression of grass fuel by shrubs, burning would need to have been frequent. For example, one of the most widespread native shrubs on the granite, *Cassinia arcuata*, is killed by fire but regenerates rapidly from seed afterwards (Semple & Koen 1993) and can set seed two years later (Parsons 1973). The role of fire in maintaining grasslands at the expense of shrublands, may have been over-estimated. In order to have a fire, continuous fuel (grasses) must be present, *i.e.* in order to have a grassland fire, you must first have a grassland (Archer 1994).

The most likely explanation for the relative abundance of shrubs on rocky hills, *v.* lower slopes is the presence/absence of a continuous sward of perennial grasses. The absence of this feature on non-granite soils adjacent to the granites was noted by Clunies Ross (1898, cited earlier). In woodlands further west, Biddiscombe (1963) observed that native grasses had difficulty establishing on stony sites following clearing and were soon suppressed by shrubs. The necessity of a competitive stand of perennial grasses for preventing shrub recruitment in western NSW was suggested by Booth *et al.* (1996) and for preventing sifton bush recruitment in central western NSW, by Campbell *et al.* (1990). In the latter study it was noted that on non-arable land, a competitive (exotic) pasture could not be established due to the low fertility soils.

It is suggested, therefore, that soils of low fertility (*e.g.* rocky, shallow, low nutrient status, low water-holding capacity) are incapable of supporting a continuous sward of perennial grasses. Gaps provide regeneration niches for shrubs which have low nutrient requirements (*e.g.* xeromorphs) and/or are better able to exploit the limited supply of nutrients. Fire may have assisted in maintaining a low frequency of shrubs provided sufficient fire-tolerant perennial grasses were present to outcompete shrub seedlings.

Conclusions

Numbers of shrub taxa on the Bathurst Granites is not high. Previous surveys and a roadside survey of the western part of the granite recorded 107 taxa. Diversity and numbers of shrubs were highest on the more rugged parts of the granite. Very few native shrubs were recorded on the low-lying areas - particularly in the vicinity of Bathurst. There is some evidence that shrub numbers and diversity on granite, compared to surrounding areas, is low in other parts of NSW.

Historical records suggest that shrubs were infrequent - apart from perhaps the more rugged areas (where little information is available) - at the time of settlement. These records also suggest that much of the granite, apart from areas of higher elevation, supported open grassy woodlands - probably more open than suggested by present "remnants" - and, near Bathurst, grasslands.

Exotics comprise about 20% of the present shrub flora of the Bathurst Granites. Diversity and numbers of exotic shrubs are highest on areas of the granite that have been subjected to the most disturbance. Gullies, in particular, are major sites of exotic shrub increase.

Non-granite areas adjacent to the Bathurst Granite commonly support high numbers and a high diversity of native shrubs. This observation, together with the general absence of shrubs on the most fertile parts of the granite, suggest that shrubbiness is a consequence of low fertility and, in particular, the inability of low fertility sites to support a dense sward of perennial grasses.

Though shrubs may be desirable components of on-farm tree plantations on the Bathurst Granites, the resulting vegetation is unlikely to represent the pre-european settlement vegetation, except on rocky hills. The latter sites would also be the most suitable for direct seeding due to reduced herbaceous competition. However, environmental changes associated with european settlement, *e.g.* erosion, increased fertility in some areas and increased frequency of wingless grasshoppers, may increase or decrease the likelihood of success at particular sites.

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Appendix I: Shrubs and shrub-like plants of the Bathurst Granites and immediate surrounds

Family/Species	Habit and height (in metres where stated) /absence (-) on granite soil	from Harden surveys (see footnote 1)	Source A to E refer to previous on granite sites on Ordivician, Silurian & Devonian			on non granite sites Permian	Roadside survey Presence (✓) Frequency[3] (1990-1992). All are shrubs or have shrubby form unless x = roadside survey		
*naturalised in the region	otherwise stated		/1	(no voucher)			landscapes[2]		
*?possibly naturalised	v = roadside survey								
(voucher identified by							/8		
the National Herbarium)			Pm	Ro	Ba	Ra			
A. Species recorded on granite									
AMYGDALACEAE									
**Prunus* spp.	small tree	x	-	✓	✓	✓	14	0	0
APIACEAE									
Platysace lanceolata	1.5	A	-	-	-	-	-	-	-
ARALIACEAE									
Polyscias sambucifolia spp. C	5	v	-	✓	-	-	1	0	0
ASTERACEAE									
Cassinia aculeata	2.5	v	-	✓	-	-	1	0	1
C. arcuata	2	x	✓	✓	✓	✓	32	7	0
C. laevis	3	B	-	-	-	-	-	-	-
C. longifolia	2.5	x	✓	-	✓	-	4	2	0

