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THE VEGETATION OF THE EURUNDEREE SAND MASS, HEADLANDS AND PREVIOUS ISLANDS IN THE MYALL LAKES AREA, NEW SOUTH WALES

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ABSTRACT

Myerscough, P. J. & Carolin, R. C. (School of Biological Sciences, University of Sydney, New South Wales, Australia 2006) 1986. The vegetation of the Eurunderee sand mass, headlands and previous islands in the Myall Lakes area, New South Wales. Cunninghamia 1(4): 399-466. Of 17 plant communities recognized as occurring in the Eurunderee embayment, Myall Lakes, New South Wales, 13 occur on sand and are the particular concern of this paper. Community recognition was based upon qualitative field observation. As well, the identities of six were checked using species-pair associations based on point-quadrat data. Similarities between 13 communities were examined using species frequencies; ordering of the communities in terms of similarities apparently reflects environmental gradients in both drainage and presumed soil nutrient status. A Principal Coordinate Analysis was carried out on nine of the sand-based communities, also using species frequencies. The first two axes seemingly reflect the same environmental variables as in the similarity analysis: average height of the surface above the water-table and relative age of the sand surface which is assumed to be inversely proportional to soil nutrient status. Ecotones between some of the communities were examined and are mostly fairly sharp except for those between Wet Heath and Dry Heath.

Variation of the Eurunderee vegetation is discussed in relation to land systems present, vegetation of other areas of coastal sand and Quaternary changes on the eastern Australian coast. Age, hydrological characteristics, degree of podzolization and nutrient stocks of the sand surfaces all appear to be important in variation of the vegetation. As age and degree of podzolization increase in freely draining sand surfaces, plants that are highly sclerophyllous, many of which have well developed underground organs such as lignotubers, are increasingly apparent in the vegetation.

INTRODUCTION

Coaldrake (1961) showed that vegetation on the coastal sands in eastern Queensland could be related to the land systems present. This paper describes the vegetation of part of the Myall Lakes area in relation to the characteristics of its land systems, particularly those of the sand masses.

The Eurunderee area

The area considered here (Figure 1) is between the lake systems and the ocean from Mungo Brush to Smiths Lake and Seal Rocks, and is designated the Eurunderee area using the name of the parish in which most of it lies. It includes the Eurunderee embayment as defined by Thom, Polach & Bowman (1978) and the Eurunderee and Seal Rocks embayments as defined by Thom, Bowman & Roy (1981), and most of it is within the present Myall Lakes National Park.

Osborn & Robertson (1939) outlined its physical and climatological features. Engel (1962), Packham (1969) and Newey (1973) gave details of its geology, while aspects of its geomorphology and palaeohistory were described by Thom (1965, 1973), Carolin (1971), who drew extensively on Shepherd's (1970) work, Thom *et al.* (1978) and Thom, Bowman & Roy (1981).

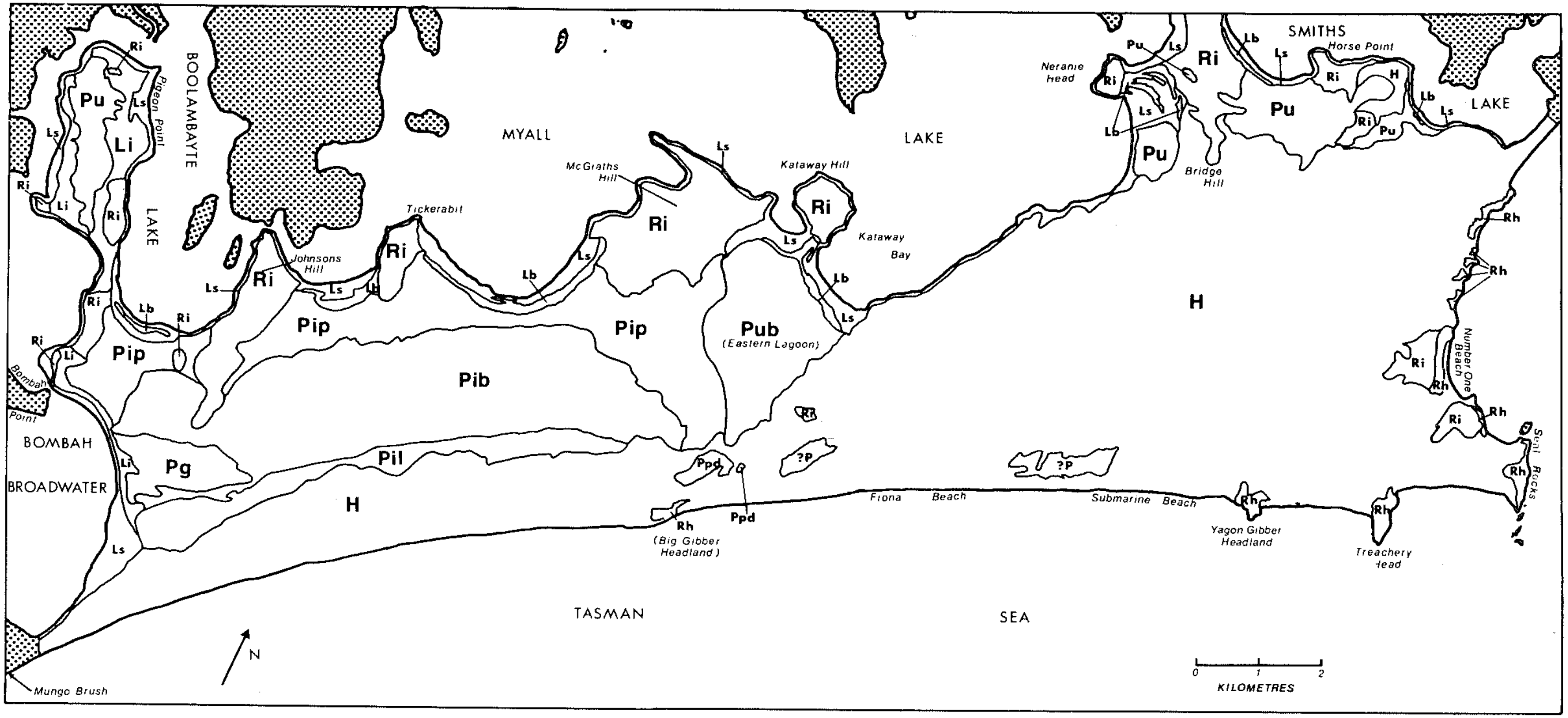


Figure 1. Eurunderee land systems map. See Table 1 for explanation of symbols. Land stippled was not part of the study area and accordingly was not assigned to land systems. The map base used was an enlargement of the 1:70 000 map of Myall Lakes National Park published by the Central Mapping Authority of New South Wales in 1981 with retouching of shorelines against the three appropriate 1:25 000 maps (Bombah Point, Myall Lakes & Seal Rocks) also published by C.M.A. (1977, 1977 & 1974 respectively). Mungo Brush, mentioned in the text, is just beyond the western boundary of the map on the southern shores of Bombah Broadwater.

Land systems

A land system was defined by Christian (1952) and Christian & Stewart (1953) as "an area, or group of areas, throughout which there is a recurring pattern of topography, soils and vegetation". Characteristic recurrent patterns are apparent in the topography, soils and vegetation of the area considered here, and land systems and sub-systems could be readily recognized based largely on their geological and geomorphological characteristics and their soils. These land systems and sub-systems were useful in categorizing the various land surfaces present in the area (Table 1) and in mapping their distributions (Figure 1), and in examining variation in vegetation with respect to them.

Other studies of vegetation and lands on coastal sands have used this type of approach to relate variation in vegetation to other features of land surfaces (Coaldrake, 1961; Gibbons & Downes, 1964; Specht, 1972; Ingwersen, 1976; Heyligers, Myers, Scott & Walker, 1981). Each of these studies defined categories of land surface in somewhat different ways, so it is not easy to work out equivalences between the categories used in the various studies and between those categories and the land systems and sub-systems of this study.

In this study four land systems are recognized (Figure 1 & Table 1). As with many other Australian lagoon systems (e.g., Bird, 1964), the Myall Lakes are separated from the ocean by a large sand mass accumulated around previous islands and headlands. The rock-based sites of previous islands and headlands and present headlands comprise one land system, which is subdivided into two sub-systems according to whether the sites are present headlands or are inland from the contemporary coast. The other three land systems cover the sand mass. One of them comprising Holocene wind-blown sand is not subdivided, but the other two are each divided into sub-systems. The land system comprising land shaped by the action of lake or river waters is divided into three sub-systems; one comprising lake silts and contemporary lake shores, another relict swash-bars and the third, sand masses other than obvious swash-bars away from contemporary lake shores but apparently reworked by river or lake action. The fourth land system comprising Pleistocene sands other than those worked by lake or river is divided into several sub-systems according to the mode of formation and type of land surface produced in the sands.

Mostly boundaries between land systems are clear and were easily recognized. However, at Bridge Hill and Horse Point, some sands that have been assigned to the Holocene sand land system may be Pleistocene in their age. They certainly lie to the north of the ridge of Holocene long-walled transgressive dunes described in Thom, Bowman & Roy (1981), but their vegetation and topographic settings are more characteristic of Holocene than Pleistocene sand surfaces. It was difficult to recognize clear-cut boundaries between the Pleistocene sand and the lake sediments land systems in the area south-east of Neranie Head and to a lesser extent on the peninsula south of Pigeon Point. Within the Pleistocene sand land system the various sub-systems were mostly easily recognized, but between the southern end of Johnsons Hill and Bombah Point the western boundary between the inner parabolic dunes and the differentiated Inner Barrier could not be distinguished clearly and accordingly is somewhat arbitrary in Figure 1.

The Pleistocene sands show generally low relief with the exception of the dune perched on the northern side of the Big Gibber and the largely aeolian complex east of Bombah Point. The Pleistocene deposits include sands of the Inner Barrier of Thom (1965).

The work of Thom (1965), Shepherd (1970), Thom, Bowman & Roy (1981) and Chapman, Geary, Roy & Thom (1982) allows the relative ages and modes of deposition of the Pleistocene sands to be outlined. Probably the earliest deposit was the aeolian dune sheet perched on the northern side of the Big Gibber. This may have been laid down about 500 000 years ago during the period of formation of the "Ancient Dunes" of Benussi (1975) and Clifford &

TABLE 1

Characteristics of Eurunderee land systems

Parent material		Land		Topography	*Soils
type	sub-type	System	sub-system (symbol in Figure 1)		
Rock	—	Rock	(i) Inland (Ri)	Mostly hills with moderate relief	Lithosols and red and yellow podzolics
			(ii) Headland (Rh)	Seaward-facing slopes often steepening at the base into cliffs	Black headland**
Sand	Pleistocene sand	Pleistocene sand	(ii) Perched dune (Ppd)	Aeolian dune with moderately steep slopes perched on northern side of Big Gibber	Podzol
			(ii) Early Inner Barrier (Pu)	Mostly low-lying and periodically waterlogged, but with some freely drained sand-sheets on slopes overlying rock	Humus podzols mainly, but podzols on freely draining sites
			(iii) Inner parabolic dunes (Pip)	Parabolic dunes of subdued relief and gentle slopes with lower sites periodically waterlogged	Catenary sequences of podzols and humus podzols
			(iv) Differentiated Inner Barrier (Pib)	A system of more or less parallel beach ridges of low relief and gentle slopes with intervening swales periodically waterlogged	As above
			(v) Undifferentiated Inner Barrier (Pub)	Mostly low-lying and periodically waterlogged with a very few low rises towards its edges	Mainly humus podzols, but podzols on the freely draining areas

		(vi) Glacial dune complex (Pg)	A complex of dunes of moderate relief and slopes overlying and including parts of the differentiated Inner Barrier	Podzols, but humus podzols in low-lying sites
		(vii) Probable re-exposed surface (?P)	Low-lying complex of low rises and intervening, periodically waterlogged depressions	? Weakly developed podzols and humus podzols.
		(viii) Inter-Barrier lagoon (Pil)	Low-lying with little relief	Humus podzols and some open water with organic muds
Holocene sand	Holocene sand (Outer Barrier)	— (H)	Transgressive dunes, stabilized except near beach, of considerable relief (up to nearly 100m), frequently with steep slopes, freely draining except for a very few sites.	Weakly developed podzols
Lake-influenced sediments	Lake-influenced sediments	(i) Lake silts and current lake shores (Ls)	Mostly at or below water level, but with some sandy beaches	Mostly organic muds, but also some wave-washed sands.
		(ii) Relict sand-bars (Lb)	Old swash-bars of low relief and very gentle slopes	? Podzols and humus podzols
		(iii) Sand of probable fluvial (and lacustrine) origin (Li)	Sand sheets of moderate to low relief with generally gentle but with some localized moderately steep slopes.	Podzol

*Soil terminology based on Stace *et al.* (1968); **Soil type of Parbery (1947) — see also Corbett (1972)

Specht (1979) on North Stradbroke Island and similarly aged dunes on other dune islands off south-eastern Queensland. This dune sheet on the Big Gibber had a giant podzol similar to those described on the "Ancient Dunes" of North Stradbroke Island by Thompson & Ward (1975) and Clifford & Specht (1979). Unfortunately it was largely destroyed in recent sand-mining operations. Other Pleistocene sands were probably laid down much later, though it is not possible to suggest a date for deposition of sands on the peninsula south of Pigeon Point and southeast of Neranie Head and south of Smiths Lake, which have been assigned to the early Inner Barrier sub-system. In terms of the chronology given in Chapman *et al.* (1982), the inner parabolic dunes were probably deposited about 125 000 years ago during the highest sea level reached during the Last Interglacial period. These were followed by the beach ridges of the differentiated Inner Barrier. The area of undifferentiated Inner Barrier between Kataway Bay and the Big Gibber was probably formed as a back-wash lagoon or saltmarsh behind the inner parabolic dunes and beach ridges. It is fringed on its northern, western and southern edges by remnants of low ridges that could have formed by wave action in a lagoon or across a saltmarsh flooded at high tides. For brevity, this area is hereafter referred to as the Eastern Lagoon. The aeolian complex east of Bombah Point was, according to Thom, Bowman & Roy (1981), probably deposited during a period between 20 000 and 12 000 years ago under the influence of strong westerly winds in the Last Glacial period.

The Holocene sand comprising the Outer Barrier is discussed by Thom (1965), Thom *et al.* (1978) and Thom, Bowman & Roy (1981) and is taken by Chapman *et al.* (1982) as a prime example on the New South Wales coast of an episodic transgressive dune barrier. It consists of high and often steeply sloping transgressive dunes, contrasting sharply with the generally low and gently undulating Pleistocene surfaces. The Holocene surfaces date from various episodes of dune-building but mostly are not older than the stillstand in the rise in sea level about 6 500 years ago (see Thom *et al.*, 1978; and Thom, Bowman & Roy, 1981). The possible factors operating during the episodes of formation of these dunes are discussed by Thom (1978), Thom *et al.* (1978) and Chapman *et al.* (1982).

Lake-sand swash-bars occur at heads of bays on the lakes where they abut sand masses. Shepherd (1970) refers those furthermost from the present lake shores to the Pleistocene. In addition, on the peninsula south of Pigeon Point and near the junction of Boolambayte Lake and Bombah Broadwater, there are sand masses apparently deposited following lake or river action.

Some areas that could be outliers of one system or sub-system within another are not shown in Figure 1 on account of their small size but a few of them will be mentioned in the interpretation of the vegetation.

The sands are siliceous, including those of the dunes immediately behind the beaches, and consequently their soils are podzols whose stage of development and type depend on the age and hydrology of the surface (Table 1). In this respect the recent dunes are typical of those of New South Wales and are similar to those of southern Queensland rather than to most of those of South Australia (Coaldrake, 1982; Chapman *et al.*, 1982).

VEGETATION

The preliminary survey of the area's vegetation by Osborn & Robertson (1939) was conducted in almost inaccessible country, when standard vertical aerial photographs were unavailable. It is therefore understandable that they did not distinguish some of the communities recognized here, that they oversimplified the definitions and distributional patterns of communities, and that they did not adequately locate some observations. Little has been published since this survey, although recently the aquatic communities of the lakes have been described (Atkinson *et al.*, 1981). Unpublished work has included a statement by Carolin for the Linnean Society of New South Wales on the scientific importance of the area, lists of species within mining dredge-paths by Clarke, a report by Pickard & Blaxell for the National Parks and Wildlife Service of New South Wales on the vegetation, a report on a heathland investigation from Macquarie University, and a description and map of the vegetation of northern parts of the area by Anderson (1973). Though the treatment of the vegetation given below is similar to Anderson's (1973), there are two main differences. Firstly, only communities are recognized here, while Anderson (1973) distinguishes associations within communities. Secondly, in freely-drained forests a distinction is made between those on Holocene and those on Pleistocene sands, a distinction that Anderson (1973) does not make.

The term community was used instead of association for the classes of vegetation recognized here for two reasons. Firstly, a strict definition of association, as a "climax community of which the dominant stratum has a qualitatively uniform floristic composition, and which exhibits a uniform structure as a whole" (Beadle & Costin, 1952), was difficult to apply to the area's vegetation. As will be shown, there are situations where uniformity of structure is not preserved either in height or in cover of the canopy, but uniformity of floristic composition is. It was the relative uniformity of floristic composition that was the overriding consideration in the recognition of the communities described below. Secondly, the width of definition of communities recognized varied somewhat with the type of parent material on which the vegetation studied was growing. Communities on rock-based sites were more widely defined than those growing on sand, largely because the interest of the study was centred on the vegetation of the sand masses. However, the term community used here is roughly equivalent to that of association in Beadle (1981).

The present vegetation on some sites is secondary following human disturbance. Many of the inland rock-based sites were logged and cleared for grazing following European settlement. More recently, some sand-based areas have been mined. Four areas were so mined: one strip mostly in Pleistocene inner parabolic dunes west of the southern part of Johnsons Hill toward Bombah Point; another including most of the area of the Pleistocene perched dune on the northern side of the Big Gibber and extending southwest through the Holocene sands of the Outer Barrier for about five kilometres; another strip, approximately 2.5 kilometres long, west of Yagon Gibber through Holocene and re-exposed Pleistocene sands at the back of Submarine Beach; and the fourth area in the Bridge Hill ridge of the high Holocene dunes east of the Seal Rocks road. In all such disturbed sites the vegetation has been described in this survey either in its known or in its putative undisturbed state.

Community recognition

The communities recognized are listed with their structural forms under Specht's (1970) terminology in Table 2. Using floristic criteria in community recognition and definition, certain communities cover a wide range of structural types. For instance, Dry Heath sometimes contains shrubby specimens of *Eucalyptus gummifera* and *E. pilularis* but is structurally quite different from Dry Heath Forest. It was, therefore, decided that very broad structural criteria should be used with floristic criteria to recognize and define the communities. Names given to some of these communities come from the terminology of Beadle & Costin (1952) but are used here in a local restricted sense. Names given to the others were invented during the course of this study to indicate the dominant growth-forms and habitats of the communities. The exceptions to this are Dry Heath Forest, Wet Heath Forest and Intermediate Dry Forest. These were named on their similarity to other communities: Dry Heath Forest to Dry Heath; Wet Heath Forest to Wet Heath; and Intermediate Dry Forest on its position intermediate in floristic similarity between Dry Sclerophyll Forest and Dry Heath Forest. Heath forest was used by Richards (1936) for relatively sclerophyllous tropical forest growing on infertile soils, and was his translation

TABLE 2

Eurunderee plant communities, their structural forms and habitats

Dominant growth-form	Community (abbreviation)	Structural form (of Specht, 1970)	Habitat
Trees	Rainforest (RF)	Closed-forest	One rock-based site near Seal Rocks
	Wet Sclerophyll Forest (WSF)	Tall open-forest, Open-forest	Freely drained, rock-based sites not exposed to the sea
	Dry Sclerophyll Forest (DSF)	Tall open-forest, Open-forest, rarely Open-scrub	Freely drained sands, excepting the seaward front of dunes, usually with only weakly developed podzols or close to rock
	Intermediate Dry Forest (IDF)	Open-forest	Freely drained sands probably of intermediate stages of podzol development
	Dry Heath Forest (DHF)	Open-forest, Low open-forest, Woodland, Low woodland	Freely drained sands with well developed podzols
	Wet Heath Forest (WHF)	Open-forest	Sands close to but nearly always above the water-table
	Swamp Forest (SF)	Open-forest, Low open-forest, Woodland	Sands periodically submerged and nearly always waterlogged
	Fringe Forest (FF)	Open-forest	Lake margins irrespective of substrate—rock, sand or organic sediment
Small trees	Headland Thicket (HT)	Low closed-forest, Low open-forest, Closed-scrub, Open-scrub, Closed-grassland	Rock-based headlands facing the sea
	Vine Thicket (VT)	Low closed-forest, more commonly Closed-scrub	A moist protected rock-based gully facing the sea near Seal Rocks

	Beach-dune Thicket (BT)	Low open-forest, Closed-scrub, Open-scrub	Freely drained sands in stabilized transgressive dunes immediately behind the beach-front
Shrubs	Dry Heath (DH)	Closed-heath, less commonly Open-heath	Freely drained sands with well developed podzols
	Wet Heath (WH)	Closed-heath, less commonly Open-heath	Sands close to but nearly always above the water-table with well developed humus podzols
Herbs	Sand Grassland (SG)	Closed-grassland, Grassland	Freely drained stabilized sand on steep slopes facing the sea between Seal Rocks and Smiths Lake
	Foredune Complex (FC)	Grassland, Open-grassland, Herbfield, Open-herbfield	Mobile and semi-stabilized sands of beach-fronts and blow-outs
	Swamp (S)	Sedgeland, less commonly Open-heath, Open-scrub	Sands periodically submerged amd nearly always waterlogged
	Lepironia Swamp (LS)	Sedgeland, Open-sedgeland	Apparently fairly recently formed areas of open water on sands

of Winkler's (1914) term, *Heidewald,* for these forests. Such heath forests occur widely in the moist tropics (Richards, 1952; Whitmore, 1975; Specht, 1979*a*), and are the characteristic vegetation on lowland podzols which in Eastern Asia are most widespread on old beach deposits (Burnham, 1975).

