Cunninghamia 1 (1): 35–57 (1981)

VEGETATION OF THE AGNES BANKS SAND DEPOSIT, RICHMOND, NEW SOUTH WALES

D. H. BENSON

(Accepted for publication 1.5.1980)

ABSTRACT

Benson, D. H. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, New South Wales, Australia 2000) 1981. *Vegetation of the Agnes Banks sand deposit, Richmond, New South Wales. Cunninghamia* 1 (1): 35-57. The vegetation of an isolated deposit of Pliocene-Pleistocene sand, at Agnes Banks (lat. 33° 37′ S, long. 150° 41′ E) 55 km northwest of Sydney, New South Wales, which has floristic and structural affinities with both coastal heath vegetation and Hawkesbury Sandstone vegetation, was mapped and described. Low open-forest of *Banksia serrata* and *Angophora bakeri* was confined to the well-drained crests of the large dunes, woodland of *Eucalyptus sclerophylla, A. bakeri* and *B. serrata* was on well-drained and moderately well-drained positions, woodland of *E. sclerophylla, E. parramattensis* and *B. serratifolia* was on shallow sand, low open-woodland of *E. parramattensis* was confined to poorly-drained situations and sedgeland of *Lepidosperma longitudinale* was in depressions where drainage was severely impeded. Classification and ordination analyses indicate that species distribution is dominated primarily by a moisture drainage factor which produces a continuum of species. Projective canopy cover and fire also influence the distribution of the vegetation.

INTRODUCTION

Just southeast of the village of Agnes Banks (lat. 33° 37′ S, long. 150° 41′ E), 5 km southwest of Richmond, New South Wales, large Scribbly Gums (*Eucalyptus sclerophylla*), twisted Angophoras (*Angophora bakeri*), tall Banksias (*Banksia* spp.) and a host of coastal dune species flourish on an expanse of gently undulating white sand. The whole site is in many ways similar to coastal sand dune vegetation, such as that of Myall Lakes (Osborne & Robertson, 1939). Agnes Banks, however, is 55 km from the present coast and on the western margin of the Cumberland Plain, an undulating to flat area of heavy clay soils supporting a grassy woodland quite unlike that on the sand deposit. Average annual rainfall at Richmond is 790 mm (Bureau of Meteorology, 1979), which is similar to that of the Cumberland Plain but much lower than on the coast (average annual rainfall at Sydney is 1 209 mm).

About half the original sand area had been cleared or quarried by 1972 and most of the remainder committed for future sand extraction. Only a small area at the southern end will be preserved. Such an unusual area of vegetation warrants study. The description given here provides information on the structure of the vegetation and species composition, which will be useful for comparative studies, management of the remaining area and possible restoration of adjacent mined areas.

General Description of the Area

The sand at Agnes Banks was first mentioned by Maze (1942) and described in detail by Simonett (1950). The deposit is of white sand and originally covered an area of some 600 ha. The sand forms a series of low, stable, longitudinal dunes aligned east-west, with maximum amplitude of 6 m, though 3 to 4 m is more common. To the south the dunes fade into undulations. Drainage in the centre of the dune area is internal, swamps being formed in swales between the main dunes. The sand has been strongly podsolized, with a hardpan close to the surface in the swales, but discontinuous or absent from the dune crests. Sand extraction has now removed the larger dunes and disturbed much of the original drainage pattern.

Gobert (1978) described the "Agnes Banks Sand" as a stratigraphic unit of Pliocene or Pleistocene age, and probably a fluvial deposit which has been redistributed by westerly winds. Lateritized Tertiary alluvial deposits, mainly clays and silts, surround and underlie the sand, these in turn overlying the extensive Triassic Wianamatta Group which makes up the Cumberland Plain to the south and east. To the west are the Recent alluvial flats of the Hawkesbury-Nepean River, and beyond them the Triassic Hawkesbury Sandstone of the lower Blue Mountains is exposed along the Lapstone Monocline (New South Wales Dept. of Mines, 1966).

The vegetation on the sand deposit is mainly woodland to low woodland with some smaller areas of open-scrub (structural forms follow Specht, 1970). The dominant tree species, *Eucalyptus sclerophylla*, *E. parramattensis* and *Angophora bakeri*, are associated with a species-rich sclerophyllous shrub understorey, common species being *Banksia serrata*, *B. serratifolia*, *Ricinocarpos pinifolius*, *Dillwynia glaberrima*, *Leptospermum attenuatum*, *Conospermum taxifolium*, *Philotheca salsolifolia* and *Acacia brownii*. On the surrounding areas of clay the dominant tree species is *Eucalyptus fibrosa* subsp. *fibrosa*, though *E. sclerophylla*, *E. parramattensis* and *Angophora bakeri* occur occasionally. The rich shrub understorey is replaced by a more open one, predominantly of *Melaleuca decora* and *Bursaria spinosa* with a dense ground cover of grasses.

Phillips (1947) described the vegetation on both the sand deposit and the Tertiary alluvial deposits as belonging to her *Eucalyptus crebra* [*E. racemosa*]-*Angophora bakeri* Association but distinguished the Agnes Banks vegetation in a separate shrub-stratum group characterized by *Banksia serrata*. Forster *et al.* (1977) listed the main tree and shrub species on the sand deposit and included it in a list of areas of botanical conservation interest.

VEGETATION DESCRIPTION

Methods

Black and white aerial photography (Cumberland 1970 series, scale 1:15 000, date 9.7.1970 and Penrith series, scale 1:40 000, date 27.6.1966) and field traverses were used to prepare a vegetation map (Figure 1) showing the vegetation types extant in 1970. Tree canopy cover and topographic position were the main characteristics used to distinguish the different communities on the aerial photography. Field observations confirmed that these were related to species groups, and indicated particularly that drainage was an important factor in plant distribution.

In September 1976 the vegetation was sampled at 250 m intervals along north/south transects, the transects being chosen subjectively in order to sample the five plant communities. As considerable clearing had been carried out since 1970, sample points falling on cleared or mined areas were ignored, leaving 24 in essentially undisturbed native vegetation, though 8 of these had been burnt within the previous two years.

Mining and consequently destruction of the plant communities has been uneven. The highest dunes have generally been mined first, so that only small areas of their vegetation remained whereas there were still large areas of vegetation on shallower sand. Since sand depth appears to influence plant community composition, the sampling of the five communities was uneven and the majority of sampling points were located in the two communities occupying the greatest area of remaining vegetation, the *Eucalyptus sclerophylla-Angophora bakeri-Banksia serrata* woodland and the *Eucalyptus parramattensis* low open-woodland. Two communities had only one sampling point in them and one community was not sampled. Several points had been sampled previously in 1975, similar data being recorded. These data were not used in the later numerical analyses but were included in the basal area and stem density descriptions.

At each sample point all vascular plant species present within a 20 x 20 m square quadrat, hereafter referred to as a sample site, were listed or collected for later identification, and stem diameters of all individuals greater than 5 cm (d.b.h.) were recorded. Projected canopy foliage cover was measured at 50 points within the site, using a vertical sighting tube with cross-wires. Notes were made on important shrub species, position on dune, drainage, aspect, slope and evidence of fire or other disturbance.