C. quinquefaria 3	vADE	√	√	√	-	19	4	1	
Ozothamnus diosmifolius	5	x	√	-	√	-	2	1	0
CASUARINACEAE									
Allocasuarina diminuta spp. *diminuta*	5	v	-	-	√	-	1	2	0
A. littoralis	15 (tree)	D	-	-	-	-	0	0	1(v)
DILLENIACEAE									
Hibbertia diffusa	0.	3	E	-	-	-	-	-	- -
H. obtusifolia complex	0.6	CD	√	√	√		15	5	0
H. riparia comple	x	0.6	v	-	-	√	-	1	0 0
EPACRIDACEAE									
Brachyloma daphnoides	1.5	xBC	√	√	√	-	18	5	0
Epacris microphylla	1	v	-	√	-	-	1	0	0
Leucopogon lanceolatus	3	A	-	-	-	-	-	-	-
Lissanthe strigosa	0.7	vA	-	-	√	-	4	1	0
Melichrus urceolatus	1.5	x	-	√	-	-	2	0	0
Monotoca scoparia	1.2	vB	√	-	-	-	1	3	1
Styphelia triflora	2	xB	√	√	√	-	6	5	0
EUPHORBIACEAE									
Beyeria viscosa	4	B	-	-	-	-	-	-	-
FABACEAE: Mimosoideae									
**Acacia baileyana*	6	x	-	-	√	-	3	0	0
A. buxifolia	3	xE	-	√	√	-	5	2	0

A. dealbata	15 (tree)	xBCDE	√	√	√	√	36	7	1
A. falciformis	10	vBC	√	√	-	-	10	0	1
A. genistifolia	3	E	-	-	-	-	0	1(x)	0
A. gladiiformis	3	v	-	-	√	-	1	0	0
A. implexa	12 (tree)	v	√	√	√	-	7	1	0
A. lanigera	3	x	√	-	√	-	7	2	0
A. mearnsii	10 (tree)	B	-	-	-	-	-	-	-
A. melanoxylon	30 (tree)	xABCD	√	√	¸	-	10	0	1
A. obliquenervia	15	A	-	-	-	-	-	-	-
A. penninervis	8 (tree)	vCD	-	√	-	-	3	2	0
A. ulicifolia	2	vE	-	-	√	-	2	0	0
A. verniciflua	5	vC	√	√	√	-	7	1	0
A. vestita	4	x	√	√	√	-	5	1	0
FABACEAE: Faboideae									
Bossiaea buxifolia	1.3	C	-	-	-	-	-	-	-
B. obcordata	2	B	-	-	-	-	-	-	-
**Chamaecytisus palmensis*	4x	-	√	√	-	8	1	0	
**Cytisus scoparius*	2.5	xC	-	√	√	-	5	0	0
Daviesia genistifolia	2	E	-	-	-	-	0	2(v)	0
D. latifolia	5	xABCE	-	√	-	-	8	1	1
D. leptophylla [*D. virgata*]	2	x	-	√	√	-	3	6	0
Dillwynia cinerascens	1.5	v	-	√	-	-	1	0	0

D. phylicoides complex	1.5	vC	√	√	√	-	17	5	0
**Genista monspessulana*	3	x	-	√	√	-	4	0	0
Hardenbergia violacea	<2	xBCD	-	√	√	-	10	4	0
Indigofera adesmiifolia	1.5	v	-	√	√	-	3	0	0
I. australis	2.5	xABCDE	√	√	√	-	5	1	0
Oxylobium ilicifolium	3	A	-	-	-	-	-	-	-
Pultenaea procumbens	<2	vE	-	√	√		2	1	0
Swainsona galegifolia	1	AD	-	-	-	-	-	-	-
GOODENIACAE									
Dampiera purpurea [*D. brownii*]	1	E	-	-	-	-	-	-	-
LAMIACEAE									
Westringia eremicola	1.5	CE	-	-	-	-	-	-	-
MALACEAE									
**Contoneaster franchetti*	3	v	-	√	√	-	3	1	0
**C. glaucophyllus*	1+	v	-	-	√	-	1	1	0
**C. pannosus*	3	v	-	√	-	-	2	1	0
**Crataegus monogyna*		xB	√	√	√	√	25	1	1
**Malus* spp. (apple)	small tree	x	√	√	√	√	25	3	1
**Pyracantha angustifolia*	3	v	-	√	√	-	9	0	0
**P. fortuneana*	v	√	√	√	-	3	0	0	
**P. rogersiana*	3	v	-	√	√	√	10	0	0
MYRTACEAE									

Baeckea utilis	3	v	-	√	-	-	1	0	0
Callistemon sieberi		vD	-	√	-	-	1	0	0
Calytrix tetragona	2	xB	√	-	√	-	2	2	1
Kunzea parvifolia	1.5	v	-	√	√	-	4	2	0
Leptospermum myrtifolium	3	v	√	√	-	-	6	0	1
L. polygalifolium [*L. flavescens*]	7	D	-	-	-	-	-	-	-
L. trinervium [*L. attenuatum*]	5	E	-	-	-	-	-	-	-
OLEACEAE									
**Ligustrum lucidum*	10	vB	-	√	√	-	2	0	0
**L. sinense*	3	x	-	-	√	-	1	1	0
**Olea europaea* ssp. *africana*	15 (tree)	v	-	-	-	¸	1	0	0
PITTOSPORACEAE									
Bursaria lasiophylla	2.5	v	}						
B. longisepalea 2	v	}	√	√	√	-	18	2	1
B. spinosa	8	vABCE	}						
PROTEACEAE									
Banksia marginata	12	xABDE	-	√	-	-	9	0	0
Grevillea acanthifolia	3	E	-	-	-	-	-	-	-
G. arenaria	3	vBC	√	√	-	-	3	1	0
**?G. rosmarinifolia*	2	v	-	-	√	-	1	0	0
G. triternata	1	D	-	-	-	-	-	-	-
Hakea microcarpa	2	vE	-	√	-	-	1	0	0