Recognition of some communities required no detailed analysis, but the six communities outlined in Figure 2 did. Five of the communities, Dry Heath Forest, Dry Heath, Wet Heath, Swamp Forest and Swamp, occur in catenary sequences particularly in the differentiated Inner Barrier. Lack of obvious boundaries between communities in these catenary sequences makes recognition and definition of these five communities difficult. Also, it was not immediately apparent to what extent Dry Heath, which occurs extensively on Pleistocene sands, and Dry Sclerophyll Forest, which occurs predominantly on Holocene sands, were floristically similar despite their difference in structure. Accordingly, a transect, almost 4 km long, was laid out northwest to southeast, from between Johnsons Hill and Tickerabit to the coast, traversing the inner parabolic dunes, differentiated Inner Barrier, inter-Barrier lagoon and Outer Barrier (see map located in back pocket). A method of scoring the occurrences of species was chosen which over such a long transect was not too time consuming. The size of sample units was selected such that it would detect groupings in the occurrences of species at a scale that was appreciably smaller than the average length of each catenary sequence in the pattern of variation of vegetation over the system of ridges and swales of the differentiated Inner Barrier, and yet not so small that fine-scale groupings of species within localized segments of the catenary sequences could predominate over more general groupings. A point quadrat was used at 1 m intervals. For each species the hits from the point quadrats were blocked into 10 m units and these units used in the analysis for the detection of groupings in the occurrences of species. Ridges occur at a frequency of approximately five per kilometre across the differentiated Inner Barrier making the approximate average length of a catenary sequence from the top of a ridge to the lowest point of a swale 100 m. The sampling units (10 m long) are thus an order of magnitude shorter than the average length of a catenary sequence.

In the analysis of data, groupings were sought in the occurrences of the species by calculating from the hit data the degree of association between species taken a pair at a time for all pairs of species encountered. Multivariate methods of classification or ordination of the 10 m blocks of point quadrats could only indirectly show floristic groups in the occurrences of the species. Williams (1968) used such methods on data collected from 1 m^2 quadrats positioned by restricted randomization in each of 12 parallel transects across part of the differentiated Inner Barrier. His investigation assisted in interpreting the occurrences of species relative to local environmental variation, but was not particularly helpful in recognizing communities according to groupings in the occurrences of species.

The choice of a coefficient of association between species in pairs presented some problems. Since the data in each 10 m length could be expressed as estimates of cover for the species encountered it would appear possible to use Pearson's Product Moment correlation coefficient (r). However, the domain from which the data were drawn was so wide in the case of every pair of species that the number of joint non-occurrences exceeded the joint occurrences together with the single occurrences of each species. Thus, the distribution of estimates of cover in each species is not normal. The use of r was accordingly ruled out.

The data can be taken in a simplified form in which the requirements of normal distributions do not arise and where other coefficients of association are available. This is done by taking the data in binary form, recording for each species whether or not its aerial parts intersected any of the ten pins in each

10 m length of the transect. Coefficients of association available for use with binary data include the tetrachoric correlation coefficient (phi) (see Sokal & Sneath, 1963), the χ^2 coefficient of heterogeneity (Greig-Smith, 1964) and the simple matching coefficient of Sokal & Sneath (1963). However, the high numbers of joint non-occurrences in the set of data ensure that none of these coefficients is a satisfactory estimate of joint occurrence. Moreover, the χ^2 coefficient is a test of significance not of association (see Hubálek, 1982). The Jaccard coefficient was also rejected because association of a very frequent species with a relatively infrequent species in a pair will show low values of the coefficient even when the latter species only occurs with the former and never by itself.

The sort of coefficient of association required is one whose values are not dependent on the joint non-occurrences of the species in a pair and sensitively reflect the joint occurrences with respect to the less frequent of the species. Such a coefficient is available. The data take the following form:

		sp. J	
		−	+
sp. K	−	n_{jk}	n_{Jk}
	+	n_{jK}	n_{JK}

where: − is non-occurrence of a species;
+ is occurrence of a species;
n_{jk} is the number of sites in which neither species occurs;
n_{Jk} and n_{jK} are each the number of sites in which species J or species K respectively occur without the other species; and
n_{JK} is the number of sites in which the two species jointly occur.

The coefficient of association in question is:

$$\frac{n_{JK}}{\min\,[(n_{Jk} + n_{JK}),\ (n_{jK} + n_{JK})]}$$

and seems to have been first used as the "degree of faunal resemblance" by Simpson (see Hubálek, 1982, who refers to it as "A_2"). This coefficient varies in value between zero and one, takes no regard of joint non-occurrences and expresses the joint occurrence with respect to the less frequently occurring species.

Hubálek (1982) rejects this coefficient because it is asymmetric (admissibility condition 3) although he does concede that it may have a use in measuring partial or one-way associations, and this is just what is needed in this case. Furthermore it does not satisfy an "additional (optional) condition" of absolute association that he considers. This again is satisfactory in this case since the less frequent species needs to control the coefficient.

Values of this coefficient of association can be calculated between all pairs of species sampled, and values over a selected minimum can be used to express association in linked clusters. Figure 2 shows the linked clusters in the pair-wise associations in occurrences of the species along the transect when all values of the coefficient of association of 0.50 and over have been plotted. It is not clear that a satisfactory test of the statistical significance of these values is available. The minimum of 0.50 gave, in this set of data, a workable number

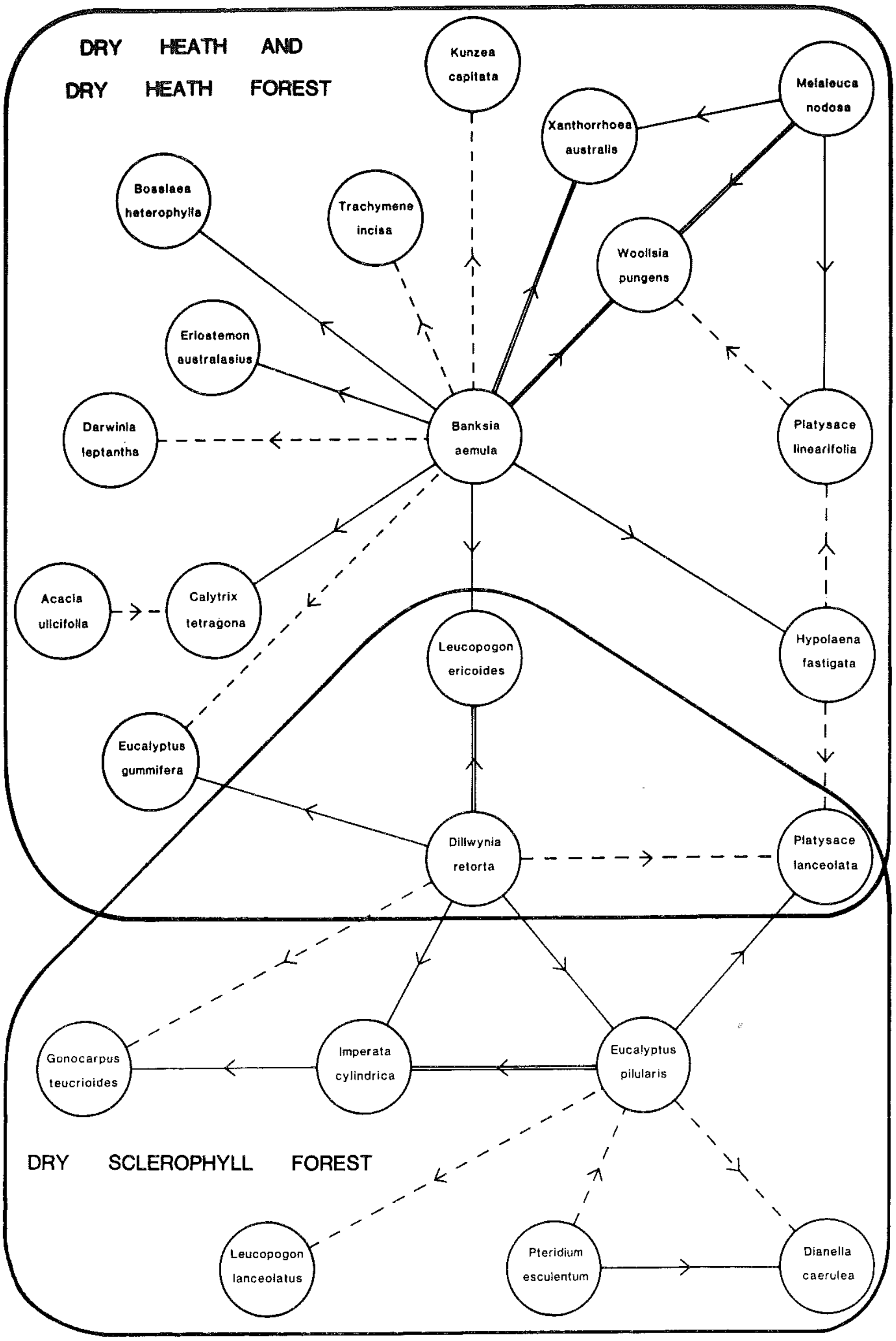
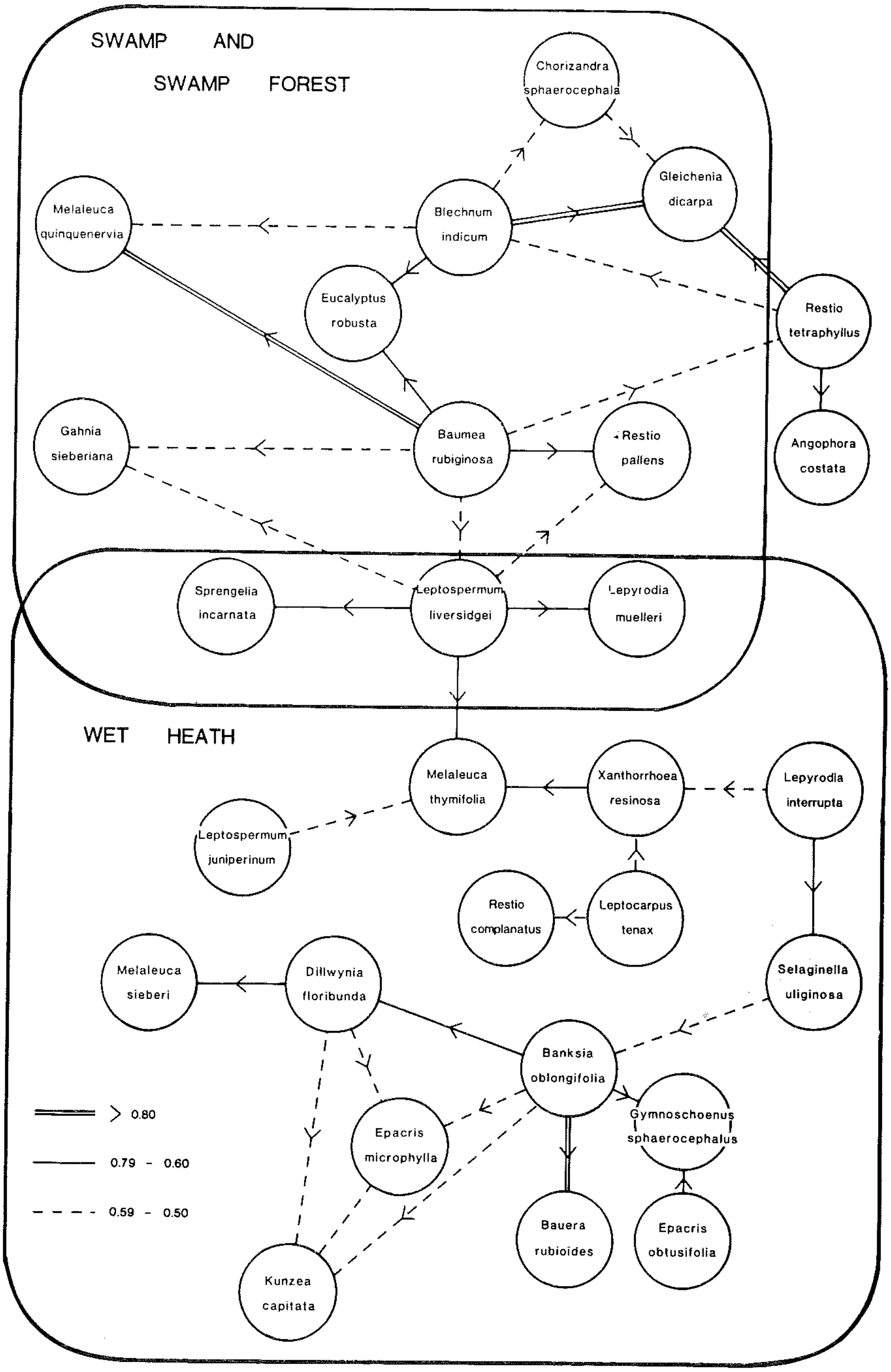


Figure 2. Summary of pair-wise associations of species in their occurrence in successive 10 m lengths along a transect taken south-east from between Johnsons Hill and Tickerabit across the inner parabolic dunes (Pip), differentiated Inner Barrier (Pib), inter-Barrier lagoon (Pil) and the Outer Barrier (H) to the sea (for approximate location of transect see map located in back pocket). An occurrence was recorded as intersection of aerial plant parts with one or more of 10 point quadrats one of which was placed at each successive metre along the 10 m length. All values of a coefficient



of association greater than 0.50 are plotted (see text for definition of the coefficient). For each pair-wise association of species shown, the species with the greater frequency of recorded occurrence on the transect is indicated by the appropriate sign (>, or = when frequencies of both spp. were equal) on the line signifying their association. The bold lines enclose clusters of species deemed to belong to particular plant communities.

of species and linkages to plot. At a minimum of 0.40, the numbers of species to be considered and of the linkages between them are too high for a plot that can be easily shown in a diagram or readily interpreted. The clusters in Figure 2 are meaningful biologically and indicate floristic groups of species on the ground as well as widely spread species whose occurrences overlap into various groupings of less widespread species. In this way, the clusters approximate to the "noda" of Poore (1964).

The floristic groupings shown in Figure 2 are related to the catenary sequences of vegetational change across the differentiated Inner Barrier and to age of freely drained surfaces.

The cluster of species comprising Swamp and Swamp Forest characterizes wet sites in the swales. As explained later, Swamp is differentiated from Swamp Forest largely by absence of trees from the former and not by any major floristic difference in the understorey. The two species of trees of Swamp Forest, *Melaleuca quinquenervia* and *Eucalyptus robusta*, occur within the cluster and *Angophora costata* is associated with it through *Restio tetraphyllus*. Neither *R. tetraphyllus* nor *A. costata* occurs in the bottoms or on the lower slopes of swales. *A. costata* occurs on freely drained sands but its occurrence extends on to surfaces closer to the water-table than those on which *Eucalyptus pilularis* and *E. gummifera* occur, the other main species of trees on freely drained sands in this transect.

The shrubs *Leptospermum liversidgei* and *Sprengelia incarnata*, and the restiad *Lepyrodia muelleri* are included in both the cluster of species comprising Swamp and Swamp Forest and the cluster of species comprising Wet Heath. The three species occur in the differentiated Inner Barrier on the lower slopes of swales where Swamp and Swamp Forest merge into Wet Heath in the catenary sequence of vegetation.

A somewhat loosely linked cluster of species of mostly shrubs and restiads comprises Wet Heath, the community characteristic of the slopes of the swales in the differentiated Inner Barrier. In this, *Banksia oblongifolia* is a prominent and physiognomically obvious species. *Kunzea capitata* occurs on the upper slopes of the swales and has been included both in the cluster of species comprising Wet Heath and in the cluster designated Dry Heath and Dry Heath Forest.

Dry Heath and Dry Heath Forest in this analysis are composed of a large cluster of species, most of which are shrubs, that occur on the ridges of the differentiated Inner Barrier. As explained later, the two communities are largely separated physiognomically on the presence or absence of trees. The cluster is centred on *Banksia aemula*, a prominent and characteristic species of these two closely related communities.

Finally, the cluster of species designated Dry Sclerophyll Forest, and including the relatively close association of *Eucalyptus pilularis* and *Imperata cylindrica*, is characteristic of forested, freely draining Holocene sands of the Outer Barrier. The species of this cluster all occur in Dry Heath Forest on Pleistocene sand but with much lower abundances than those they have on Holocene sands. *Leucopogon ericoides, Dillwynia retorta* and *Platysace lanceolata* occur with appreciable abundance in both Dry Heath Forest/Dry Heath and Dry Sclerophyll Forest and are accordingly included in each of these respective clusters.

Other communities described were fairly readily differentiated by floristic and physiognomic characteristics. One community, closely related to Wet Heath and to Swamp Forest and termed Wet Heath Forest, was recognized during the course of mapping the vegetation following the diagnosis of communities outlined by the floristic clusters in Figure 2. It consists of trees of *Melaleuca quinquenervia, Eucalyptus robusta* and *Angophora costata* with an understorey that is a mixture of Wet Heath and Swamp species. It mostly occurs on sheltered

Pleistocene sands where water is often close to the surface and which may receive run-off from nearby rock-based sites.

The map located in the back pocket shows the distribution of the communities outlined in Table 2 and described below in more detail. Subtropical Rainforest in a small area near Seal Rocks and much disturbed by human activity is mapped but not described here; it was studied and described by Clough (1979).

Community comparisons

The floristic compositions of all the communities were compared except for localized or rare communities, namely Rainforest, Vine Thicket, Sand Grassland and *Lepironia* Swamp. Data for the comparison were gathered from six sites in each community. In each community the sites were chosen to cover its full range within the study area in the geographic sense, in the range of habitats occupied and in the structural variation the community showed. At each site the area sampled was selected because it was representative of the middle of the range of variation of the structure of the community and floristic composition of the physiognomically most obvious species at the site. The range of variation of structure and composition was determined by preliminary visual assessment. Possible ecotones were avoided, and in each site all species of vascular plants occurring in each of nine quadrat units laid contiguously in a transect were recorded. A quadrat unit of 5 × 5 m was used for herbs and shrubs up to 3 m high, and a unit of 10 × 10 m for trees and shrubs over 3 m high. The transect sampled in each site thus consisted of a belt of nine 5 × 5 m quadrats from 0 to 45 m and a belt of nine 10 × 10 m quadrats from 0 to 90 m, the second belt of quadrats being superimposed on the first over the distance 0 to 45 m. The frequency of each of the 369 species recorded was calculated in each community and the communities were initially compared using the Canberra metric,

$$\text{Canb} = \frac{\sum\limits_{j = 1 \rightarrow 369} |x_{ij} - x_{kj}|}{\sum\limits_{j = 1 \rightarrow 369} x_{ij} + x_{kj}}$$

where x_{ij} is the frequency of the jth species in the ith community; and

x_{kj} is the frequency of the jth species in the kth community.

The Canberra metric is thus inversely related to similarity.

The Canberra metric was selected since the full matrix of frequencies of species in the communities could be examined, and a value of the metric would be assigned in each comparison between two communites in relation to the total number of species encountered. Only by use of such a metric could values between pairs of communities be directly inter-related. Indices of comparison such as Jaccard's or Czekanowski's coefficients (see Greig-Smith, 1964), whose values are determined solely by the pairs of samples being compared without reference to the total set of samples, do not yield values between pairs that can be directly compared across all the samples taken. The Canberra metric (see Clifford & Williams, 1976) is of the type required and is mathematically simple.

Values of the Canberra metric range between zero, for a pair of identical samples, and one, for a pair of totally dissimilar samples. To compare the communities here, it was decided that a value of the metric between two communities of 0.8 or more would be taken to indicate a lack of similarity between two such communities.

