Chapter 4: Community Analysis and Interpretation

South Bald Rock in Girraween National Park – holds a variety of communities including Closed Forest within deep crevices

Chapter 4

Community Analysis and Interpretation

4.1 Introduction

Studies concentrating on the vegetation of granitic outcrops have been undertaken throughout the world (e.g. Whitehouse 1933; Oosting & Anderson 1937; McVaugh 1943; Keever *et al.* 1951; Keever 1957; Hambler 1964; Murdy *et al.* 1970; Sharitz & McCormick 1973; Rundel 1975; Shure & Ragsdale 1977;Wyatt 1977; Phillips 1981; Wyatt 1981; Baskin & Baskin 1982; Phillips 1982; Walters 1982; Burbank & Phillips 1983; Wyatt 1984a, b; Uno & Collins 1987; Baskin & Baskin 1988; Houle & Phillips 1988; Houle & Phillips 1989a, b; Houle 1990; Porembski *et al.* 1994; Ibisch *et al.* 1995; Porembski 1995; Porembski *et al.* 1995; Porembski *et al.* 1996). Research into outcrops, and in particular granitic outcrops, has culminated in the formation of the 'Inselberg-Projeckt' supported by the Deutsche Forschungsge-meinschaft (Porembski *et al.* 1994). Outcrops have been chosen worldwide for research as they constitute clearly delimited systems suited for testing hypothesis on the maintenance of biodiversity (Porembski *et al.* 1994). In Australia, studies involving the direct investigation of granitic outcrop vegetation have occurred particularly in Western Australia and in Victoria but sparingly in other states and territories (e.g. Gillham 1961; Smith 1961; Ashton & Webb 1977; Hopper 1981; Burgman 1987; Kirkpatrick *et al.* 1988; Norris & Thomas 1991; Pignatti & Pignatti 1994). Overall the systematic study of the regional floristics of granitic outcrops is only a recent research focus (Hopper 1999).

Very few studies have described the communities on granitic outcrops in the eastern states. Beadle (1981) separately describes granitic outcrop communities from Western Australia and Victoria based on work carried out by Beard (1974a, b; 1975a, b; 1976; 1981) and Ashton and Webb (1977), and various other rocky outcrop communities in general. Very little is written about the extensive outcrop communities on the New

England Batholith, with the only statement being; 'In some areas where large granitic tors occur, some unusual species are found'.

Some studies undertaken on the vegetation of the New England Batholith have examined granitic outcrop communities, although indirectly in many instances (Maiden 1906; Williams 1969; Williams 1972; Roberts 1983; Williams 1991a, b; Williams & Wissman 1991; Binns 1992; Williams 1992a, b; Williams 1994; Binns 1995a; Clarke *et al.* 1995; Le Brocque & Benson 1995; McDonald *et al.* 1995; NSW NPWS 1995; Benson & Ashby 1996; Clarke *et al.* 1998; Hosking & James 1998; Hunter 1998b, c; Hunter *et al.* 1999). Some of these investigations have been on specific species that occur on granitic outcrops within the New England Batholith (Benson 1992; Hunter 1992; Hunter & Williams 1994; Hunter 1995; Hunter & Bruhl 1996; Hunter *et al.* 1996; Richards 1996; Hunter 1997a, b, c; Richards & Hunter 1997; Hunter 1998b; Hunter *et al.* 1998).

This chapter presents a descriptive account of the vegetation communities that occur on granitic outcrops of the New England Batholith based on semi-quantitative sampling and numerical analysis. The complicating affects that individual taxa have on the structural description of communities either due to chance occurrence or previous fire history is discussed along with issues regarding reservation and exotic species.

4.2 Methods

4.2.1 Data analysis

Analysis and data exploration was performed using options available in the PATN Analysis Package (Belbin 1995a, b). For final presentation of results, all species and their relative abundance scores were used and the analysis was performed using the Kulczynski association measure that is recommended for ecological applications (Belbin 1995a, b). For further explanation of these techniques see Section 3.2.2.

The number of groups chosen for recognition was based on a number of *a priori* methods. The point at which a leveling of a scree plot of dissimilarity and number of fusion points occurs can be an indication of the optimal cut off point. At such a point, many clusters are formed at essentially the same linkage distance. Binns (1995a) using PATN and Kulczynski described communities in the same area using a dissimilarity of *c.* 0.8 for a cut off point.

4.2.2 Nomenclature

Species lists were compiled solely from work carried out during this survey. Community names are based on the two most frequently important (sum of all abundance scores) native taxa in terms of prominence (fidelity x abundance), in the most consistent dominant stratum. Structural names follow the scheme of Specht *et al.* (1995) and are based on the most consistent uppermost stratum. The status of Australian reserves as mentioned in this chapter is discussed in Benson (1999).

4.3 Results

4.3.1 Floristics

In total, 671 vascular plant taxa from 307 genera and 99 families were recorded during the survey of granite outcrops. Only 38 taxa were exotic in origin, representing 6% of the total flora surveyed. The most common exotic taxa were *Hypochaeris radicata*, *Bidens pilosa*, *Opuntia aurantiaca*, *Conyza bonoriensis*, and *Trifolium repens*.

The ten most commonly encountered taxa on granitic outcrops on the New England Batholith were: *Cheilanthes sieberi* subsp. *sieberi* (55% of sites), *Entolasia stricta* (48%), *Leucopogon neo-anglicus* (45%), *Trachymene incisa* (42%), *Hypochaeris radicata* (40%), *Tripogon loliiformis* (39%), *Lepidosperma laterale* (38%), *Aristida jerichoensis* (37%), *Gonocarpus teucrioides* (36%) and *Leptospermum novae-angliae* (36%). Eight of the ten most commonly occurring taxa were herbaceous in nature, and only two represented shrubby taxa. Ten or more taxa were found in four genera:

Acacia (35), *Eucalyptus* (24), *Pterostylis* (13) and *Hibbertia* (13). Furthermore ten or more taxa were found in 13 families: Fabaceae (74), Poaceae (64), Myrtaceae (58), Asteraceae (55), Orchidaceae (36), Cyperaceae (24), Epacridaceae (23), Proteaceae (23), Rutaceae (21), Euphorbiaceae (20), Lamiaceae (15), Dilleniaceae (13), and Apiaceae (10).

4.3.2 Outcrop ('island') communities

Twenty-eight vascular plant communities were defined in nine major elements (Figure 4.1 & 4.2). The nine elements were defined at the dissimilarity level of 1.00. These nine elements coincided with the intuitive assessment of the authors. A summarised dendrogram produced by the Kulczynski association measure and flexible UPGMA clustering is shown in Figure 4.2. An additional 29th community that is totally distinct, but was not quantitatively sampled due to its rarity and inaccessibility.

In the following list of plant communities up to ten taxa are listed for each growth-form category. These taxa are listed in decreasing order of summed abundances within each community. The listing of restricted taxa is also based on decreasing summed abundances. Overall fidelity (percentage of quadrats) within the community is also given within brackets next to each taxon.

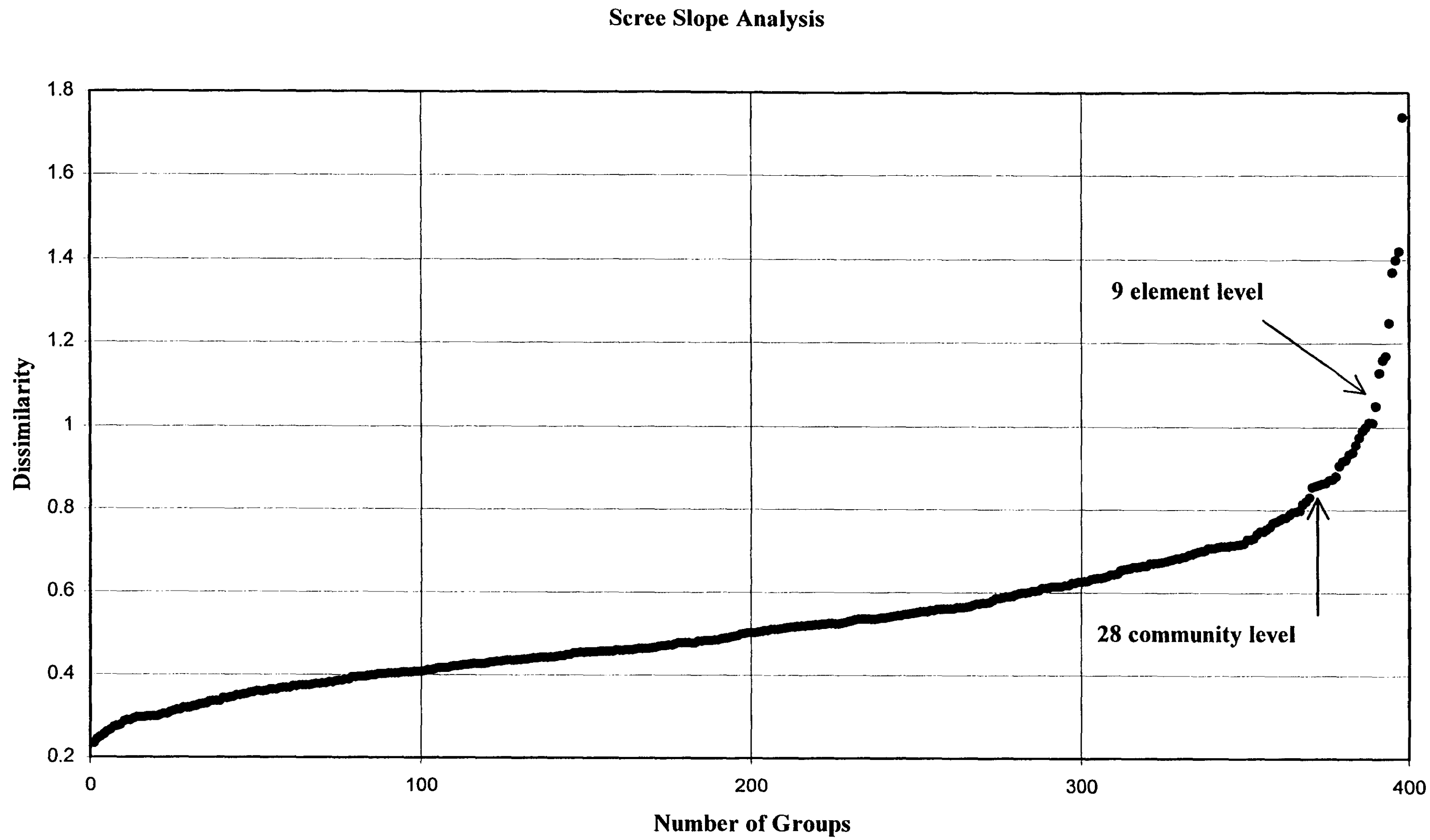


Figure 4.1: Scree plot of Kulczynski association measure and the flexible UPGMA fusion strategy results based on all outcrop ('island') plots surveyed (399 in total).

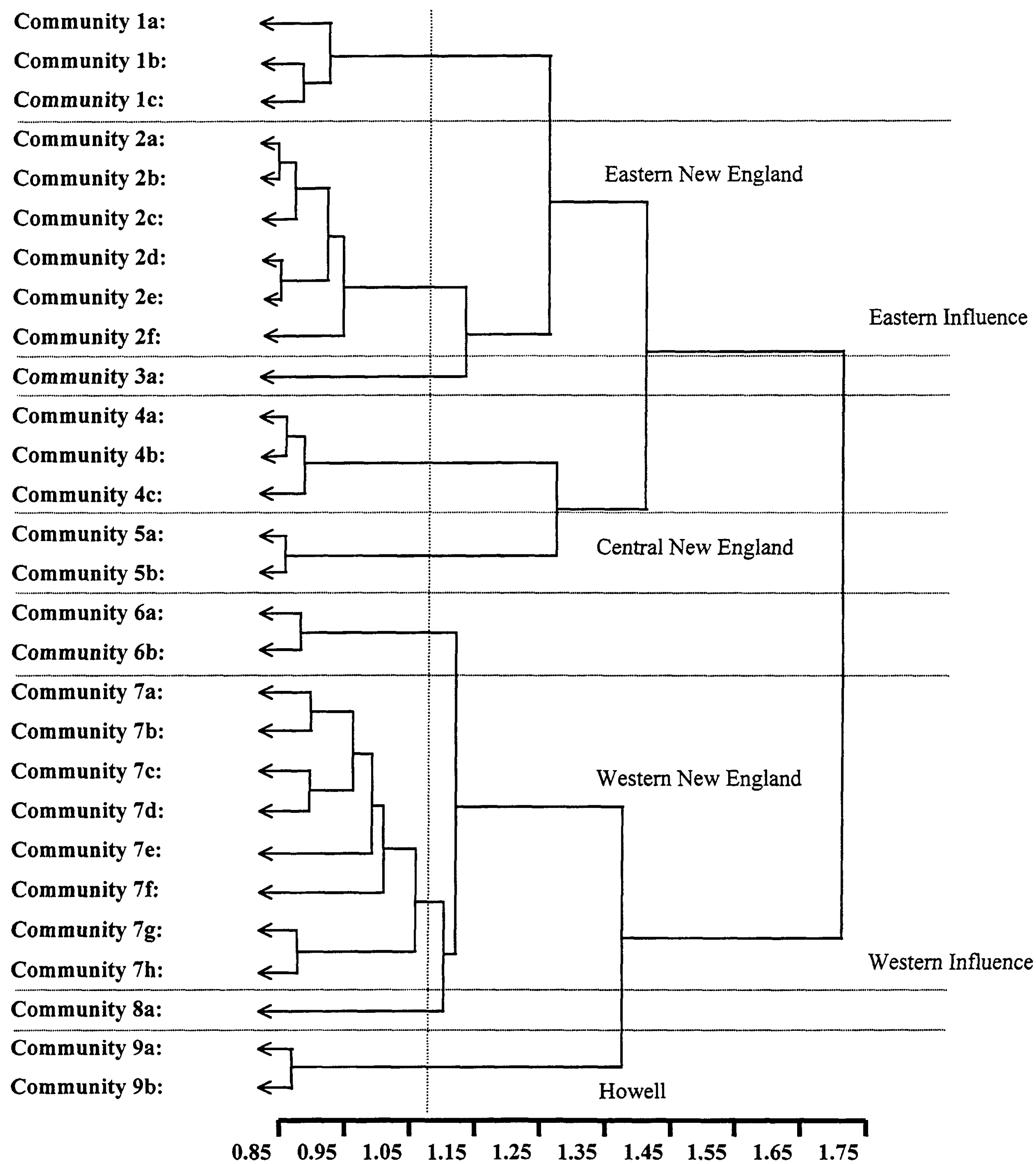


Figure 4.2: Summary dendrogram of 28 floristic communities in nine major Elements found on outcrops ('islands'), based on Kulczynski association and flexible UPGMA fusion (Section 4.2.1).

Table 4.1: Selected attributes of each of the 29 communities defined by analysis and one additional recognised community.