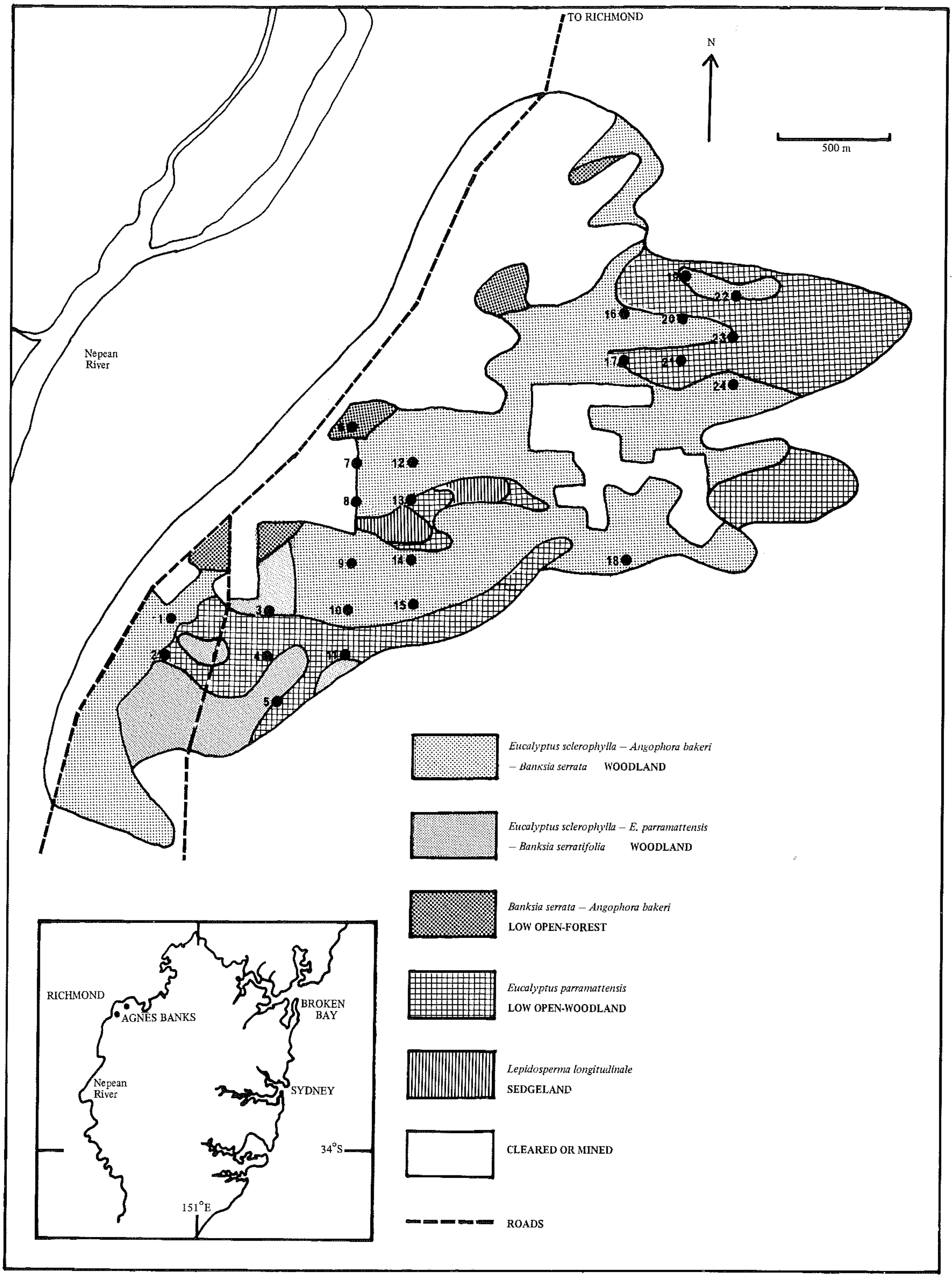

Figure 1. Vegetation map of Agnes Banks sand deposit in 1970 showing sampling sites.

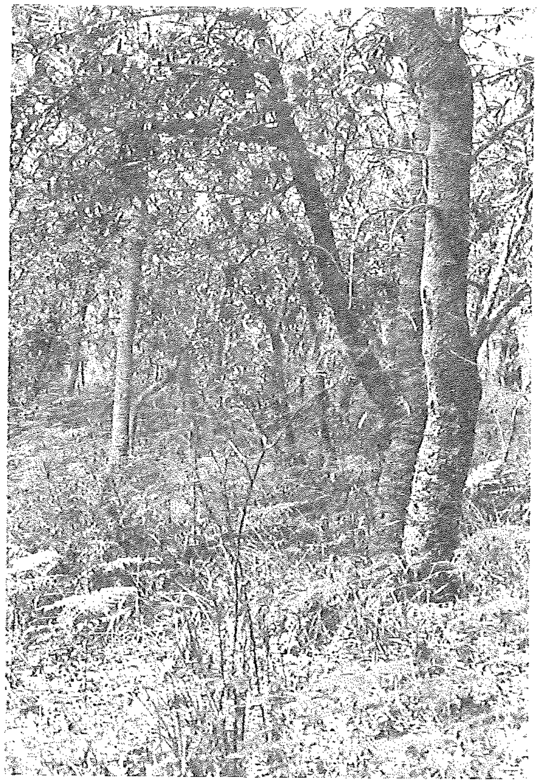

Figure 2. Low open-forest of *Banksia serrata* and *Angophora bakeri*. Understorey mainly *Pteridium esculentum*.

Figure 3. Woodland of *Eucalyptus sclerophylla*, *Angophora bakeri* and *Banksia serrata*.

Figure 4. *Banksia serratifolia* in woodland of *Eucalyptus sclerophylla*, *E. parramattensis* and *Banksia serratifolia*. Sedges predominate in foreground.

Results

Five communities were recognized and their distributions are shown in Figure 1.

1. LOW OPEN-FOREST of *Banksia serrata* and *Angophora bakeri*.

A community apparently originally confined to the well-drained crests of the large dunes, most of which have been completely removed by sand extraction. The main trees are *Banksia serrata* and *Angophora bakeri*, up to 10 m high but the community may have occasional large, emergent trees of *Eucalyptus sclerophylla* (Scribbly

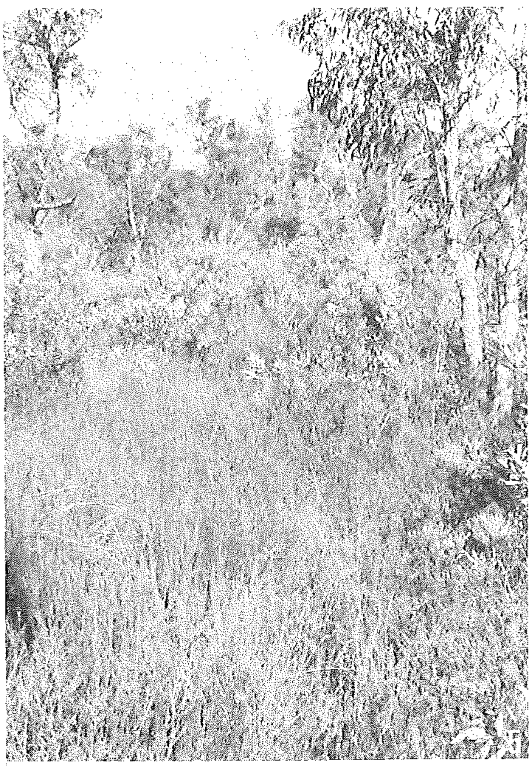

Figure 5. Low open-woodland of *Eucalyptus parramattensis* with *Banksia aspleniifolia*.

Figure 6. Sedgeland of *Lepidosperma longitudinale* and *Melaleuca thymifolia* with woodland of *E. sclerophylla* in background.

Gum) up to 13 m. There is an open understorey of *Pteridium esculentum* and *Imperata cylindrica* and scattered shrubs including *Ricinocarpos pinifolius*, *Eriostemon myoporoides* and *Bossiaea rhombifolia*.

2. WOODLAND of *Eucalyptus sclerophylla*, *Angophora bakeri* and *Banksia serrata*.

This is the most widespread community, found on well-drained and moderately well-drained sites. It is dominated by trees of *Eucalyptus sclerophylla* 10 to 15 m high, together with smaller trees of *Angophora bakeri* and *Banksia serrata*. A large number of sclerophyllous shrub species is characteristic of the understorey, common species being *Leptospermum attenuatum*, *Conospermum taxifolium*, *Ricinocarpos pinifolius* and *Isopogon anemonifolius*.

3. WOODLAND of *Eucalyptus sclerophylla*, *Eucalyptus parramattensis* and *Banksia serratifolia*.

At the southern end of the sand deposit is woodland that is also dominated by *Eucalyptus sclerophylla* but appears to be restricted to shallower or less well-drained sand than Community 1. Small trees of *E. parramattensis* (Drooping Red Gum) up to 10 m high and large shrubs of *Banksia serratifolia* up to 7 m are generally present. An understorey of sclerophyllous shrubs, similar to that in Community 2 is usually present.

4. LOW OPEN-WOODLAND of *Eucalyptus parramattensis*.

This community is confined to poorly-drained situations. Small trees of *E. parramattensis* less than 10 m high, either in clumps or as scattered individuals, are dominant though *E. sclerophylla* and *Angophora bakeri* may be present occasionally. The understorey is dominated by *Banksia aspleniifolia*, which in the most low-lying areas forms a low shrubland, devoid of trees. Large tussocks of sedges and rushes are common. One sedge species, *Restio pallens*, common on the north coast of New South Wales and in southern Queensland, reaches its southern limit at Agnes Banks.

5. SEDGELAND of *Lepidosperma longitudinale*.

Sedgeland, with the small shrub *Melaleuca thymifolia*, occurs in a limited area in depressions between the main dunes where drainage is severely impeded.

The floristic composition of the sand dune area, the frequencies of many species (based on 24 sampling sites) and their growth-forms are shown in Table 1.

TABLE 1

Species recorded on the Agnes Banks sand, with MULTBET species groups, growth-forms, frequencies of occurrence and mode of regeneration after fire.