From the values of the Canberra metric obtained (Table 3) and using only those less than 0.8, the communities are seen to be interconnected in a sequence of similarities (Figure 3). In the sequence, wetland communities are at one end

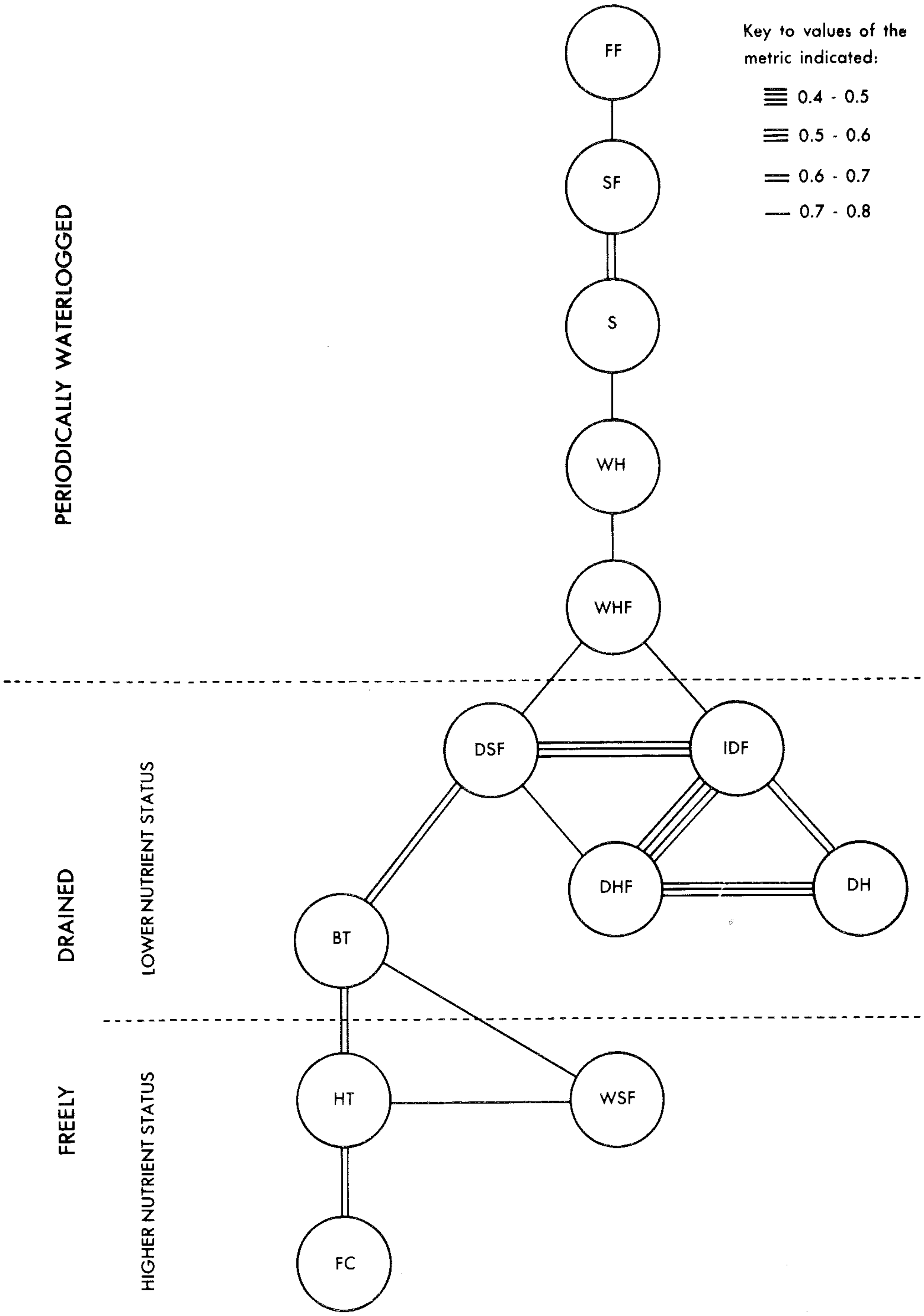


Figure 3. Comparison of communities using values of the Canberra metric less than 0.8. It should be noted that the lower the value of this metric the greater the similarity between communities. (For full names of the communities see Table 2).

and communities of dry land at the other end. Within the communities of dry land there are groups that can be related to differences in probable nutritional status. Communities that are probably of relatively high nutritional status (Foredune Complex, Headland Thicket and Wet Sclerophyll Forest) are grouped loosely together and those probably of low nutrient status (Dry Heath, Dry Heath Forest, Intermediate Dry Forest and Dry Sclerophyll Forest) are more closely grouped. Beachdune Thicket connects the two groups. Such a nutritional interpretation is supported by the ages and degree of podzolization of the surfaces on which the communities characteristically occur. The Foredune Complex and Beach-dune Thicket, which occur on recently deposited surfaces, are at one end and Dry Heath and Dry Heath Forest, which occur on highly podzolized Pleistocene surfaces, at the other of this sequence of communities from freely draining sands.

Comparison of sand-based communities

Nine of the 12 sand-based communities were compared in greater detail. The three omitted were the highly localized Sand Grassland and *Lepironia* Swamp and the continuously disturbed Foredune Complex.

The six sites sampled in each community were treated individually. Patterns in the floristic relationships of the 54 sites were explored through Principal Coordinate Analysis in the GOWER and GOWERCOR programs from the CSIRO TAXON package (see Milne, 1976), using Euclidean chord distance, which is sensitive to differences in proportions of species' frequencies rather than to differences in the frequency values themselves (Orlóci, 1967; 1975).

The first two axes extracted in the analysis (Figure 4) have a discernible relation to the environmental variation. The first axis appears to reflect mainly drainage, with sites of the periodically waterlogged communities registering positive and those of the freely draining communities negative values. Clearly the axis does not reflect the degree of waterlogging in a simple way since Wet Heath sites are more strongly positive than most of the Swamp Forest sites. The second axis appears to reflect age of the surfaces; the younger sites registering positive and the older negative values. This tendency is clear-cut in the freely drained sites where the stands of Intermediate Dry Forest, which are particularly typical of late Pleistocene sites, occupy a position between the stands of Dry Heath and Dry Heath Forest, which occur predominantly on earlier Pleistocene sands, and those of Dry Sclerophyll Forest, characteristic of Holocene sands. The waterlogged sites are not well spread on the axis. This result is perhaps hardly suprising since they are all from Pleistocene sands. However, some of the sites giving the most positive values included in the spread of Wet Heath Forest occur near the base of rock hills from which some run-off of nutrients might be expected, suggesting again that the age sequence apparent in the freely draining communities may be related to variations in nutrient status.

Community descriptions

Communities are described in the sequence in which they are listed in Table 2. Communities on the sand masses are the primary interest of this paper and are described in greater detail than those on the rock-based soils.

The codes of Pryor & Johnson (1971) for species of *Eucalyptus* and *Angophora* are given at the first mention of the name of any eucalypt or angophora species in the description of community. This is to allow ready assessment of the affinities of eucalypt species occurring together in the same community.

Nomenclature of species generally follows that of Jacobs & Pickard (1981), and authorities are only given for the specific names which are not those in Jacobs & Pickard.

TABLE 3

Values of Canberra metric (an index of dissimilarity) from the floristic comparison of the commoner Eurunderee plant communities

Community*	WSF	DSF	IDF	DHF	WHF	SF	FF	HT	BT	DH	WH	FC	S
WSF	0												
DSF	0.875	0											
IDF	0.907	0.567	0										
DHF	0.968	0.729	0.454	0									
WHF	0.834	0.758	0.750	0.862	0								
SF	0.963	0.959	0.983	0.935	0.823	0							
FF	0.928	0.988	0.991	0.992	0.940	0.783	0						
HF	0.782	0.818	0.854	0.904	0.831	0.951	0.933	0					
BT	0.792	0.695	0.805	0.899	0.831	0.944	0.966	0.622	0				
DH	0.989	0.839	0.655	0.598	0.825	0.978	0.995	0.936	0.924	0			
WH	0.998	0.961	0.927	0.943	0.703	0.868	0.981	0.976	0.940	0.874	0		
FC	0.930	0.954	0.975	0.976	0.970	0.973	0.955	0.695	0.867	0.991	0.989	0	
S	1	0.916	0.973	0.956	0.915	0.635	0.894	0.982	0.985	0.954	0.740	0.998	0

* Full names of communities are given in Table 2.

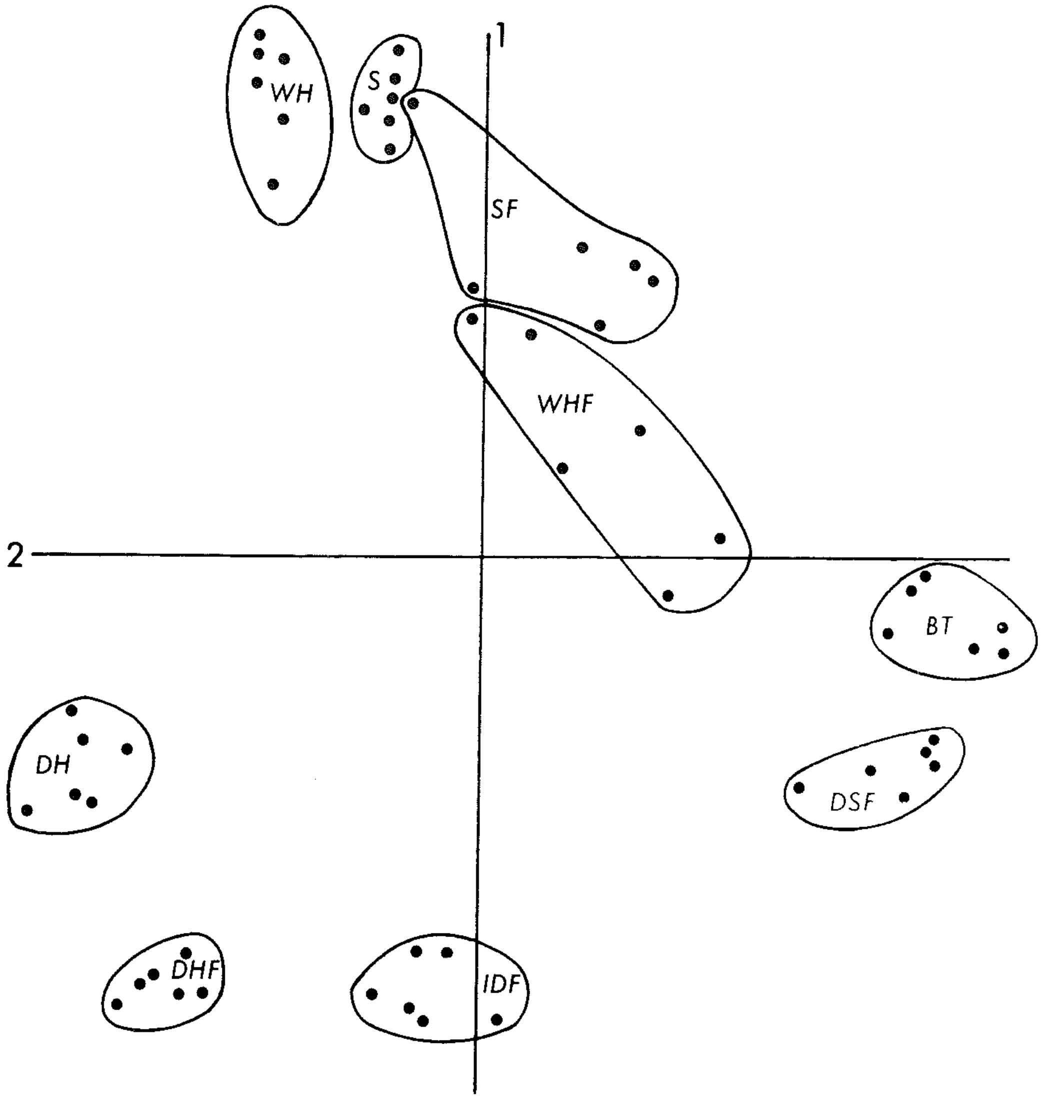


Figure 4. Ordination of stands of nine common sand-based communities on the first two axes extracted in a principal co-ordinate analysis. (For full names of communities see Table 2).

WET SCLEROPHYLL FOREST (Figure 5)

Tree stratum (to c. 35 m): e.g., AAABB *Angophora floribunda,* CCC:B *Eucalyptus maculata,* SWA:A *Eucalyptus microcorys,* SUV:D *Eucalyptus paniculata, Syncarpia glomulifera.*

Small tree stratum (to c. 15 m): e.g., *Casuarina torulosa, C. littoralis, Melaleuca styphelioides, Lophostemon confertus* (R.Br.) Peter G. Wilson & J. T. Waterhouse (=*Tristania conferta*).

Shrub stratum (to c. 1.5 m): e.g., *Oxylobium ilicifolium, Daviesia ulicifolia.*

Soils: lithosols, red and yellow podzolics.

This community occurs on the rock-based soils of prior islands and headlands, but it has been very largely altered by man's activities, including complete clearing of extensive areas. Recent regeneration in cleared areas from which stock have been excluded consists largely of *Acacia parramattensis* and

Figure 5. Wet Sclerophyll Forest on eastern slopes of Johnsons Hill. *Eucalyptus paniculata, E. punctata, E. maculata* and *Acacia longifolia* (regrowth following clearing).

Casuarina spp., but on Tickerabit much of the woody regeneration at considerable distances up the slope from the lake consists of *Casuarina glauca* and *Melaleuca quinquenervia,* which are confined to the lake fringes in uncleared but otherwise similar situations.

The community includes all but the sandier facies of Anderson's (1973) fl layered forest association.

DRY SCLEROPHYLL FOREST (Figure 6)

Tree stratum (to c. 40 m): MAIAA *Eucalyptus pilularis* and AAADAA *Angophora costata.* Many over-mature to dead trees of the former; rarely CAFUF *Eucalyptus gummifera* towards the northeastern parts; very rarely SWA:A *E. microcorys,* probably when rock is near the surface.

Small tree stratum (to c. 15 m): *Banksia serrata, Xylomelum pyriforme,* and *Monotoca elliptica,* with *Casuarina torulosa* when rock is near the surface. Saplings and young trees of tree stratum.

Shrub stratum (to 3 m): *Aotus ericoides, Dillwynia retorta, Gompholobium latifolium* and *G. grandiflorum, Leucopogon lanceolatus,* and very many others depending on the fire history of area. *Xanthorrhoea australis* and *Macrozamia communis* are locally common.

"Herb" stratum: *Pteridium esculentum* (Forst.f.) Cockayne, *Imperata cylindrica, Panicum simile, Gonocarpus teucrioides* and many others, probably depending on the recent fire history of the area.

Soils: poorly developed podzols, with humus-stained A_1, bleached A_2 horizon, and B horizon sometimes distinct but usually poorly developed or lacking.

In this forest on Holocene sand, dominated by *Angophora costata* and *Eucalyptus pilularis*, there are many over-mature and standing dead trees of *E. pilularis* despite extensive logging operations. In contrast, there are few standing dead trees of *A. costata*; its dead timber seems to degrade much faster than that

Figure 6. Dry Sclerophyll Forest on Holocene dunes about 1 km south of Bridge Hill. *Angophora costata* and *Eucalyptus pilularis, Banksia serrata* with *Macrozamia communis, Pteridium esculentum.*

of *E. pilularis.* Data of Fox, Fox & McKay (1979) indicate that after about 10 years following fire the amount of litter on the forest floor reaches a steady-state average of about 1.7 kg m^{-2}, with a turn-over time of somewhat over three years. Evidence of firing is extensive, and charcoal layers, exposed some distance below the surface during sand-mining operations, indicated that fires, at times fierce, have been a feature of the vegetation of these dunes for some time. Indeed, Thom *et al.* (1978) give a C^{14} date of 2 320 ± 110 years B.P. for one of these charcoal-rich zones.

The tree stratum varies from pure *Angophora costata* through mixed stands to pure *Eucalyptus pilularis.*

Northeast of the Bungwahl–Seal Rocks road occasional *Eucalyptus microcorys*, and more frequent groups of *Casuarina torulosa* probably indicate rock at no great depth below the sand. The occurrence of *Eucalyptus gummifera* in the same area was more puzzling since it was not associated with rock near the surface (a mining track has now removed it). Here, Anderson (1973) assigns *E. gummifera* to a distinct association, the Bloodwood–*Angophora costata* association, in her layered forest community. Elsewhere, *E. gummifera* occurs in Dry Sclerophyll Forest only where Holocene sand thinly overlies Pleistocene sand or rock. Otherwise, on the sand mass it is confined to Dry Heath Forest and Dry Heath.

Dry Sclerophyll Forest without *Eucalyptus gummifera* is equivalent to Anderson's (1973) Blackbutt–*Angophora costata* association, but, as mapped by her, this association includes patches of our Dry Heath Forest. Dry Sclerophyll Forest also covers the sandier facies of Anderson's (1973) fl layer forest association, which includes *Casuarina torulosa*, but mostly this association lies within Wet Sclerophyll Forest.

Dry Sclerophyll Forest varies somewhat in form, most likely due to exposure and fires. A scrub of *Eucalyptus pilularis*, almost a pure stand, with

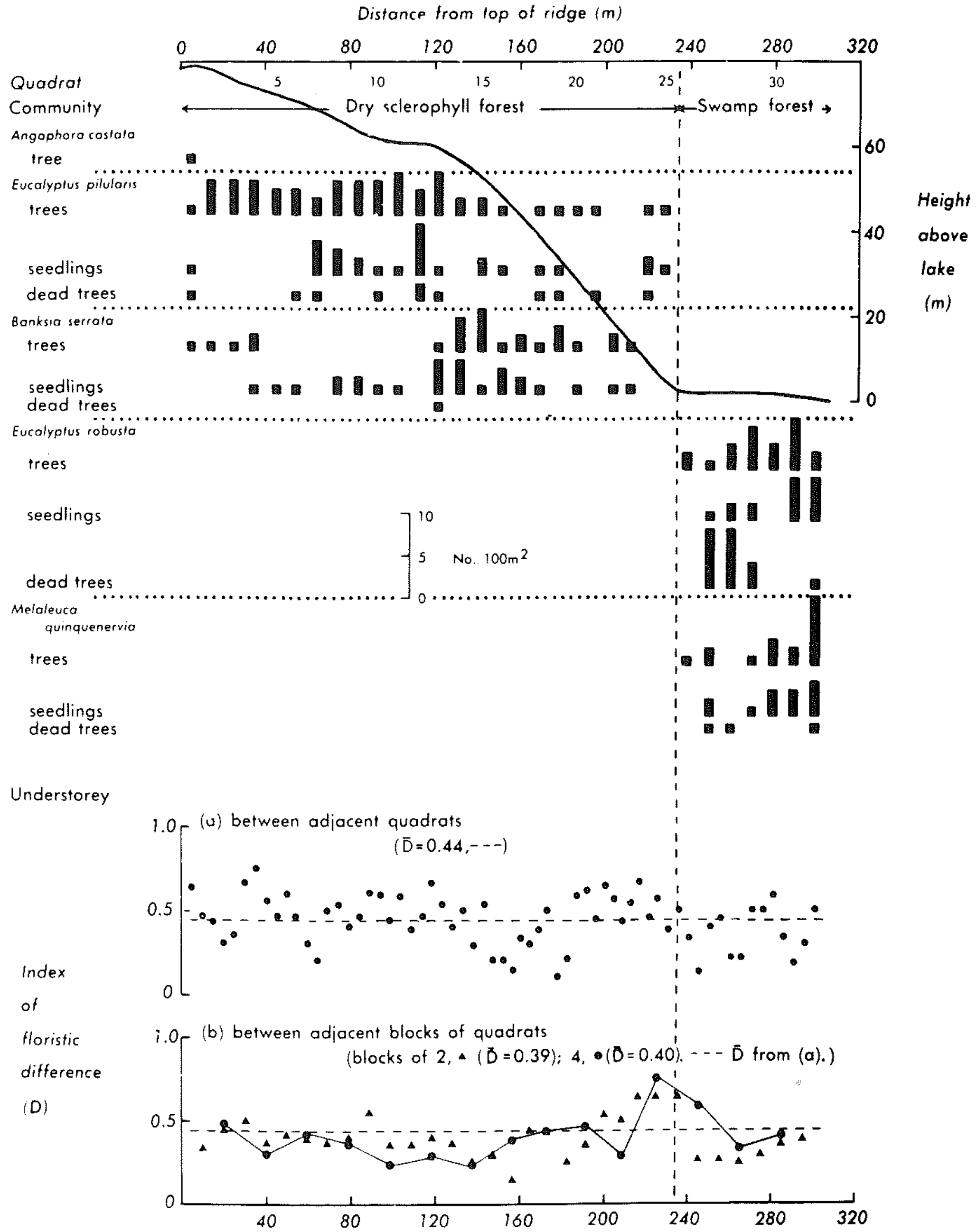


Figure 7. Transect (10 m wide) from ridge to lake down north-facing slope of dune adjacent to Myall Lake east of Kataway Bay (for approximate location see map located in back pocket), showing variation in surface topography, plant communities, and density of live and dead trees and tree seedlings (less than 2 m high). The plot of density, scored in 10 × 10 m quadrats laid on the ground surface, does not correspond with horizontal distance because of the slope. The designation of "Swamp Forest" near the top of the figure includes a narrow strip of Fringe Forest on the lake shore. Small trees of *Acacia implexa* (10 trees in quadrat 25) and of *Synoum glandulosum* (six trees in quadrat 25 and two in quadrat 26) and tall erect shrubs of *Pultenaea blakelyi* occurred at the ecotone between Dry Sclerophyll Forest and Swamp Forest. Variation in floristic composition of the understorey is shown in values of an index of floristic difference (D) between adjacent 5 × 5 m quadrats and between adjacent blocks of quadrats.

$$D = \frac{\sum\limits_{m=1 \rightarrow n} \left| x_{mj} - x_{m(j+1)} \right|}{n}$$

multiple stems to 2-4 m high, occurs between Yagon Gibber and Big Gibber on seaward slopes that rise to the forest proper. *Eucalyptus pilularis* scrub also occurs locally on the small exposed hillocks and ridges above Wet Heath, immediately inland from the long, bare transgressive dune on Fiona and Submarine Beaches. The associated species seem to differ little from those in pure *E. pilularis* forest.