Community Number	Number of Samples	Dominant Taxa	Common Structural Type	Locality	Number of Taxa	Mean Taxa Per Sample	Number of Exotic Taxa
1a	16	*Leptospermum novae-angliae – Kunzea obovata*	Heathland	BC	126	40	3
1b	14	*Kunzea obovata*	Heathland	BC BL	104	30	3
1c	22	*Leptospermum novae-angliae*	Heathland	BC	117	32	3
2a	5	*Leptospermum novae-angliae – Brachyloma saxicola*	Heathland	BL CH GR DM	133	44	-
2b	4	*Acacia viscidula – Kunzea opposita*	Heathland	JB	67	39	1
2c	3	*Leptospermum novae-angliae – Leucopogon cicatricatus*	Heathland	CR	47	24	1
2d	31	*Leptospermum novae-angliae – Acacia latisepala*	Heathland	BR DM JB	202	29	7
2e	7	*Leptospermum novae-angliae – Dodonaea viscosa*	Heathland	BR	107	29	4
2f	21	*Kunzea bracteolata – Leucopogon melaleucoides*	Heathland	BR	103	19	5
3a	23	*Kunzea bracteolata – Leptospermum novae-angliae*	Heathland	GR	147	36	3
4a	14	*Leucopogon neo-anglicus – Micromyrtus sessilis*	Shrubland	BH CH GR	99	28	1
4b	38	*Prostanthera staurophylla – Kunzea bracteolata*	Shrubland	TT	169	33	2
4c	2	*Babingtonia odontocalyx – Brachyloma saxicola*	Shrubland	TT	42	27	1
5a	23	*Calytrix tetragona – Leptospermum novae-angliae*	Shrubland	KP SR WW	134	33	1
5b	11	*Allocasuarina brachystachya*	Shrubland	SR	98	44	-
6a	2	*Cymbopogon refractus – Tripogon loliiformis*	Grassland	AT	67	48	10
6b	10	*Prostanthera nivea – Acacia viscidula*	Shrubland	MB	98	32	12
7a	12	*Cheilanthes sieberi – Brachyscome stuartii*	Herbfield	BH EC KP TT WB	150	33	3
7b	4	*Leptospermum brevipes – Calytrix tetragona*	Shrubland	ML	36	36	2
7c	6	*Gonocarpus teucrioides – Isotoma axillaris*	Herbfield	HC WB	85	29	1
7d	4	*Calytrix tetragona – Cryptandra amara subsp. amara*	Shrubland	SR	86	37	4
7e	9	*Calytrix tetragona – Kunzea obovata*	Shrubland	PM	100	36	2
7f	15	*Calytrix tetragona – Ozothamnus obcordatus*	Shrubland	IB	117	28	2
7g	44	*Cheilanthes sieberi – Arthropodium milleflorum*	Herbfield	FR ML SR WB YH	212	31	15
7h	6	*Cheilanthes sieberi – Isotoma axillaris*	Herbfield	FR ML	56	20	5
8a	11	*Aristida vagans – Tripogon loliiformis*	Grassland	KL	101	34	7
9a	33	*Babingtonia densifolia – Homoranthus prolixus*	Shrubland	HC WB	111	29	6
9b	6	*Homoranthus prolixus*	Shrubland	HC	81	43	10
10	-	*Quintinia sieberi-Rapanea* spp.	Closed Scrub	BC BR CR	-	-	-

Element 1: Glen Innes Shrubby Open Scrubs and Closed Heaths

These communities are restricted to high altitude areas north and south east of Glen Innes. Structurally they are mainly closed heaths although the mallee *Eucalyptus codonocarpa* may be present forming shrubby open scrubs. Occasionally other tree species occur, such as *Eucalyptus andrewsii*, *E. campanulata*, *E. williamsiana*, and *E. cameronii*, giving a shrubby low open woodland structure. In some instances *Leptospermum novae-angliae* at its tallest and densest will form closed scrub.

Community 1a: *Leptospermum novae-angliae - Kunzea obovata* heath (Warra Heaths).

Geology: Oban River Leucoadamellite.

Trees: *Eucalyptus codonocarpa* (56%), *E. acaciiformis* (38%), *E. caliginosa* (31%).

Shrubs: *Platysace lanceolata* (94%), *Leptospermum novae-angliae* (100%), *Kunzea obovata* (94%), *Leucopogon neo-anglicus* (81%), *Allocasuarina rigida* subsp. *rigida* (69%), *Acacia ulicifolia* (81%), *A. venulosa* (63%), *Mirbelia confertiflora* (69%), *Hovea* sp. A (88%), *Dillwynia phylicoides* (63%).

Herbs: *Entolasia stricta* (100%), *Monotaxis macrophylla* (75%), *Gonocarpus teucrioides* (75%), *Muehlenbeckia costata* (69%), *Lepidosperma gunnii* (75%), *Actinotus gibbonsii* (81%), *Schoenus apogon* (81%), *Stypandra glauca* (56%), *Dampiera stricta* (56%), *Gonocarpus micranthus* (50%).

Restricted taxa: *Monotaxis macrophylla*, *Muehlenbeckia costata*, *Mirbelia confertiflora*, *Eucalyptus codonocarpa*, *Brachyloma saxicola*, *Leionema ambiens*, *Phebalium ozothamnoides*.

Threats and conservation status: This community has been little degraded and almost all surveyed occurrences are within Crown Mountain Flora Reserve (Warra State Forest) and adjacent private properties. No occurrences are reserved in National Parks. A large-scale *Cannabis* plantation, burnt out in 1994, that has caused disturbance within Reserve including outcrop areas. This habitat is potentially threatened by goats, grazing of domestic stock, and hobby farm subdivisions that are nearby Warra State Forest.

Community 1b: *Kunzea obovata* heath (Butterleaf Heaths).

Geology: Kingsgate Granite & Oban River Leucoadamellite.

Trees: *Eucalyptus codonocarpa* (39%), *E. andrewsii* (15%), *E. williamsiana* (15%), *E. campanulata* (8%), *Allocasuarina littoralis* (54%).
Shrubs: *Leucopogon neo-anglicus* (85%), *Kunzea obovata* (92%), *Leptospermum novae-angliae* (77%), *Philotheca myoporoides* subsp. *epilosum* (77%), *Brachyloma saxicola* (69%), *Calytrix tetragona* (31%), *Hibbertia riparia* (31%), *Acacia viscidula* (39%), *Allocasuarina rigida* subsp. *rigida* (39%), *Acacia venulosa* (54%), *Epacris microphylla* (23%).
Herbs: *Brachyscome stuartii* (85%), *Schoenus apogon* (92%), *Lepidosperma gunnii* (85%), *Entolasia stricta* (77%), *Gonocarpus micranthus* (54%), *Austrodanthonia monticola* (46%), *Cheilanthes sieberi* (46%), *Trachymene incisa* (39%), *Gonocarpus oreophilus* (46%), *Empodisma minus* (54%).
Restricted taxa: *Philotheca myoporoides* subsp. *epilosum, Brachyloma saxicola, Eucalyptus codonocarpa, Leucopogon cicatricatus, Cryptandra lanosiflora, Mirbelia confertiflora, Muehlenbeckia costata, Monotaxis macrophylla, Lasiopetalum ferrugineum* var. *cordatum.*
Threats and conservation status: Much of this community is in private ownership. However Mount Scott, one of the largest outcrops on the New England Batholith, is within Butterleaf State Forest parts of which have been designated as preserved native forest by the State Forests of New South Wales. One site also occurs within Crown Mountain Flora Reserve. This community is not reserved in National Parks. The community may be threatened by disturbance from goats and grazing of domestic stock.

Community 1c: *Leptospermum novae-angliae* Heath (Backwater Heaths).
Geology: Oban River Leucoadamellite.
Trees: *Eucalyptus codonocarpa* (36%), *E. caliginosa* (18%), *E. dalrympleana* (5%).
Shrubs: *Leptospermum novae-angliae* (96%), *Leucopogon neo-anglicus* (91%), *Kunzea obovata* (91%), *Brachyloma saxicola* (91%), *Prostanthera scutellarioides* (77%), *Allocasuarina rigida* subsp. *rigida* (68%), *Calytrix tetragona* (64%), *Mirbelia confertiflora* (86%), *Hibbertia acicularis* (74%), *Boronia anemonifolia* (64%).
Herbs: *Lepidosperma gunnii* (82%), *Gonocarpus teucrioides* (86%), *Entolasia stricta* (82%), *Brachyscome stuartii* (73%), *Austrodanthonia monticola* (68%), *Lomandra longifolia* (59%), *Gahnia sieberiana* (55%), *Empodisma minus* (36%), *Trachymene incisa* (55%), *Schoenus apogon* (59%).

Restricted taxa: *Brachyloma saxicola*, *Mirbelia confertiflora*, *Cryptandra lanosiflora*, *Eucalyptus codonocarpa*, *Pseudanthus divaricatissimus*, *Thelionema grande*, *Cyphanthera albicans* subsp. *albicans*.

Threats and conservation status: No sites of this community type are known within the current reservation system. Off park reservation is provided by a conservation agreement on the property 'Wattleridge'. Community 1c is potentially threatened by change in land ownership, hobby farms, goats and grazing by domestic stock.

Element 2: New England Escarpment Shrubby Open Scrubs and Heaths.

Structurally these communities are mainly closed heaths. As with element one the mallee, *Eucalyptus codonocarpa* may be present, giving the appearance of shrubby open scrubs. Similarly, many other eucalypt species may sporadically occur such as *Eucalyptus cameronii*, *E. andrewsii*, *E. banksii* and *E. caliginosa* giving a shrubby low open woodland structure. Occasionally *Leptospermum novae-angliae* at its tallest and densest will form closed scrub. This element is widespread along the eastern escarpment of the New England Batholith from north of Tenterfield to east of Armidale.

Community 2a: *Leptospermum novae-angliae - Brachyloma saxicola* Heathland (Escarpment Heaths).

Geology: Kingsgate Granite, Chaelundi Complex – Granite, Stanthorpe Adamellite, Dandahra Creek Granite.

Trees: *Eucalyptus codonocarpa* (20%), *E. cameronii* (20%), *E. bridgesiana* (20%), *E. andrewsii* (20%), *E. campanulata* (20%), *E. scias* subsp. *apoda* (20%), *Allocasuarina torulosa* (20%).

Shrubs: *Leptospermum novae-angliae* (60%), *Leucopogon neo-anglicus* (40%), *Brachyloma saxicola* (80%), *Boronia anethifolia* (60%), *Monotoca scoparia* (100%), *Kunzea bracteolata* (20%), *Pimelea linifolia* (60%), *Callitris monticola* (20%), *Acacia falciformis* (40%), *Leucopogon lanceolatus* (80%), *Acrotriche aggregata* (20%).

Herbs: *Lomandra longifolia* (100%), *Gonocarpus oreophilus* (80%), *Entolasia stricta* (100%), *Patersonia sericea* (60%), *Xanthorrhoea glauca* (40%), *Trachymene incisa* (60%), *Lepidosperma neesii* (20%), *Caustis flexuosa* (20%), *Stylidium laricifolium* (20%), *Dianella tasmanica* (60%).

Restricted taxa: *Brachyloma saxicola, Kunzea bracteolata, Eucalyptus codonocarpa, Muehlenbeckia costata, Bertya cunninghamii, Philotheca myoporoides* subsp. *epilosum, Leucopogon cicatricatus, Acacia floydii, Acianthus apprimus, Eucalyptus scias* subsp. *apoda.*

Threats and conservation status: Four of the five sites surveyed are reserved. The sites are within Gibraltar Range National Park, Guy Fawkes River National Park, Demon Nature Reserve and one of the sites at Butterleaf State Forest is within preserved native forest under the control of State Forests of New South Wales. Patches on private land are little disturbed, although areas close to cleared grazing lands are prone to disturbance from cattle and the spread of weeds.

Community 2b: *Acacia viscidula - Kunzea opposita* Heath (Jondol Heaths).

Geology: Billyrimba Leucoadamellite.

Trees: *Eucalyptus andrewsii* (100%), *Allocasuarina littoralis* (75%), *Eucalyptus brunnea* (25%).

Shrubs: *Acacia viscidula* (100%), *Leucopogon neo-anglicus* (100%), *Kunzea opposita* (75%), *Platysace lanceolata* (75%), *Leptospermum novae-angliae* (75%), *Prostanthera nivea* (50%), *Brachyloma saxicola* (75%), *Zieria cytisoides* (50%), *Acrotriche aggregata* (100%), *Mirbelia speciosa* subsp. *speciosa* (50%).

Herbs: *Lomandra longifolia* (100%), *Trachymene incisa* (100%), *Entolasia stricta* (75%), *Stylidium laricifolium* (75%), *Gonocarpus teucrioides* (75%), *Austrodanthonia linkii* (50%), *Laxmannia compacta* (50%), *Bulbostylis densa* (75%), *Stypandra glauca* (50%), *Digitaria breviglumis* (50%).

Restricted taxa: *Brachyloma saxicola, Persoonia rufa, Leionema dentatum.*

Threats and conservation status: This community not known to be within any reserve. Forest Lands State Forest (JB) was recently logged in 1994; however the outcrops within it are relatively undisturbed.

Community 2c: *Leptospermum novae-angliae - Leucopogon cicatricatus* Heath (Round Mountain Heaths).

Geology: Round Mountain Leucoadamellite.

Trees: *Eucalyptus caliginosa* (67%), *Banksia integrifolia* (33%).

Shrubs: *Leptospermum novae-angliae* (100%), *Leucopogon cicatricatus* (100%), *Leucopogon neo-anglicus* (100%), *Epacris microphylla* (67%), *Monotoca scoparia*

(67%), *Platysace lanceolata* (100%), *Leucopogon lanceolatus* (67%), *Comesperma sylvestre* (33%), *Prostanthera scutellarioides* (33%), *Elaeocarpus holopetalus* (33%).
Herbs: *Trachymene incisa* (100%), *Carex gaudichaudiana* (100%), *Eragrostis brownii* (67%), *Trachymene incisa* (33%), *Poa sieberiana* (100%), *Brachyscome stuartii* (33%), *Lepidosperma laterale* (100%), *Dianella caerulea* (33%), *Austrodanthonia monticola* (33%), *Gahnia sieberiana* (100%).
Restricted species: *Leucopogon cicatricatus, Eucalyptus codonocarpa.*
Threats and conservation status: All sites surveyed are within Cathedral Rock National Park. Due to the dissected nature of these outcrops, visitor impact is minimal despite high visitor frequency in some areas.