MULTBET species group	Botanical name	Growth-form	Frequency of occurrence % (24 sites)	Regeneration after fire V = vegetative S = seedling
	PTERIDOPHYTES			
	Adiantaceae			
1	*Cheilanthes tenuifolia*	Fb	8	?V
	Dennstaedtiaceae			
6	*Pteridium esculentum*	Fb	33	V
	Schizaeaceae			
..	*Schizaea bifida*	Fb	4	?V
	GYMNOSPERMS			
	Zamiaceae			
..	*Macrozamia spiralis*	sS	8	V
	ANGIOSPERMS			
	DICOTYLEDONS			
	Apiaceae			
1	*Platysace ericoides*	sS	83	V
1	*Trachymene incisa*	Fb	92	V S
	Apocynaceae			
..	*Parsonsia straminea*	Cl	4	..
	Asteraceae			
..	*Cassinia aculeata*	sS	..	..
..	*C. uncata*	sS	8	..
..	**Conyza albida*	Fb	8	?S
..	*Helichrysum diosmifolium*	sS	4	V
4	**Hypochoeris radicata*	Fb	46	S
..	*Lagenifera stipitata*	..	4	..
..	*Senecio quadridentatus*	Fb	4	..
	Campanulaceae			
..	*Wahlenbergia* sp.	Fb	8	..
	Cassythaceae			
..	*Cassytha glabella*	Tw	4	?S
3	*C. pubescens*	Tw	67	?S
	Casuarinaceae			
..	*Casuarina littoralis*	tS	4	?S
	Dilleniaceae			
..	*Hibbertia diffusa*	sS	4	..
3	*H. fasciculata*	sS	75	S
	Droseraceae			
5	*Drosera peltata*	Fb	13	..
..	*D. pygmaea*	Fb	8	..
5	*D. spathulata*	Fb	17	..
	Epacridaceae			
3	*Brachyloma daphnoides*	sS	54	V
2	*Leucopogon ericoides*	sS	54	S
3	*L. virgatus*	sS	46	V
3	*Monotoca scoparia*	sS	67	V
..	*Styphelia laeta*	sS	4	..
	Euphorbiaceae			
4	*Amperea xiphoclada*	Gr	50	V
..	*Poranthera microphylla*	..	4	?S
3	*Ricinocarpos pinifolius*	S	79	V

MULTBET species group	Botanical name	Growth-form	Frequency of occurrence % (24 sites)	Regeneration after fire V = vegetative S = seedling
	Fabaceae			
7	*Bossiaea heterophylla*	sS	25	V
3	*B. rhombifolia*	sS	63	V
7	*Daviesia acicularis*	sS	13	..
2	*Dillwynia floribunda*	sS	54	S
3	*D. glaberrima*	sS	79	V S
7	*Gompholobium minus*	sS	38	S
6	*Hardenbergia violacea*	Tw	33	V
6	*Hovea linearis*	sS	33	V
..	*Indigofera australis*	sS	4	V
..	*Mirbelia rubiifolia*	sS	4	..
..	*Pultenaea elliptica*	sS	..	..
	Goodeniaceae			
..	*Dampiera stricta*	Fb	..	V
3	*Goodenia bellidifolia*	Fb	25	..
..	*Scaevola ramosissima*	Fb	4	..
	Haloragaceae			
5	*Gonocarpus micranthus*	Fb	33	?V
	Loganiaceae			
6	*Mitrasacme polymorpha*	Fb	33	S
	Mimosaceae			
2	*Acacia brownii*	sS	63	V
..	*A. bynoeana*	sS	4	..
2	*A. elongata*	S	75	V
..	*A. floribunda*	tS	..	?S
..	*A. parramattensis*	tS	..	?S
3	*A. ulicifolia*	sS	54	S
	Myrtaceae			
3	*Angophora bakeri* AAABD	sT	71	V S
..	*A. floribunda* AAABB	T	..	..
2	*Baeckea diosmifolia*	sS	54	V
..	*Callistemon citrinus*	sS	4	V
..	*C. linearis*	sS	8	V
..	*C. pinifolius*	sS	4	V
2	*Eucalyptus parramattensis* SNECF	sT	63	V S
3	*E. sclerophylla* MATKB	sT or T	75	V S
2	*Kunzea capitata*	sS	54	V
3	*Leptospermum attenuatum*	S	75	V
5	*L. flavescens*	S	42	V
..	*L. parvifolium*	sS	4	?V
5	*Melaleuca thymifolia*	sS	13	V
	Olacaceae			
7	*Olax stricta*	sS	21	..
	Polygalaceae			
..	*Comesperma ericinum*	sS	..	S
	Proteaceae			
2	*Banksia aspleniifolia*	S	63	V S
3	*B. serrata*	tS or sT	54	V S
5	*B. serratifolia*	tS	17	V S
7	*B. spinulosa*	S	38	V
3	*Conospermum taxifolium*	sS	67	V S
6	*Grevillea mucronulata*	sS	21	V S
5	*Hakea sericea*	S	13	S
..	*H. dactyloides*	S	4	?V
3	*Isopogon anemonifolius*	sS	63	V S
7	*Persoonia laurina*	sS	30	V
3	*P. nutans*	sS	58	S
5	*Petrophile pulchella*	S	13	S
..	*P. sessilis*	sS	8	..
	Rubiaceae			
..	*Opercularia* sp.	Fb	4	..
7	*Pomax umbellata*	sS	17	..

MULTBET species group	Botanical name	Growth-form	Frequency of occurrence % (24 sites)	Regeneration after fire V = vegetative S = seedling
	Rutaceae			
..	*Eriostemon myoporoides* ..	S	..	..
6	*Philotheca salsolifolia*	sS	42	V
	Santalaceae			
..	*Omphacomeria acerba*	sS	..	..
	Solanaceae			
..	*Duboisia myoporoides*	S	..	?V
	Stylidiaceae			
1	*Stylidium graminifolium*	Fb	88	V
	Thymelaeaceae			
1	*Pimelea linifolia*	sS	100	S
	MONOCOTYLEDONS			
	Centrolepidaceae			
..	*Centrolepis strigosa*	Gr	8	..
	Cyperaceae			
2	*Cyathochaeta diandra*	Gr	38	V
..	*Lepidosperma longitudinale* ..	Gr	..	..
..	*Ptilanthelium deustum*	Gr	8	V
1	*Schoenus brevifolius*	Gr	71	V
3	*S. ericetorum*	Gr	54	V
	Haemodoraceae			
1	*Haemodorum corymbosum* ..	Gr	88	V
	Iridaceae			
..	*Patersonia sericea*	Gr	4	..
	Juncaceae			
7	*Juncus continuus*	Gr	13	V
..	*J. planifolius*	Gr	..	..
	Liliaceae			
..	*Burchardia umbellata*	Gr	..	..
..	*Dianella laevis*	Gr	8	?V
4	*D. revoluta*	Gr	46	?V
..	*Stypandra caespitosa*	Gr	..	..
	Orchidaceae			
..	*Caladenia alba*	Gr	4	?V
..	*Caleana major*	Gr	..	?V
7	*Calochilus* sp.	Gr	17	?V
..	*Glossodia minor*	Gr	4	?V
..	*Microtis* sp.	Gr	4	?V
..	*Pterostylis longifolia*	Gr	4	?V
..	*Thelymitra aristata*	Gr	..	?V
..	*T. longifolia*	Gr	8	?V
	Poaceae			
..	*Aristida ramosa*	Gr	4	..
..	*A. vagans*	Gr	17	..
..	*A. warburgii*	Gr	4	..
..	*Cynodon dactylon*	Gr	4	..
6	*Digitaria parviflora*	Gr	33	..
4	*Entolasia stricta*	Gr	67	..
4	*Eragrostis brownii*	Gr	46	..
..	*E. leptostachya*	Gr	4	..
..	*Imperata cylindrica*	Gr	8	V
..	*Microlaena stipoides*	Gr	4	?V
..	**Setaria geniculata*	Gr	4	..
..	*Themeda australis*	Gr	4	..
	Restionaceae			
7	*Hypolaena fastigiata*	Gr	21	V
5	*Leptocarpus tenax*	Gr	25	?V
..	*Lepyrodia muelleri*	Gr	..	?V
2	*L. scariosa*	Gr	63	?V
5	*Restio pallens*	Gr	21	V

MULTBET species group	Botanical name	Growth-form	Frequency of occurrence % (24 sites)	Regeneration after fire V = vegetative S = seedling
	Xanthorrhoeaceae			
7	*Lomandra cylindrica*	Gr	33	V
7	*L. filiformis*	Gr	8	V
4	*L. glauca*	Gr	67	V
7	*L. longifolia*	Gr	25	V
..	*L. multiflora*	Gr	4	V
..	*Xanthorrhoea minor*	Gr	67	V
..	*X. resinosa* subsp. *resinosa*	Gr		
	Xyridaceae			
..	*Xyris complanata*	Gr	4	..

* = exotic species

Nomenclature follows Jacobs & Pickard (in press). *Eucalyptus* and *Angophora* codings follow Pryor & Johnson (1971). *Acacia brownii* is correctly so spelled, not "brownei".

Growth-form: T = tree, sT = small tree, tS = tall shrub, S = shrub, sS = small shrub, Fb = forb, Gr = graminoid, Cl = climber, Tw = twiner.

Regeneration after fire: ? indicates likely mode based on growth-form or on Purdie & Slatyer (1976).

Table 2 shows structural data for the plant communities arranged in order of increasingly impeded drainage. In general structural characters measured appear to be correlated with this gradient. Basal area, stem density, canopy cover and bare ground per cent are all highest in the well drained low open-forest and woodland communities and decrease towards the sedgeland while ground cover density shows the reverse trend. Only canopy height does not follow this trend, being highest in the woodland communities. The low open-forest may originally have had emergent trees. A few stumps exist but from the small remnants surviving it is now difficult to be certain how common these emergent trees may have been.