Fox (1979) has distinguished two types of shrubby understorey in Dry Sclerophyll Forest. One, in which fabaceous shrubs dominate, is associated with *Eucalyptus pilularis* and in the *E. pilularis* scrub mentioned above, while the other, a heathy understorey, occurs under *Angophora costata*-dominated canopy on higher ground. Fox & McKay (1981) indicate the relative extent of the two types of understorey in the area between Fiona and Submarine Beaches and Myall Lake, and also give data on the regrowth of *Aotus ericoides, Correa reflexa, Pteridium esculentum* and *Ricinocarpos pinifolius*, with *P. esculentum* achieving maximum cover within the first year following fire and declining in cover thereafter.

Under high fire frequency the usually shrubby understorey is apparently replaced by a more grassy understorey in which *Imperata cylindrica* is predominant. This tendency was also noted in southeastern Queensland and discussed by Coaldrake (1961). Dry Sclerophyll Forest with grassy understorey occurs near Seal Rocks where fires have been increasingly frequent over recent years.

The general composition of Dry Sclerophyll Forest is shown in two transects (Figures 7 and 8), both on scarp slopes. Although the two samples differ in composition, one with low frequency of *Angophora costata* (Figure 7) and the other with low frequency of *Eucalyptus pilularis* (Figure 8), variation down along each transect is small until relatively low on the slope, where presumably there is a relatively high water-table most of the time. Here a band of relatively shallow-rooted or water-demanding species occurs, for example, the rainforest species *Rhodomyrtus psidioides*, and Wet Sclerophyll species *Kennedia rubicunda*, *Pultenaea blakelyi* and *Acacia* spp. Also, *Gahnia clarkei*, a tussock sedge, frequently marks the boundary between Dry Sclerophyll Forest and swampy areas at the foot of sandy scarps.

The changing floristic composition of understorey plants across the boundary of the swampy areas and Dry Sclerophyll Forest is shown in Figures 7 and 8, in the variation of an index of floristic difference between adjacent blocks of quadrats. Values of the index for adjacent 5 x 5 m quadrats in the transects are on average higher than those for adjacent blocks of quadrats, and do not show such definite changes across the boundary between communities. Presumably values of the index at this scale reflect intrinsic patterns (Poore, 1964) within communities as much as differences across boundaries between them. In contrast, values of the index for adjacent blocks of quadrats reflect differences across the boundaries, showing maxima at the Dry Sclerophyll Forest/Swamp Forest boundary in each transect for each of the three block sizes examined.

Undoubtedly, the composition of the shrub stratum at any one site largely depends on its recent fire history, though no data are available to show this. In Figures 7 and 8 the Dry Sclerophyll Forest understorey was floristically very

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where x_{mj} is the occurrence of species m in quadrat j (with values of 1 if it is present; 0 if absent), and n is the total number of species in quadrats j and (j + 1) taken together.

The index is a simplified form of the Canberra metric, discussed earlier in the text. The simplification is two-fold: firstly, only binary data are used; and secondly, the value the index takes is local to each pair of quadrats or adjacent blocks of quadrats in a comparison. The value of the index varies between zero, when the species composition of the two quadrats is identical, and one when the quadrats have no species in common.

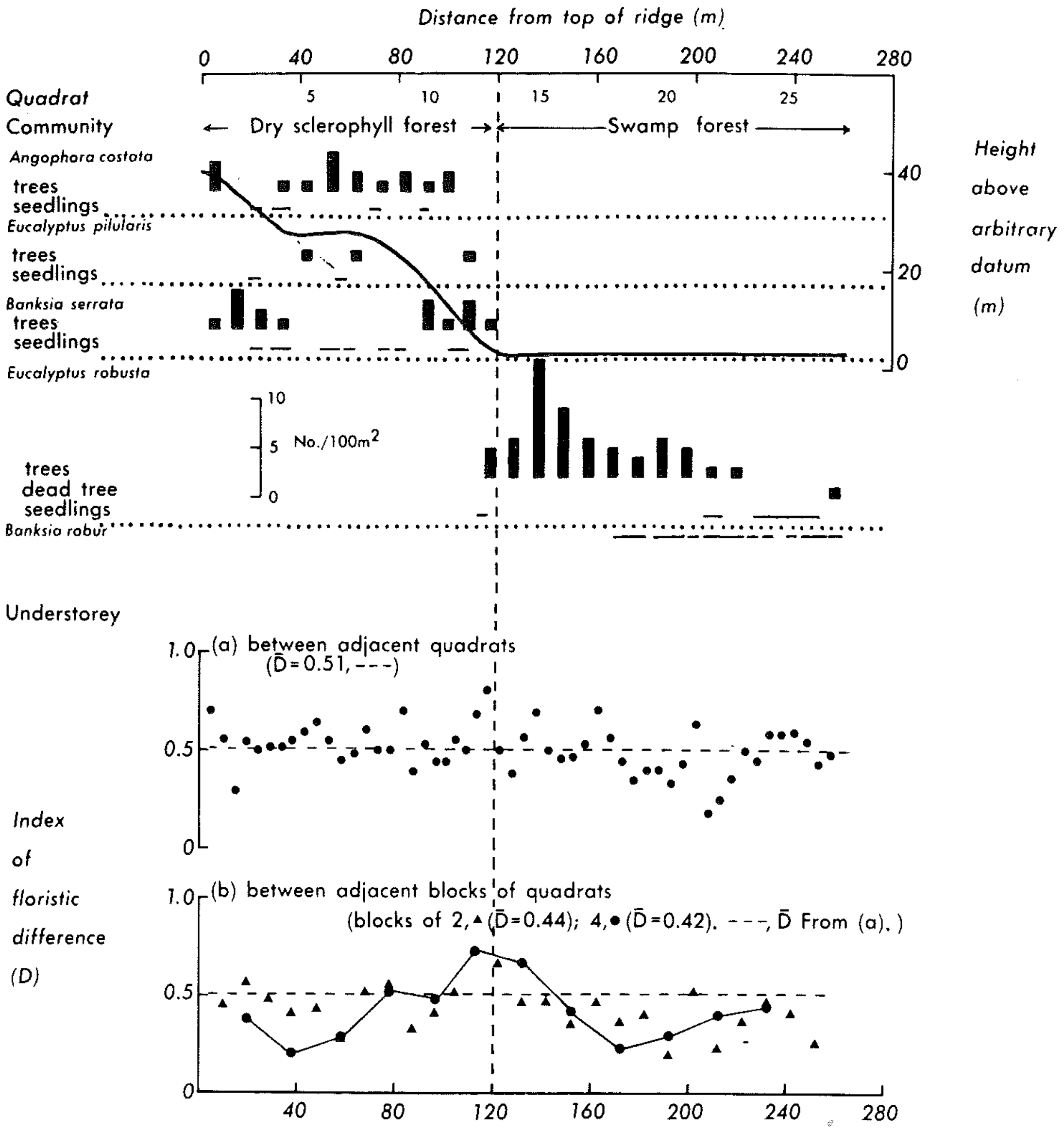

Figure 8. Transect from ridge top to swampy ground of the Eastern Lagoon down northwest facing slope of dune southeast of Kataway Bay (see map located in back pocket for approximate location of transect), showing variation in surface topography, plant community, density of living and dead trees, and the presence (—) of tree seedlings (<2 m high) and of *Banksia robur* shrubs. Tree density scored in successive 10 × 10 m quadrats; presence of tree seedlings and *B. robur* bushes in 5 × 5 m quadrats, together with understorey species. Variation in floristic composition of the understorey from the ridge top is shown in values of an index of floristic differences (see Figure 7) between adjacent quadrats and adjacent blocks of quadrats. The designation of Swamp Forest near the top of the figure also includes a strip (quadrats 22–27 inclusive) that could more correctly be termed Swamp.

similar in the two transects, with a value of 0.72 for Czechanowski's coefficient (see Greig-Smith, 1964).

There were in the first transect (Figure 7), omitting the ecotone (Quadrats 25 and 26), 32 understorey species in the Dry Sclerophyll Forest (forty-eight 5 x 5 m quadrats), with two species, *Aotus ericoides* and *Pteridium esculentum*, occurring in over 90 per cent of the quadrats and 11 species in under 10 per cent of them. In the Swamp Forest (twelve 5 x 5 m quadrats) there were 17 understorey species, with two, *Gleichenia dicarpa* R.Br. and *Baumea*

TABLE 4

Dry Sclerophyll Forest soils—chemical analyses of oven-dry samples

Transect No.	1 (Figure 7)								2 (Figure 8)			
Position of sample	ridge top			mid-slope			lower-slope		ridge top		mid-slope	
Depth (cm)	O–5	5–20	20–50	0–5	5–20	20–50	0–5	5–50	0–5	5–50	0–5	5–50
Loss on ignition (%)	7.3	2.5	0.5	3.3	4.3	0.1	6.5	2.1	8.2	0.1	9.5	0.6
Total nitrogen (%)	0.09	0.04	0.01	0.04	0.05	0.01	0.09	0.03	—	—	0.12	0.01
Total phosphorus (p.p.m)	35	32	20	25	—	—	24	22	51	18	30	7
Potassium (i) total (meq/100 g) . .	0.381	0.281	0.271	0.294	0.212	0.179	0.281	0.205	0.263	0.092	0.261	0.066
(ii) exchangeable	0.079	0.052	0.018	0.061	0.059	0.028	0.169	0.114	0.115	0.020	0.097	0.041
Exchangeable sodium (meq/100 g)	0.094	0.074	0.030	0.050	0.059	0.038	0.109	0.113	0.261	0.036	0.148	0.063
Exchangeable calcium (meq/100 g)	1.000	0.424	—	0.521	0.519	0.050	1.697	0.773	1.148	0.050	1.747	0.150
Total magnesium (meq/100 g) . .	1.275	0.066	0.271	1.192	0.123	0.181	0.905	0.197	0.146	0.024	0.658	0.484

— = not analysed. Analysis of total nitrogen by Kjeldahl method; of total phosphorus spectrophotometrically using ammonium molybdate on a neutralized nitric/perchloric/sulphuric acid digest; of K, Na, Ca and Mg with an atomic absorption spectrophotometer on an ammonium chloride extract for exchangeable cations, and on a neutralized nitric/perchloric/sulphuric acid digest for total amounts. (Methods used are mostly described in Allen *et al.* (1974), but the use of ammonium chloride to extract exchangeable cations is described in Piper (1950).)

arthrophylla, occurring in over 80 per cent and four species in under 10 per cent of the quadrats. Again omitting the ecotone, only two species, *Dianella caerulea* and *Kennedia rubicunda*, occurred in both communities.

There were in the second transect (Figure 8), also omitting the Dry Sclerophyll Forest/Swamp Forest ecotone (Quadrat 13), 38 understorey species in the Dry Sclerophyll Forest (twenty-four 5 x 5 m quadrats), with two species, *Dillwynia retorta* and *Pteridium esculentum*, occurring in over 90 per cent and nine species in under 10 per cent of the quadrats. In the Swamp Forest and Wet Heath taken together (twenty-eight 5 x 5 m quadrats), there were 40 understorey species, with three, *Blechnum cartilagineum* Sw., *Gleichenia dicarpa* and *Leptospermum juniperinum*, occurring in over 80 per cent and 12 species in under 10 per cent of the quadrats. Omitting the DSF/SF ecotone, only two species, *Pteridium esculentum* and *Leucopogon lanceolatus*, occurred in both communities and did so in the Swamp Forest only close to the ecotone.

Dry Sclerophyll Forest occurs most extensively on the high transgressive dunes of Holocene sand (map located in back pocket), but it is also characteristic of freely drained sites on old lake sand-bars (subsystem Lb in Figure 1) and on Inner Barrier sands round the base of old rock islands, such as McGraths Hill, often extending some distance from the bases of hills, particularly into the inner parabolic dunes. Dry Sclerophyll Forest soils generally show little profile development. Borings to 8 m deep on the high transgressive dune ridge east of Myall Lake, showed an incipient B horizon approximately 1 m deep. Casual observation elsewhere in the forest tends to confirm the general picture, as do observations of Anderson (1973) and Lewis (1973) in its northern areas and Lewis (1978) in Holocene dunes of the Outer Barrier southwest of Big Gibber.

The relatively low nutrient status of the soils (Table 4), also shown in more detailed observations by Lewis (1973, 1978), scarcely differs from that of Dry Heath Forest and Dry Heath soils on Pleistocene sands (Figures 11 and 20, pp. 427 and 438). As in Hawkesbury sandstone communities (Hannon, 1958), a higher proportion of nutrients in the ecosystem is probably in plant and animal tissues relative to soil components than in many other types of ecosystem.

INTERMEDIATE DRY FOREST (Figure 9)

Tree stratum (to c. 25 m): MAIAA *Eucalyptus pilularis,* AAADAA *Angophora costata,* CAFUF *Eucalyptus gummifera.*

Small tree stratum (to c. 8 m): *Banksia serrata, B. aemula.*

Shrub stratum (to c. 3 m): *Dillwynia retorta, Calytrix tetragona, Xanthorrhoea australis, Macrozamia communis.*

"Herb" stratum (to c. 1 m): *Pteridium esculentum, Coleocarya gracilis.*

Soils: podzols.

This forest, intermediate in structure and composition between Dry Sclerophyll Forest and Dry Heath Forest, is characteristic of the Late Pleistocene wind-blown sand sheet east of Bombah Broadwater, and of parts of the inner parabolic dunes whose surfaces may have been secondarily disturbed at some stage. Within it *Banksia serrata* and *B. aemula* occur together.

The trees of the main canopy are taller and better developed than in Dry Heath Forest but the canopy height never reaches the maximum attained in Dry Sclerophyll Forest.

DRY HEATH FOREST (Figure 10)

Tree stratum (to c. 20 m): MAIAA *Eucalyptus pilularis,* AAADAA *Angophora costata,* CAFUF *Eucalyptus gummifera, Melaleuca quinquenervia.*

Figure 9. Intermediate Dry Forest on sands of the Glacial dune complex (Pg) east of Broadwater. *Banksia serrata, B. aemula, Eucalyptus gummifera, E. pilularis* with *Dillwynia retorta.*

Figure 10. Dry Heath Forest on sands of differentiated Inner Barrier (Pib) between Bombah Broadwater and Johnsons Hill. *Angophora costata, Eucalyptus gummifera, Banksia aemula* with *Dillwynia retorta, Actinotus helianthi.*

Small tree stratum (to c. 3 m): *Banksia aemula.*

Shrub stratum (to c. 3 m): *Dillwynia retorta, D. glaberrima, Calytrix tetragona, Kunzea capitata, Leptospermum attenuatum, Melaleuca nodosa.*

"Herb" stratum: e.g., *Selaginella uliginosa* (Labill.) Spring, *Lomandra glauca, Hypolaena fastigata, Restio tetraphyllus* ssp. *meiostachyus.*

Soils: podzols.

Dry Heath Forest occurs on the Inner Barrier and is particularly well developed on the inner parabolic dunes. It has a number of species in common with Dry Sclerophyll Forest but there are notable differences. Particularly striking is the lack of *Banksia serrata.* On the other hand *B. aemula* is common in Dry Heath Forest but absent from Dry Sclerophyll Forest. *Eucalyptus gummifera* is common in Dry Heath Forest but absent from Dry Sclerophyll Forest except in the northeastern parts of this area and a narrow strip between Big Gibber and Yagon Gibber, which may be caused by rocky bars below the sand or an old Pleistocene surface that is only just covered.

The overall tree density is considerably less than in Dry Sclerophyll Forest. Indeed, locally, tree canopies are so widely spaced that the community is structurally a woodland. The whole aspect is one of lower productivity than in the Dry Sclerophyll Forest although there are no quantitative data on this point. The soils certainly show a very distinct difference, displaying a well developed podzol profile, with B horizon being located at 1.5 m or deeper.

To some extent the presence of Dry Heath Forest may be determined by the average height of the water-table, particularly on the differentiated Inner Barrier. Thus the higher ridges carry Dry Heath Forest, the trees getting more and more depauperate as the ridges decrease in height and giving way to Dry Heath on the lower slopes and the lower ridges. On the inner parabolic dunes, however, Dry Heath Forest tends to be replaced by Wet Heath as the altitude decreases with scarcely any intervening Dry Heath (Figure 11). The difference may be due to fire frequency as indicated under Dry Heath. On the peninsula south of Pigeon Point, where greater protection from fire might be expected, Dry Heath Forest on the gentle slopes into the central depression gives way down-slope to a community with an open Swamp Forest canopy and a Wet Heath understorey (Figure 12). Similar transitions also occur near McGraths Hill and Kataway Hill where a similar degree of protection from fire might also be expected.

WET HEATH FOREST (Figure 13)

Tree stratum (to c. 20 m): AAADAA *Angophora costata,* SECAF *Eucalyptus robusta, Melaleuca quinquenervia.*

Small tree stratum (to c. 5 m): *Melaleuca sieberi.*

Shrub stratum (to 2 m): *Banksia oblongifolia* R.Br., *Melaleuca nodosa, Acacia elongata, Xanthorrhoea resinosa* ssp. *fulva.*

"Herb" stratum: *Schoenus brevifolius, Baumea rubiginosa, Empodisma minus, Panicum simile, Gonocarpus micrantha, Restio tetraphyllus* ssp. *meiostachyus.*

Soils: humus podzols.

Wet Heath Forest has a well developed tree canopy. The ground surface is usually uneven and poorly drained with small shallow pools remaining in lower spots for some time after rain. The composition of the understorey accordingly varies with the microtopography and ranges from species occurring in Swamp Forest to those occurring in Wet Heath and on lower sites in Dry Heath Forest.

Wet Heath Forest characteristically occurs on low-lying ridges and gentle slopes on Pleistocene sands of the early Inner Barrier (Pu), undifferentiated Inner Barrier (Pub) and inner parabolic dunes (Pip). It is the most extensive type of forest on the low ridges on the northern and western sides of Eastern Lagoon near McGraths Hill and Kataway Hill.