Community 2d: *Leptospermum novae-angliae – Acacia latisepala* Heath (Granite Belt Heaths).
Geology: Stanthorpe Adamellite, Billyrimba Leucoadamellite.
Trees: *Eucalyptus andrewsii* (32%), *E. banksii* (29%), *E. prava* (13%), *E. campanulata* (6%), *E. scias* subsp. *apoda* (6%), *Callitris endlicheri* (6%), *E. dealbata* (6%), *E. scoparia* (3%).
Shrubs: *Philotheca myoporoides* subsp. *epilosum* (61%), *Leptospermum novae-angliae* (71%), *Acacia latisepala* (55%), *Dodonaea viscosa* (48%), *Acacia adunca* (26%), *Leptospermum polygalifolium* subsp. *transmontanum* (58%), *Leucopogon neo-anglicus* (45%), *Kunzea bracteolata* (29%), *Leucopogon melaleucoides* (48%), *Leionema rotundifolium* (23%).
Herbs: *Lomandra longifolia* (100%), *Entolasia stricta* (87%), *Trachymene incisa* (84%), *Gonocarpus oreophilus* (61%), *Lepidosperma laterale* (55%), *Brachyscome stuartii* (29%), *Calandrinia pickeringii* (36%), *Digitaria breviglumis* (35%), *Stylidium laricifolium* (45%), *Stypandra glauca* (32%).
Restricted taxa: *Philotheca myoporoides* subsp. *epilosus*, *Acacia latisepala*, *Acacia adunca*, *Kunzea bracteolata*, *Leionema rotundifolium*, *Muehlenbeckia costata*, *Leionema ambiens*, *Prostanthera* sp. B, *Thelionema grande*, *Callitris monticola*, *Eucalyptus scias* subsp. *apoda*, *Plectranthus suaveolens*, *Homoranthus papillatus*, *H. lunatus*, *Callistemon flavovirens*, *Acacia floydii*, *A. macnuttiana*.
Threats and conservation status: This community is reserved within Girraween, Bald Rock and Boonoo Boonoo National Parks and Demon Nature Reserve.

Community 2e: *Leptospermum novae-angliae – Dodonaea viscosa* Heathland (Granite Belt Heaths).

Geology: Stanthorpe Adamellite.

Trees: *Allocasuarina littoralis* (14%), *Eucalyptus codonocarpa* (14%), *E. campanulata* (29%), *Eucalyptus banksii* (14%), *Eucalyptus dalrympleana* (14%).

Shrubs: *Leptospermum novae-angliae* (86%), *Philotheca myoporoides* subsp. *epilosum* (86%), *Dodonaea viscosa* (57%), *Acacia viscidula* (57%), *Acacia venulosa* (29%), *Kunzea bracteolata* (29%), *Leptospermum variable* (14%), *Plectranthus suaveolens* (14%), *Acrotriche aggregata* (29%), *Leucopogon lanceolatus* subsp. *lanceolatus* (43%).

Herbs: *Schoenus apogon* (100%), *Lepidosperma laterale* (86%), *Entolasia stricta* (71%), *Trachymene incisa* (71%), *Brachyscome stuartii* (100%), *Gonocarpus oreophilus* (57%), *Bulbostylis densa* (43%), *Austrodanthonia linkii* (43%), *Gonocarpus micranthus* (29%), *Actinotus gibbonsii* (29%).

Restricted taxa: *Philotheca myoporoides* subsp. *epilosum, Kunzea bracteolata, Plectranthus suaveolens, Thelionema grande, Acacia latisepala, Eucalyptus codonocarpa, Homoranthus papillatus, Mirbelia confertiflora, Muehlenbeckia costata, Callitris monticola, Leionema ambiens.*

Threats and conservation status: This community is reserved in Girraween and Bald Rock National Parks.

Community 2f: *Kunzea bracteolata – Leucopogon melaleucoides* Heathland (Granite Belt Heaths).

Geology: Stanthorpe Adamellite.

Trees: *Callitris endlicheri* (33%), *Eucalyptus banksii* (10%), *E. dealbata* (14%), *E. prava* (5%), *E. radiata* (5%), *E. campanulata* (5%), *E. codonocarpa* (5%), *E. dalrympleana* (5%), *E. scoparia* (5%).

Shrubs: *Kunzea bracteolata* (100%), *Leucopogon neo-anglicus* (90%), *Philotheca myoporoides* subsp. *epilosum* (76%), *Leucopogon melaleucoides* (81%), *Leionema ambiens* (29%), *Leptospermum novae-angliae* (38%), *Acacia adunca* (29%), *Callistemon pallidus* (24%), *Pimelea linifolia* (19%), *Leptospermum polygalifolium* subsp. *transmontanum* (24%).

Herbs: *Trachymene incisa* (100%), *Lomandra longifolia* (95%), *Lepidosperma laterale* (52%), *Brachyscome stuartii* (52%), *Entolasia stricta* (43%), *Crassula sieberiana*

(43%), *Schoenus apogon* (29%), *Thelionema grande* (38%), *Gahnia sieberiana* (38%), *Gonocarpus teucrioides* (24%).

Restricted taxa: *Kunzea bracteolata*, *Philotheca myoporoides* subsp. *epilosus*, *Thelionema grande*, *Leionema ambiens*, *Acacia adunca*, *Phebalium rotundifolium*, *Acacia latisepala*, *Leucopogon cicatricatus*, *Prostanthera* sp. B, *Callitris monticola*, *Eucalyptus codonocarpa*, *E. scoparia*, *Muehlenbeckia costata*, *Plectranthus suaveolens*.

Threats and conservation status: This community is reserved within Girraween and Bald Rock National Parks.

Element 3: Gibraltar Range Shrubby Open Scrubs and Heaths.

This community is composed mainly of heaths although the mallee, *Eucalyptus codonocarpa*, is present in a few localities forming shrubby open scrub. Tree species such as *Eucalyptus notabilis, E. ligustrina*, *E. radiata* and *E. acaciiformis* may occur giving the appearance of shrubby low open woodland structure.

Community 3a: *Kunzea bracteolata - Leptospermum novae-angliae* Heath (Gibraltar Range Heaths).

Geology: Dandahra Creek Granite.

Trees: *Eucalyptus codonocarpa* (35%), *E. notabilis* (35%), *E. ligustrina* (35%), *E. radiata* (4%), *E. acaciiformis* (4%).

Shrubs: *Kunzea bracteolata* (91%), *Leucopogon neo-anglicus* (87%), *Leptospermum novae-angliae* (87%), *Callistemon comboynensis* (65%), *Calytrix tetragona* (57%), *Allocasuarina rigida* subsp. *rigida* (78%), *Platysace ericoides* (57%), *Grevillea acerata* (65%), *Epacris microphylla* (39%).

Herbs: *Lepidosperma gunnii* (87%), *Lepidosperma laterale* (91%), *Entolasia stricta* (96%), *Trachymene incisa* (83%), *Laxmannia compacta* (83%), *Lomandra longifolia* (65%), *Schoenus melanostachys* (39%), *Aristida ramosa* (52%), *Xanthorrhoea glauca* (65%), *Schoenus apogon* (48%).

Restricted taxa: *Grevillea acerata*, *Mirbelia confertiflora*, *Acacia brunioides* subsp. *brunioides*, *Brachyloma saxicola*, *Eucalyptus codonocarpa*, *Persoonia rufa*, *Callitris monticola*, *Cryptandra lanosiflora*, *Acacia* sp. aff. *torringtonensis*, *Hibbertia villosa*, *Leionema dentatum*, *Acacia barringtonensis*.

Threats and conservation status: This community occurs within Gibraltar Range National Park and is in most instances relatively undisturbed. Some localities have had minor damage by stray cattle from neighbouring properties.

Element 4: Central New England Shrublands.

Low shrubs dominate these communities which are more open in structure than the previous two elements forming shrubby low open shrublands. Taller shrubs such as *Acacia pycnostachya*, *Leptospermum novae-angliae* and *Kunzea bracteolata* may be present but they rarely dominate as they do in elements one and two. *Callitris endlicheri* and various eucalypt species such as *Eucalyptus prava* may also be present giving the appearance of shrubby low open woodland. The latter structure is particularly apparent at Torrington where the granite outcrops are highly dissected.

Community 4a: *Leucopogon neo-anglicus* - *Micromyrtus sessilis* Low Shrubland (Bolivia Hill Shrublands).

Geology: Bolivia Range Leucoadamellite, Chaelundi Complex (Granite), Mount Mitchell Adamellite (Porphyritic).

Trees: *Callitris endlicheri* (50%), *Eucalyptus prava* (36%), *E. caliginosa* (14%), *E. dealbata*, *E. bridgesiana* (7%).

Shrubs: *Leucopogon neo-anglicus* (100%), *Micromyrtus sessilis* (100%), *Kunzea bracteolata* (71%), *Boronia anethifolia* (71%), *Kunzea obovata* (57%), *Leptospermum novae-angliae* (36%), *Acacia viscidula* (57%), *Acacia pycnostachya* (64%), *Leptospermum brevipes* (36%), *Cryptandra lanosiflora* (43%).

Herbs: *Digitaria breviglumis* (100%), *Gonocarpus teucrioides* (100%), *Austrodanthonia monticola* (79%), *Entolasia stricta* (93%), *Bulbostylis densa* (100%), *Lepidosperma laterale* (86%), *Brachyscome stuartii* (86%), *Tripogon loliiformis* (79%), *Cheilanthes sieberi* (86%), *Lepidosperma gunnii* (64%).

Restricted taxa: *Kunzea bracteolata*, *Acacia pycnostachya*, *Cryptandra lanosiflora*, *Philotheca myoporoides* subsp. *epilosum*, *Brachyloma saxicola*, *Acacia adunca*, *Mirbelia confertiflora*, *Boronia boliviensis*, *Thelionema grande*, *Homoranthus croftianus*.

Threats and conservation status: This community is almost entirely in freehold ownership with only minor occurrences in Guy Fawkes River National Park. The community is relatively undisturbed but is threatened by feral goats and changes in ownership. The area is under investigation for purchase by the National Parks and Wildlife Service of New South Wales.

Community 4b: *Prostanthera staurophylla - Kunzea bracteolata* Low Shrubland (Torrington Shrublands).

Geology: Mole Granite (rarely porphyritic).

Trees: *Eucalyptus prava* (90%), *Callitris endlicheri* (66%), *Eucalyptus andrewsii* (26%), *Acacia neriifolia* (11%), *Eucalyptus dealbata* (5%).

Shrubs: *Leucopogon neo-anglicus* (100%), *Prostanthera staurophylla* (82%), *Kunzea bracteolata* (53%), *Leptospermum novae-angliae* (58%), *Leucopogon melaleucoides* (74%), *Acacia viscidula* (55%), *Brachyloma saxicola* (58%), *Hibbertia sp.* B (55%), *Micromyrtus sessilis* (24%), *Calytrix tetragona* (21%).

Herbs: *Brachyscome stuartii* (84%), *Entolasia stricta* (87%), *Tripogon loliiformis* (79%), *Digitaria breviglumis* (79%), *Lepidosperma laterale* (68%), *Laxmannia compacta* (74%), *Gonocarpus teucrioides* (50%), *Cheilanthes sieberi* subsp. *sieberi* (79%), *Aristida jerichoensis* (63%), *Isotoma axillaris* (53%).

Restricted taxa: *Prostanthera staurophylla, Kunzea bracteolata, Brachyloma saxicola, Hibbertia* sp. B, *Leionema rotundifolium, Phebalium glandulosum* subsp. *eglandulosum, Acacia latisepala, Dodonaea hirsuta, Philotheca myoporoides* subsp. *epilosum, Micrantheum ericoides, Boronia granitica, Melichrus erubescens, Acacia granitica, Persoonia terminalis* subsp. *terminalis, Leionema ambiens, Pseudanthus ovalifolius, Acacia macnuttiana, Acacia torringtonensis, Acacia betchei, Hakea macrorhyncha, Pultenaea stuartiana, Homoranthus lunatus, Acacia williamsiana.*

Threats and conservation status: This community occurs within Torrington State Recreation Area under the management of the New South Wales National Parks and Wildlife Service. This reserve is at present a multi-purpose reserve that allows many activities to occur and reservation is not as secure as a formal Nature Reserve or National Park. Much of the land has been disturbed in the past by mining, grazing and, in some places, frequent fires. Some mining leases are still under option and may be taken up.

Community 4c: *Babingtonia odontocalyx - Brachyloma saxicola* Shrubland (Torrington Woodlands).

Geology: Mole Granite.

Trees: *Eucalyptus prava* (100%), *Callitris endlicheri* (100%), *Eucalyptus andrewsii* (100%).

Shrubs: *Babingtonia odontocalyx* (100%), *Brachyloma saxicola* (100%), *Leptospermum brevipes* (100%), *Leucopogon biflorus* (100%), *Leucopogon melaleucoides* (100%), *Boronia anethifolia* (50%), *Hibbertia obtusifolia* (50%), *Hibbertia* sp. B (50%), *Styphelia triflora* (100%), *Acacia falciformis* (50%).

Herbs: *Entolasia stricta* (100%), *Calandrinia eremaea* (50%), *Juncus remotiflorus* (50%), *Lobelia gracilis* (50%), *Patersonia sericea* (100%), *Pomax umbellata* (50%), *Trachymene incisa* (100%), *Asplenium flavellifolium* (50%), *Davallia pyxidata* (50%), *Dianella revoluta* (50%)

Restricted taxa: *Babingtonia odontocalyx, Brachyloma saxicola, Hibbertia* sp. B., *Boronia granitica, Persoonia terminalis* subsp. *terminalis, Leionema rotundifolium.*

Threats and conservation status: The community is conserved within the Torrington State Recreation Area. Grazing and inappropriate fire regimes are threats to this community. Although only sampled here by two sites this community is apparently very common in the south western areas of the Torrington pluton (Clarke *et al.* 1998).

Element 5: Severn Shrublands.

These communities are restricted to the northwest of Glen Innes. *Leucopogon neo-anglicus* and *Calytrix tetragona* often dominate forming low open shrublands, or taller species may be present such as *Allocasuarina brachystachya, Allocasuarina inophloia, Acacia williamsiana* or *Micromyrtus grandis* giving a shrubby tall shrubland structure. If *Eucalyptus prava, E. caleyi* or *Callitris endlicheri* are present a shrubby low open woodland structure is apparent.

Community 5a: *Calytrix tetragona – Leptospermum novae-angliae* Shrubland (Kings Plains Shrublands).

Geology: Undifferentiated.

Trees: *Callitris endlicheri* (61%), *Eucalyptus prava* (70%), *E. caleyi* (22%), *Acacia neriifolia* (9%), *Eucalyptus albens* (4%), *E. crebra* (4%), *E. dealbata* (4%), *E. mckieana* (4%).
Shrubs: *Leucopogon neo-anglicus* (96%), *Calytrix tetragona* (91%), *Leptospermum novae-angliae* (100%), *Melichrus urceolatus* (78%), *Cryptandra amara* var. *floribunda* (74%), *Kunzea obovata* (52%), *Allocasuarina brachystachya* (48%), *Leucopogon attenuatus* (70%), *Hibbertia riparia* (44%), *Homoranthus biflorus* (30%).
Herbs: *Tripogon loliiformis* (96%), *Aristida jerichoensis* (96%), *Cheilanthes sieberi* (91%), *Digitaria breviglumis* (87%), *Fimbristylis dichotoma* (74%), *Trachymene incisa* (83%), *Lepidosperma laterale* (87%), *Laxmannia compacta* (83%), *Entolasia stricta* (78%), *Goodenia bellidifolia* (57%).
Restricted taxa: *Allocasuarina brachystachya, Homoranthus biflorus, Acacia torringtonensis, Micromyrtus grandis, Acacia williamsiana, Boronia granitica, Leionema rotundifolium, Astrotricha roddii, Callistemon pungens, Hibbertia* sp. B, *Zieria odorifera, Eucalyptus mckieana.*
Threats and conservation status: Conservation of this community occurs in Kings Plains National Park and Severn River Nature Reserve. Threats to the community include grazing on private property and feral goats across all tenures.