Tables 3 and 4 show basal area and densities for the tree species in these communities. Again a gradient in dominance can be observed from well drained to poorly drained, species ordering being *B. serrata-A. bakeri-E. sclerophylla-B. serratifolia-E. parramattensis.*

The distributions of species within a number of genera are interesting. Carolin (1970) pointed out that at Myall Lakes, species in the same genus frequently showed distinctly different habitat preferences apparently related to soil drainage, though possibly due to competition. At Agnes Banks there is evidently a similar situation with regard to the following species, *Dillwynia glaberrima* and *D. floribunda*, *Leptospermum attenuatum* and *L. flavescens*, and *Banksia serrata*, *B. serratifolia* and *B. aspleniifolia*.

Fire also appears to be an important ecological factor. Fire has been common in the past. There are charcoal remains on many trees, even at sites where a dense shrub understorey and leaf litter suggest that it is some years since the last burning. Adaptations to fire are very common in the vegetation, and many species regenerate from underground perennating organs such as lignotubers or rhizomes. The mode of regeneration of 65 species was recorded (Table 1). Of these, over 80% of species showed evidence of vegetative resprouting and less than 20% regenerated by seedlings alone. Among these were a number of genera within which species responded differently. *Dillwynia floribunda*, *Acacia ulicifolia* and *Leucopogon ericoides* regenerate only by seedlings but *Dillwynia glaberrima*, *Acacia brownii*, *A. elongata*, and *Leucopogon virgatus* may survive fire and resprout. Species relying solely on seedling establishment do not appear to show any preference for either more or less frequently burnt sites and are distributed through most plant communities.

TABLE 2

Structural data for 20 x 20 m quadrats in mapped plant communities

	Low open-forest *B. serrata* *A. bakeri*	Woodland *E. sclerophylla* *A. bakeri* *B. serrata*	Woodland *E. sclerophylla* *E. parramattensis* *B. serratifolia*	Low open-woodland *E. parramattensis*	Sedgeland
Number of 20 x 20 m sites recorded*	1 (1)	14	1	8	(1)
Estimated canopy height (m)	(9)–10	8–20	12	6–12	(1)
Canopy cover (%)	52–(67)	6–44	6	2–16	not measured
Basal area (m^2/ha)	33.0, (43.5)†	15.4 SD 9.3	9.1†	6.5 SD 4.7	(0)†
Stem density (stem/ha)	950, (1 675)†	671 SD 280	525†	375 SD 217	(0)†
Ground cover density	mid-dense to open	dense to open	mid-dense	dense to mid-dense	dense
Estimated % bare ground	(40)–50	10–60	30	5–30	(0)

* Sites in brackets were the 20 x 20 m sites recorded in April 1975. They are not included in the later numerical analyses.

† = actual figures.

TABLE 3

Mean basal areas (m^2/ha) for tree species in mapped plant communities

Species	Low open-forest *B. serrata* *A. bakeri*	Woodland *A. bakeri* *B. serrata*		Woodland *E. sclerophylla* *E. parramattensis* *B. serratifolia*		Low open-woodland *E. parramattensis*	
	Mean basal area m^2/ha	Mean basal area m^2/ha	Percentage of total basal area	Mean basal area m^2/ha	Percentage of total basal area	Mean basal area m^2/ha	Percentage of total basal area
Banksia serrata	20.8, (23.3)†	2.2 SD 2.3	14	..	..	0.1 SD 0.2	1
Angophora bakeri	22.7, (9.7)†	7.9 SD 6.3	51	1.3†	14	0.2 SD 0.5	3
Eucalyptus sclerophylla	..	4.4 SD 4.8	28	0.9†	10	1.7 SD 3.8	26
Banksia serratifolia	..	0.2 SD 0.8	1	6.9†	76	0.01 SD 0.03	<1
Eucalyptus parramattensis	..	0.5 SD 1.2	3	..	..	4.5 SD 2.3	69
Number of 20 x 20 m sites recorded*	1 (1)	14	..	1	..	8	..

* = sites in brackets were 20 x 20 m sites recorded in April 1975. They are not included in the later analyses.

† = actual figures.

TABLE 4

Mean plant densities (plants/ha) for tree species (>5 cm dbh) in mapped plant communities

Species	Low open-forest *B. serrata* *A. bakeri*	Woodland *A. bakeri* *B. serrata*		Woodland *E. sclerophylla* *E. parramattensis* *B. serratifolia*		Low open-woodland *E. parramattensis*	
	Mean plant density pls/ha	Mean plant density pls/ha	Percentage of total density	Mean plant density pls/ha	Percentage of total density	Mean plant density pls/ha	Percentage of total density
Banksia serrata	800, (1·000)†	125 SD 126	23	..	..	28 SD 80	10
Angophora bakeri	125, (675)†	259 SD 140	47	125†	28	6 SD 18	2
Eucalyptus sclerophylla	..	41 SD 29	7	125†	28	34 SD 44	12
Banksia serratifolia	..	18 SD 67	3	200†	44	3 SD 9	1
Eucalyptus parramattensis	..	25 SD 47	5	..	..	212 SD 142	75
Number of 20 x 20 m sites recorded*	1 (1)	14	..	1	..	8	..

* = Sites in brackets were 20 x 20 m sites recorded in April 1975. They are not included in the later analyses.

† = Actual figures.

VEGETATION ANALYSIS

Methods

During mapping and description of the plant communities, considerable intergradation between them was recognized. This was particularly noticeable in the understorey species, whose topographic positions appeared to reflect a gradient of drainage change, both across the five communities, and within particular communities. There was also evidence of frequent fire, (charcoal remains on trees, dead shrub remains, localized patches of species regarded as indicators of frequent fire, e.g. *Pimelea linifolia*) and the question of its importance in determining the distribution of shrub species was raised.

The data from the 24 sampling sites recorded in 1976 were therefore subjected to both classification and ordination analyses. Because of the concentration of most sampling in two communities, the *E. sclerophylla-Angophora bakeri-Banksia serrata* woodland and the *E. parramattensis* low open-woodland, most discussion is confined to the relationships within and between these two. However, some idea of the relationships of the two communities each represented by only one site may be indicated by the position of those sites in the classification or ordination analyses.

Presence/absence data of species recorded from more than 10% of the sites, i.e. more than 2 of the 24, (Table 1) were analysed using programs from the TAXON library on the CSIRO CSIRONET Control Data Cyber 76 computer. Programs used were the agglomerative polythetic classification program MULTBET (Lance & Williams, 1967), the principal coordinate ordination program GOWER (Gower, 1966) and the diagnostic programs GROUPER and GOWECOR. Of 131 species recorded from the sites, 70 were used in the analyses. Both normal and inverse MULTBET analyses were carried out and the results plotted in a two-way table of site groups against species groups.

Results

Following convention the MULTBET analyses are discussed as though divisive, i.e. down the hierarchy. In the normal analysis the first major division is between well-drained and poorly-drained sites, the former corresponding generally to sites in the *Eucalyptus sclerophylla-Angophora bakeri-Banksia serrata* woodland and the latter to sites in the *Eucalyptus parramattensis* low open-woodland. Species contributing to the dry-site groups are *Leptospermum attenuatum*, *Bossiaea rhombifolia*, *Ricinocarpos pinifolius* and *Isopogon anemonifolius*. These are generally known to be species of well-drained or deep sandy situations. Species contributing to the wet-site groups are *Leptospermum flavescens*, *Drosera spathulata*, *Baeckea diosmifolia* and *Gonocarpus micranthus*, species normally found in poorly-drained or moist situations.

Lower divisions in the analysis could not be interpreted satisfactorily.

The first axis of the GOWER ordination of sites (accounting for 26.8% of the variation) is interpreted as reflecting a moisture/drainage gradient (Figure 7). Species correlated with ordination axes were obtained from the diagnostic program GOWECOR. Positively correlated with the first axis were *Acacia ulicifolia* (0.83), *Leptospermum attenuatum* (0.83), *Bossiaea rhombifolia* (0.81), *Ricinocarpos pinifolius* (0.76) and *Hovea linearis* (0.75), species of well-drained or deep sandy situations. Negatively correlated were *Leptospermum flavescens* (−0.85), *Baeckea diosmifolia* (−0.81), *Gonocarpus micranthus* (−0.76), *Leptocarpus tenax* (−0.75) and *Drosera spathulata* (−0.74), species normally found in poorly-drained or moist situations.

The response of the species to the postulated moisture/drainage gradient is shown in Table 5. Here the MULTBET species groups, arranged approximately according to the first GOWECOR species axis, are tabulated against the sites arranged in first GOWER site axis order. Though some species are restricted to either the well-drained or poorly-drained ends of the gradient, many species overlap.

TABLE 5

Ordination of sites by first GOWER axis (moisture/drainage gradient) tabulated against MULTBET species groups arranged approximately according to first GOWER species axis.