Small trees of *Melaleuca sieberi* up to 5 m high occur in the wettest facies of Wet Heath Forest with *Baumea arthrophylla,* B. *rubiginosa* and *Schoenus brevifolius. Melaleuca sieberi* occurs as a shrub to 2 m high in Wet Heath on the differentiated Inner Barrier (Pib) where more frequent and intense burning

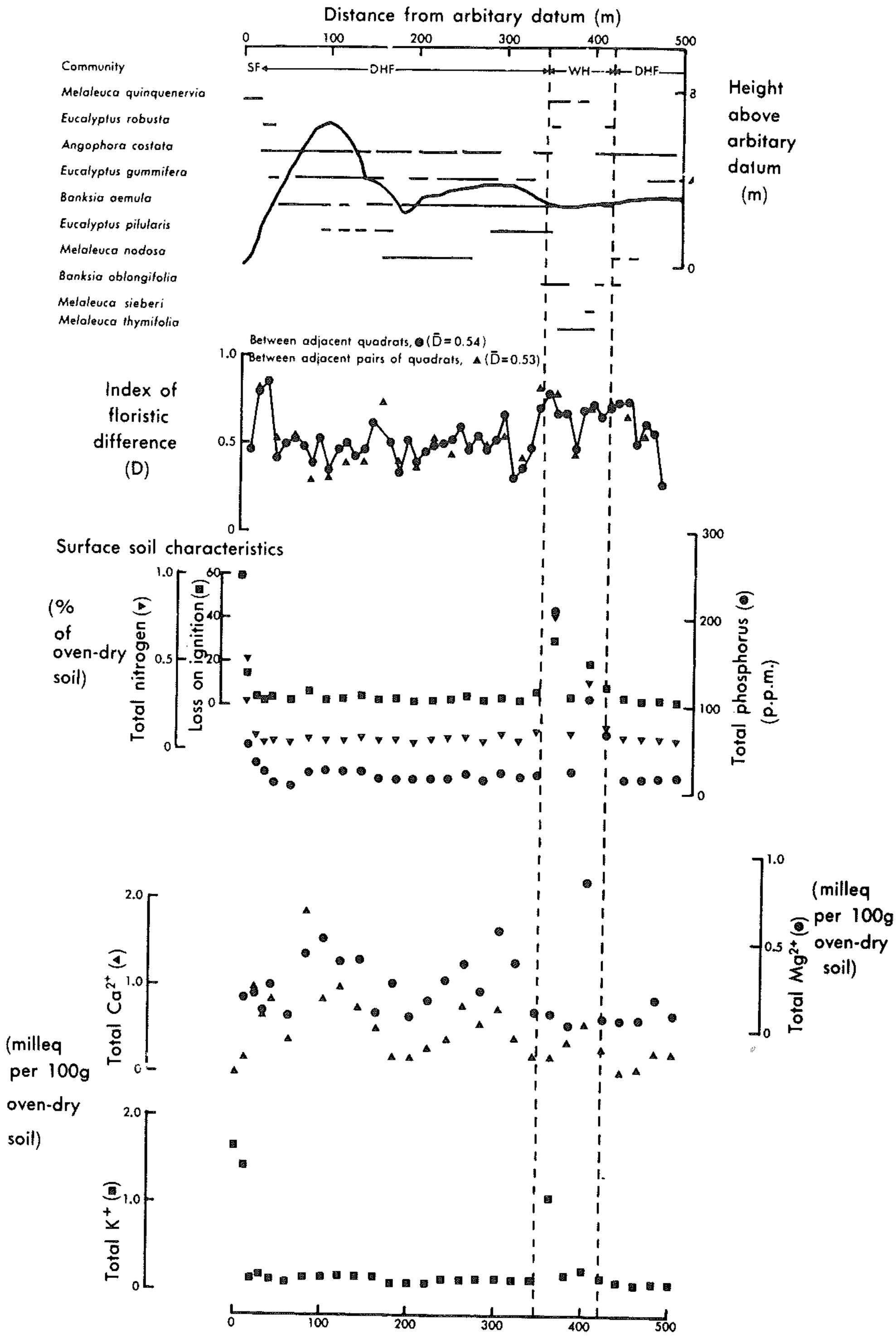

Figure 11. Transect approximately west to east across the junction of the inner parabolic dunes and differentiated Inner Barrier between Tickerabit and Johnsons Hill (see map located in back pocket for approximate location), showing variation in surface topography, plant community, and the presence (—) of tree species scored in 10 × 10 m quadrats and species of shrubs of the same genera as the trees present but scored in quadrats 10 m long and 5 m wide. Variation in floristic composition of the understorey in the forests and the main canopy in Wet Heath is shown in values of the index of floristic differences between adjacent 5 × 5 m quadrats and adjacent pairs of quadrats (see Figure 7). Variation of characteristics of the top 5 cm of soil below the litter layer is shown. (For methods of soil analysis see Table 4. For abbreviations of plant communities see Table 2).

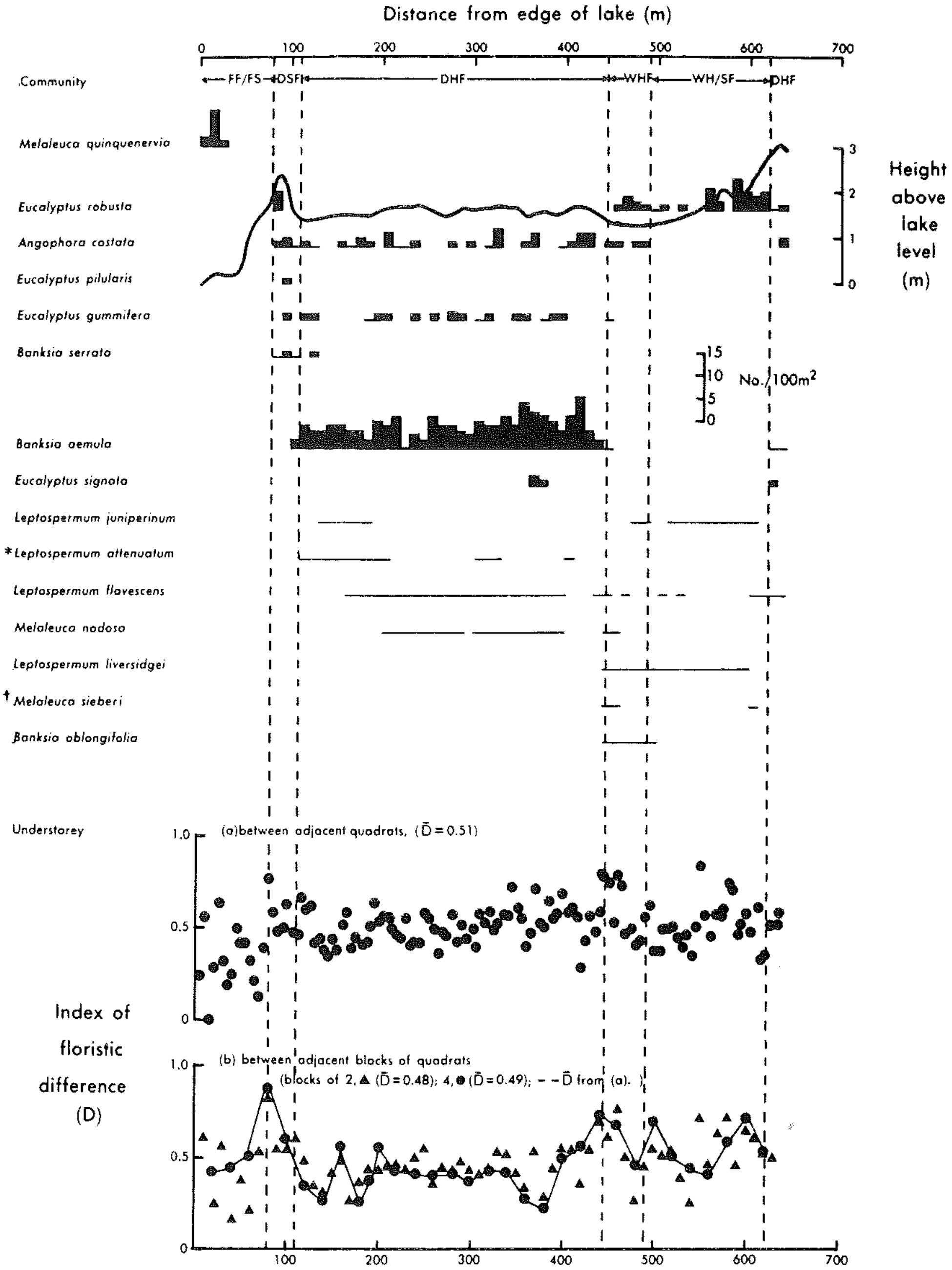

Figure 12. Transect approximately southwest to northeast from the lake edge on the western side of the peninsula south of Pigeon Point (for approximate location of transect see map located in back pocket), showing variation in surface topography, plant community, density of live trees in successive 10 × 10 m quadrats. The presence (—) in successive quadrats 10 m long and 5 m wide of seedlings and saplings of each of the main species of trees is shown where live trees were not already recorded for it in a given 10 × 10 m quadrat. The presence (—) of shrubs is similarly shown where they belong to species in the same genera as the tree species. However presence (—) was recorded in *Leptospermum attenuatum** from data compounded from scoring small trees in 10 × 10 m quadrats and understorey individuals in 10 × 5 m quadrats and in *Melaleuca sieberi*† from individual small trees in 10 × 10 m quadrats. Variation in floristic composition of the understorey scored in successive 5 × 5 m quadrats is shown in values of an index of floristic differences (see Figure 7) between adjacent quadrats and adjacent blocks of quadrats. Communities designated near the top of the figure as WHF and WH/SF were ecotonal and were mapped on the map located in back pocket as DHF and WH respectively. (For abbreviations of names of communities see Table 2).

* scored as trees and shrubs

† scored as trees

Figure 13. Wet Heath Forest on sands of differentiated Inner Barrier (Pib) at the southeastern edge of Johnsons Hill. *Angophora costata* with *Banksia oblongifolia, Leptocarpus tenax, Restio tetraphyllus.*

may occur (see comment under Dry Heath). It may be partly fire regime that limits Wet Heath Forest to sheltered areas on Pleistocene sand, in contrast to exposed situations where it is replaced by Wet Heath. Where Wet Heath Forest occurs close to the rock-based prior islands, species such as *Banksia spinulosa* and *Pultenaea microphylla* are present. This presence may be due to some downwash enrichment. In other places Wet Heath Forest appears to be an extended ecotone between Dry Heath Forest and Swamp Forest.

SWAMP FOREST (Figure 14)

Tree stratum (to 20 m): *Melaleuca quinquenervia,* SECAF *Eucalyptus robusta.*

Small tree stratum: almost always absent.

Shrub stratum (to 2 m): *Leptospermum juniperinum, Acacia elongata;* often absent.

"Herb" stratum: *Blechnum cartilagineum* Sw., *B. campfieldii* Tindale, *Restio tetraphyllus* ssp. *meiostachyus, Chorizandra sphaerocephala, Baumea athrophylla.*

Soils: almost no profile development, very high organic matter from surface downwards.

Swamp Forest, equivalent to Tree Swamp of Anderson (1973), is dominated in the tree layer by *Melaleuca quinquenervia* and *Eucalyptus robusta.* The proportions of these species vary, but their presence or absence does not seem to be related to the relative depth of water. However, while *E. robusta* is usually the more abundant in sites with appreciable waterflow, *M. quinquenervia* is usually the more abundant in "sump" sites where water stands or seeps into the ground when the water-table drops. *Melaleuca quinquenervia* tends to show stepping of size classes. This feature is often in the sapling stages and implies that regeneration occurs only under certain periodically realized conditions. In Swamp Forest the relative water-table is high and accumulation of soil organic matter is presumably related to this factor. Figure 11 shows that loss on ignition is high in these soils and that the nutrient status is also high, particularly in total nitrogen and phosphorus.

Figure 14. Swamp Forest at the eastern end of the inter-Barrier lagoon (Pil). *Melaleuca quinquenervia* with *M. sieberi, Callistemon citrinus, Restio* spp.

In typical Swamp Forest there is much colloidal organic material in the soil and the ground flora consists largely of *Blechnum camfieldii, Villarsia exaltata, Chorizandra sphaerocephala* and *Baumea arthrophylla.* With continued accumulation of organic matter, the soil surface is raised and species requiring somewhat drier conditions appear, such as *Blechnum cartilagineum, Gahnia sieberiana, Spartothamnella juncea, Callistemon citrinus,* and *Empodisma minus. Empodisma minus,* in particular, marks a significant change in the character of Swamp Forest. It tends to build up large hummocks and to form peaty islands which are colonized by Wet Heath species, particularly the smaller growing ones such as *Epacris obtusifolia, Sprengelia* spp. and *Schoenus brevifolius.* Indeed, the situation on these islands can be almost ecotonal (see Figure 20, p. 438) and in general may represent a phase in the supplanting of Swamp Forest by Wet Heath. Swamp Forest trees, particularly *Melaleuca quinquenervia,* survive in increasingly heathy conditions better than the ground flora of this community and are possibly eliminated eventually by increased fire frequency or intensity.

Swamp Forest is scattered throughout the Eurunderee sand mass wherever the water-table is at or very near the surface. There are, however, exceptions to this generalization that are discussed under Swamp and *Lepironia* Swamp. Swamp Forest is particularly common amongst the inner parabolic dunes. There are also narrow strips in the lower parts of the differentiated Inner Barrier and along the base of the landward scarp of the Outer Barrier. Such a strip of Swamp Forest widens into a very extensive area towards the outlet of the inter-Barrier lagoon into Broadwater.

There are patches of Swamp Forest in the Outer Barrier, including two in the large, high sand mass in the northeast of the area. It is possible that such patches are growing on parts of the older land surface over which sand of the Outer Barrier was blown.

Osborn & Robertson (1939) drew attention to a particular facies of Swamp Forest, containing *Livistona australis,* near Mungo Brush, which is beyond the limits of this survey. *Livistona australis* occurs in a wind-pruned thicket of *Melaleuca quinquenervia* behind a semi-mobile foredune 500 m northwest of Treachery Head. This thicket has been mapped as Swamp Forest in the map located in the back pocket, though its understorey is more characteristic of

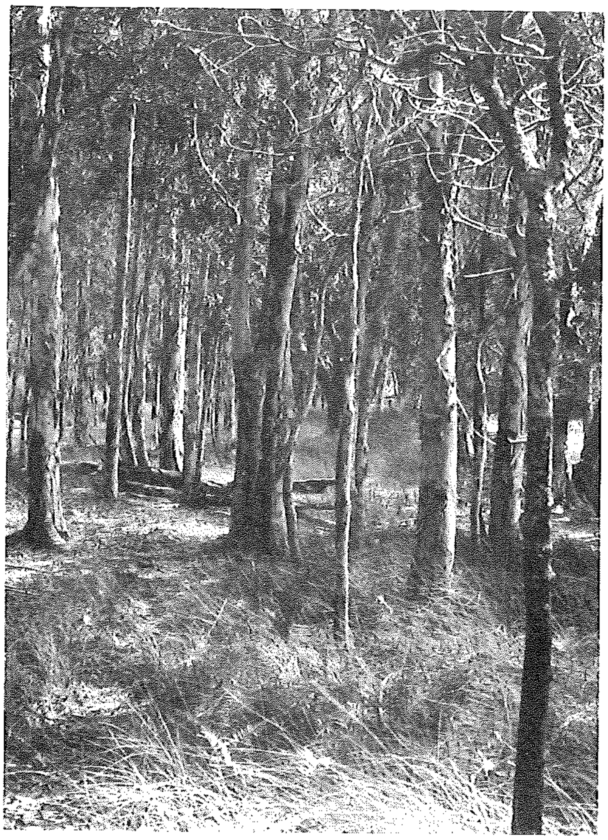

Figure 15. Fringe Forest on shores of Bombah Broadwater near Nerong (Dirty) Creek (out of the study area to the northwest). *Melaleuca quinquenervia, Casuarina glauca* with *Baumea* spp.

Beach-dune Thicket, its soil surface having been raised by recently arrived wind-blown sand.

FRINGE FOREST (Figure 15)

Tree stratum (to 20 m): *Casuarina glauca, Melaleuca quinquenervia.*

Shrub stratum: usually lacking.

"Herb" stratum: *Baumea juncea, B. articulata, Cladium procerum.*

Soils: various, but usually highly organic and highly reducing with no profile development.

This forest, the Lake Margin Association of Anderson (1973), occurs in a thin strip along the margins of the lakes and, for the purpose of this description, includes their emergent communities.

The two main tree species frequently grow together but, generally, at the bases of the old rocky islands *Casuarina glauca* tends to dominate whilst on the sands themselves *Melaleuca quinquenervia* is the more abundant. *Dendrobium teretifolium* and *Platycerium bifurcatum* (Cav.) C. Chr. occur as epiphytes of *Casuarina glauca.* The herb stratum is often dominated by *Baumea juncea,* particularly away from the immediate lake edge. At the lake edge and extending into standing water *Baumea articulata* and *Cladium procerum* tend to form extensive communites excluding other species. Rafts of *Cladium procerum* grow out over the water and break off, at least at their extremities, when heavy winds occur in the right direction, so there is no general extension of the sedgebeds. In standing water over mud, *Schoenoplectus validus* often

Figure 16. Headland Thicket at southern end of Number One Beach, Seal Rocks. *Banksia integrifolia* with *Melaleuca armillaris*.

occurs, thinly spread, sending out rather superficial rhizomes into deeper water. Once again, with strong onshore or alongshore winds these rhizomes are torn up and there is no general extension. Stands of *Phragmites australis* are frequent in standing water over a sandy or rocky substratum. The extension of this species into the lakes seems to be controlled by factors other than direct wind or wave action since it produces rhizomes deeper in the substratum than *Schoenoplectus validus.*

Along the shores of Smiths Lake, the lakeward edge of the Fringe Forest is higher above the average lake level than it is in the Myall Lakes system. This distribution pattern can be related to the greater salinities, similar to or even slightly above those of the sea, that the waters of Smiths Lake attain. *Juncus krausii* is commoner at its lakeward edge than it is in the Myall Lakes system. Also, *Cladium procerum* and *Schoenoplectus validus* do not extend outwards from its shores, and *Sarcocornia quinqueflora*, absent from the shores of the other lakes, occurs on saline muddy flats in sheltered bays.

HEADLAND THICKET (Figure 16)

Small tree stratum (to c. 8 m): e.g., *Cupaniopsis anacardioides, Banksia integrifolia, Synoum glandulosum, Acmena smithii.*

Shrub stratum (to c. 3 m): Same species as trees, together with *Breynia oblongifolia, Acacia longifolia.*

"Herb" stratum: e.g., *Hibbertia scandens, Oplismenus imbecillis, Imperata cylindrica, Themeda australis.*

Soils: black headland soils.

A thicket consisting of a mixture of rainforest and sand-dune species is found facing the sea on the rocky headlands of Big Gibber, Yagon Gibber, Treachery Head and some of the cliffs near Seal Rocks. The trees are usually severely affected by the onshore winds, particularly towards the seaward side where the relatively salt-wind tolerant *Cupaniopsis anacardioides* and *Banskia integrifolia* occur as stunted wind-pruned bushes. Near Seal Rocks, *Melaleuca*

Figure 17. Vine Thicket west of Number One Beach, Seal Rocks. Stems mostly of *Eupomatia laurina* with mainly *Cissus hypoglauca* and *Blechnum cartilagineum, Doodia aspera.*

armillaris occurs in this situation. Within the shelter of these trees to landward, the less tolerant species, such as *Synoum glandulosum, Acmena smithii* and *Trema aspera* occur, often with extensive lianas or semi-lianas, for example, *Hibbertia scandens, Cissus antarctica, Stephania japonica* and *Kennedia rubicunda.* The individual headlands show relatively minor differences, presumably due to different histories or rock-types. For instance, Yagon Gibber has many more introduced species such as *Chloris gayana, Paspalum dilatatum* and *Pennisetum clandestinum,* than Big Gibber. Moreover, on Yagon Gibber a large area of grassland extends seaward beyond the thicket, and contains many of the introduced species together with *Themeda australis* and *Lomandra longifolia,* scattered shrubs of *Westringia fruticosa* and many Foredune Complex species, for example, *Correa alba, Isolepis nodosa, Carpobrotus glaucescens* and *Hydrocotyle bonariensis.* The steeper cliffs north of Seal Rocks are often very wet from springs in the joints and carry many Foredune Complex species.

Headland Thicket includes the Headlands and Rocky Outcrops Association (fd. 2) of Anderson (1973) and the more coastal facies of her Depauperate Relic Vine Shrub Community.

VINE THICKET (Figure 17)

Small tree stratum (to c. 8 m): e.g., *Rhodomyrtus psidioides, Acmena smithii, Eupomatia laurina, Cupaniopsis anacardioides, Banksia integrifolia.*

Lianas: *Smilax australis, Cissus hypoglauca.*

Soils: yellow podzolic.

This dense thicket occurs in a broad shallow gully sloping fairly steeply and facing the sea. The Seal Rocks road descends to the shore along its southern

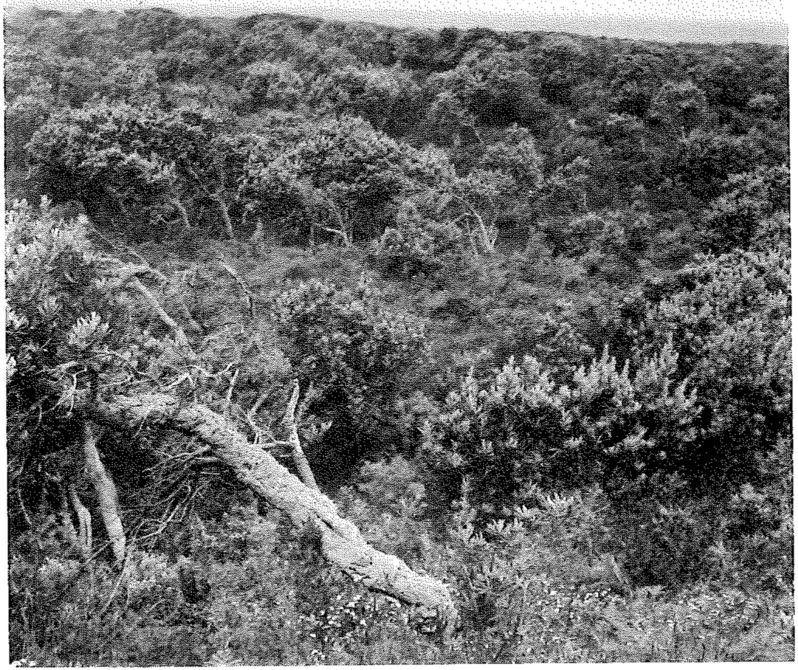

Figure 18. Beach-dune Thicket south of Bombah Broadwater. *Banksia serrata* in foreground with *Leptospermum laevigatum* on more seaward ridge in the middle distance.

side. The gully appears to be more sheltered from onshore winds and to receive a better supply of groundwater than otherwise similar rock-based gullies to the north. The close cover of low trees, mostly of rainforest species with a dense tangle of vines, makes this community difficult to traverse. There is little or no groundcover but shade-tolerant ferns such as *Doodia aspera* R. Br. occur locally. To seaward and along its northern edge the community grades into Headland Thicket, with which it has species in common such as *Banksia integrifolia* and *Cupaniopsis anacardioides*. At the head of the gully it grades into Wet Sclerophyll Forest, which in turn grades into a facies of Dry Sclerophyll Forest rich in *Dodonaea triquetra*, with a quantity of *Acacia parramattensis* across the ecotone. The Vine Thicket community is probably a stage in regrowth following the destruction of a taller forest canopy. Certainly at the head of the gully there are several tall dead standing eucalypt stems.