Community 5b: *Allocasuarina brachystachya* Shrubland (Severn Shrublands).
Geology: Undifferentiated.
Trees: *Eucalyptus prava* (82%), *E. caleyi* (64%), *Callitris endlicheri* (27%), *Eucalyptus dealbata* (9%).
Shrubs: *Calytrix tetragona* (100%), *Allocasuarina brachystachya* (100%), *Leucopogon attenuatus* (91%), *Leptospermum novae-angliae* (100%), *Cryptandra amara* var. *floribunda* (91%), *Melichrus urceolatus* (91%), *Aotus subglauca* (91%), *Leucopogon neo-anglicus* (55%), *Acacia torringtonensis* (91%), *Hibbertia riparia* (73%).
Herbs: *Pterostylis daintreana* (82%), *Schoenus apogon* (91%), *Austrodanthonia monticola* (100%), *Goodenia bellidifolia* (91%), *Aristida jerichoensis* (100%), *Trachymene incisa* (82%), *Drosera peltata* (91%), *Entolasia stricta* (82%), *Cheilanthes sieberi* subsp. *sieberi* (82%), *Lepidosperma laterale* (82%).
Restricted taxa: *Allocasuarina brachystachya, Acacia torringtonensis, Persoonia terminalis* subsp. *terminalis, Leionema rotundifolium, Astrotricha roddii, Hibbertia* sp. B, *Acacia williamsiana.*

Threats and conservation status: This community occurs in Severn River Nature Reserve. This reserve is relatively inaccessible and undisturbed, however feral goats are known in the area. Cattle, sheep and goats graze on neighbouring properties.

Element 6: Moonbi Shrublands and Grasslands.

These communities are found north and northwest of Tamworth. Those to the west are mainly graminoid while those near Moonbi often have a shrub component. Occasionally species such as *Eucalyptus prava*, *Ficus rubiginosa*, *Callitris endlicheri*, or *C. glaucophylla* may be present giving the structural appearance of shrubby open scrub or grassy low open woodland. *Triodia scariosa* is also present in patches in the Moonbi area.

Community 6a: *Cymbopogon refractus - Tripogon loliiformis* Grassland (Attunga Grasslands).

Geology: Attunga Creek Adamellite

Trees: *Eucalyptus prava* (50%), *Callitris endlicheri* (100%).

Shrubs: *Canthium odoratum* (100%), *Desmodium brachypodum* (50%), *Melichrus urceolatus* (50%), *Notelaea microcarpa* (50%), *Alphitona excelsa* (50%), *Swainsona galegifolia* (50%).

Herbs: *Cymbopogon refractus* (100%), *Tripogon loliiformis* (100%), *Digitaria brownii* (100%), *Cheilanthes distans* (100%), *Cheilanthes sieberi* subsp. *sieberi* (100%), *Glycine clandestina* (100%), *Paspalidium constrictum* (100%), *Dichondra* sp. A (100%), *Aristida ramosa* (50%), *Aristida vagans* (50%).

Restricted taxa: none recorded.

Threats and conservation status: This community is unreserved. Grazing by goats is the only major threat.

Community 6b: *Prostanthera nivea - Acacia viscidula* Shrubland (Moonbi Shrublands).

Geology: Moonbi Adamellite.

Trees: *Callitris glaucophylla* (80%), *Eucalyptus prava* (50%), *E. dealbata* (20%), *Acacia neriifolia* (80%), *Ficus rubiginosa* (20%), *Brachychiton populneus* (20%).

Shrubs: *Prostanthera nivea* (100%), *Acacia viscidula* (100%), *Zieria cytisoides* (20%), *Hibbertia* sp. "grandiflora" (40%), *Bertya cunninghamii* (30%), *Olearia elliptica* (40%), *Dodonaea viscosa* (20%), *Desmodium brachypodum* (10%), *Correa reflexa* (10%), *Hovea lanceolata* (10%).
Herbs: *Paspalidium constrictum* (100%), *Cheilanthes sieberi* (70%), *Gonocarpus teucrioides* (60%), *Commelina cyanea* (90%), *Arthropodium milleflorum* (100%), *Austrodanthonia linkii* (90%), *Tripogon loliiformis* (80%), *Cyperus fulvus* (100%), *Stypandra glauca* (70%), *Microlaena stipoides* (70%).
Restricted taxa: *Hibbertia* sp. "grandiflora", *Bertya cunninghamii.*
Threats and conservation status: This community is unreserved. The community in the past has been logged for *Callitris*, and at present is disturbed by goats. The community has a relatively high number of exotic species.

Element 7: Western New England Shrublands and Herbfields.

This element is widely distributed down the western portion of the Batholith. These communities are dominated by herbaceous species that may occasionally have a scattered shrub overstorey. *Callitris endlicheri, Eucalyptus prava, E. dealbata* and other low trees or the mallee, *E. quinniorum* may be present giving the appearance of low open woodland.

Community 7a: *Cheilanthes sieberi - Brachyscome stuartii* Herbfield (Eagle Creek Herbfields).

Geology: Bolivia Range Leucoadamellite, Mount Mackenzie Adamellite, Mole Granite, (undifferentiated) Leucoadamellite.
Trees: *Callitris endlicheri* (63%), *Eucalyptus prava* (50%), *E. dealbata* (19%), *E. andrewsii* (25%), *E. albens* (6%), *E. caleyi* (6%).
Shrubs: *Leucopogon neo-anglicus* (69%), *Plectranthus parviflorus* (56%), *Melichrus urceolatus* (69%), *Prostanthera nivea* (50%), *Calytrix tetragona* (31%), *Acacia macnuttiana* (38%), *Cryptandra amara* var. *floribunda* (25%), *Leptospermum novae-angliae* (19%), *Acacia viscidula* (19%), *Kunzea obovata* (13%).
Herbs: *Brachyscome stuartii* (81%), *Cheilanthes sieberi* subsp. *sieberi* (88%), *Tripogon loliiformis* (88%), *Digitaria breviglumis* (75%), *Gonocarpus teucrioides*

(88%), *Fimbristylis dichotoma* (69%), *Aristida jerichoensis* (56%), *Trachymene incisa* (63%), *Entolasia stricta* (75%), *Commelina cyanea* (53%).

Restricted taxa: *Acacia macnuttiana, Callistemon pungens, Acacia pycnostachya, Philotheca myoporoides* subsp. *epilosum, Brachyloma saxicola, Kunzea bracteolata, Acacia adunca, Zieria odorifera, Mirbelia confertiflora.*

Threats and conservation status: This community is unreserved. Most sites are in private ownership except for Severn State Forest near Ashford in New South Wales. Severn State Forest was logged in 1996. Much of the land around Eagle Creek has been severely degraded, with considerable clearing even on the outcrops. Grazing is intense from sheep and goats at Eagle Creek.

Community 7b: *Leptospermum brevipes - Calytrix tetragona* Shrubland (Balala Shrublands).

Geology: Banalasta Adamellite.

Trees: *Eucalyptus prava* (25%).

Shrubs: *Leptospermum brevipes* (100%), *Calytrix tetragona* (100%), *Acacia viscidula* (100%), *Hovea beckeri* (50%), *Zieria cytisoides* (25%), *Cryptandra amara* subsp. *floribunda* (25%), *Dodonaea viscosa* (25%), *Brachyloma daphnoides* subsp. *glabrum* (25%), *Prostanthera nivea* (75%).

Herbs: *Gonocarpus teucrioides* (100%), *Danthonia monticola* (100%), *Cheilanthes sieberi* subsp. *sieberi* (100%), *Crassula sieberiana* (75%), *Stypandra glauca* (50%), *Trachymene incisa* (50%), *Isotoma axillaris* (75%), *Aristida jerichoensis* (25%), *Drosera peltata* (25%), *Cymbopogon refractus* (25%).

Restricted taxa: none recorded.

Threats and conservation status: The community is unreserved. Although protected by the current landholder, changes in ownership may also bring changes in management.

Community 7c: *Gonocarpus teucrioides - Isotoma axillaris* Herbfield (Warrabah Herbfields).

Geology: Gilgai Granite, (undifferentiated) Leucoadamellite.

Trees: *Callitris endlicheri* (83.3%), *Eucalyptus prava* (50%), *Acacia neriifolia* (50%) *Eucalyptus dealbata* (50%), *Acacia falcata* (17%), *Eucalyptus andrewsii* (17%), *E. caleyi* (17%).

Shrubs: *Ozothamnus obcordatus* (100%), *Leucopogon muticus* (83%), *Calytrix tetragona* (50%), *Hibbertia linearis* (67%), *Dodonaea viscosa* (100%), *Persoonia cornifolia* (100%), *Homoranthus prolixus* (17%), *Leucopogon melaleucoides* (17%), *Hovea lanceolata* (17%), *Grevillea ramosissima* (17%).

Herbs: *Gonocarpus teucrioides* (83%), *Isotoma axillaris* (83%), *Cheilanthes sieberi* subsp. *sieberi* (100%), *Aristida jerichoensis* (50%), *Cymbopogon refractus* (50%), *Cyperus fulvus* (50%), *Lepidosperma laterale* (50%), *Pomax umbellata* (67%), *Stypandra glauca* (67%), *Brachyscome stuartii* (83%).

Restricted taxa: *Homoranthus prolixus*, *Zieria odorifera*, *Callistemon pungens*.

Threats and conservation status: This community is unreserved and is threatened by feral goats.

Community 7d: *Calytrix tetragona - Cryptandra amara* subsp. *amara* Shrubland (Severn Shrublands).

Geology: Undifferentiated.

Trees: *Callitris endlicheri* (50%), *Acacia neriifolia* (75%), *Eucalyptus dealbata* (75%), *E. prava* (25%), *E. macrorhyncha* (25%).

Shrubs: *Calytrix tetragona* (100%), *Cryptandra amara* subsp. *amara* (75%), *Melichrus urceolatus* (100%), *Beyeria viscosa* (50%), *Leucopogon meleleucoides* (75%), *Leucopogon muticus* (75%), *Leptospermum brevipes* (75%), *Cassinia uncata* (75%), *Ozothamnus obcordatus* (50%), *Olearia elliptica* (50%).

Herbs: *Cheilanthes sieberi* subsp. *sieberi* (100%), *Cyperus fulvus* (100%), *Aristida jerichoensis* (75%), *Wahlenbergia graniticola* (75%), *Cymbopogon refractus* (100%), *Portulaca filifolia* (75%), *Digitaria breviglumis* (75%), *Arthropodium milleflorum* (75%), *Triodia scariosa* (25%), *Crassula sieberiana* (75%).

Restricted taxa: *Hibbertia* sp. B, *Acacia macnuttiana*, *Olearia gravis*.

Threats and conservation status: This community is unreserved. Threats to the community are mainly from goats and possible changes in management strategies.

Community 7e: *Calytrix tetragona – Kunzea obovata* Shrubland (Parlour Mountain Shrublands).

Geology: Parlour Mountain Leucoadamellite.

Trees: *Eucalyptus prava* (89%), *E. youmanii* (22%), *E. dealbata* (11%).

Shrubs: *Leucopogon neo-anglicus* (100%), *Calytrix tetragona* (100%), *Kunzea obovata* (100%), *Hibbertia riparia* (44%), *Acacia triptera* (44%), *Hibbertia* sp. aff. *monogyna* (56%), *Leucopogon melaleucoides* (78%), *Boronia anethifolia* (44%), *Persoonia cornifolia* (67%), *Prostanthera nivea* (33%).

Herbs: *Austrodanthonia linkii* (100%), *Lepidosperma laterale* (89%), *Digitaria breviglumis* (100%), *Cheilanthes sieberi* (100%), *Entolasia stricta* (89%), *Gonocarpus teucrioides* (89%), *Trachymene incisa* (89%), *Aristida jerichoensis* (89%), *Paspalidium constrictum* (56%), *Lobelia gracilis* (78%).

Restricted taxa: *Hibbertia* sp. aff. *monogyna*, *Mirbelia confertiflora*, *Eucalyptus youmanii*, *Acacia granitica*, *Boronia granitica*.

Threats and conservation status: This community is unreserved. Selective logging has occurred over much of the area and cattle and sheep graze most properties. Furthermore, feral goats and cattle threaten some outcrops.

Community 7f: *Calytrix tetragona – Ozothamnus obcordatus* Shrubland (Ironbark Shrublands)

Geology: (Undifferentiated) Leucoadamellite

Trees: *Callitris endlicheri* (73%), *Eucalyptus prava* (47%), *Acacia neriifolia* (33%), *Eucalyptus dealbata* (20%), *E. quinniorum* (20%), *E. caleyi* (7%), *E. macrorhyncha* (7%).

Shrubs: *Calytrix tetragona* (80%), *Leucopogon neo-anglicus* (40%), *Ozothamnus obcordatus* (53%), *Leptospermum novae-angliae* (40%), *Leucopogon muticus* (67%), *Leptospermum brevipes* (33%), *Cryptandra amara* var. *floribunda* (33%), *Homoranthus bornhardtiensis* (27%), *Prostanthera nivea* (47%), *Boronia anethifolia* (27%).

Herbs: *Cheilanthes sieberi* (100%), *Gonocarpus tetragynus* (93%), *Trachymene incisa* (73%), *Danthonia monticola* (80%), *Tripogon loliiformis* (67%), *Isotoma anethifolia* (73%), *Isolepis hookeriana* (53%), *Brachyscome stuartii* (33%), *Stypandra glauca* (47%), *Hydrocotyle peduncularis* (40%).

Restricted taxa: *Homoranthus bornhardtiensis*, *Eucalyptus quinniorum*, *Cyphanthera albicans* subsp. *albicans*, *Callistemon pungens*.

Threats and conservation status: This community is reserved in Ironbark Nature Reserve. Feral goats and rabbits are in all areas and are the only threat.

Community 7g: *Cheilanthes sieberi* subsp. *sieberi - Arthropodium milleflorum* Herbfield (Flaggy Range Herbfields).

Geology: Tilmunda Adamellite, Banalasta Adamellite, (undifferentiated) Leucoadamellite, Yarrowyck Granodiorite.