Well-drained sites ——————→ Poorly-drained sites

Species groups	Botanical name	7	8	12	6	14	9	16	22	3	13	15	19	10	18	24	1	17	23	2	4	20	5	21	11
3	*Acacia ulicifolia*	x	x	x	x	x	x	x	x	x	x	..	x	..	..	x	x	..	..	..	..	..	..	..	x
	Angophora bakeri	x	x	x	x	x	x	x	x	x	x	x	x	x	..	x	x	..	x	..	..	..	..	..	x
	Bossiaea rhombifolia	x	x	x	x	x	x	x	x	x	x	..	x	x	..	x	..	x	x	..	..	..	..	..	..
	Leucopogon virgatus	x	..	x	..	x	..	x	..	x	x	x	x	x	..	..	..	x	x	..	..	..	..	..	..
	Schoenus ericetorum	x	x	x	..	x	x	x	x	x	x	x	x	..	..	x	..	..	..	x	..	..	..	..	..
	Banksia serrata	x	x	x	x	x	x	x	..	x	x	x	..	..	x	x	..	x	..	..	..	..	..	..	..
	Brachylome daphnoides	..	x	x	x	x	x	x	x	x	..	x	..	x	x	x	..	..	..	x	..	..	..	..	..
	Cassytha pubescens	x	x	x	x	x	x	x	..	..	x	x	..	x	x	x	x	x	..	x	..	..	x	..	..
	Conospermum taxifolium	..	x	x	..	..	x	x	x	..	x	x	x	x	x	x	..	x	..	x	x	x	..	..	x
	Dillwynia glaberrima	x	..	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	..	x	x	..	x	..	..
	Eucalyptus sclerophylla	x	x	x	..	x	x	x	x	x	x	x	..	x	x	x	x	..	x	..	..	x	x	..	x
	Hibbertia fasciculata	x	x	x	..	x	x	x	x	..	x	x	x	x	x	x	x	x	x	x	..	x	..	..	..
	Isopogon anemonifolius	x	x	x	x	x	x	x	..	x	x	x	..	x	x	x	..	..	x	..	..	..	..	..	x
	Leptospermum attenuatum	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	..	..	..	..	..	..
	Monotoca scoparia	x	x	x	x	x	x	x	x	x	x	x	..	x	x	x	..	..	..	x	..	..	x	..	..
	Persoonia nutans	x	x	x	x	x	x	x	..	..	x	x	..	..	x	..	x	x	x	x	..	..	..	..	..
	Ricinocarpos pinifolius	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	..	..	..	..	..
1	*Haemodorum corymbosum*	x	x	x	x	x	..	x	x	x	x	x	x	x	x	x	..	x	x	x	x	x	x	x	..
	Pimelea linifolia	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Platysace ericoides	x	..	..	x	x	..	x	x	x	x	x	x	x	x	..	x	x	x	x	x	x	x	x	x
	Schoenus brevifolius	..	..	..	..	x	..	x	x	x	..	x	x	..	x	x	x	x	x	x	x	x	x	x	x
	Stylidium graminifolium	x	x	x	x	x	x	x	x	x	..	x	x	x	..	x	x	x	x	x	..	x	x	x	x
	Trachymene incisa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	..	x	x	x	x	x	x	x	..	x
4	*Amperea xiphoclada*	x	x	..	..	..	..	x	x	x	x	..	..	..	..	x	x	x	..	x	x	..	x	..	..
	Dianella revoluta	x	x	..	x	x	x	x	x	..	..	x	x	..	..	..	x	..	..	..	..	x	..	..	..
	Entolasia stricta	x	x	x	x	..	..	x	..	x	x	..	x	..	x	..	x	x	x	x	x	x	..	x	..
	Eragrostis brownii	x	..	..	x	..	x	..	x	..	..	x	x	..	..	..	x	x	..	x	x	..	..	x	..
	Hypochoeris radicata	x	x	..	x	..	x	..	..	x	x	x	x	x	x	..	x	x	..	..	..	..	..	..	..
	Lomandra glauca	x	x	..	x	x	x	..	x	x	x	x	x	x	x	x	x	x	..	..	x	..	..	..	..

Species Group	Botanical name	7	8	12	6	14	9	16	22	3	13	15	19	10	18	24	1	17	23	2	4	20	5	21	11
6	*Digitaria parviflora*	x	x	..	..	..	x	x	x	x	x	..	..	..	..	..	x	..	..	..	..	..	..	..	..
	Grevillea mucronulata	x	x	x	x	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Hardenbergia violacea	x	x	x	x	x	..	x	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..
	Hovea linearis	x	x	x	x	x	..	x	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Mitrasacme polymorpha	x	x	..	..	..	x	x	..	x	x	x	..	x	..	..	..	..	..	..	..	..	..	..	..
	Philotheca salsolifolia	x	x	x	x	..	x	..	x	x	..	x	..	..	..	..	..	..	x	..	..	..	..	..	..
	Pteridium esculentum	x	x	x	x	x	..	x	..	..	x	..	..	..	..	..	x	..	..	..	..	..	..	..	..
2	*Acacia brownei*	..	..	..	..	x	x	..	x	x	..	..	x	x	x	x	..	x	x	x	..	x	x	x	x
	Acacia elongata	..	x	..	..	x	x	..	..	x	x	x	x	x	x	x	x	..	x	x	x	x	x	x	x
	Cyathochaeta diandra	..	x	..	..	..	..	..	x	x	x	x	x	x	..	..	..	..	..	..	x	..	..	x	..
	Dillwynia floribunda	..	x	..	..	..	x	..	x	x	..	x	x	..	..	..	..	..	x	x	x	x	x	x	x
	Kunzea capitata	..	..	..	..	..	..	..	..	x	x	x	x	x	x	..	..	x	x	..	x	x	x	x	x
	Leucopogon ericoides	..	x	..	..	x	x	..	..	..	..	x	x	..	x	..	x	x	x	x	..	x	..	x	x
	Baeckea diosmifolia	..	..	..	..	..	..	..	..	..	x	x	..	x	x	..	x	x	x	x	x	x	x	x	x
	Banksia aspleniifolia	..	x	..	..	..	..	x	..	x	x	x	..	x	x	x	x	x	x	x	x	x	x	x	..
	Eucalyptus parramattensis	..	..	..	..	..	..	x	..	x	x	..	x	..	x	x	x	x	x	x	x	x	x	x	x
	Lepyrodia scariosa	..	..	..	..	..	..	x	..	..	x	x	..	x	x	x	x	x	x	x	x	x	x	x	x
7	*Banksia spinulosa*	..	x	..	..	x	..	x	..	x	..	..	..	..	..	..	..	x	..	..	..	x	x	x	x
	Lomandra cylindrica	..	x	..	x	..	..	..	..	..	x	..	..	x	..	..	x	..	..	x	..	..	x	x	..
	Lomandra longifolia	..	..	..	x	..	..	..	..	..	x	..	x	..	..	..	x	x	..	..	..	..	..	..	x
	Persoonia laurina	..	..	..	x	x	..	x	..	x	..	..	..	..	..	..	x	..	x	..	..	..	x	..	..
	Pomax umbellata	..	..	..	x	..	..	..	..	..	..	..	x	x	..	..	x	..	..	..	..	..	..	..	..
	Bossiaea heterophylla	..	..	..	..	..	x	..	x	..	..	..	x	x	..	x	..	x	..	..	..	..	..	..	..
	Calochilus sp.	..	..	..	..	x	x	..	..	..	x	..	..	..	..	..	..	..	x	..	..	..	..	..	..
	Daviesia acicularis	..	x	..	..	..	..	..	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Gompholobium minus	..	x	..	..	x	x	..	x	..	x	x	x	..	..	..	..	x	..	..	..	..	x	..	..
	Hypolaena fastigiata	..	..	..	..	..	..	x	..	..	..	x	..	..	x	x	..	..	x	..	..	..	..	..	..
	Juncus continuus	..	..	..	..	..	..	..	..	..	x	..	..	..	..	x	..	..	..	..	..	..	x	..	..
	Lomandra filiformis	..	x	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Olax stricta	..	x	..	..	..	..	..	..	..	x	x	..	..	x	..	..	..	x	..	..	..	..	..	..
5	*Banksia serratifolia*	..	..	..	..	..	..	..	..	x	..	..	..	x	..	..	..	..	..	x	x	..	..	..	..
	Drosera peltata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	x	x
	Drosera spathulata	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	x	..	x	x	..
	Gonocarpus micranthus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	x	x	x	x	x	x	x
	Goodenia bellidifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	x	x	..	..	x	x	x
	Hakea sericea	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	x	..	..	x
	Leptocarpus tenax	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	x	x	x	x	..	x
	Leptospermum flavescens	..	..	..	..	..	..	..	..	..	..	..	x	x	..	..	x	x	x	x	x	x	x	..	x
	Melaleuca thymifolia	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	x	..	x
	Petrophile pulchella	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	x	..	..	x	..	..	..	..	..
	Restio pallens	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	x	..	x	x	..	x	..	..