Lomatia myricoides	5	vABCD	-	√	-	-	2	0	1
L. silaifolia	2	B	-	-	-	-	-	-	-
Personia linearis	vB	√	-	√	-	2	0	1	
P. oxycoccoides	A	-	-	-	-	-	-	-	
RHAMNACEAE									
Cryptandra amara	1	E	-	-	-	-	-	-	-
Discaria pubescens [*D. australis*]	2.5	E	-	-	-	-	-	-	-
Pomaderris angustifolia	3	vC	-	√	-	-	1	0	0
P. betulina	3	vC	-	√	-	-	1	0	0
P. eriocephala	3	vC	√	-	-	-	1	0	0
ROSACEAE									
**Rosa rubiginosa*		xBCD	√	√	√	√	33	2	1
Rubus parvifolius		vDE	-	√	-	-	6	0	0
**Rubus* spp. (blackerrries)		xBC	√	√	√	¸	36	5	1
RUTACEAE									
Correa reflexa [*C. speciosa*]	1.5	E	-	-	-	-	-	-	-
Eriostemon myoporoides	2	D	-	-	-	-	-	-	-
E. trachyphyllus	7	vB	√	-	-	-	1	0	0
Zieria cytisoides	3	v	√	-	-	-	1	0	0
SANTALACEAE									
Exocarpos cuppressiformis	8	xABCD	√	√	√	-	18	6	1
E. strictus	3.5	xCE	√	√	-	-	4	0	0

SAPINDACEAE									
Dodonaea viscosa spp. *angustifolia*	5	x }	√	√	-	-	2	0	0
D. viscosa spp. *angustissima*	4	v } ABC	√	√	√	-	5	2	0
D. viscosa spp. *cuneata*	3	x }	√	√	-	-	2	0	0
SIMAROUBACEAE									
**Ailanthus altissima*	to 8 (tree)	B	-	-	-	-	-	-	-
SOLANACEAE									
**Lycium ferocissimum*	4	x	-	√	√	√	15	0	0
THYMELAEACEAE									
Pimelea stricta	1.5	v	-	√	-	-	1	0	0
VIOLACEAE									
Hymenanthera dentata	4	vB	-	√	√	-	7	0	1
TOTAL NO. OF TAXA RECORDED	107	35	59	50	10	78	48		
B.Species recorded on adjacent non-granite areas only									
ARALIACEAE									
Astrotricha longifolia	3	v	-	-	-	-	0	1	0
EPACRIDACEAE									
Leucopogon attenuatus	0.6	x	-	-	-	-	0	1	0
L. microphyllus var. *pilibundus*	1	v	-	-	-	-	0	1	0
EUPHORBIACEAE									

Phyllanthus hirtellus	0.8	x	-	-	-	-	0	1	0
FABACEAE									
Acacia gunnii	2	v	-	-	-	-	0	1	0
A. paradoxa	4	x	-	-	-	-	0	2	0
A. terminalis	5	v	-	-	-	-	0	2	0
Pultenaea subternata		x	-	-	-	-	0	2	0
P. sp. F	v	-	-	-	-	0	1	0	
MYRTACEAE									
Kunzea ericoides	5	x	-	-	-	-	0	1	0
Leptospermum continentale	2	v	-	-	-	-	0	0	1
L. multicaule	<2	x	-	-	-	-	0	1	0
PROTEACEAE									
Grevillea ramosissima	3	x	-	-	-	-	0	1	0
Hakea decurrens	3	v	-	-	-	-	0	2	0

1. Sources other than roadside survey:

A. Keith & Benson (1988): *E. fastigata - E. dalrympleana - E. viminalis*; Mt. Blaxland complex; *E. melliodora - E. viminalis; E. radiata - E. dalrympleana* communities east of the Great Dividing Range

B. National Parks & Wildlife Service (undated): Plant species list for Evans Crown Nature Reserve

C. Wakefield (1994): River Lett Hill & Rocks Creek

D. Maiden & Cambage (1909): Mt. Blaxland to O'Connell

E. Clunies Ross (1898): granite areas near Bathurst

2. Soil landscapes as defined by Kovac *et al.* (1990) Pm = Pine Mountain Ro=Rocks (including Marrangaroo and Round Mount landscapes of King

1993, 1994)

Ba = Bathurst Ra = Raglan

3. Frequencies are relative only as sample size varied and sites with only naturalised shrubs were not sampled.