Trees: *Callitris endlicheri* (66%), *Acacia neriifolia* (56%), *Eucalyptus prava* (48%), *E. dealbata* (30%), *Callitris glaucophylla* (7%), *Acacia leiocalyx* (18%), *Angophora floribunda* (16%), *Ficus rubiginosa* (14%), *Casuarina cunninghamiana* (2%), *Brachychiton populneus* (7%), *Eucalyptus quinniorum* (7%).

Shrubs: *Leptospermum brevipes* (30%), *Calytrix tetragona* (30%), *Prostanthera nivea* (32%), *Cryptandra amara* var. *floribunda* (43%), *Cassinia quinquefaria* (34%), *Acacia viscidula* (30%), *Leucopogon muticus* (30%), *Ozothamnus obcordatus* (18%), *Homoranthus prolixus* (7%), *Melichrus urceolatus* (35%).

Herbs: *Cheilanthes sieberi* (100%), *Tripogon loliiformis* (93%), *Arthropodium milleflorum* (91%), *Crassula sieberiana* (86%), *Aristida jerichoensis* (86%), *Digitaria breviglumis* (77%), *Calandrinia eremaea* (75%), *Cymbopogon refractus* (64%), *Cyperus fulvus* (57%), *Gonocarpus teucrioides* (43%).

Restricted taxa: *Homoranthus prolixus, Acacia granitica, Kunzea bracteolata, Eucalyptus quinniorum, Eucalyptus youmanii, Acacia williamsiana.*

Threats and conservation status: This community is subject to intense grazing from domestic and feral animals especially goats. Examples of this community are reserved within Warrabah National Park and Mount Yarrowyck Nature Reserve.

Community 7h: *Cheilanthes sieberi* subsp. *sieberi - Isotoma axillaris* Herbfield (Flaggy Range Herbfields).

Geology: Tilmunda Adamellite, Banalasta Adamellite.

Trees: *Acacia neriifolia* (83%), *Callitris endlicheri* (33%), *Eucalyptus prava* (50%), *E. quinniorum* (50%), *E. youmanii* (50%).

Shrubs: *Ozothamnus obcordatus* (33%), *Cassinia quinquefaria* (17%), *Olearia viscidula* (50%), *Persoonia cornifolia* (50%), *Cryptandra amara* var. *floribunda* (33%), *Leptospermum novae-angliae* (33%), *Melichrus urceolatus* (17%), *Acacia ulicifolia* (17%), *Calytrix tetragona* (17%), *Cassinia uncata* (17%), *Correa reflexa* (17%), *Leptospermum brevipes* (17%).

Herbs: *Cheilanthes sieberi* subsp. *sieberi* (83%), *Isotoma axillaris* (67%), *Urtica incisa* (50%), *Crassula sieberiana* (50%), *Austrodanthonia monticola* (100%), *Aristida* *jerichoensis* (33%), *Lobelia gracilis* (67%), *Calandrinia eremaea* (50%), *Lepidosperma laterale* (83%), *Einadia hastata* (33%).

Restricted taxa: *Eucalyptus quinniorum, Eucalyptus youmanii.*

Threats and conservation status: This community is unreserved. Goats are the major threat to this community.

Element 8: Kwiambal Grasslands.

This community is restricted to the area surrounding the junction of the Severn and Macintyre Rivers and is dominated by grasses and other herbaceous taxa. Sparsely distributed shrub species may occasionally occur such as *Melichrus urceolatus* or *Acacia williamsiana* giving the appearance of low open shrubland. *Callitris endlicheri, C. glaucophylla* or eucalypts such as *E. dealbata* or *E. prava* amongst others giving an overall appearance of low open woodland.

Community 8a: *Aristida vagans - Tripogon loliiformis* Grassland (Kwiambal Grasslands).

Geology: (undifferentiated) Granite.

Trees: *Eucalyptus dealbata* (82%), *Callitris glaucophylla* (77%), *Acacia leiocalyx* (46%), *Callitris endlicheri* (27%), *Ficus rubiginosa* (27%), *Corymbia dolichocarpa* (18%), *Casuarina cunninghamiana* (9%).

Shrubs: *Melichrus urceolatus* (91%), *Plectranthus parviflorus* (82%), *Leptospermum brevipes* (64%), *Acacia williamsiana* (46%), *Astrotricha roddii* (36%), *Olearia ramosissima* (36%), *Prostanthera saxicola* (36%), *Hovea lanceolata* (18%), *Mirbelia pungens* (18%), *Phyllanthus carpentariae* (27%).

Herbs: *Aristida vagans* (100%), *Tripogon loliiformis* (90%), *Cheilanthes sieberi* subsp. *sieberi* (100%), *Commelina cyanea* (100%), *Crassula sieberiana* (82%), *Aristida ramosa* (73%), *Gonocarpus tetragynus* (73%), *Aristida jerichoensis* (46%), *Bulbostylis barbata* (24%), *Stylidium laricifolium* (55%).

Restricted taxa: *Acacia williamsiana, Astrotricha roddii, Olearia gravis.*

Threats and conservation status: The community is often disturbed and is threatened primarily from feral animals, particularly goats. Some localities within Severn River State Forest are being logged. Some areas are within the proposed Kwiambal National

Park, however most are not within present park boundaries. The boundaries of the National Park are not fixed at this stage and further inclusions may add to the reservation status of this community.

Element 9: Howell Shrubland.

These communities occur at primarily around Copeton Dam and Goonoowigal near Inverell with a minor occurrence at Warrabah. Low shrubs, particularly *Homoranthus prolixus* and *Babingtonia densifolia* dominate. Occasionally all shrubs may be absent giving a grassland structure, or *Callitris endlicheri* and various eucalypts such as *E. dealbata* and *E. prava* may be present giving the appearance of a low open woodland.

Community 9a: *Babingtonia densifolia - Homoranthus prolixus* Shrubland (Howell Shrublands).
Geology: Gilgai Granite, (undifferentiated) Leucoadamellite.
Trees: *Callitris endlicheri* (88%), *Eucalyptus dealbata* (52%), *E. prava* (24%), *Acacia neriifolia* (21%).
Shrubs: *Babingtonia densifolia* (91%), *Homoranthus prolixus* (85%), *Leucopogon neo-anglicus* (76%), *Acacia triptera* (58%), *Micromyrtus sessilis* (33%), *Leucopogon melaleucoides* (64%), *Ozothamnus obcordatus* (36%), *Prostanthera nivea* (39%), *Acacia granitica* (52%), *Philotheca myoporoides* subsp. *conduplicata* (36%).
Herbs: *Paspalidium constrictum* (97%), *Lepidosperma laterale* (97%), *Cheilanthes sieberi* subsp. *sieberi* (100%), *Tripogon loliiformis* (91%), *Gonocarpus tetragynus* (79%), *Brachyscome stuartii* (76%), *Aristida jerichoensis* (82%), *Trachymene incisa* (67%), *Lobelia gracilis* (79%), *Fimbristylis dichotoma* (61%).
Restricted taxa: *Homoranthus prolixus, Acacia granitica, Zieria odorifera, Dodonaea stenophylla, Hibbertia kaputarensis, Boronia granitica, Leionema rotundifolium.*
Threats and conservation status: This community is probably unreserved. However as this is the most common community in the Howell (HC) area it is possible that this community may occur on the western side of Copeton Dam where small outcrops occur in the Copeton State Recreation Area. Feral goats are abundant and are a threat to this community.

Community 9b: *Homoranthus prolixus* Shrubland (Howell Shrublands).
Geology: Tingha Granite.
Trees: *Acacia neriifolia* (33%), *Eucalyptus dealbata* (17%), *E. prava* (17%), *Callitris endlicheri* (17%).
Shrubs: *Homoranthus prolixus* (100%), *Leucopogon neo-anglicus* (68%), *Acacia triptera* (83%), *Babingtonia densifolia* (68%), *Cryptandra amara* subsp. *floribunda* (17%), *Leucopogon melaleucoides* (17%), *Philotheca myoporoides* subsp. *conduplicata* (17%), *Olearia elliptica* (17%), *Persoonia cornifolia* (17%), *Prostanthera nivea* (83%).
Herbs: *Paspalidium constrictum* (100%), *Cheilanthes sieberi* subsp. *sieberi* (100%), *Commelina cyanea* (100%), *Lepidosperma laterale* (100%), *Brachyscome stuartii* (100%), *Portulaca filifolia* (83%), *Einadia hastata* (100%), *Tripogon loliiformis* (100%), *Portulaca oleracea* (83%), *Oxalis chnoodes* (100%).
Restricted taxa: *Homoranthus prolixus, Zieria odorifera, Monotaxis macrophylla.*
Threats and conservation status: This community is unreserved. Feral goats are the major threat.

Closed Forest

The community was not quantitatively surveyed because of its very restricted occurrence and difficulties of access. It has been included here for completeness. This community is restricted to deep crevices, clefts and sheltered areas on large granitic outcrops or between large boulders.

Community 10: *Quintinia sieberi - Rapanea* spp. Closed Forest (Eastern New England Closed Scrub).
Geology: Oban River Leucoadamellite, Round Mountain Leucoadamellite, Stanthorpe Adamellite.
Common taxa: *Quintinia sieberi*, *Rapanea* spp., *Notelaea* sp. A., *Leptospermum polygalifolium* subsp. *montanum*, *Tasmannia glaucophylla*, *Cyathea australis*, *Trochocarpa laurina.*
Threats and conservation status: All known occurrences are within some form of reservation. The community has been observed along the eastern escarpment of the batholith at Crown Mountain Flora Reserve, Girraween National Park, and Cathedral

Rock National Park. Due to inaccessibility this community is little disturbed and not considered to be under threat.

4.4 Discussion

4.4.1 Comparison with overseas granitic outcrop vegetation communities

World wide, the description of the vegetation communities on granitic outcrops have been based primarily on qualitative data and/or annotated species lists. Most early descriptions are based on the variation in structure within individual outcrops rather than at a regional scale. Richards (1957) describes the vegetation on Nigerian outcrops as being composed of sedge dominated ephemeral flush vegetation. Burbank and Platt (1964) subjectively divided communities on individual outcrops in the eastern United States into *Diamorpha*, Lichen-Annual, Annual-Perennial and Herb-Shrub communities. Similarly, Houle & Phillips (1989a) defined *Sedum smallii*, Lichen-Annual and Annual-Perennial communities on individual outcrops. Whitney and Moeller (1982) used ordination techniques to resolve community dynamics on a single large rock outcrop. These communities were arbitrarily subdivided, as Whitney & Moeller (1982) found, the low alpha diversity combined with high beta diversity an intractable problem creating unsatisfactory results.

Fuls *et al.* (1992) regionally surveyed and quantitatively analysed rock outcrops in South Africa and found that all could be described collectively as *Cymbopogon plurinodis-Aristida canescens* Grassland. A variety of woody species were sometimes present, their presence although altering the structure, did not change the floristic associations (Fuls *et al.* 1992). The graminoid taxa on South African outcrops were found to have wide ecological amplitudes while the shrubs were confined to specific ecological niches (Fuls *et al.* 1992) (Chapter 8).

Barthlott *et al.* (1993) defined a number of community or habitat types they perceived as occurring on all tropical and subtropical granite outcrops. The habitat types are as follows:

1. Exposed surfaces
2. Drainage channels
3. Rock crevices
4. Rock pools
5. Flat depressions
6. Monocotyledenous mats
7. Ephemeral or wet flush vegetation

These habitat types have been used subsequently as a basis for describing the vegetation on outcrops throughout the tropics (Ibisch *et al.* 1995; Porembski 1995; Porembski & Brown 1995; Gröger & Barthlott 1996; Porembski *et al.* 1996; Porembski *et al.* 1997). Dörrstock *et al.* (1996) concentrated solely on a descriptive account of west African Ephemeral Flush Vegetation. Porembski *et al.* (1998) quantitatively studied, via the placement of survey sites and numerical classification techniques, the floristics of the Monocotyledenous Mats in Venezuela.

Such overseas studies are difficult to compare directly to the present study as they have, in the majority, been qualitatively described and are based on subjectively defined habitat types within individual outcrops. In this present study outcrops have been treated as a single vegetation unit in a regional wide semi-quantitative relevé sampling and subsequent numerical analysis technique. Some comparison can be made. It is obvious from perusal of the literature that the structure of these outcrop communities are often variable within a single outcrop and between nearby outcrops. It is also apparent that overall, the structure of the predominant vegetation unit becomes simpler (e.g. shrubland to grassland) as climate becomes more 'arid'. Such changes in structure, within outcrops, and in general across regions occurred here. My results have shown structure varying within individual outcrops but in the main becoming structurally simpler in the western regions of the batholith where the climate is warmer and drier.

The basic habitat types described by Barthlott *et al.* (1993) do not appear to be universal, at least in the Australian perspective. Hopper (1999) notes that Australian granitic outcrops do not have the Monocotyledonous Mat habitat type. This is supported by the results shown here. Additionally, outcrops of the New England Batholith are devoid of Rock Pool vegetation. Also missing in outcrops on the east of the batholith are herbaceous Flat Depression vegetation or Ephemeral Flush vegetation. The subjectively defined habitat types used in a number of overseas investigations of granitic outcrops are not transferable entities in the Australian or at least the New England Batholith perspective. A non-subjective technique that does not rely on non-universal habitat types is required if proper comparisons of communities and their dynamics are to be fruitful.

4.4.2 Comparison with described granitic outcrop vegetation communities within Australia

Floristic descriptions of communities on granite outcrops within Australia occurred as early as 1810 (Brown 1810). Diels (1906) commented on the flora of Western Australian outcrops as 'interesting'. However, systematic studies of the regional floristics on outcrops has only been a recent research topic (Hopper 1999). The first detailed account of the communities on Australian granite outcrops appears to be that of Smith (1962) who studied the rock flora of the Porongurup Range in Western Australia. Main (1967) in a lyrical account traced the changes occurring on a granite outcrop in the Western Australian wheat belt over an entire year. Marchant (1973) gave a general account of the environment and unusual distributional features of many outcrop plants. The methods of description used by these early workers mirrored that of the early work overseas, i.e. subjectively segregating communities into habitat types on individual outcrops.

Beard (1974a, b; 1975a, b; 1976; 1981) presented the first regional account of the nature of outcrops within Australia, and were given greater emphasis in the combined volume published by Beard (1990). This work was systematic yet qualitative, but gives a good account of the changes in structure from the higher rainfall areas of the west, consisting mainly of shrublands, to the simpler structure of communities to the east of annual herbfields. Ornduff (1987) surveyed nine granite outcrops in Western Australia but the survey was qualitative in design and emphasized habitat types similar to those of Barthlott *et al.* (1993), including rock pool communities (gnammas) of *Isoetes*. This study also showed that most species on Western Australian outcrops were herbaceous self-pollinating annuals. As with the work of Fuls *et al.* (1992) described above, Pignatti and Pignatti (1994) quantitatively surveyed a small number of communities on rock outcrops and defined by multivariate analysis a class of ephemeral community (*Centrolepidi-Hydrocotyletea* community). Hopper (1997; 1999) investigated the nature of granite outcrop communities in Western Australia on a regional scale and described communities similar to those of Barthlott *et al.* (1993) including rock pool (gnammas) and Ephemeral Flush communities. The structure of Western Australian outcrop communities change from shrubland to ephemeral herbfields along a decreasing rainfall gradient as do the communities presented here. In comparison to the results presented here Western Australian outcrops have higher floristic richness (Hopper 1999). However, unlike the Western Australian communities annuals do not dominate on the New England Batholith outcrops.