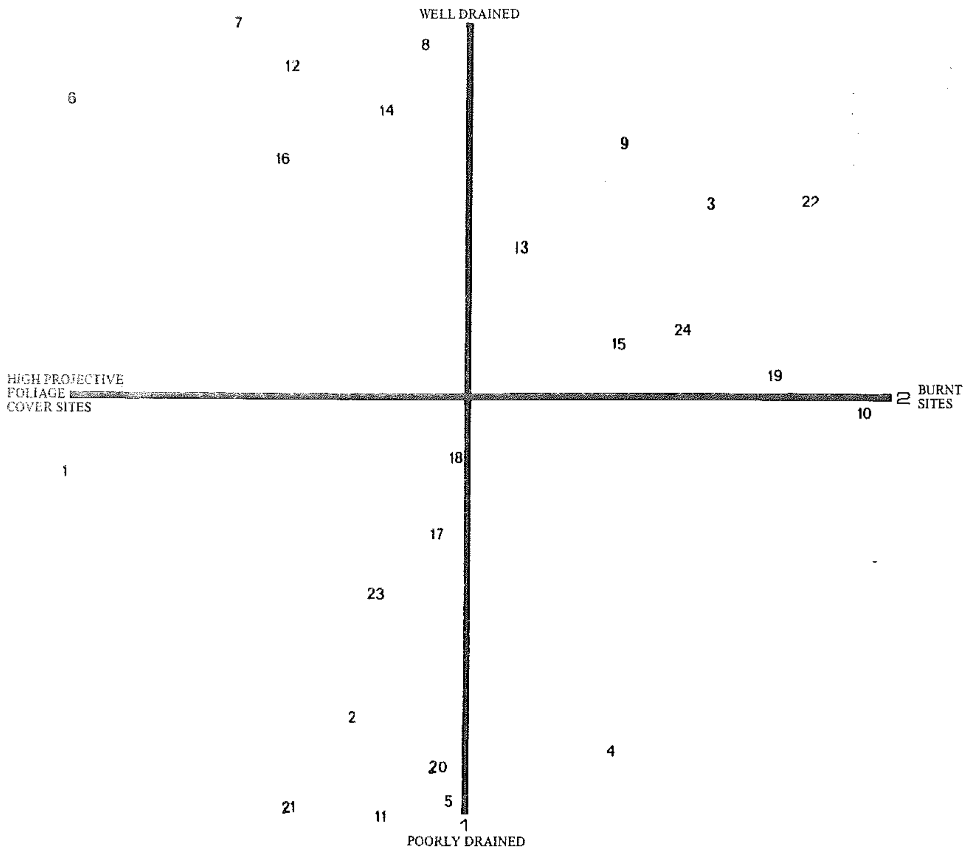

Figure 7. The first two axes of the site ordination.

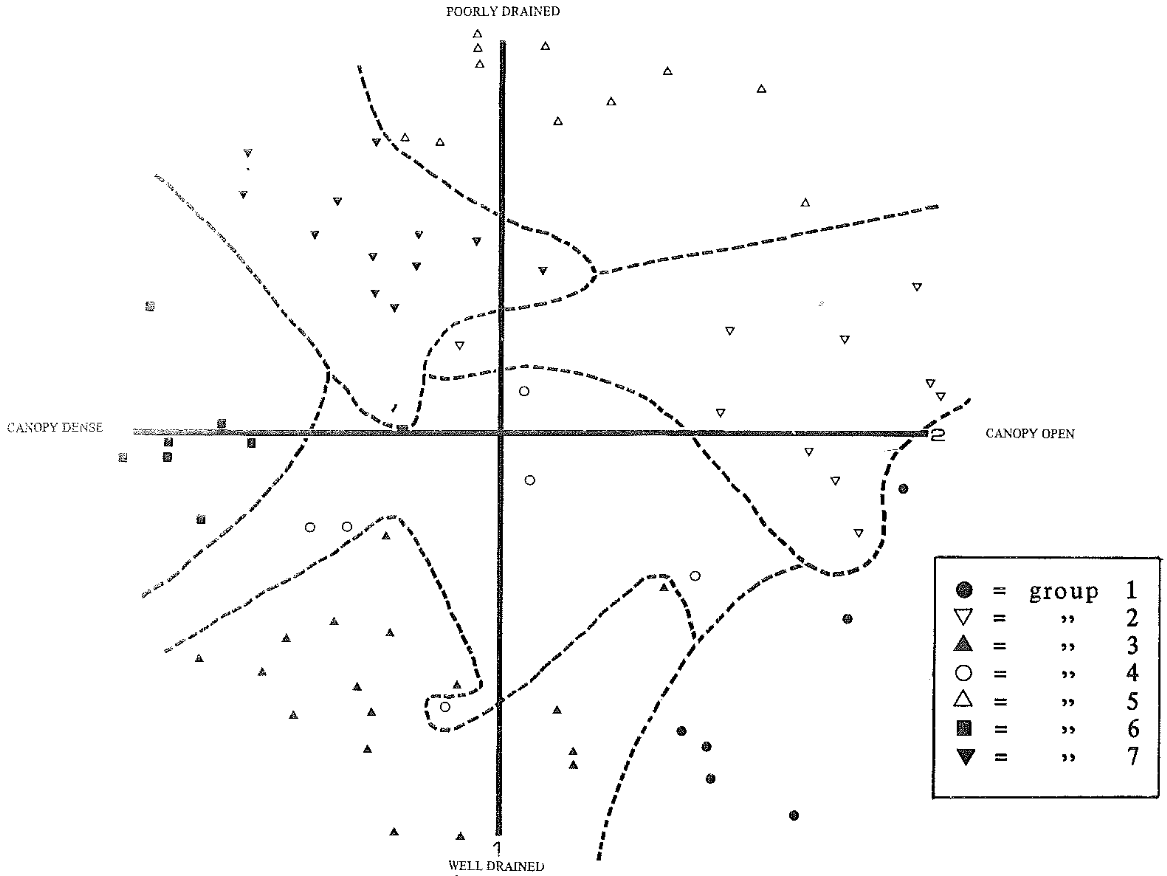

Figure 8. The first two axes (moisture/drainage and canopy cover) of the species ordination showing the separation of the species groups (see Tables 5 and 6 for composition of groups).

By inspection, however, a division can be drawn, probably between sites 1 and 17, a division which almost entirely agrees with the first division of the MULTBET site classification. The habitats indicated by the MULTBET species groups are given in Table 6.

The second site axis (accounting for 8.2% of variation) has burnt sites at one end, and sites with highest projective foliage cover at the other. Species positively correlated are *Bossiaea heterophylla* (0.70), *Acacia brownei* (0.50) and *Cyathochaeta diandra* (0.59). The first two species resprout vegetatively after fire although they are legumes, which generally regenerate rapidly from seed. *Cyathochaeta diandra* is reported by Siddiqi *et al.* (1976) as the most abundant species in the earliest stages of regrowth after fire in coastal ground-water heath in Bouddi National Park. Negatively correlated are *Pteridium esculentum* (−0.61), *Entolasia stricta* (−0.58) and *Persoonia nutans* (−0.55). *Pteridium esculentum*, a rhizomatous fern, is common after fire but removed by regular burning. *Entolasia stricta* may appear rapidly after burning but persists for a long time afterwards. From field observations, only *Persoonia nutans* seems to be restricted to sites with a dense projective foliage canopy cover that are not frequently burnt.

The third axis (accounting for 8.1% of variation) again has burnt sites at one end, but is not related to projective foliage cover. Species positively correlated are *Hypochoeris radicata* (0.50), an exotic species which may indicate disturbance, *Dillwynia floribunda* (0.47) which regenerates from seed after fire and *Eragrostis brownii* (0.46). Species negatively correlated are *Hypolaena fastigiata* (−0.67), *Lepyrodia scariosa* (−0.58) and *Olax stricta* (−0.58). Siddiqi *et al.* (1976) included *Hypolaena fastigiata* in a list of low-growing species which grew well in the early stages of regrowth after a fire and recorded *Lepyrodia scariosa* within a year of burning.

The first two axes of the species ordination account for 26.1 and 19.3% of the variance in the vegetation data respectively. The first axis is again related to a moisture/drainage gradient (Figure 8) and confirms the importance of the character in determining the type of vegetation. The second axis appears to be related to the site projective foliage cover. Sites positively correlated with this axis are sites 20 (4% projective foliage cover), 21 (4%), 5 (8%), 11 (4%) and 2 (16%). Site 6, with the highest projective foliage cover of all sites (52%), is negatively correlated with this axis. Members of species-group 6 are concentrated at the high canopy cover end of the axis (Figure 8). This group includes *Pteridium esculentum*, which had a correlation with high canopy cover along site axis 2, and *Hardenbergia violacea* and *Grevillea mucronulata*. The latter two species generally colonize disturbed sites, particularly where the canopy has been destroyed, yet here appear to be confined to sites where disturbance has been minimal and projective foliage cover is high. Axis 3 (6.1% of variation) is possibly related to fire; there is a positive correlation with burnt sites 19 (0.61) and 22 (0.57). Species at the positive end of the axis are *Eragrostis brownii*, *Entolasia stricta*, *Amperea xiphoclada*, *Bossiaea heterophylla* and *Olax stricta*.

Quantitative Analysis

The separation of the sites into two communities is illustrated by Figure 9, which shows percentage basal areas for the dominant tree species. *Angophora bakeri* and *Eucalyptus parramattensis*, the two main dominants, are very rarely found together, and are confined to the dry and wet communities respectively. *Banksia serrata* is most common at the very dry end, but *Eucalyptus sclerophylla* does not appear to be influenced by variations in moisture/drainage and occurs in many situations.

Figure 10 shows the projective foliage cover change along the gradient. The dry sites, although showing marked fluctuations have a high projective foliage cover (mean [transformed data] = 24% + 15.8, −12.8) and confirm the use of the structural formation woodland (Specht, 1970) while the wet sites (mean [transformed data] = 6% + 5.1, −3.6) are in open-woodland.