Anderson (1973) includes this community within her more broadly defined Depauperate Relic Vine Community.

BEACH-DUNE THICKET (Figure 18)

Small trees (to c. 8 m): *Banksia serrata, Banksia integrifolia, Leptospermum laevigatum, Cupaniopsis anacardioides, Pittosporum undulatum.*

Shrub stratum (to c. 3 m): *Dodonaea triquetra, Acacia longifolia, Correa reflexa.*

"Herb" stratum: *Pteridium esculentum, Gonocarpus teucrioides, Tetratheca thymifolia, Imperata cylindrica, Cymbopogon refractus.*

Soils: sand with minimal profile development, an organically stained A_1 horizon grading into undifferentiated beach-sand.

This community occurs at certain sites along the sea front but is generally protected by the foredune. In many places the foredune is broken through in long parabolic blow-outs or more complicated areas of disruption and in such

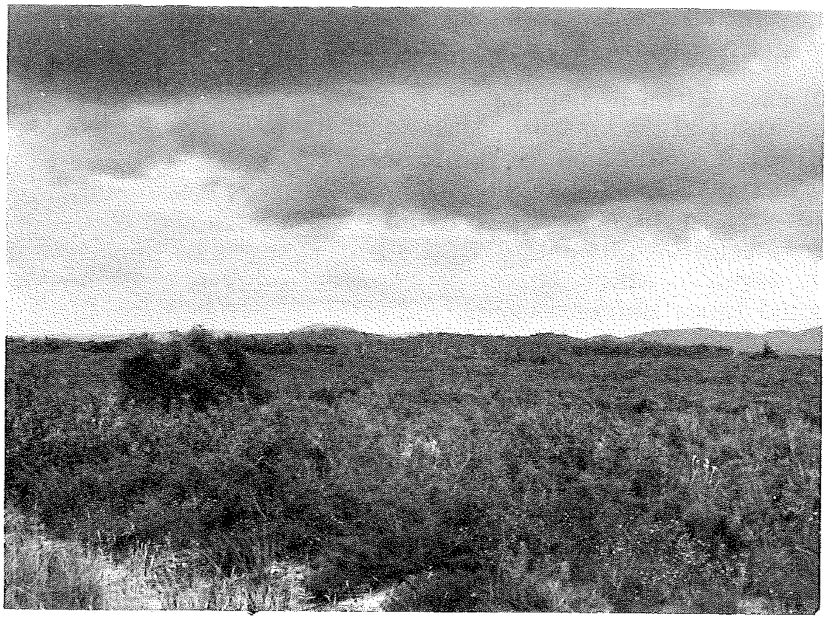

Figure 19. Dry Heath on ridge of differentiated Inner Barrier (Pib) about 1.5 km northwest of Big Gibber. *Banksia aemula, Acacia suaveolens.*

cases the Beach-dune Thicket may be exposed to the sea. In these recent blowouts, except right at their mouths, it is the species of this community that colonize the bare sand and generally not those of the Foredune Complex. It seems that the early stages of Pidgeon's (1940) sand-dune succession can only be applied to a prograding beach. Otherwise the situation is, strictly speaking, a zonation, which may show little if any change over appreciable periods of time, and can be related in part to the relative degree of protection from onshore winds. It is on the landward lee slopes behind the beach-dune that the rather more mesic species occur such as *Cupaniopsis anacardioides, Synoum glandulosum, Pittosporum undulatum* and even the distinctly rainforest species *Acmena smithii.*

The community includes the Hind Dune Scrub Community of Anderson (1973) and probably the more shrubby facies of her Sandy Foredunes Associations (fd. 2).

DRY HEATH (Figure 19)

Shrub stratum (to 2 m): mainly the same shrubs as found in Dry Heath Forest together with stunted specimens of CAFUF *Eucalyptus gummifera,* and very occasionally MAIAA *E. pilularis* and AAADAA *Angophora costata.*

"Herb" stratum: mainly the same as in Dry Heath Forest.

Soils: podzols with B horizon 1-1.5 m below the surface.

On the differentiated Inner Barrier, Dry Heath occurs on flanks of the higher dunes between Dry Heath Forest and Wet Heath, and on summits of the lower dunes as shown in Figure 20. It occupies an intermediate position with regard to water-table between these two communities. However, as was indicated when discussing Dry Heath Forest, Dry Heath, which is virtually Dry Heath Forest without trees, is not found in intermediate situations on the inner parabolic dunes. The low relief and parallel form of the ridges of the differentiated Inner Barrier may enable fires to sweep over them more frequently and with greater intensity than the more complex parabolics with somewhat higher relief. Local tradition is that fires have been more frequent on the "moors" as the differentiated Inner Barrier is known locally. Such a severe fire regime may prevent growth of Dry Heath Forest trees when the water-table is relatively high.

Root excavation in Dry Heath Forest close to Wet Heath boundaries has shown that roots of *Angophora costata* and *Eucalyptus pilularis* penetrate below the B horizon but, since all these roots were found to be dead after a periodic but irregular rise of the water-table to the B horizon, it seems that lower portions of the root-system must be renewed after each such rise of water level. Thus, effective exploitation of the soil by the root systems of these species is relative to average depth of water-table. The apparently more severe fire regime on the differentiated Inner Barrier may periodically greatly damage shoot systems with resultant reduced capacity for renewal. On the inner parabolic dunes, shoot damage may be generally less severe and less frequent. It seems probable that Dry Heath is in Clements' (1936) terminology, a disclimax, resulting from an interaction of fire-exposure and water-table fluctuation.

Eucalyptus pilularis has no lignotuber and does not survive as a small tree through a very high fire frequency or intensity. However, *Eucalyptus gummifera,* a lignotuberous species, can apparently stand up rather more effectively to burning and high water-table. This species occurs in Dry Heath with an almost mallee growth-form, often with numerous stems arising from large lignotubers at ground level, as described in the occurrence of the species on certain Hawkesbury sandstone areas in the Sydney region (Mullette, 1978). MAG:C *Eucalyptus acmenoides* also occurs in a low mallee form locally in Dry Heath on the differentiated Inner Barrier, occasionally reaching about 8 m in patches of Dry Heath Forest (M. Fox, pers. comm.).

Banksia aemula is very common, but is also reduced to a shrub with a large lignotuber-like mass. Outward growth from this mass following periodic burning results in divisions of the original plants into separate units. Patterns of distribution of this species in Dry Heath indicate repeated division of the original plants (Siddiqi, 1971). Other species that survive fires in lignotuber-like masses, such as *Melaleuca nodosa,* may also show a similar pattern. Yet other species, such as *Dillwynia* spp., *Epacris,* spp. and *Boronia* spp., regenerate after fire from seed. Thus the relative abundance of species in any one area may depend on its fire history, although Siddiqi, Carolin & Myerscough (1976) have shown that recovery in terms of species presence can be remarkably quick in coastal heath.

Whilst Dry Heath occurs mainly on the differentiated Inner Barrier one very interesting outlier (though mostly destroyed by sand mining) occurs in a very different topographical situation, on the perched dune of Pleistocene sand on the northern side of Big Gibber. It differs from the main area of Dry Heath in having a greater abundance of stunted *Eucalyptus gummifera*, but its species composition seems to be similar.

WET HEATH (Figure 21)

Shrub stratum (to c. 2 m): *Banksia oblongifolia, Xanthorrhoea resinosa* ssp. *fulva, Hakea teretifolia, Dillwynia floribunda, Leptospermum liversidgei, L. juniperinum.*

Undershrub stratum (to 1 m): *Bauera rubioides, Boronia parviflora, Epacris microphylla, E. paludosa, E. obtusifolia.*

"Herb" stratum: *Blandfordia grandiflora, Burchardia umbellata, Lepyrodia interrupta, Restio complanatus.*

Soils: Humus podzols.

The distinction between Wet Heath and Dry Heath is only slightly clearer than between Dry Heath Forest and Dry Heath. All three communities represent slightly different, but distinguishable, reactions to different conditions on the dunes of the Inner Barrier. Wet Heath occurs where the water-table is high enough for the formation of humus podzols but is not high enough to interfere with profile development as in Swamp Forest.

The Inner Barrier dune slopes show a most interesting distribution of species. Carolin (1971) has shown that within several genera, the species replace each other vicariously down the slope. Giving the Dry Heath species first and progressing down the slope, notable sequences are: *Dillwynia retorta–D. glaberrima–D. floribunda; Boronia pinnata–B. falcifolia–B. parviflora* and *Leptospermum attenuatum–L. flavescens–L. juniperinum–L. liversidgei.*

Each species has a limited range, but the position down the gradient at which one species replaces another differs between genera, so that on a gently sloping surface the change in species composition of the vegetation is gradual and continuous, and does not show in clear-cut changes in the values of the index of floristic difference between alternate 5 × 5 m quadrats or successive pairs of alternate quadrats (Figure 20). Although boundaries between Wet Heath and Dry Heath are difficult to set up at any one site, the data from the long transect indicated that Wet Heath can be distinguished on the associated occurrence of species (Figure 2). Williams (1968), using an hierarchial arrangement based on polythetic classification, found that groups corresponding to Dry Heath, Wet Heath and Swamp Forest defined in Figure 2 could be recognized.

Many Wet Heath species show similar features of survival through fire to those already discussed in Dry Heath species and reported in previous accounts of heath vegetation in Australia.

Interesting outliers of this community occur behind the long bare transgressive dune on Fiona and Submarine Beaches, between Yagon Gibber and Big Gibber. Wet Heath covers the flanks and, in some cases, the summits of slight rises between Swamp Forest remnants. This complex has mostly been destroyed by recent sand mining.

The Scrub Swamp Association of Anderson (1973), with *Banksia robur* and *Leptospermum liversidgei,* is a form of Wet Heath characteristic of sites with marked seasonal groundwater movement, and peat accumulation between fires. It is scattered through the inner parabolic dunes but it is most extensive and best developed on the Pleistocene sand surfaces near the foot of the high Holocene transgressive dunes (e.g., Figure 8), especially behind the embayment on Myall Lake southeast of Neranie, and in the area south of Horse Point. Here the water-table of the high dunes may be expected to rise and emerge seasonally.

SAND GRASSLANDS (Figure 22)

Trees and shrubs: absent or tree and shrub species present only as scattered low-growing individuals (< 0.5 m high).

"Herb" stratum: *Themeda australis, Imperata cylindrica, Lomandra longifolia, Isolepis nodosus, Cymbopogon refractus, Pteridium esculentum, Senecio spathulatus, Stephania japonica, Eragrostis brownii.*

Soils: weakly developed podzols with organically stained A_1 horizon and shallow B horizon apparent but no A_2 horizon.

Sand Grassland is limited to steep sand slopes facing the ocean north to northeast along the stretch of coast between Number One Beach and the entrance to Smiths Lake. Scattered within it there are low plants of taller growing woody species such as *Banksia integrifolia, Notelaea ovata* and *Monotoca elliptica.* Sand Grassland may be an ephemeral community depending for its continued existence on a high incidence of fire under exposure to onshore

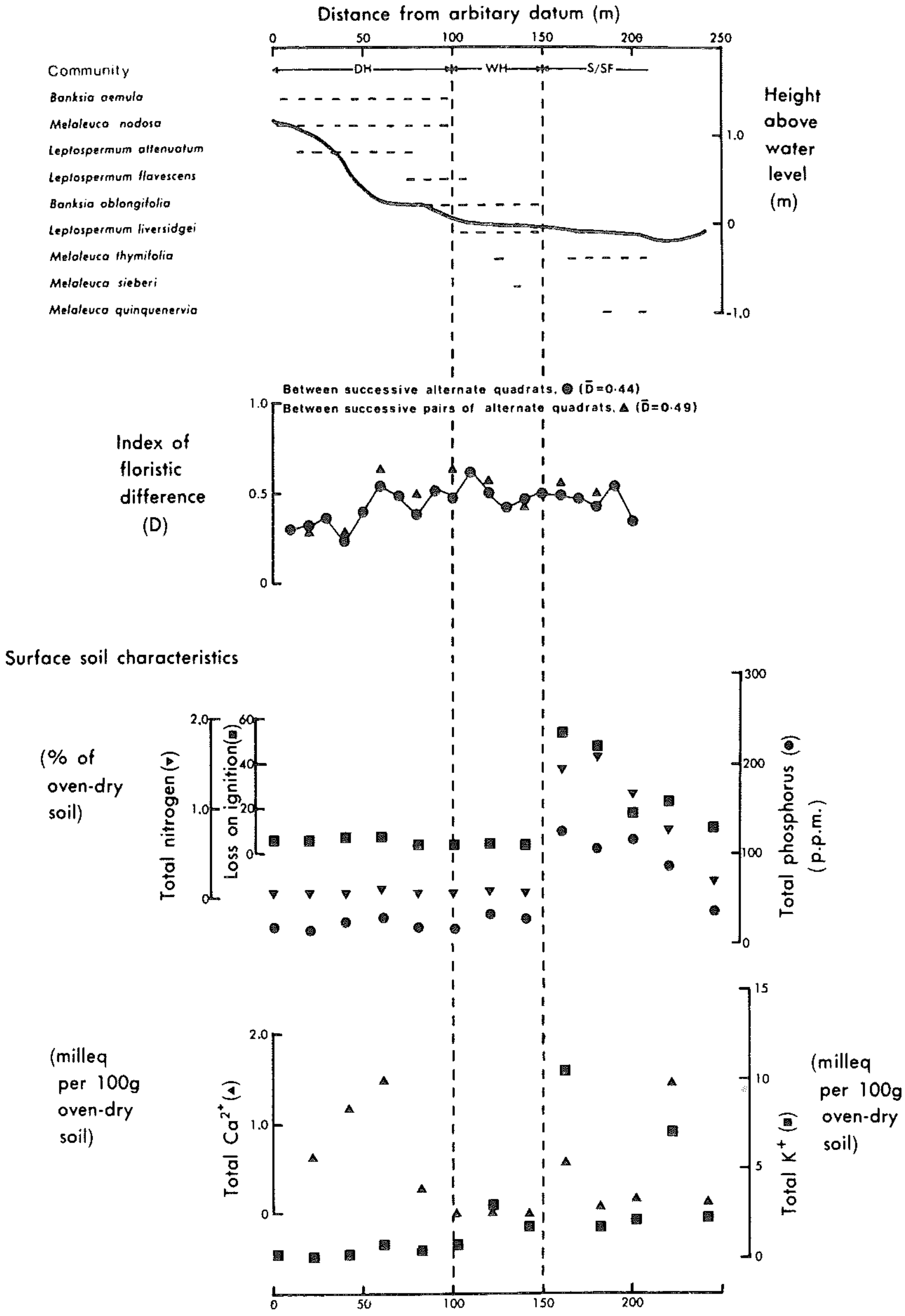

Figure 20. Transect approximately south to north from near to the top of one of the most inland dune-ridges of the differentiated Inner Barrier south of McGraths Hill (see map located in back pocket for approximate location of transect), showing variation in surface topography, plant community, and the presence (—) both of certain of the shrub species encountered in alternate 5×5 m quadrats and of the tree *Melaleuca quinquenervia*, scored in successive adjacent 10×10 m quadrats. Variation in floristic composition of the shrubs and understorey between alternate 5×5 m quadrats scored and between successive pairs of these quadrats is shown in the values of an index of floristic differences (see Figure 7). Variation of characteristics of the top 5 cm of soil below the litter layer is also shown. (For methods of soil analysis see Table 4. For abbreviations of plant communities see Table 2).

Figure 21. Wet Heath on differentiated Inner Barrier (Pib) about 1.5 km northwest of Big Gibber. *Xanthorrhoea resinosa* ssp. *fulva*, *Banksia oblongifolia* and *Leptocarpus tenax*. To the left Dry Heath with *Banksia aemula*, and to the right a narrow band of Swamp with *Callistemon citrinus*.

Figure 22. Sand Grassland about 350 m north of the northern end of Number One Beach, Seal Rocks. *Imperata cylindrica, Lomandra longifolia, Actinotus helianthi, Correa alba, Pteridium esculentum*.

northeasterly winds. In some sites where it abuts Dry Sclerophyll Forest there are dead *Eucalyptus pilularis* trees present, indicative of a recent extension of Sand Grassland into the edge of the Dry Sclerophyll Forest. Given a sufficiently long period free from fire, the woody plants within it would probably grow up to form a wind-pruned canopy.

Figure 23. Foredune Complex south of Bombah Broadwater on two berms and cut face of dune. More seaward berm with *Spinifex hirsutus*, *Senecio lautus* ssp. *maritimus*. More landward berm with *Spinifex hirsutus*, *Senecio lautus*, *Scaevola calendulacea*. Cut face of dune with *Scaevola calendulacea*, *Hibbertia scandens*, *Euphorbia spormannii*, and at the top *Leptospermum laevigatum*.

FOREDUNE COMPLEX (Figure 23)

Here, shrubs and herbs are more or less at the same stratum level, and no species shows a particular dominance except in specific zones. The Foredune Complex occurs at the berm and on the steep seaward dune scarp over the crest of which it gives way to Beach-dune Thicket. Three zones can be delimited within the Foredune Complex: (1) the scarp face, where *Spinifex* and *Hydrocotyle* occur with other species; (2) the berm, where *Spinifex* and *Hydrocotyle* predominate and; (3) the *Cakile* zone seaward of the berm.

The steep scarp, with sand frequently close to the angle of repose, results from episodes of undercutting of the dunes by the sea and usually has a sparse cover of plants with much bare sand between them. Although such plants include *Scaevola calendulacea* and *Senecio lautus* ssp. *maritimus*, which accumulates sand and forms low hummocks (Osborn & Robertson, 1939), little sand accumulation occurs on the face.

The berm, which disappears during episodes of undercutting, is also frequently disturbed during winter storms, while the *Cakile* zone on the strand-line is even more frequently disturbed.

The community appears to be largely equivalent to Anderson's (1973) Sandy Foredune Association (fd. 1).

SWAMP (Figure 24)

Small tree and shrub stratum: absent or a few *Melaleuca quinquenervia* and *Banksia robur*.

"Herb" stratum: *Schoenus brevifolius, Restio complanatus, Lepyrodia muelleri, Baumea rubiginosa, Utricularia spp.*

Soils: usually more or less peaty with high loss on ignition.

Swamp, equivalent to the Sedge Swamp association of Anderson (1973), occurs in the in-filled inter-Barrier lagoon. It consists largely of restionaceous and cyperaceous species with *Empodisma minus* tending to form hummocks that Wet Heath species may colonize.

Figure 24. Swamp at eastern end of inter-Barrier lagoon (Pil). *Restio* spp., *Schoenus* spp., *Baumea* spp., *Gahnia sieberiana*, with Dry Heath in foreground.

Figure 25. *Lepironia* Swamp in Glacial dune complex (Pg) east of Bombah Broadwater. *Lepironia articulata, Villarsia exaltata, Lepidosperma longitudinale*, with fringing *Melaleuca quinquenervia* in the foreground.

Gymnoschoenus sphaerocephalus is common in extensive areas of Swamp near Horse Point and forms steep-sided hummocks by the upward growth of its tussocks. It is not common in Swamp elsewhere in the area. Stunted specimens of *Melaleuca quinquenervia* are thinly scattered through the community, but *Eucalyptus robusta* appears not to occur in Swamp proper.

Swamp also occurs throughout the differentiated Inner Barrier where conditions are suitable, but mostly these areas are too small to map at the scale of 1:25 000. There are also other, more extensive areas of Swamp in the Eastern Lagoon and on low-lying ground south and east of Horse Point. Swamp mostly grades rather gradually into Swamp Forest, and has a somewhat deeper water-table than Swamp Forest.

The surface level in the Eastern Lagoon appears to be such that many Swamp and Wet Heath species can tolerate the conditions, and its vegetation is mapped here as a mixture of two communities. Such a mixture does not occur extensively elsewhere.

LEPIRONIA SWAMP (Figure 25)

"Herb" stratum: *Lepironia articulata.*

Soils: organic muds.