Research elsewhere in Australia has been more sporadic. Ashton and Webb (1977) presented a quantitative multivariate ordinal analysis of transect data conducted from Wilsons Promontory in Victoria. This survey as with most other studies was based initially on subjectively delimited habitat zones. The results show communities on outcrops changing in structure and floristics on an altitudinal gradient and with proximity to the ocean. In general, the structure becomes more complex at higher elevations and includes some refugial closed forest species (*Nothofagus*, *Tasmannia* etc.). Kirkpatrick *et al.* (1988) analyzed quadrat data from a single rock outcrop and found that communities substantially intergraded but still were able to define four communities.

The work on Australian granite outcrop vegetation communities is scant in most instances, although prolific in Western Australia, it is primarily of a qualitative descriptive nature. Major granite outcrop areas within Australia need to be systematically surveyed and analyzed to enable greater comparability of results. Work elsewhere within Australia indicates that some of the major trends in vegetation structural changes described here are evident. Some significant communities are lacking in the New England Batholith and eastern Australia in general (Ashton & Webb 1977), notably Ephemeral Flush and gnamma (rock pool) communities. It is also apparent that there is difficulty in defining outcrop communities based on quantitative data when sample sizes are small and not on a regional scale.

4.4.3 Comparison with previous investigations in the north east of New South Wales

Almost all the previous survey work on the outcrop flora of the New England Batholith deals with the areas included within Elements One to Three. The vegetation on the western side of the Batholith has been only described by the studies of Bowlay (1992), Clarke *et al.* (1995), Le Brocque and Benson (1995), Clarke *et al.* (1998) and Hunter (1998c).

Specht *et al.* (1974) describes four alliances for New South Wales of some relevance to the granitic outcrops of the New England Batholith. Problems in defining alliances based on structure are apparent. Some alliances are defined many times, for example the New England outcrop community *Leptospermum* spp.-*Allocasuarina rigida*, is defined at least three times as: Tall Montane Shrubland, Closed Montane Heath, and Open Montane Heath. Furthermore, *Eucalyptus codonocarpa* is considered as distinct from the heath alliances on the New England Tablelands. Although Specht *et al.* (1995) have provided a more quantitative analysis in the definition of communities, they again define *Eucalyptus codonocarpa* as a separate community from the floristically similar but structurally different adjacent heath communities, defined by these authors as *Allocasuarina rigida* - *Leptospermum* spp. - *Kunzea bracteolata*. This is surprising as Specht *et al.* (1995) is based on floristic analysis. Benson & Ashby (1996) and these results suggest that the heath communities on granitic outcrops and the *Eucalyptus codonocarpa* communities are floristically similar. Specht *et al.* (1995) and NSW NPWS (1995) define a *Eucalyptus scoparia* community as distinct from the heath communities. *Eucalyptus scoparia* is an infrequent species of heaths within the Girraween and Bald Rock areas and does not affect overall floristic distinction when it occurs. Individual communities described on floristic grounds may have a range of structures.

Specht *et al.* (1974) define three heath/shrubland alliances for New South Wales that are of relevance to this study, namely *Calytrix tetragona*, *Epacris brevifolia* and *Leptospermum novae-angliae - Allocasuarina rigida*. As only a few frequent taxa are given it is difficult to establish the true similarity of their communities to those defined. However, based on the dominant species they give, the *Calytrix tetragona* alliance may approximate those communities defined in element four. Those of the latter two alliances may somewhat approximate Elements One and Two, with some notable differences. The *Epacris brevifolia* group as defined by Specht *et al.* (1974) includes dominant taxa that are found primarily on outcrops, together with those from wet heaths in the region. For example, this alliance is defined as containing *Hakea microcarpa* and *Epacris brevifolia* both of which are restricted to areas of poor drainage, whereas *Cryptandra lanosiflora* and *Leucopogon neo-anglicus* are granitic outcrop endemics. These combinations of species cannot be reconciled with the data presented here.

Specht *et al.* (1995) define a heath community *Allocasuarina rigida - Leptospermum* spp. - *Kunzea bracteolata*. This community is equivalent to Elements One to Three. The species *Allocasuarina rigida* was also used to define communities on the New England Batholith by Specht *et al.* (1974) and the NSW NPWS (1995). In this survey *Allocasuarina rigida* is neither frequent nor abundant, and hence its use as a defining species by Specht *et al.* (1995) in their quantitatively defined communities is anomalous. This species may certainly become dominant in areas around the Mount Warning Shield (e.g. Lamington National Park) but is infrequent in most outcrops on the New England Batholith. *Leptospermum novae-angliae* is probably the best defining species for granitic outcrop areas particularly those within Elements One to Three.

The New South Wales National Parks and Wildlife Service (1995) in their survey of the upper north-east of New South Wales identified several associations of relevance to granitic outcrops, although it is not stated that they occur on outcrops. They define several associations that I have included within Elements Two and Three. The associations they define are: *Kunzea bracteolata - Allocasuarina littoralis*, *Kunzea bracteolata - Boronia bipinnata*, *Kunzea bracteolata - Grevillea acerata*, *Kunzea bracteolata - Leptospermum novae-angliae* and *Leptospermum novae-angliae - Leptospermum variabile*. Most of these associations are narrowly defined and the first and last would fall within Community 2a, while the other three would fall within Community 3a.

Binns (1992; 1995a) describes communities that occur on granite outcrops on the New England Batholith. These are similar to those defined in Element Two. Benson & Ashby (1996) in their survey of the Guyra area defined a community found on granitic outcrops. This community was variable in structure and termed 'Mallee (*Eucalyptus codonocarpa*) and Heath on Rocky Outcrops on Leucogranite'. This community corresponds directly to Community 1c, 'Backwater Heaths'.

Bowlay (1992), Clarke *et al.* (1995) and Le Brocque and Benson (1995) surveyed areas and defined communities within the north-western portion of the New England Batholith. Le Brocque and Benson (1995) included Community 5b within a broader *Eucalyptus caleyi/Allocasuarina inophloia* association. Clarke *et al.* (1995) defined two rocky outcrop communities, *Eucalyptus prava* and *E. dealbata-E. caleyi-Callitris endlicheri*, which are defined on the species in the upper stratum. These two communities being based on the same data are synonymous with Community 5a *Leucopogon neo-anglicus-Calytrix tetragona* Low Shrubland. Similarly using some of the same data Clarke *et al.* (1998) define a *Eucalyptus prava – Callitris endlicheri – E. andrewsii* community that is synonymous with Community 4b and *Eucalyptus prava – E. dealbata – Callitris endlicheri* community that is synonymous with Community 7a.

4.4.4 Classifying outcrop communities

The communities found on granitic outcrops have a high proportion of restricted taxa that make them distinct from the surrounding forest vegetation. This fact has been noted elsewhere in Australia (Aston & Webb 1977; George *et al.* 1979; Beadle 1981; Hopper *et al.* 1997; Hopper 1999) and within the region under investigation (Binns 1995a). The communities are often visually variable from one patch to another within the same area in both structure and dominant taxa. Overall, floristic similarity may vary little between these patches yet traditionally they have been given different names often based simply on structure. Each community is derived from a limited source pool. However, the populations found within patches of vegetation on outcrops are comparatively very small and isolated, they are therefore prone to changes in dominant taxa based on an increase in the probability of extinction and chance colonisation and establishment (Dörrstock *et al.* 1996; Hopper 1999). This has caused problems in the delimitation of rocky outcrop communities.

Binns (1992; 1995a) found problems in using traditional methods based on consistent structure and consistent dominant taxa for outcrop communities on the New England Batholith. Binns stated that composition appeared to be highly variable both within and between patches, with no obvious pattern, and that composition may depend on chance colonisation. Hambler (1964) who qualitatively described granite outcrop communities in western Nigeria using a structural system also noted such problems. Hambler wrote, 'All observable communities cannot be fitted into this classification since a multiplicity of different habitats often occurs in a small area giving a mosaic community. Where a community can be typified by the occurrence of a dominant species the supporting flora may vary from place to place owing partly to variations in the age and condition of the dominant species, and perhaps partly to barriers to dissemination between the island hills'.

Many of these problems are likely to be based on the scale and intensity of sampling. Binns (1992; 1995a) sampled only a small number of outcrops over a large area and therefore, the consistency that is apparent in a more intensive investigation is not easily quantified. Similarly, Hambler (1964) concentrating on a few outcrops within the same area was unable to see any consistency on the small scale of his survey. I have found that communities will be consistent in their overall shared taxa within each defined community regardless of the presence or absence of specific taxa in the upper-most stratum or visual differences in structure. Benson and Ashby (1996) also noted that the dominant species in the upper stratum of one patch may or may not be present in an adjacent patch (e.g. *Eucalytpus codonocarpa*) yet the similarity in overall floristics was high.

4.4.5 Representation in conservation reserves

Conservation often follows the *ad hoc* reservation of areas with the least potential for commercial land use (Pressey & Tully 1994). Granitic outcrop areas generally have a low potential for commercial land use. The more inaccessible granitic outcrop areas are the most highly represented in the reserve system while those more accessible are the least conserved. Element Two occurs in six National Parks (Table 4.2), and all of the communities within this group are within at least one National Park. No communities within Element Six or Nine are in any form of on or off park reservation. Element Seven has eight communities within it, five unreserved. Reservation priorities for granitic outcrop communities are suggested and the following priority list for the New England Batholith is presented:

Element unreserved.

Element 6: Community 6a & 6b.

Element 9: Community 9a & 9b.

Element under represented in the reserve network.

Element 7: Community 7b, 7c, 7d, 7e & 7h unreserved.

Element 2: Community 2b unreserved.

Element Conserved Well - all communities conserved, none within the National Park or Nature Reserve network.

Element 1: Community 1a, 1b & 1c.

Element 4: Community 4b & 4c.

Overall, most granitic outcrop communities are less disturbed compared to other habitats. However, feral goats are a considerable problem in almost all the regions investigated, particularly those in the western portion of the region. In addition, evidence suggests that outcrop communities are fragile and likely to be more easily modified or invaded by weedy taxa than the systems that surround them (Wyatt & Fowler 1977; Pate & Dixon 1982; Walters & Wyatt 1982; Binns & Chapman 1993; Fleischmann *et al.* 1996; Hunter 1998d; Hopper 1999)

Table 4.2: Summary of the current types of conservation reserves known to include the nine vegetation Elements. Private Reserve includes areas under conservation agreements with National Parks and Wildlife Service.

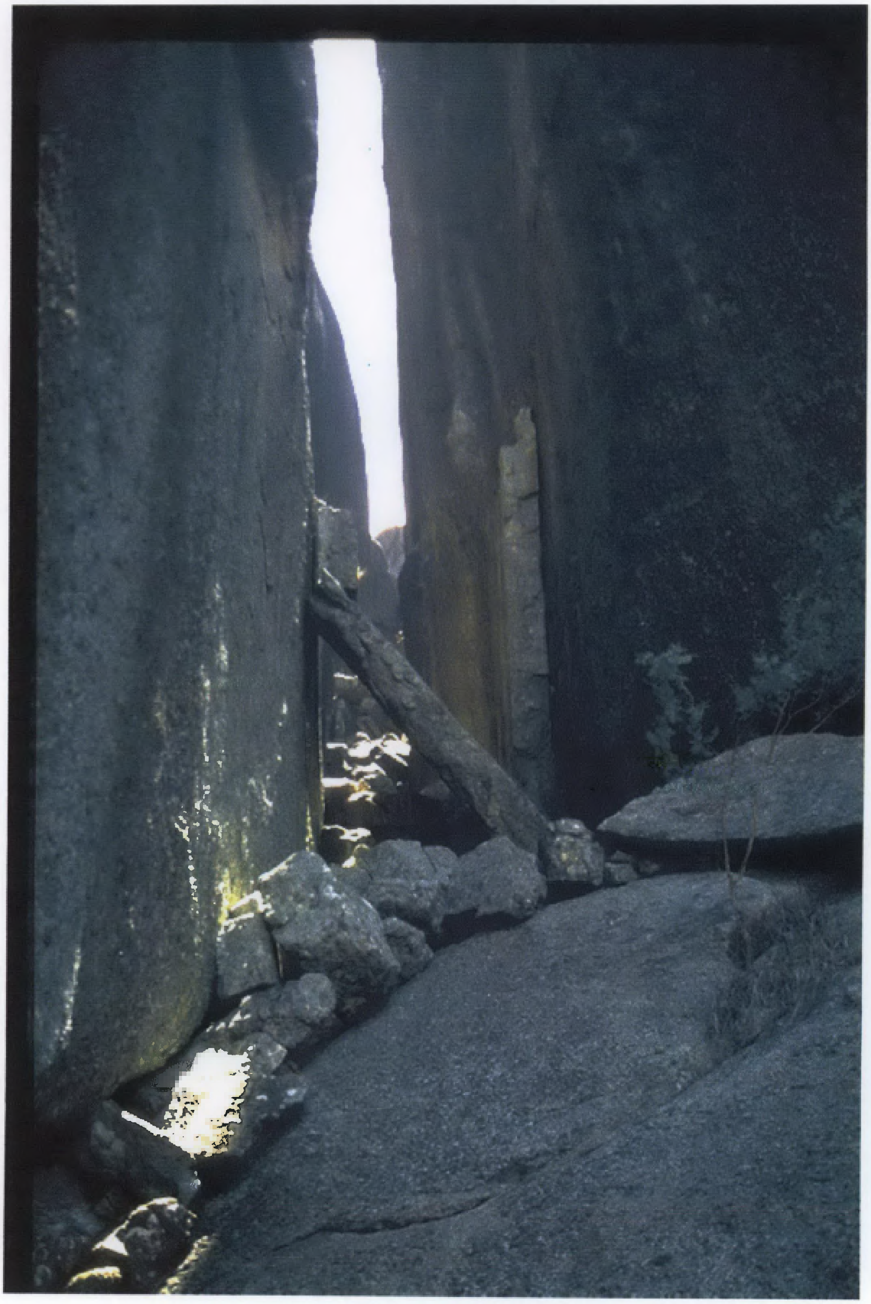
Element Number	Private Reserve	Designated State Forest Preserve	State Recreation Area	Nature Reserve	National Park
1	1	2	-	-	-
2	-	1	-	1	6
3	-	-	-	-	1
4	-	-	1	-	-
5	-	-	-	1	1
6	-	-	-	-	-
7	-	-	1	3	2
8	-	-	-	-	1
9	-	-	-	-	-

4.4.6 Exotic species

Within the New England Batholith exotic species are a minor floristic component. Only 6% of the flora were exotic in origin and most of these were ubiquitous weeds found in most communities in the north east of New South Wales. This represents a comparatively low percentage, even though most areas surrounding outcrops have been extensive modified for agriculture and grazing for over 100 years. Many exotic taxa where common, none where considered to be of concern on the granite outcrops in the batholith. Similar percentages of exotic taxa have been recorded on granite outcrops elsewhere (Porembski *et al.* 1998; Wyatt 1997). However, on Western Australian outcrops the percentages of weedy taxa are considerably higher and can be as high as 39% but commonly around 20% (Ornduff 1987). Such differences are difficult to assess. Hopper (1997) attributes the high number of exotic taxa on Western Australian outcrops to an absence of major glacial soil stripping as an evolutionary force acting on the flora. Within the batholith the percentage of weedy taxa increases to the west (Table 4.1) where community structures are simpler and composed primarily of herbaceous taxa and are more similar to communities described for the majority of Western

Australian outcrops. The glacial hypothesis does not explain the differences noted in the percentages of exotic species across the New England Batholith that as a flora would have evolved under the same glacial regime. The glacial hypothesis should also apply to the Seychelles outcrops where glacial processes have also not occurred yet the outcrops there are more natural than the surrounding forests (Fleischmann *et al.* 1996). Furthermore, even in highly disturbed outcrop areas on the New England Batholith, such as at goat camps, the number of exotic species are not as high as on outcrops in Western Australia. The glacial hypotheses (Hopper 1997) may play a part in explaining the scale of differences noted between Western Australian outcrops and those of the New England Batholith, however further research needs to be conducted to understand other processes that may be involved.