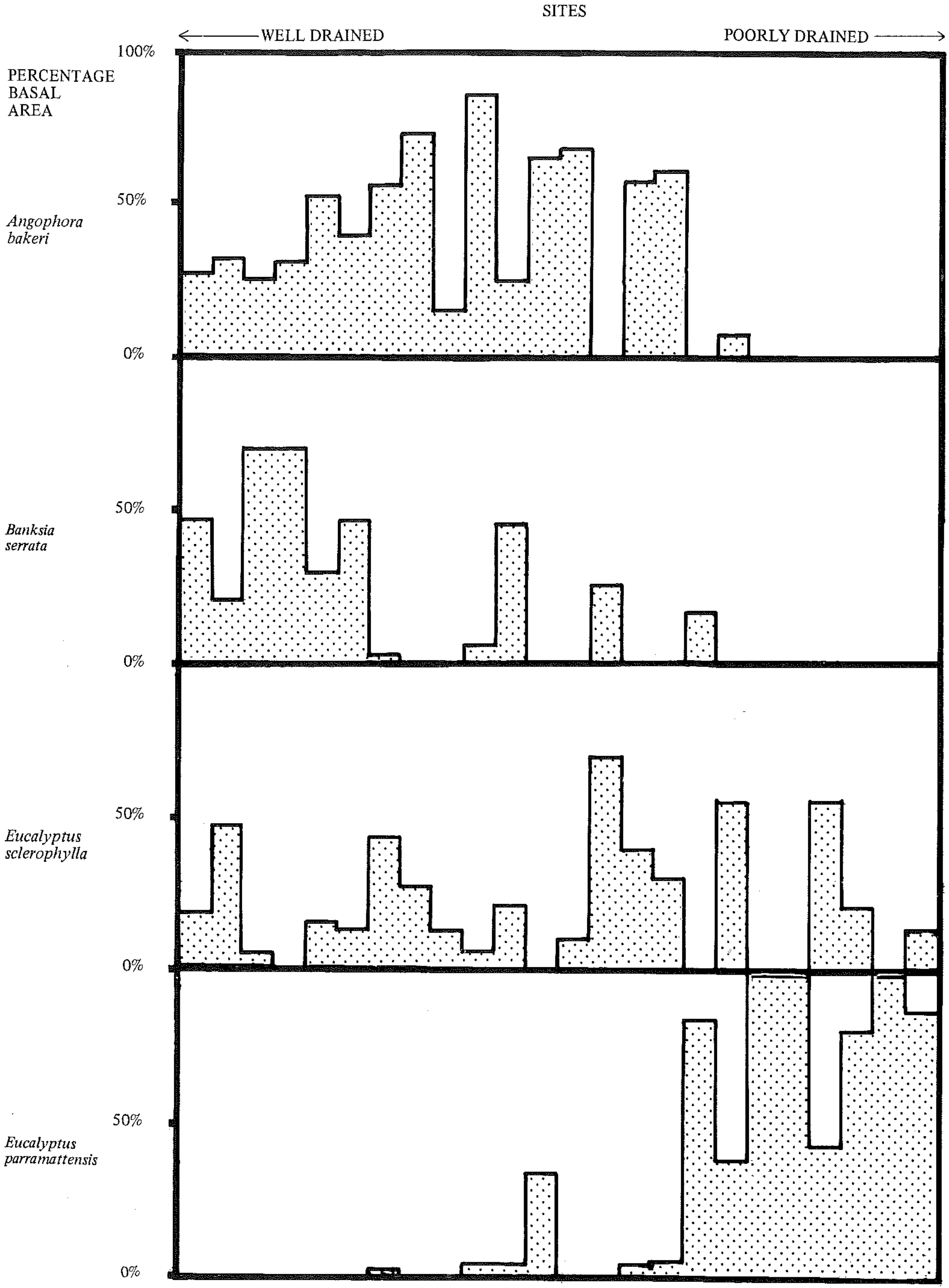

Figure 9. Percentage basal area for *Angophora bakeri*, *Banksia serrata*, *Eucalyptus sclerophylla* and *E. parramattensis*.

TABLE 6

Habitats and life-forms indicated by Multbet Species Groups

Species Group 1

Species occurring on almost all sites, indicating presence of sandy soil but evidently not reflecting drainage, moisture, fire or disturbance conditions.

2 shrubs, 2 herbs, 2 graminoids.

Species Group 2

Species occurring on most sites except those of site group 10 which are dry sites with high canopy cover recordings.

7 shrubs, 1 small tree.

Species Group 3

Species occurring regularly on all dry sites and on occasional wet sites. Species completely absent from wet sites are *Acacia ulicifolia, Bossiaea rhombifolia, Leucopogon virgatus, Schoenus ericetorum, Banksia serrata, Brachyloma daphnoides, Leptospermum attenuatum, Persoonia nutans* and *Ricinocarpos pinifolius.*

2 trees, 13 shrubs, 1 graminoid, 1 twiner.

Species Group 4

Species occurring irregularly on all sites. All graminoids except *Hypochoeris radicata*, a rosette herb and the only exotic weed included in the analysis.

Species Group 5

Species restricted to wettest or most poorly drained sites.

5 shrubs, 4 herbs, 2 graminoids.

Species Group 6

Species restricted to driest sites but also appear to be correlated with high projective canopy cover readings. Sites may be burnt, though most have not been for a long time.

3 shrubs, 1 graminoid, 1 herb, 1 twiner and 1 fern.

Species Group 7

Species of low frequency occurring sporadically on any sites. No concentrations with any site groups evident.

7 shrubs, 1 herb, 5 graminoids.

DISCUSSION

An estimate of the similarity of the vegetation at Agnes Banks to that of other areas is difficult to make in the absence of comparative sampling. On a visual impression it appears to be most similar to coastal vegetation, but this impression is probably influenced by the presence of the white, dune sand topography, which is unlike that of typical Hawkesbury Sandstone country of much of the Sydney district. Structurally the vegetation is sclerophyllous woodland, similar to both Hawkesbury Sandstone vegetation and coastal vegetation. Floristically, there are also similarities with both types. Of the tree species, *Eucalyptus sclerophylla, Angophora bakeri* and *Banksia serrata* all occur on Hawkesbury Sandstone. *E. parramattensis* is found on sandy soils, though not commonly on Hawkesbury Sandstone. Only *B. serratifolia* is restricted to coastal sand-dune areas, the nearest recorded locality to Agnes Banks being Cooper Park, near Bondi, a coastal locality, 60 km to the south-east. It is common in the Myall Lakes area where it grows on the sand deposits of apparently lower nutrient status and greater age than those supporting *Banksia serrata* (R. Carolin pers. comm.).

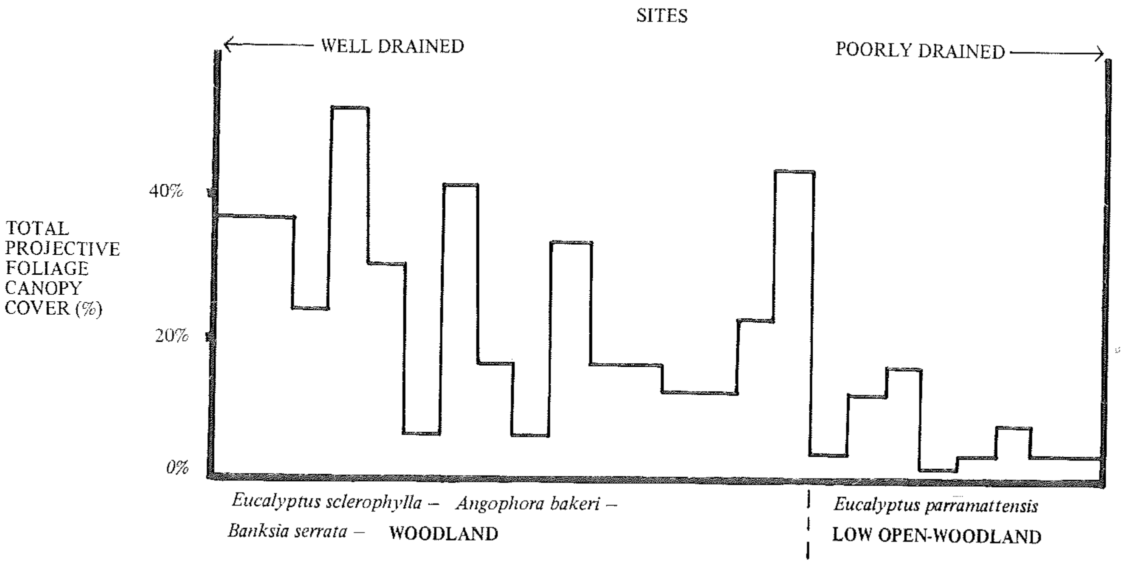

Figure 10. Total projective foliage canopy cover plotted for sites ordinated by first GOWER axis (moisture/drainage gradient). See Table 5 for site order.