The dominant plant often occurs in Fringe Forest, but this community neither fringes the lakes nor contains either species of the dominant Fringe Forest trees. Only three areas are known: the two near Smiths Lake are flanked by Dry Sclerophyll Forest at the foot of the steep landward scarp of the Holocene transgressive dunes and by Dry Heath Forest along their northwestern sides; the third, near Broadwater, is mainly surrounded by Dry Sclerophyll Forest. Consisting almost entirely of open stands of *Lepironia articulata* in permanent standing water to c. 1 m deep, the community also contains *Lepidosperma longitudinale* in shallower water at the swamp near Bombah Broadwater.

DISCUSSION

Vegetation and land systems

The plant communities of the Eurunderee area are related in their occurrence to characteristics of the land systems (Table 5).

The rock-based land system is mostly clearly differentiated in its vegetation from the sand-based land systems. There are, however, two situations in which differences in vegetation between sand and rock-based parent materials are not clear-cut. The first is at the lake edges where Fringe Forest occurs on both rocky and sandy shores, though, as mentioned earlier, there tends to be a higher proportion of *Casuarina glauca* than *Melaleuca quinquenervia* in the trees on rocky shores, and conversely on sandy and muddy shores a higher proportion of *Melaleuca quinquenervia.* The second is in the occurrence of a thin layer of Holocene sand over rock in some small areas near Seal Rocks, where rainforest species and species characteristic of Dry Sclerophyll Forest and Beach-dune Thicket occur together. The vegetation of such ecotonal sites has been mapped here as Dry Sclerophyll Forest but Clough (1979) recognized some of them as rainforest.

The land systems on sand vary in vegetation with differences in soils, which are related to the age, mode of origin and topography of the surfaces. The Holocene sands vary less in vegetation than the Pleistocene sands. On the Pleistocene sands the vegetation varies in structure from forest to heath and sedgeland, often with relatively minor topographic variation. The structure of the vegetation on Holocene sands varies from the open herbfield and grassland of the Foredune Complex of the beach-front to forest inland, but inland there is little change in structure of the forest with major topographic variation. Only in a few depressions that are at or below the level of the water-table does Dry Sclerophyll Forest give way to Swamp Forest or in one area, where deep water collects, to *Lepironia* Swamp. On the low-lying lake-influenced sediments, Dry Sclerophyll Forest on freely drained sand gives way to Swamp or Swamp Forest in waterlogged sites, or to Fringe Forest on the lake shores themselves.

Between the Holocene and Pleistocene sands the boundaries in vegetation are mostly very sharp, particularly where the high Holocene dunes encroach on low-lying Pleistocene surfaces (e.g., Figure 8). However, there are some areas of sand close to rock on Bridge Hill and on Horse Point that carry Dry Sclerophyll Forest that adjoins Intermediate Dry Forest or Dry Heath Forest. Some of these sands carrying Dry Sclerophyll Forest that have been assigned to the Holocene may, in fact, be Pleistocene sand surfaces.

TABLE 5

Summary of occurrence of communities in the Eurunderee land systems

Land		Communities*
System	sub-system (symbol in Figure 1)	
Rock	(i) Inland (Ri)	(RF), WSF
	(ii) Headland (Rh)	HT, (VT)
Pleistocene sand	(i) Perched dune (Ppd)	(DHF) DH
	(ii) Early Inner Barrier (Pu)	(DSF), DHF, WHF, SF WH S
	(iii) Inner parabolic dunes (Pip)	(DSF), IDF, DHF, WHF, SF, WH S [c]
	(iv) Differentiated Inner Barrier (Pib)	((DSF)), DHF, (WHF), SF DH, WH S [c]
	(v) Undifferentiated Inner Barrier (Pub)	IDF, DHF, WHF, SF WH S
	(vi) Glacial dune complex (Pg)	DSF, IDF, DHF, SF WH S, LS
	(vii) Probable re-exposed surface (?P)	WHF, SF WH S
	(viii) Inter-Barrier lagoon (Pil)	SF ((DH)), WH S
Holocene sand (Outer Barrier)	— (H)	DSF, SF BT, SG, FC, (LS)
Lake-influenced sediments	(i) Lake silts and current lake shores (Ls)	SF, FF S
	(ii) Relict sand-bars (Lb)	DSF
	(iii) Sand of probable fluvial (and lacustrine) origin (Li)	DSF

*full names of communities are given in Table 2; ( ) = of rare occurrence; (( )) = isolated patch only; [c] = catenary sequences of communities common.

As indicated, the Pleistocene sands have the greatest variation in vegetation of any of the three land systems on sand in the Eurunderee area, both structurally and floristically. This can be related to the range of soil conditions that occur. The soils on these sands are all well developed, but vary with age of the surface, degree of nutrient enrichment from the surrounding areas, and with drainage.

Drainage is particularly important across the low-lying ground of all the Pleistocene surfaces except for what is probably the oldest surface, the aeolian perched dune on the northern side of the Big Gibber, and the youngest, the aeolian Glacial dune complex east of Bombah Broadwater. These two surfaces are raised above the general level of the other Pleistocene surfaces. On these other, low-lying surfaces, sequences of soils and vegetation occur in relation to drainage and height above the water-table. These catenary sequences are particularly well developed in the inner parabolic dunes and across the ridges and swales of the differentiated Inner Barrier. The following sequences are commonly found as the ground surface drops from a freely drained ridge to nearer the water-table in a swale—in the soils: podzol, humus podzol to swamp soil; and correspondingly, in the vegetation: Dry Heath Forest or Dry Heath, Wet Heath, to Swamp or Swamp Forest.

Nutrient enrichment of the characteristically infertile soils of the Pleistocene sands by run-off from surrounding rock-based sites seems to be apparent in parts of the inner parabolic dunes, where Dry Sclerophyll Forest, Intermediate Dry Forest or certain facies of Wet Heath Forest occur. In parts of the undifferentated Inner Barrier, particularly the Eastern Lagoon, there is some clay and silt with the sands, and the higher proportion of certain species such as *Hakea teretifolia* in the vegetation here than elsewhere may be related to this.

Ages of the Pleistocene sands in the Eurunderee area range from perhaps 500 000 to approximately 20 000 years before present (Thom, Bowman & Roy, 1981), and the degree of development of soils and types of vegetation they carry vary accordingly. Both the oldest, the perched dune on the Big Gibber, and the youngest surface, the Glacial dune complex east of Bombah Broadwater, are aeolian in origin, as are the inner parabolic dunes, which were laid down about 125 000 years ago. The oldest, the perched dune, has a particularly well developed podzol with deep B horizons. Its predominant vegetation is Dry Heath while the predominant vegetation of freely drained sites on the two younger aeolian Pleistocene sands is forest; on the inner parabolic dunes predominantly Dry Heath Forest and locally Intermediate Dry Forest; and on the Glacial dune complex predominantly Intermediate Dry Forest and locally Dry Sclerophyll Forest. On the Holocene aeolian sands of the Eurunderee area, there is only Dry Sclereophyll Forest on freely drained sites away from the sea. Data in Thom, Polach & Bowman (1978), Thom, Bowman & Roy (1981) and in Thom *et al.* (1981) indicate that most of the Holocene sands at the surface in the Eurunderee area have been deposited less than 3 500 years ago. In the Eurunderee area, with increasing age of freely drained aeolian surfaces, there is thus a sequence in the soils and vegetation, from very recently stabilized surfaces carrying Beach-dune Thicket with minimal soil development, to Dry Sclerophyll Forest on Holocene sands with incipient podzols further inland, to Intermediate Dry Forest on podzols on the Glacial dune complex, to Dry Heath Forest on podzols on the inner parabolic dunes, to Dry Heath on the perched dune with its deep podzols. The sequence in vegetation (Figures 3 & 4) is related to development and depth of the podzols.

There is no corresponding age sequence of beach ridges in the Eurunderee area. The differentiated Inner Barrier is the only well developed system of beach ridges occurring in the area. Beach ridges of similar age, about 125 000 years before present, occur nearby in the valley of the Upper Myall River and immediately southwest of the study area in the Fens Embayment. Also in the Fens Embayment there are Holocene beach ridges that, on data presented in Thom, Polach & Bowman (1978) and Thom *et al.* (1981), were laid down between about 5 000 and 3 500 years ago. They are thus older than the aeolian Holocene dunes of the Eurunderee area. They have podzols with B horizons at about 2 m deep and carry predominantly heath (Clements, pers. comm.). This heath is similar to the Dry Heath of the Eurunderee area with *Banksia aemula* and *Leptospermum attenuatum* occurring in some abundance, but differs in having relatively high amounts of *Casuarina distyla*. The Pleistocene beach ridges in the Fens Embayment carry a similar range of vegetation to those in the Eurunderee area but do have some MATK:D *Eucalyptus signata. E. signata* is absent from the differentiated Inner Barrier but does not occur very locally on areas of the undifferentiated Inner Barrier on the peninsula south of Pigeon Point, and there are a few isolated trees on Pleistocene sands immediately east of Bombah Broadwater.

The presence of heath and podzols on the Holocene beach ridges in the Fens Embayment is perhaps puzzling. It may indicate that podzolization and decline of fertility may be inherently more rapid on sands of beach ridges than on aeolian sands. In favour of this, it could be argued that plants on beach ridges have a smaller rooting volume available to them above the water-table than do plants growing on aeolian dunes, and thus a smaller "working capital" (term of Beadle & Burgess, 1949) of nutrients initially available to them. Loss of nutrients from this working capital may rapidly reduce it below the thresholds at which podzols readily develop and development of heath is strongly favoured. Furthermore, it could be argued that such loss of nutrients would be accelerated by frequent firing, and that this could have occurred on these beach ridges as they lie between the sea and the Lower Myall River along which Aborigines could have been expected to spend much time.

Taking beach ridges in the Eurunderee area, the valley of the Upper Myall River and the Fens Embayment, it seems that the forest becomes more common on freely drained sites the more inland they are, the higher above the water-table and the more sheltered they are by surrounding higher ground. Relationships between types of vegetation on beach ridges in the Fens Embayment are currently being studied by Clements and in the valley of the Upper Myall River by Carolin and Myerscough.

Vegetation of Eurunderee and other areas of coastal sand.

The Eurunderee area is important in the interpretation of vegetation on Holocene and Pleistocene sands on the eastern coast of Australia. The Pleistocene and Holocene sand masses are well developed and clearly differentiated in the Eurunderee area, and characteristic types of vegetation are associated with them. South of Newcastle to Jervis Bay, the only Pleistocene coastal sands are in small areas of wind-blown sand perched on cliff tops and headlands (Chapman *et al.,* 1982). South of Jervis Bay to the Victorian border, the only coastal sands that occur are Holocene, while on the northern coast of New South Wales, southeastern coast of Queensland and the dune islands off that coast, Pleistocene sands are extensive and Holocene deposits are in comparison limited in extent and development (Chapman *et al.,* 1982).

On the Holocene sands, the vegetation that has the greatest similarity between different parts of the eastern coast of Australia is the Foredune Complex. The Foredune Complex in the Eurunderee area is very similar to that described for the central (Pidgeon, 1940) and south coasts (Austin & Sheafe, 1976; Ingwersen, 1976) of New South Wales. It is also similar to that described for the north coast of New South Wales (Heyligers *et al.,* 1981) and, though it lacks some more tropical species such as *Ischaemum triticeum,* it is similar to that described for the coast of southeastern Queensland (Blake, 1938; 1968; Herbert, 1951) and for North Stradbroke Island (Clifford & Specht, 1979) and Moreton Island (Durrington, 1977). The similarities of vegetation of the Foredune Complex on the coast of eastern Australia are broadly outlined in Table 23.3 of Beadle (1981). Along the eastern coast of New South Wales, the Foredune Complex appears to be highly susceptible to invasion by *Chrysanthemoides monilifera.*

Beach-dune Thicket, as recognized here in the Eurunderee area, is less uniform in subtropical areas along the eastern coast of Australia. In southeastern Queensland, although *Banksia integrifolia* remains an important component, species that do not occur as far south as the Myall Lakes area, such as *Pandanus pedunculatus* and *Casuarina equisetifolia* var. *incana,* are important in this type of vegetation (e.g., Blake 1968; Durrington, 1977) while others, such as

Leptospermum laevigatum, do not occur. On the north coast of New South Wales, the equivalent type of vegetation frequently has a component of rainforest species on the lee slopes of the frontal dunes (e.g., Heyligers *et al.,* 1981). Beach-dune Thicket of the Eurunderee area is typical of similar vegetation on the central (Pidgeon, 1940) and southern coasts (Austin & Sheafe, 1976; Ingwersen, 1976) of New South Wales, but it has a different complement of species from comparable vegetation on calcareous dunes on the Victorian coast bordering Bass Strait (Parsons, 1966), though both *Leptospermum laevigatum* and *Banksia integrifolia* occur in that vegetation (Parsons, 1966).

The forest characteristic of the Holocene sands of the Eurunderee area, termed Dry Sclerophyll Forest in this study, clearly belongs to the *Eucalyptus pilularis—Angophora costata* Suballiance of the *Eucalyptus pilularis* Alliance of Beadle (1981). Under Baur's (1965) system, Dry Sclerophyll Forest of this study mainly belongs to the Blackbutt-Bloodwood/Apple forest type, forest type no. 41 in the Blackbutt league, but pure stands of *Angophora costata* in it would fall into the Smoothbarked Apple-Banksia forest type, forest type no. 107 in the Scribbly Gum-Stringybark-Silvertop Ash league. Dry Sclerophyll Forest of the Eurunderee area, as defined in this study, appears to be confined to the lower north and central coast of New South Wales. On Moreton Island, the *Eucalyptus pilularis* open forest of Durrington (1977) has a degree of similarity, with *E. pilularis* as dominant and the occurrence of *Banksia serrata* in the understorey and *Pteridium esculentum* and *Imperata cylindrica* in the ground layer, but it contains a number of tree and other species which are not part of Dry Sclerophyll Forest of the Eurunderee area. On the south coast of New South Wales, the forests developed on Holocene sands usually have SECAD *Eucalyptus botryoides* with or without *E. pilularis* and include the *Eucalyptus botryoides, Eucalyptus pilularis* and mixed *E. botryoides–E. pilularis* forests of Ingwersen (1976), the *E. botryoides–Banksia* spp. and *E. pilularis–E. botryoides* communities of Austin & Sheafe (1976), and the Bangalay-Banksia forest type (no. 108) of Baur (1965). In their understorey *Banksia serrata, Pteridium esculentum* and *Imperata cylindrica* are prominent components, as they are in the forest on Holocene sands at Wonboyn south of Eden beyond the geographical range of *E. pilularis.*

The plant communities on the Pleistocene sands of the Eurunderee area are part of the range of vegetation found on the Pleistocene sands between Sydney and Fraser Island. South of Newcastle, the areas of Pleistocene sands are mostly on cliff tops and carry heath dominated by *Banksia aemula,* as described in Bouddi National Park by Siddiqi, Carolin & Anderson (1973), very similar to Dry Heath of the Eurunderee area. These dry heaths and similar ones of Pleistocene sands of northern New South Wales (Benson, 1976; Heyligers *et al.,* 1981) and North Stradbroke Island (Clifford & Specht, 1979; Specht, 1979b), Moreton Island (Durrington, 1977) and presumably other parts of the coast of southeastern Queensland fall into *Banksia serratifolia (aemula)* Alliance of Beadle (1981). The *Banksia aspleniifolia (oblongifolia)* and *Banksia robur* Alliances of Beadle (1981) cover Wet Heath as defined in the Eurunderee area. There are few heaths dominated by *Banksia oblongifolia* or *B. robur* on Pleistocene coastal sands south of Newcastle, but they are well developed on parts of the Inner Barrier systems of the Newcastle Bight and Fens Embayment (Clements, pers. comm.) and in suitable habitats on other areas of Pleistocene sands northwards along the coast of New South Wales, as at Angourie (Benson, 1976), into southern Queensland.

The forests and woodlands associated with the heaths on Pleistocene sands occur northward from the Newcastle Bight to Fraser Island. Those of the Eurunderee area do not fit readily into Beadle's (1981) alliances, but fall somewhat between his *Eucalyptus signata–E. intermedia–E. nigra* Suballiance of the *Eucalyptus intermedia–E. acmenoides–E. signata–E. nigra* Alliance, *Eucalyptus pilularis–Angophora costata* Suballiance of the *E. pilularis* Alliance, and his *Banksia serratifolia (aemula)* and *Banksia aspleniifolia (oblongifolia)*

Alliances. Perhaps they are best regarded as more related to the two heath alliances than to the forest alliances, in which case Dry Heath Forest and Intermediate Dry Forest in the Eurunderee area should be related to the *Banksia serratifolia (aemula)* Alliance, and Wet Heath Forest to the *Banksia aspleniifolia (oblongifolia)* Alliance of Beadle (1981). The heath forests and woodlands of the Pleistocene sands of the Eurunderee area are closely related to those in similar habitats in northern New South Wales, as at Angourie (Benson, 1976) and in Bundjalung National Park (Heyligers *et al.*, 1981), and on the dune islands off the southern coast of Queensland, on Moreton Island (Durrington, 1977) and North Stradbroke Island (Clifford & Specht, 1979), particularly in the understorey, but they lack some tree species such as CAFID *Eucalyptus intermedia*, MAIBB *E. planchoniana*, AAACA *Angophora woodsiana* and *Callitris columellaris* and some understorey species such as *Strangea linearis*, the southern limits of whose distributions on the coast lie north of the Myall Lakes area.

The heaths and associated forests and woodlands of the Pleistocene sands of the central and northern coast of New South Wales and the southeastern coast of Queensland and its off-shore dune islands form a closely related complex of plant communities, which are clearly different from those on Pleistocene coastal sands in northern Queensland, as described by Pedley & Isbell (1971), Specht (1979b) and Pyke & Jackes (1981).

Swamp and Swamp Forest of the Eurunderee sand mass are similar to those in wetlands on other coastal sands of northern New South Wales and southern Queensland. The Eurunderee Swamp Forest and Fringe Forest do not fit easily into the *Eucalyptus robusta* Alliance of Beadle (1981), nor do Swamp or *Lepironia* Swamp fit well into his *Calorophus minor* (*Empodisma minus*)–*Leptocarpus tenax* Alliance. The Eurunderee Swamp is clearly closely related to coastal bogs of Goodrick (1970). Communities similar to the Eurunderee Swamp and Swamp Forest occur very locally on coastal sands south of Newcastle as far as the Tuggerah Lakes, but occur more extensively on coastal sands on the north coast of New South Wales and in southern Queensland, as on Moreton Island (Durrington, 1977). *Lepironia* swamps are distinctive and occur on coastal sands in northern New South Wales (Goodrick, 1970; Heyligers *et al.*, 1981) and in southern Queensland, as on Moreton Island (Durrington, 1977).

Quaternary changes and vegetation of coastal sands of northern New South Wales and southern Queensland.

As indicated above, the Eurunderee sand mass is part of a complex of Pleistocene and Holocene coastal sands stretching from Newcastle to the coast of southern Queensland and the dune islands lying off it. The bedrock of this part of the coast has apparently been remarkably stable tectonically during the Quaternary and, accordingly, present levels of Pleistocene and Holocene sand sheets directly reflect the original levels at which they were deposited on the coast. This complex of coastal sands north from Newcastle to Fraser Island is distinctive geomorphologically, and, as shown above, its vegetation, particularly on its Pleistocene sands, forms a distinctive unit, clearly differentiated from the vegetation on old coastal sands in tropical Queensland and from that on the Holocene sands of the coast south of Sydney.

The vegetation of coastal sands along this portion of the eastern coast was obviously more extensive when sea level was lower than at present, and less extensive approximately 125 000 years ago when the sea level was higher and the shores farther inland than at present. In the Eurunderee area 125 000 years ago there were possibly few stabilized sand sheets with podzols, with the probable exception of wind-blown sands in place on the lee side of the Big Gibber and possibly other headlands. Such areas could have provided refugia for species such as *Banksia aemula* which now rarely occur off highly podzolized sands. Failing the availability of local refugia, such species may have migrated south from refuges on podolized sands on the 'Ancient Dunes' of North Stradbroke Island and other dune islands off southern Queensland. Such southward migration would probably have occurred most readily during glacial periods when sea levels were low and extensive sand sheets were exposed to seaward of present shore lines. Also, over spans of time of 100 000 years the possibility of appreciable genetic change and associated change of occupancy of habitats on species cannot be ruled out.

During 100 000 years or more of exposure, appreciable podzolization of Pleistocene sands has occurred, and it has been suggested that nutrient stocks in such sands have been depleted and this has influenced the sort of vegetation they carry. Circumstantial evidence for this suggestion comes from four sources: the degree of podzolization evident; the type and structure of the vegetation present; estimates of nutrient stocks in the system; and attributes of plants in the vegetation.