Chapter 5: Evenness, Richness and Diversity



Deep crevice in a large Inselberg at 'Bornhardtia' near Ironbark

Chapter 5

Eveness, Richness and Diversity

5.1 Introduction

The distribution of abundances amongst species in communities is a basic feature that is best measured by evenness (Smith & Wilson 1996). When each species is present in equal abundance a high evenness is the result, but if species differ widely in their abundances then the community has low evenness. Evenness is essentially one of two components of species diversity, richness being the other (Hill 1973; Smith & Wilson 1996).

The review in Chapter 1 highlights the overall impression that the flora of outcrops have a number of stochastic distributions and abundances. Additionally, outcrop communities have been difficult to define both structurally and floristically (Chapter 4). Such observations indicate that the differences between individual sites may be high compared to that of other communities. This has implications in terms of the strategies used to reserve granitic outcrop systems. Beta diversity measures the changes in turnover of species between habitats (Hobbs 1992). Therefore, a measure of beta diversity may elucidate the degree to which these observations are true.

This chapter will describe the major changes in richness, beta diversity and evenness across the New England Batholith. Richness will not be analysed in great detail, as this will be accomplished in subsequent chapters. Beta diversity is potentially correlated with other descriptive analysis methods such as species saturation and nestedness, which are dealt with in Chapter 7. A brief description of the variation in beta diversity across the batholith is provided here. Changes in evenness and the potential correlates are of significance in explaining the maintenance of biodiversity across the batholith. Specific questions include:

- Are there discernable patterns in species richness at the 0.1 ha scale accross the batholith?
- Are there discernable patterns in beta diversity across the batholith?
- What are the patterns in the distribution of abundances on the batholith?
- Are there significant differences between the richness, beta diversity and evenness on islands as compared to the surrounding virtual 'sea'?
- Can correlations be found between these patterns and selected environmental variables?

5.2 Methods

An accepted terminology exists for the decomposed components of spatial scale. The minimum scale sampled is termed the 'grain' and the maximum scale of distance between samples is the 'extent' (Wiens 1989; Reed *et al.* 1993; Palmer & White 1994). The sampling strategy outlined and completed during this project (Chapter 2) allows for analyses to be performed at a number of grain and extent sizes. Palmer and White (1994) define scale dependence as the degree to which ecological phenomena vary as a function of grain and extent. Degrees of extent includes; 1) the New England Batholith as a single entity, 2) nine vegetation Elements (Chapter 4), and 3) 24 'archipelagos' (Chapter 2). Grain sizes include; 1) quadrat data, 2) outcrop data and the 3) nine Elements and 24 'archipelagos' (2 and 3 derived from cumulative quadrat data).

5.2.1 Richness and diversity

Wilson and Shmida (1984) discussed and tested a number of widely used beta diversity equations. They concluded that the beta diversity measure proposed by Whittaker (1960) came closest to fulfilling all the criteria they tested, and therefore, should be of most use in ecological applications. The Whittaker (1960) beta diversity measure is calculated by the following formula:

$$B_w = \frac{S}{\bar{a}} - 1$$

Where *S* is the total number of species recorded for the system, and ā is the average number of species found within each sample.

Analyses of beta diversity are calculated based on the richness of each quadrat as this is a consistently applied sample size used throughout the whole batholith, a basic requirement for use of this diversity measure.

5.2.2 Analysis of evenness

A number of evenness indices have been proposed, many of which are measures aligned to diversity (Smith & Wilson 1996). Smith and Wilson (1996) conducted tests on a number of evenness indices and concluded that E_{var} (Camargo 1993) was the best index of evenness for general use. This index is independent of species richness and is symmetric to degrees of abundance. In addition E_{var} provides a good Molinari shape (i.e. responds well to changes in evenness) and although it has a few minor problems it is the only index judged to have no severe problems (Smith & Wilson 1996). E_{var} is based on the variance in abundance over number of species and is calculated by the following formula:

$$E_{\mathrm{var}} = 1 - \frac{2}{\pi} \arctan\left\{ \sum_{s=1}^{S} \left(\ell n(\chi_t) - \sum_{t=1}^{S} \ell n(\chi_t) / S \right)^2 \right\} / S$$

This variance is taken over log abundances, to examine the proportional difference, and to ensure the index is independent of the units used. The variance is then converted to a 0—1 range, with 0 being the minimum evenness and 1 the maximum (Smith & Wilson 1996).

Determinations of evenness have been calculated at three grain sizes. The grain sizes include presence-absence data of species on individual outcrops, presence-absence of species at individual plots and sum of all relative abundances (Chapter 2) from each plot.

Forward Stepwise Multiple Linear Regression of the E_{var} values against variables used in Chapter 3 and the Quotient of Insularity (Chapter 3) was performed (see Section 3.2.2 for methodology). These analyses were conducted in order to assess any significant correlations with evenness.

5.3 Results

5.3.1 Richness

The mean species richness on a 0.1 ha basis is significantly lower on the outcrops ('islands') at all 'archipelagos' compared with the surrounding flora ('sea') of the same 'archipelagos' (*t*-test $p < 0.000000$) (Table 5.1). The mean species richness is 33.48 on outcrops and 48.05 in the surrounding flora ('sea'). The highest mean plot richness for an outcrop was found at Demon (DM; 56.67), and the second highest at Attunga (AT; 47.76), which is below the overall mean for the surrounding flora. The richness of sites at the 0.1 ha size does not vary significantly across the batholith both on the outcrops and in the surrounding flora ('sea').

The mean species richness across the 27 communities on outcrops of the batholith (Chapter 4) varies considerably but non-significantly (Table 5.2). Communities 2f and 7b have the lowest mean richness values but come from significantly different areas on the batholith (Bald Rock (BR) & Mount Lookout (ML)) (Chapter 4). The highest mean species richness was found at Moonbi (MB), one of the more 'arid' areas of the batholith (Chapter 2). The overall mean richness of communities (27 groups) and 'archipelagos' (24 groups) are almost identical (Table 5.3).

5.3.2 Beta diversity

The beta diversity of the surrounding vegetation ('sea') sites is significantly lower than that of the outcrop ('island') sites (*t*-test $p < 0.000606$) despite a few 'sea' areas being slightly higher than their incorporated outcrops ('islands') (Bolivia Hill (BH), Cathedral Rock (CR) & Willows (WW)) (Table 5.1). The lowest beta diversity for 'archipelagos' was found at Attunga (AT; 0.40) and the highest at Bald Rock (BR; 7.57). The measurement of beta diversity is not independent of species pool size and therefore these extremes in values are comparative only. Community 7b (ML) has the lowest calculated beta diversity score (Table 5.2), indicating that there is very little difference at all among plots within this community. The beta diversity of communities and 'archipelagos' as a whole, are almost identical (Table 5.3). Table 5.4 presents the clearest comparison of beta diversity values as the outcrops chosen are of the same size. Outcrops of the same size from the same 'archipelago' can have very different beta diversity results (Table 5.4; e.g. BC4O & BC7O). No significant correlations could be found between beta diversity and the environmental variables tested.

5.3.3 Evenness

The index of evenness has been calculated at three different grain sizes. The amount of information incorporated in calculating evenness (presence-absence compared to summed abundances) significantly affects the answer obtained (Table 5.5). The difference between the three methods of calculating evenness was proportional and statistically significant (all cross *t*-tests $p < 0.000000$). The more information incorporated in calculating evenness the comparatively less even a sample appears.

The surrounding floras ('sea') are statistically more even than their incorporated 'archipelagos' (0.807 'sea', 0.750 'islands'; *t*-test $p < 0.000706$) (Table 5.5). As the evenness index is independent of sample size cross comparisons at all grain sizes can be made. The lowest overall evenness score was obtained from analysis of the entire batholith or Backwater (BC) 'archipelago' (Table 5.5 & 5.7; Figure 5.1) depending on the grain size used in the analysis. Highest evenness was obtained from the Demon (DM) and Chaelundi (CH) 'archipelagos' (Table 5.7), both of which, are the smallest 'archipelagos' sampled. No significant changes were noted in evenness across the batholith in outcrops of the same size (Table 5.6).

Only one highly significant correlation was found between evenness and environmental variables. The larger range in boulder sizes is correlated with an increase in evenness across 'archipelagos'. An addition small but significant correlation was found between beta diversity and evenness (Figure 5.3). As beta diversity increases, evenness increases.

Table 5.1: Comparison of richness and beta diversity on outcrops ('islands') and the surrounding vegetation ('sea') at each of the 'archipelagos' examined. β_w = Whittakers beta diversity.

'Archipelago'	Outcrop Total Richness	Outcrop Quadrat Mean Richness	β_w	'Sea' Total Richness	'Sea' Quadrat Mean	β_w
Attunga	67	47.76	*0.40*	NA	NA	*NA*
Backwater	168	36.92	*3.55*	117	52.05	*1.25*
Bolivia Hill	80	27.54	*1.91*	140	47.00	*1.98*
Butterleaf	108	30.33	*2.56*	NA	NA	*NA*
Bald Rock	197	22.98	*7.57*	169	48.15	*2.51*
Chaelundi	62	31.00	*1.00*	79	43.33	*0.82*
Cathedral Rock	46	26.53	*0.73*	97	50.07	*0.94*
Demon	115	56.67	*1.03*	118	64.67	*0.83*
Eagle Creek	93	32.10	*1.90*	107	46.50	*1.30*
Flaggy Range	136	26.08	*4.24*	104	41.00	*1.54*
Gibraltar Range	164	36.28	*3.52*	138	45.00	*2.07*
Howell	147	31.49	*3.67*	102	45.17	*1.23*
Ironbark	107	27.87	*2.84*	120	56.20	*1.14*
Jondol	84	38.80	*1.17*	97	43.40	*1.24*
Kwiambal	100	33.55	*1.98*	100	45.43	*1.20*
Kings Plains	109	38.67	*1.82*	132	51.83	*1.55*
Moonbi	97	31.70	*2.06*	104	44.67	*1.33*
Mount Lookout	50	19.67	*1.54*	NA	NA	*NA*
Parlour Mountains	100	35.56	*1.81*	104	50.20	*1.07*
Severn River	149	37.09	*3.02*	125	43.67	*1.86*
Torrington	196	32.95	*5.95*	132	46.50	*1.84*
Warrabah	155	32.35	*3.79*	120	48.17	*1.49*
Willows	73	31.33	*2.33*	129	36.80	*2.51*
Yarrowyck	55	28.00	*1.96*	63	34.40	*0.83*

Table 5.2: Richness and beta diversity of each of the communities defined on granitic outcrops of the New England Batholith (Chapter 4). β_w = Whittakers beta diversity.

Community	Total Richness	Mean Richness per Quadrat (0.1 ha)	β_w
1a	125	39.88	2.13
1b	108	30.29	2.57
1c	117	32.41	2.61
2a	132	41.60	2.17
2b	67	34.50	0.94
2c	46	24.00	0.92
2d	202	27.74	6.28
2e	107	29.43	2.64
2f	103	18.90	4.45
3a	147	35.96	3.09
4a	99	28.14	2.52
4b	168	32.89	4.12
4c	41	26.50	0.55
5a	158	32.92	3.80
5b	98	44.00	1.23
6a	67	44.00	0.52
6b	97	47.50	1.04
7a	150	31.70	3.73
7b	36	33.20	0.08
7c	82	17.00	3.82
7d	85	29.17	1.91
7e	100	37.25	1.69
7f	107	27.87	2.84
7g	201	30.53	5.58
7h	56	19.50	1.87
8a	100	33.55	1.98
9a	111	29.06	2.82
9b	81	43.00	0.88

Table 5.3: Richness and beta diversity of Elements (Chapter 4) and higher extents of outcrop sites across the New England Batholith. β_w = Whittakers beta diversity.

Extent	Total Richness	Mean Richness Per Quadrat (0.1 ha)	β_w
Element 1	199	34.13	4.83
Element 2	324	26.49	11.23
Element 3	147	35.96	3.09
Element 4	205	31.43	5.52
Element 5	147	36.40	3.04
Element 6	126	34.33	2.67
Element 7	322	29.98	9.74
Element 8	100	33.55	1.98
Element 9	140	31.21	3.49
All Elements	665	190	2.50
Community	665	110.77	5.00
Archipelago	665	110.71	5.01

Table 5.4: Richness and beta diversity of the largest outcrops ('islands') sampled across the New England Batholith (see Section 5.3.3). β_w = Whittakers beta diversity.

Outcrop ('Island')	Total Richness	Mean Richness Per Quadrat (0.1 ha)	β_w
BR5O	76	26.3	1.89
BC12O	73	39.0	0.87
BC8O	91	41.0	1.22
BR11O	41	15.3	1.68
BR17O	45	17.2	1.62
BR18O	67	22.6	1.97
GR10O	78	35.5	1.20
HC14O	81	43.0	0.88
HC5O	52	26.5	0.96
MB2O	72	28.5	1.53
SR5O	88	48.7	0.81
BC4O	51	30.4	0.68
BC7O	71	30.6	1.32
BL7O	61	30.0	1.03
BR15O	42	19.6	1.14
IB1O	54	24.2	1.23

Table 5.5: Evenness of outcrop 'archipelagos' across the New England Batholith determined at three grain sizes and comparison with the surrounding vegetation at one grain size.