The percentage of the Agnes Banks flora recorded from Hawkesbury Sandstone areas and coastal sand dune areas is given in Table 7. Strong affinities with the Sandstone flora are indicated by the similarity with Dharug National Park where 67% of the Agnes Banks flora also occurs. However, considering the large total number of species at Dharug, and the size of the area investigated (c. 12 000 ha), what is probably most surprising is that 33% of species at Agnes Banks were not recorded at Dharug. This is probably due to drainage and nutrient differences between the sandy soils developed on Hawkesbury Sandstone and the deep sands at Agnes Banks, and supports the general view that geology is the major determinant of plant distribution in the Sydney area (Pidgeon, 1937).

Coastal sand dune vegetation affinities are indicated in the 47% of the Agnes Banks flora found at Myall Lakes and the 25% found at North Stradbroke Island, Queensland. Apart from coastal areas, the only similar sand deposit recorded for the Sydney district is on the Mellong Range near Putty, 60 km north of Agnes Banks. Forster *et al.* (1977) describe the vegetation there as Medium Open-forest of *Eucalyptus sclerophylla* and *E. parramattensis.* Although a full species list is not available, a combined list of 64 species included only 31% of the Agnes Banks flora. A full species list is likely to include a higher proportion than this. *Banksia serratifolia* has not been recorded.

The drainage factor has long been used to explain the distributions of plant communities within coastal sand areas. Osborne & Robertson (1939) recognized dune *Eucalyptus* forest, dry heath, wet heath and swamp communities related to sand depth and drainage, each with floristic differences, but also with extensive ecotones between them. Numerical studies by Siddiqi *et al.* (1973) and Connor & Clifford (1971) showed that similar vegetation could be divided into floristic groups related to moisture/drainage conditions. Connor & Clifford found, however, that there was considerable species overlap in the groups formed.

The numerical analyses of the vegetation at Agnes Banks support the descriptions of the two major communities sampled, the *Eucalyptus sclerophylla-Angophora bakeri-Banksia serrata* woodland on dry well-drained sites, and the *Eucalyptus parramattensis* low open-woodland on poorly-drained sites, but emphasize the continuous gradient between them. Of the communities mapped, but only sampled with one site, the site ordination (Table 5) placed the only site in the *Banksia*

TABLE 7

Similarity of Agnes Banks flora to that of coastal dune and Hawkesbury Sandstone floras

Locality	Distance and direction from Agnes Banks	Vegetation	Total species recorded	Number of species in common with Agnes Banks	Percentage of Agnes Banks flora (total 129 spp.)	Reference
Dharug National Park . .	40 km, NE . .	mainly dry sclerophyll forest on Hawkesbury Sandstone	514	86	67%	Matthew (1973)
Myall Lakes	200 km NE on coast	heath forest, dry heath, wet heath on dune sand	204	61	47%	Carolin & Myerscough (1977)
North Stradbroke Island, Queensland	700 km NE off coast	open-forest to herbfield on dune sand	119	32	25%	Connor & Clifford (1972)
Mellong Range	60 km, N . .	medium open-forest on sand	64	40	31%	Forster *et al.* (1977) and author

serrata-Angophora bakeri low open-forest (Site 6) at the well drained end, as expected. Site 3, the only site in the *Eucalyptus sclerophylla-E. parramattensis-Banksia serratifolia* woodland, had been recently burnt and was grouped with intermediate dry sites of the *E. sclerophylla-A. bakeri-B. serrata* woodland most of which had been similarly burnt. In the species classification *Banksia serratifolia* is grouped with species of poorly drained situations (species group 5) whereas *Banksia serrata* is grouped with those of the best drained situations (species group 3). There is no evidence that the sites in the *Eucalyptus sclerophylla-E. parramattensis-Banksia serratifolia* woodland behave differently from sites in the *Eucalyptus sclerophylla-Angophora bakeri-Banksia serrata* woodland though *Banksia serrata* evidently prefers better drained sites than *Banksia serratifolia*. There were no sites in the *Lepidosperma longitudinale* sedgeland, but its floristic composition and topographic position indicate that it would be located at the extreme wet end of the moisture/drainage gradient.

Other factors, particularly fire, and location on supposedly older areas, were also considered important. The analyses indicate that the moisture/drainage factor is by far the dominating influence on plant species distribution, though the quantitative sampling was not detailed enough to show how important it was in determining the abundance of individual species.

The results suggest that projective canopy cover is also an important factor in the distribution of the understorey species. However, the behaviour of two species, should be noted; on nearby areas of different geological substrate (Wianamatta Shale and Hawkesbury Sandstone) *Hardenbergia violacea* and *Grevillea mucronulata* are colonizers following disturbance, which is often associated with canopy removal. On the Agnes Banks sand they are restricted to sites that have the highest cover and have remained unburnt for a long period.

An estimate of the relative importance for plant distribution of the two factors, moisture/drainage and canopy cover, is indicated by the percentage variation these account for in the species ordination. The axis attributed to moisture/drainage accounts for 26.1% of the total variance and that attributed to canopy cover 19.3%. The next three axes together account for only 16.9% of the total variance.

A third factor, fire, though of much less importance, is indicated from general observations and in some of the analyses. Although eight of the 24 sites had been burnt within the previous 2 years (probably in Dec. 1974), no particular site or species groups are clearly indicative of recent fire, though it is indicated in some axis components. Purdie & Slatyer (1976) have reported that, for dry sclerophyll forest near Canberra, most of the regrowth from surviving organs, from residual seed and from seed released after fire, commences in the first 12 months after burning. This seems to be the case for the vegetation at Agnes Banks, and the recording of species presence alone is inadequate to detect differences between areas burnt at different times in the past.

ACKNOWLEDGMENTS

I wish to thank Helen Bryant for her help in collecting the data and preparing the diagrams, and my colleagues at the National Herbarium of New South Wales, particularly R. G. Coveny, S. W. L. Jacobs, M. D. Fox and J. M. Powell for help with the identification of specimens and comments on the manuscript.

REFERENCES

Bureau of Meteorology (1979). *Climatic survey Sydney, region 5, New South Wales.* Department of Science and the Environment, Canberra.

Carolin, R. C. (1970). Myall Lakes—an ancient and modern monument. *Proc. Ecol. Soc. Austral.* **5**, 123–129.

Carolin, R. C. & Myerscough, P. J. (1977). Floristic list for the Eurunderee Sand Masses, Myall Lakes National Park. Unpub. Ms., Botany Dept., University of Sydney.

Connor, D. J. & Clifford, H. T. (1972). The vegetation near Brown Lake, North Stradbroke Island. *Proc. Roy. Soc. Queensland.* **83**, 69–82.

Forster, G. R., Campbell, D., Benson, D. & Moore, R. M. (1977). *Vegetation and soils of the western region of Sydney.* CSIRO Division of Land Use Research Technical Memorandum 77/10.

Gobert, V. (1978). Proposed nomenclature for the Cainozoic sediments of the Penrith-Windsor area. *Quarterly Notes of the Geological Survey of N.S.W.* **32**, 1–9.

Gower, J. C. (1966). Some distance properties of latent root and vector methods used in multivariate analysis. *Biometrika* **53**, 325–338.

Jacobs, S. W. L. & Pickard, J. (in press). *Plants of New South Wales.* Government Printer, Sydney.

Lance, G. N. & Williams, W. T. (1967). Mixed-data classificatory programs. I. Agglomerative systems. *Austral. Comput. J.* **1**, 15–20.

Matthew, P. (1973). Flora of the Dharug National Park, New South Wales. Unpub. report. (Copy held in Royal Botanic Gardens Library).

Maze, W. H. (1942). Land utilization surveys in the Kurrajong-Windsor district, New South Wales. *Austral. Geographer* **4**, 155–174.

N.S.W. Department of Mines (1966). Sydney 1:250 000 geological series sheet. 3rd Edn.

Osborne, T. G. B. & Robertson, R. N. (1939). A reconnaissance survey of the vegetation of the Myall Lakes. *Proc. Linn. Soc. N.S.W.* **64**, 279–296.

Phillips, M. E. (1947). Vegetation of the Wianamatta Shale and associated soil types. Unpub. M.Sc. thesis, University of Sydney.

Pidgeon, I. M. (1937). The ecology of the Central Coastal area of New South Wales. I. The environment and general features of the vegetation. *Proc. Linn. Soc. N.S.W.* **62**, 315–340.

Pryor, L. D. & Johnson, L. A. S. (1971). *A classification of the Eucalypts.* Australian National University, Canberra.

Purdie, Rosemary W. & Slatyer, R. O. (1976). Vegetation succession after fire in sclerophyll woodland communities in south-eastern Australia. *Austral. J. Ecol.* **1**, 223–236.

Siddiqi, M. Y., Carolin, R. C. & Anderson, D. J. (1973). Studies in the ecology of coastal heath in New South Wales. I. Vegetation structure. *Proc. Linn. Soc. N.S.W.* **97**, 211–224.

Siddiqi, M. Y., Carolin, R. C. & Myerscough, P. J. (1976). Studies in the ecology of coastal heath in New South Wales. III. Regrowth of vegetation after fire. *Proc. Linn. Soc. N.S.W.* **101**, 53–63.

Simonett, D. E. (1950). Sand dunes near Castlereagh. *Austral. Geographer* **5**, 3–10.

Specht, R. J. (1970). Vegetation. In *The Australian environment* (Ed. G. W. Leeper), pp. 44–67, Edn. 4. CSIRO—Melbourne University Press, Melbourne.