'Archipelago'	Outcrop Level	Quadrat Level	Sum of all Abundances	'Sea': sum of all Abundances
Backwater (BC)	0.904	0.814	0.633	0.784
Bolivia Hill (BH)	0.930	0.884	0.707	0.833
Butterleaf (BL)	0.941	0.905	0.768	NA
Bald Rock/Girraween (BR)	0.905	0.846	0.702	0.745
Chaelundi (CH)	0.981	0.981	0.864	0.824
Demon (DM)	0.981	0.981	0.890	0.869
Eagle Creek (EC)	0.927	0.915	0.752	0.806
Flaggy Range (FR)	0.895	0.881	0.733	0.832
Gibraltar Range (GR)	0.896	0.863	0.702	0.753
Howell (HC)	0.885	0.8135	0.623	0.808
Ironbark (IB)	0.905	0.938	0.782	0.815
Mount Jondol (JB)	0.974	0.965	0.836	0.791
Kwiambal (KL)	0.927	0.914	0.776	0.791
Kings Plains (KP)	0.913	0.893	0.735	0.809
Moonbi (MB)	0.975	0.921	0.774	0.792
Mount Lookout (ML)	0.974	0.948	0.803	NA
Parlour Mountains (PM)	0.943	0.920	0.773	0.788
Severn River (SR)	0.924	0.857	0.693	0.825
Torrington (TT)	0.857	0.839	0.716	0.800
Warrabah (WB)	0.910	0.873	0.733	0.805
Willows (WW)	0.959	0.937	0.784	0.887
Yarrowyck (YH)	0.958	0.944	0.798	0.794

Table 5.6: Evenness calculated for each of the largest outcrops ('islands') on the New England Batholith (see Section 5.3.3).

Outcrop ('Island')	Number of Quadrats	Quadrat Level	Sum of all abundances
BR5O	7	0.949	0.815
BC12O	6	0.923	0.778
BC8O	6	0.940	0.796
BR11O	6	0.953	0.801
BR17O	6	0.944	0.792
BR18O	6	0.944	0.795
GR10O	6	0.929	0.734
HC14O	6	0.918	0.722
HC5O	6	0.921	0.718
MB2O	6	0.942	0.790
SR5O	6	0.914	0.748
BC4O	5	0.930	0.721
BC7O	5	0.948	0.798
BL7O	5	0.941	0.834
BR15O	5	0.942	0.755
IB1O	5	0.943	0.789

Table 5.7: Evenness calculated at larger extent sizes for outcrops ('islands') (see Section 5.3.3).

Grain	Number of Samples	Plot level	Sum of all abundances
NE Batholith	216 outcrops	0.853	0.542
Element 1	18 outcrops	0.906	0.637
Element 2	25 outcrops	0.914	0.736
Element 4	40 outcrops	0.860	0.683
Element 5	18 outcrops	0.908	0.632
Element 7	71 outcrops	0.883	0.653
Community	27 communities	0.891	NA
'Archipelago'	24 'archipelagos'	0.897	NA

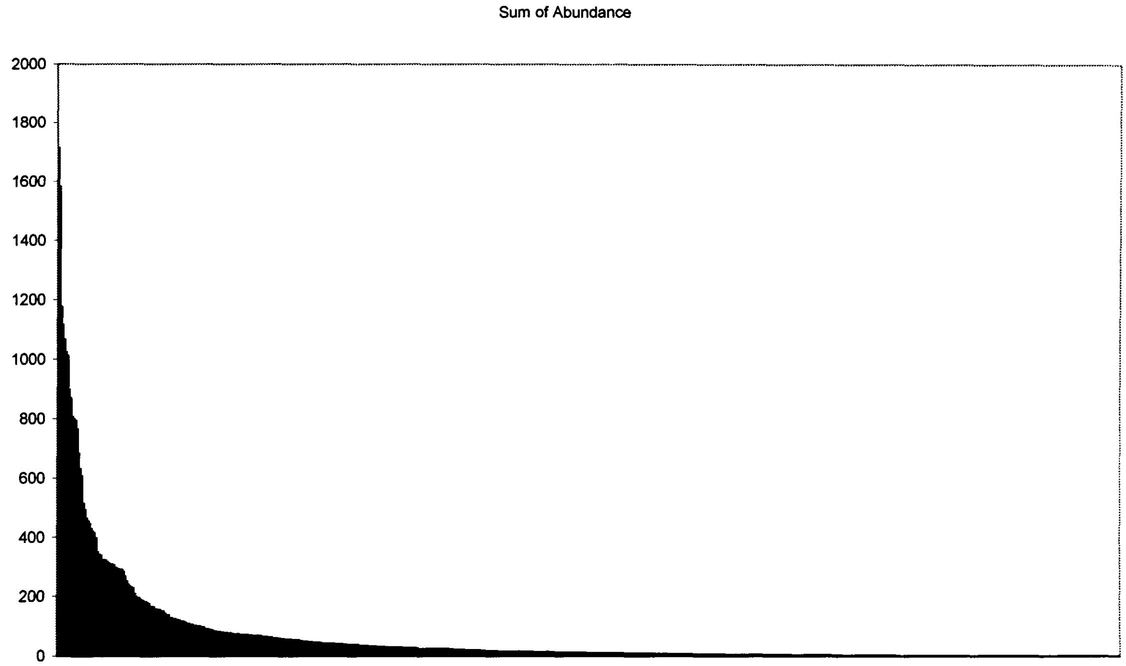


Figure 5.1: Graphical representation of the evenness of all species and their summed abundances from outcrops across the entire New England Batholith. Note that across the entire batholith there are a few very common species but a large number of rarely occurring species.

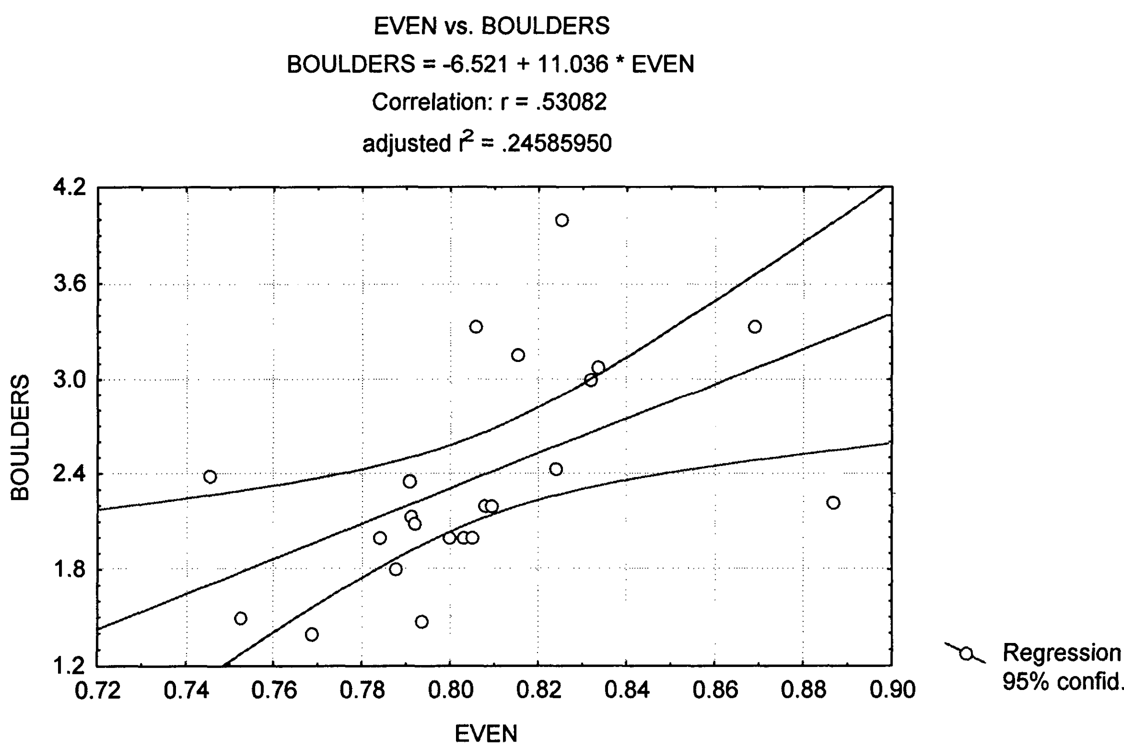


Figure 5.2: The correlation between the range of boulder sizes (1—5 scale; Chapter 2) and evenness. There is a significant correlation ($P < 0.000000$) between the size range of boulders and the degree of evenness was found.

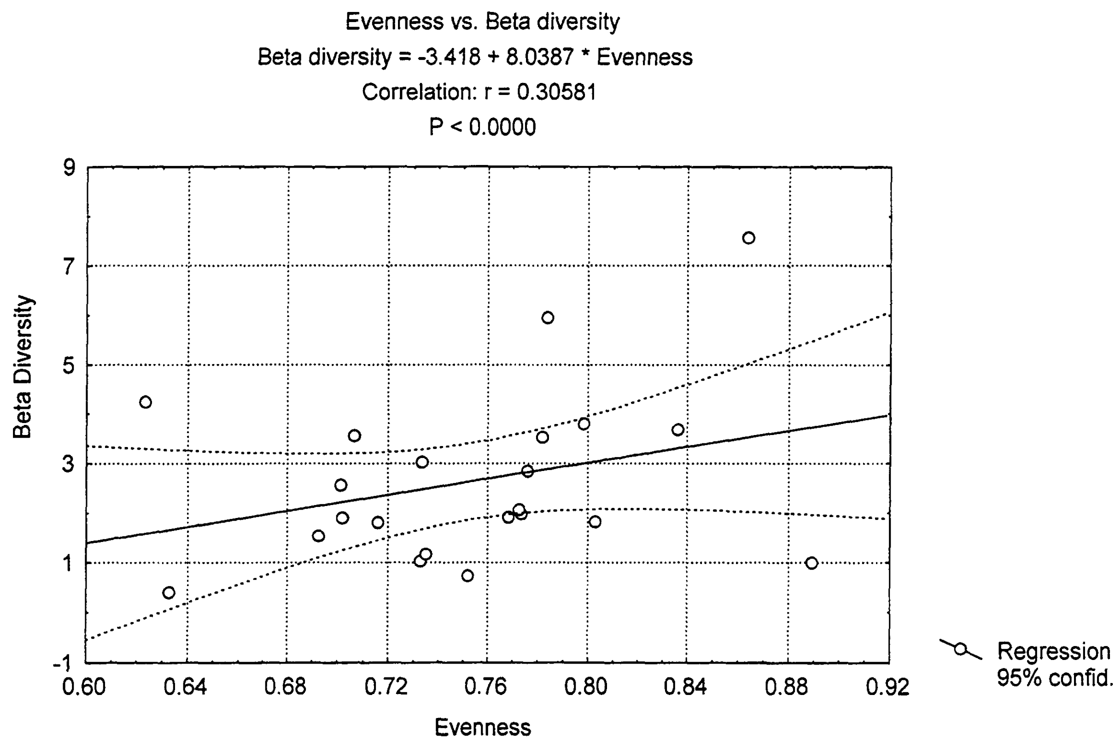


Figure 5.3: Relationship between beta diversity and evenness. There is a small significant positive correlation between beta diversity and evenness.

5.4 Discussion

The species richness at 0.1 ha on outcrops of the New England Batholith is similar to other semi-arid and arid environments within Australia (Rice & Westoby 1983). As granitic outcrops are considered 'semi-arid' environments in more mesic surroundings (Chapter 1), it is not surprising that their richness at a site scale is similar to vegetation from semi-arid environments. The richness of the surrounding flora ('sea') sites is similar to eastern Australian heaths and scrubs but higher than those found for eastern Australian forests in general (Rice & Westoby 1983). Despite the significant changes in climate (Chapter 2) and associated distribution and abundance of life forms across outcrops ('islands') of the batholith, from grasslands and herbfields to shrublands and heaths (Chapter 4), the richness at the 0.1 ha does not vary significantly (Table 5.1). Similar comparisons can be made with the surrounding flora ('sea') sites, which also vary in structure but not significantly in richness (Appendix G; Table 5.1). The mean richness of communities and 'archipelagos' was almost identical and this is because most communities were limited to a single 'archipelago' (Table 5.3; Chapter 4).

Overall, outcrop ('island') sites have significantly higher beta diversity than the surrounding communities ('sea'). This indicates that adjacent sites are far more different (in terms of beta diversity) on outcrops than they are in the surrounding communities. This feature has been noted by a number of authors (Chapter 1) and correlates with the difficulty found in circumscribing outcrop floristic communities structurally (Chapter 4). Large differences between adjacent sites promote the maintenance of diversity and richness at the landscape level (gamma diversity). Despite outcrops having a lower per site richness (0.1 ha; alpha diversity) than surrounding forests they maintain a high richness across the landscape by having a higher beta diversity. The implications of having low site richness (alpha diversity) but greater differences between sites are that many smaller reserves may support more species (Chapter 7). The choice between large or small reserves has commonly been abbreviated as the SLOSS (Single-Large-Or-Several-Small) debate. Further evidence that supports the implications of beta diversity for this debate will be presented in Chapter 7.

The distribution of abundances is significantly less 'even' on outcrops compared to that of the surrounding flora. This indicates that there is a greater difference in the abundances of species on outcrops than in the surrounding vegetation. Outcrops have a few very common species, a large number of rarely occurring species, and few of intermediate abundance in general (see also Chapter 3). The least even score (based on sum of all abundances, Table 5.7) was obtained from the analysis of all outcrops on the batholith. This may be explained by the relatively few ubiquitous species across the whole batholith and the large number of restricted species. Only two significant correlations with evenness were found, one with the distribution of boulder sizes, and a link with beta diversity. These correlations indicate that evenness is increased if there is a large range in boulder sizes and where the differences between different sites are maximised. The implications of this are difficult to determine. A large range of boulder sizes could increase the niches available and locally increase within site beta diversity and decrease the potential of a few species to dominate. In other words no species can achieve high abundances and most are of moderate abundance (see Chapter 8 for a comparable correlation with evenness). Similarly, the correlation between evenness and beta diversity is likely to be due to no small group of species becoming dominant and achieving high levels of abundance. Despite evenness being a major component of diversity there are no comparative analyses to put these patterns of evenness into a worldwide perspective.

It has been noted that the overall richness at 0.1 ha is lower on the outcrop ('islands') in comparison to the surrounding floras ('sea'). Beta diversity is significantly higher in general on outcrops ('islands'), but evenness is lower as compared to the surrounding floras ('sea'). There is a small correlation between factors that may disrupt the dominance of individual species (such as large and varied sizes of boulders) and an increase in the evenness of species abundances. In addition, beta diversity is significantly correlated with evenness. This indicates that the more different adjacent sites are, the more even the abundances of individuals will be. The results indicate that diversity and richness are maintained across the batholith via stochastic distributions of species, comparatively high variations in abundances and by landscape richness (beta & gamma diversity) as opposed to site richness (alpha diversity). The analyses of evenness needs to be conducted in communities other than granitic outcrops to enable greater understanding of factors that influence this measure.