On the degree of podzolization evident, on raised wind-blown sand surfaces at Cooloola, Thompson (1981) and Walker *et al.* (1981) concluded that with increasing age of the surface the depth to the B horizons increases and the amounts of total phosphorus and potassium in the surface layers of the soil decreases. The Eurunderee area is without such a comprehensive sequence of wind-blown sands of various ages and sufficient relief to allow control of the depth of B horizons other than by water-table. The Pleistocene dunes perched on the Big Gibber alone are of sufficient relief, and contrast sharply in their deep, highly developed podzols and Dry Heath vegetation with the adjoining wind-blown Holocene dunes carrying Dry Sclerophyll Forest on incipient podzols in which the B horizon is at most only about 1.5 m deep.

On the type and structure of vegetation present, Westman (1978) has suggested that on North Stradbroke Island the decrease in stature of forest on older dunes deposited 500 000 or more years ago may be due to loss of nutrients from the systems, particularly potassium and phosphorus. At Cooloola, Walker *et al.* (1981) showed that height, structure and estimated biomass of the vegetation increased initially with age of the sands from a type of beach-dune thicket to tall layered forest, and thereafter declined with age until on the oldest surfaces the vegetation is predominantly shrubs with little tree crown cover. They attribute this pattern to an initial increase in the working capital of nutrients brought into circulation by weathering of minerals in the soil, and then following the complete release by weathering of all nutrients in the rooting zone, a subsequent run-down of the working capital, with losses of nutrients in leaching not being entirely balanced by gains in rainfall and dry deposition from the atmosphere. The nutrient balance of forest dominated by *Eucalyptus signata* on Pleistocene dunes on North Stradbroke Island has been shown by Westman (1978) to be partly dependent on inputs of nutrients in rain and salt spray. In the Eurunderee area, a sequence of vegetation types similar to that found at Cooloola by Walker *et al.* (1981) can be seen with age of surfaces on wind-blown sands, passing from Beach-dune Thicket to tall Dry Sclerophyll Forest on the high Holocene dunes, to the lower, more open tree canopy of Intermediate Dry Forest on the Glacial dune complex, to the yet more open and lower tree canopy of Dry Heath Forest on the Pleistocene inner parabolic dunes, and finally to Dry Heath on the Pleistocene perched dune on the Big Gibber. As suggested earlier, progression through such a sequence may be accelerated on low beach ridges where the position of the B horizon is controlled by the shallow water-table, the rooting zone for the plants is more restricted, and therefore the potential pool of nutrients is likely to be much more limited than in wind-blown sands in high dunes. In addition, repeated fires may pass more frequently and burn more intensely over a terrain of low beach ridges and may further accelerate depletion of the limited nutrient stocks. Certainly, heaths are widespread on the Pleistocene beach ridges in the Eurunderee area and also on the early Holocene beach ridges in the Fens Embayment. These heaths on beach ridges are comparable to the pygmy forests in California on highly podzolized sands over shallow water-tables, described by Westman (1975) and Westman & Whittaker (1975).

Nutrient stocks are thus seen as crucial in the above hypothetical schemes of vegetational change with age of the sand surfaces. Clearly the schemes would be on firmer ground if comparative data on total nutrient stocks were available from sand systems of a range of ages. To date, there have been only two studies of nutrient stocks in systems on coastal sands between Newcastle and Fraser Island. One study, that of Westman & Rogers (1977), was in a forest dominated by *Eucalyptus signata* on a younger Pleistocene dune on North Stradbroke Island. The other was in the Eurunderee area by Lewis (1978) in Dry Sclerophyll Forest on Holocene dunes of the Outer Barrier southwest of the Big Gibber. The nutrient stocks per unit area of ground in the biomass and dead material were determined in comparable ways in the two studies, but those in the soil were not. The stocks of potassium and calcium in the biomass and litter were similar in both sites. Magnesium in the biomass at the North Stradbroke site was approximately a third that at the Eurunderee site as was the stock of nitrogen in the biomass. The most striking difference between the two sites was in the stocks of phosphorus in the biomass and litter. At the North Stradbroke site the stock of phosphorus in the litter was about a third of that in the dead material at the Eurunderee site, while in the biomass the stock of phosphorus at the North Strtadbroke site was only about 15 per cent of that at the Eurunderee site. Comparison of data from the two sites thus supports the notion that as the sand surface ages the stock of the key nutrient phosphorus becomes depleted, in accord with the hypothetical scheme proposed. However, this comparison between a forest on Holocene sand and one on a Pleistocene sand surface is confounded with the geographical separation of the sites between the Myall Lakes and North Stradbroke Island, and is incomplete in that stocks of nutrients in the soils of the two sites were not estimated on a sufficiently similar basis to allow comparison. Clearly, such a comparison of nutrient stocks between systems on sand surfaces of different ages would be far better made in the same geographical area.

Certain attributes of the plants on older sand surfaces can be related to the depletion of nutrient stocks that is hypothesized to have occurred under prolonged weathering of these surfaces. These attributes relate to economical usage, efficient uptake and retention of nutrients, especially phosphorus (Beadle, 1966; 1968; Jeffrey, 1967; Siddiqi & Carolin, 1976), and include the increasingly sclerophyllous nature of the plants apparent on progressively older sand surfaces, the increased tendency to form lignotuberous masses of tissue in the soil surface and increased resistance of mature individuals to elimination by fires and a related lower reproductive effort in seed production.

The increasingly sclerophyllous nature of the vegetation is apparent across the age sequence of wind-blown dunes in the Eurunderee area, where species with mesomorphic leaves are reasonably abundant in Beach-dune Thicket, but at the other end of the sequence in Dry Heath nearly all the species of plants present are markedly sclerophyllous. It has been cogently argued that plants with highly lignified leaves make sparing use of phosphate that is generally in short supply in their characteristic habitats (Loveless, 1961; 1962; Beadle, 1966; 1968).

The tendency of many plants in the Eurunderee Dry Heath Forest and Dry Heath to have large lignotuber-like organs has already been mentioned. In *Eucalyptus gummifera*, the mallee form that has large lignotuber-like organs with a capacity for storage of phosphate (Mullette, 1978) is particularly apparent in Dry Heath especially on the Big Gibber, whereas in its rare occurrence on the Eurunderee Holocene dunes *Eucalyptus gummifera* was almost entirely present in the form of a single-stemmed tree. Unfortunately, like the Pleistocene perched dune on the Big Gibber, the part of the Holocene high dunes carrying *E. gummifera* have had their original vegetation destroyed by sand mining over the last 10 years.

The increasing tendency for mature individuals to be long-lived, highly resistant to elimination by fire and to have relatively low seed reproduction on older sands can be seen in some closely related species. Thus, *Leptospermum laevigatum* is common in the Beach-dune Thicket of the Eurunderee area but does not usually occur in Dry Heath, while *L. attenuatum* occurs only on old, well podzolized sands. Many individuals of *L. attenuatum* survive through fires, while individuals of *L. laevigatum* are readily killed by fire (Burrell, 1981). Mature individuals of *L. laevigatum* usually carry a large crop of seeds in their canopies the whole year round, while those of *L. attenuatum* shed their seeds soon after fruits have ripened. In *Banksia* in the Eurunderee area, *B. integrifolia* is almost entirely confined to the Holocene sands and *B. aemula* to the Pleistocene sands. *B. serrata* is intermediate between the two in its occurrence, that is, on Holocene sands, but not as close to the shoreline as *B. integrifolia*, and only on Pleistocene sands where nutrient enrichment seems likely to have taken place or where the sand surface was laid down in the late Pleistocene, as in the Glacial dune complex. Mature individuals of *B. aemula* survive most fires, particularly in the lignotuberous form in which they occur in Dry Heath, and normally they carry a relatively small crop of seeds. In *B. integrifolia*, the mature individuals are relatively easily killed but produce large crops of seed which are shed annually. In *B. aemula* and *B. serrata*, the fruits are serotinous and normally only shed their seeds when the branch bearing them dies, which occurs when the mature plants are burnt. Mature plants of *B. serrata* appear to be somewhat intermediate between those of *B. integrifolia* and *B. aemula* in their resistance to fire and in their seed output. The relative seed weights in the species are graded from *B. integrifolia* with the lightest seeds to *B. aemula* with the heaviest seeds. Seeds of *B. aemula* have appreciable amounts of stored phosphorus (Grundon, 1972). Its heavier, well endowed seedlings may be expected to have a selective advantage over those of the other two species in the highly infertile sands in which *B. aemula* grows. The neatly graded series apparent in the Eurunderee area in the distribution of these three species of *Banksia* is not maintained on the Cooloola sands where *B. integrifolia* occurs on Pleistocene sands as well as younger sands, while *B. serrata* appears to be confined to younger sands (Walker *et al.*, 1981). On North Stradbroke Island also, *B. integrifolia* occurs on Pleistocene as well as younger sands (Durrington, 1977). This suggests either that the attributes of the species may not be so readily linked to their distribution across a series of sands of increasing age, as they appear to be in the Eurunderee area, or that the attributes may vary somewhat between different parts of their geographical range.

The four strands of circumstantial evidence taken together—the attributes of the species in the types of vegetation, nutrient stocks in the systems, the types and structure of the vegetation, and the relative podzolization of the sands—make a reasonable argument for linking depletion of nutrient stocks to change of vegetation type with increasing age of the sand surfaces in wind-blown dunes. It also appears likely that old beach ridges present a situation in which the effective working capital of nutrients may be initially lower and consequent depletion of nutrients generates change from forest to heath more quickly than on aeolian dunes of the same elevation.

The sand masses of the Eurunderee area and their vegetation are significant as part of the complex of coastal sands and their associated vegetation that lie between Fraser Island and Newcastle, while the aeolian Holocene sands of the Eurunderee area are unique in southeastern Australia in their elevation, extent and form and in the extensive high Dry Sclerophyll Forest that has developed on what are relatively recently stabilized surfaces.

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APPENDIX 1

Myall Lakes Checklist

Some records of Pteridophytes are from Timms, B. & Timms, B. Ferns of Myall Lakes National Park. *Hunter Natural History*, 9, 74–88. Nomenclature of cycads and angiosperms largely follows Jacobs, S. W. L. & Pickard, J. (1981). *Plants of New South Wales: a census of the cycads, conifers and angiosperms*. Government Printer, Sydney. Authorities for names are only given where they differ from those in Jacobs & Pickard (1981).

sa = submerged aquatic
fa = floating aquatic
* indicates introduced species

Communities:

WSF	Wet Sclerophyll Forest	HT	Headland Thicket
DSF	Dry Sclerophyll Forest	VT	Vine Thicket
IDF	Intermediate Dry Forest	BT	Beach-dune Thicket
DHF	Dry Heath Forest	DH	Dry Heath
WHF	Wet Heath Forest	WH	Wet Heath
SF	Swamp Forest	SG	Sand Grassland
FF	Fringe Forest	FC	Foredune Complex
S	Swamp	LS	*Lepironia* Swamp

PTERIDOPHYTA

ADIANTACEAE	
Adiantum aetheopicum L.	WSF
A. hispidulum Swartz	WSF
Cheilanthes sieberi Kunze	WSF
ASPIDIACEAE	
Lastreopsis microsora (Endl.) Tindale	VT
ASPLENIACEAE	
Asplenium obtusatum Forst. f. var. *difforme* (R.Br.) Benth.	HT
AZOLLACEAE	
Azolla pinnata R.Br.	fa
BLECHNACEAE	
Blechnum camfieldii Tindale	S
B.cartilagineum Sweet	DSF,DHF,S,FF,WHF,SF,VT
B.indicum Burm.f.	S,SF,FF
Doodia aspera R.Br.	WSF,VT
CYATHEACEAE	
Culcita dubia (R.Br.) Maxon	WHF,DSF
DENNSTAEDTIACEAE	
Histiopteris incisa (Thunb.) Smith	WHF
Pteridium esculentum (Forst.f.) Cockayne	WSF,DSF,DHF,DH,WH,BT,HT,SG
GLEICHENIACEAE	
Gleichenia dicarpa R.Br.	WH,S,SF,WHF
LYCOPODIACEAE	
Lycopodium deuterodensum Hert.	WH,S,SF,WHF
L. laterale R.Br.	WH,S,SF,WHF
LYGODIACEAE	
Lygodium scandens (L.) Swartz	WH,WHF,S,SF
OSMUNDACEAE	
Todea barbara (L.) T. Moore	FF

POLYPODIACEAE	
Platycerium bifurcatum (Cav.) C. Chr.	FF
SCHIZAEACEAE	
Schizaea bifida Willd.	DHF,DH
SELAGINELLACEAE	
Selaginella uliginosa (Labill.) Spring	WH,S,SF,WHF
SINOPTERIDACEAE	
Pellaea falcata (R.Br.) Fée	WSF
THELYPTERIDACEAE	
Christella dentata (Forsk.) Brownsey & Jermy	WSF
Cyclosorus interruptus (Willd.) H. Ito	S

GYMNOSPERMAE

ZAMIACEAE	
Macrozamia communis	DHF,DSF,IDF

ANGIOSPERMAE—MONOCOTYLEDONES

ARECACEAE (PALMAE)	
Livistona australis	VT,DSF,SF
BURMANNIACEAE	
Burmannia disticha	SF
CENTROLEPIDACEAE	
Centrolepis strigosa	WH,S
COMMELINACEAE	
Commelina cyanea	WSF,DSF,IDF,HT,FC
CYPERACEAE	
Baumea articulata	SF,FF
B. arthrophylla	SF,FF,LS,WHF
B. muelleri	WH,S
B. juncea	SF,S,FF,SG
B. rubiginosa	WH,SF,S,WHF
Carex appressa	WSF,S,SF,VT
C. declinata	SF
C. longebrachiata	WSF,SF,FF,VT
C. pumila	FC
Caustis pentandra	DHF,DH
C. recurvata	DSF
Chorizandra cymbaria	WH,SF
C. sphaerocephala	WH,SF,S
Cladium procerum	FF
*Cyperus brevifolius**	WSF
C. gracilis	WSF,DSF,DHF,DH
C. polystachyos	FF
Gahnia aspera	WSF,DSF,VT
G. clarkei	WHF,SF,DHF
G. melanocarpa	WSF
G. sieberiana	WH,SF,FF,S
Gymnoschoenus sphaerocephalus	WH,S
Isolepis inundata R.Br.	SF,S,FF
I. nodosa (Rottb.) R.Br.	BT,HT,FC,SG
I. pachylepis S. T. Blake	WH
Lepidosperma flexuosum	WH
L. forsythii	WH
L. laterale R.Br.	DSF,DHF,DH,IDF,WH,SG
L. longitudinale	FF,LS
L. neesii	WH,S
L. quadrangulatum	SF
Lepironia articulata	SF,LS
Ptilanthelium deustum	DH,WH

Rhynchospora brownii	WSF
Schoenus brevifolius	WH,SF,S
S. ericetorum	DHF,DH,WH
S. maschalinus	WH,SF,FF,HT
Schoenoplectus litoralis (Schrad.) Palla	FF
S. validus (Vahl) A. & D. Löve	FF
DIOSCOREACEAE	
Dioscorea transversa	WSF,HT
ERIOCAULACEAE	
Eriocaulon scariosum	WH,SF,S,FF
HAEMODORACEAE	
Haemodorum corymbosum	DHF,DH,WH
H. planifolium	DSF,IDF,DHF
HYDROCHARITACEAE	
Vallisneria gigantea	sa
IRIDACEAE	
*Gladiolus gueinzii**	FC
Patersonia glabrata	DSF,DHF,DH
P. longifolia	WH
P. sericea	DHF,DH
*Romulea rosea**	WSF
*Sisyrinchium iridifolium**	WSF
JUNCAEAE	
*Juncus cognatus**	WSF,DSF
J. continuus	WSF,SF
J. kraussii	FF
J. planifolius	DSF
J. usitatus	WSF,BT
JUNCAGINACEAE	
Maundia triglochinoides	FF
Triglochin procera	sa,SF,S
LILIACEAE	
Blandfordia grandiflora	DHF,DH,WH
Burchardia umbellata	DHF,DH,WH
Dianella caerulea	DSF,DHF,DH,IDF,WHF,SG
D. laevis	WSF
Sowerbaea juncea	WH
Stypandra caespitosa	DSF
Tricoryne elatior	DSF,DHF,IDF,WH,WHF
LOMANDRACEAE	
Lomandra glauca ssp. *glauca*	DHF,DH,IDF
L. longifolia ssp. *longifolia*	WSF,DSF,DHF,IDF,WHF, FF,BT,HT,FC,SG
L. micrantha	DSF
L. multiflora	WSF
NAJADACEAE	
Najas marina ssp. *armata*	sa
ORCHIDACEAE	
Acianthus caudatus	DSF
Caladenia carnea	DSF
C. catenata (Smith) Druce	DHF, DH
Caleana major	DSF, DHF
Calochilus paludosus	DSF
Chiloglottis reflexa	DSF
Dendrobium teretifolium	FF
Dipodium punctatum	DSF
Diuris aurea	DHF, DH
Glossodia major	DHF, DH
G. minor	DSF,DHF,DH

Lyperanthus suaveolens	DSF
Pterostylis nana	DSF
P. nutans	DH
POACEAE (GRAMINEAE)	
Agrostis avenacea	WSF,DSF,DHF,DH,IDF
Anisopogon avenaceus	DSF,DHF,DH,IDF,HT
*Axonopus affinis**	WSF,DSF
*Chloris gayana**	FC,HT
*Cortaderia selloana**	DH,WH
Cymbopogon refractus	WSF,DSF, BT,HT,FC,SG
Cynodon dactylon	WSF,DSF
Danthonia tenuior	WSF
Dichelachne crinita	DSF,DHF,BT,FC
D. micrantha	WHF
Digitaria parviflora	WSF,DSF
*Echinochloa crus-galli**	WSF
Echinopogon ovatus	WSF,DSF,DHF,IDF,HT
*Ehrharta erecta**	DSF
Entolasia marginata	WSF,DH,IDF,WH
E. stricta	DHF,DH
Eragrostis brownii	WSF,DSF,DHF,DH,SG
E. elongata Jacq.	DSF,DHF,DH
Eriachne pallescens	DH
Hemarthria uncinata	S
Imperata cylindrica	WSF,DSF,DHF,IDF,WHF,SG,HT,BT
Ischaemum australe	WSF,DSF
Microlaena stipoides	WSF
Oplismenus aemulus (R.Br.) Kunth	WSF
O. imbecillis	SF,HT
Panicum simile	DSF,DHF,DH,IDF,SG,WHF
*Parapholis incurva**	WH
Paspalidium aversum	DSF
P. radiatum	DSF
*Paspalum dilatatum**	WSF,DSF,HT
P. orbiculare	WSF,DSF
*Pennisetum cladestinum**	HT
Phragmites australis	FF
Plinthanthesis paradoxa	WSF,DSF,DHF,DH
Poa labillardieri	WSF
P. poiformis	SG
Pseudoraphis paradoxa	WH
Spinifex hirsutus	FC
*Sporobolus africanus**	WSF,DSF
*Stenotaphrum secundatum**	WSF
Themeda australis	WSF,DSF,DHF,DH,IDF,WHF,SG,HT
*Vulpia bromoides**	SF,WSF,DSF,FF,HT,FC
Zoysia macrantha	BT,HT,FC,SG
PHILESIACEAE	
Eustrephus latifolius	WSF,DSF
Geitonoplesium cymosum	WSF,DSF
POTAMOGETONACEAE	
Potamogeton pectinatus	sa
P. perfoliatus	sa
P. tricarinatus	sa
RESTIONACEAE	
Coleocarya gracilis	DHF,IDF
Empodisma minus	WH,SF,S,WHF
Hypolaena fastigiata	DHF,DH,IDF
Leptocarpus tenax	DHF,DH,IDF,WH,WHF,S
Lepyrodia interrupta	DH,WH,WHF
L. gracilis	WH
L. muelleri	SF,S
L. scariosa	WH,WHF

Restio complanatus	WH,S
R. pallens	WH,WHF,SF,S
R. tetraphyllus ssp. *meiostachyus*	DSF,DHF,DH,WH,WHF,SF,S
RUPPIACEAE	
Ruppia megacarpa	sa
SMILACACEAE	
Smilax australis	HT,VT
S. glyciphylla	WSF
TYPHACEAE	
Typha orientalis	FF
XANTHORRHOEACEAE	
Xanthorrhoea australis ssp. *australis*	DSF,DHF,DH,IDF,WH,WHF
X. macronema	WSF,WHF
X. media ssp. *latifolia*	WSF
X. resinosa ssp. *fulva*	WH,WHF
XYRIDACEAE	
Xyris gracilis	WH
X. juncea	WH,WHF
X. operculata	WH
ZOSTERACEAE	
Zostera capricorni	sa
DICOTYLEDONES	
ACANTHACEAE	
Brunoniella australis	WSF
Pseuderanthemum variabile	WSF
AIZOACEAE	
Carpobrotus glaucescens	BT,HT,FC
Macarthuria neocambrica	WH
APIACEAE (UMBELLIFERAE)	
Actinotus helianthi	DSF,DHF,DH,SG,IDF
A. minor	DH,WH
Centella asiatica	S
Hydrocotyle acutiloba (F.Muell.) Wakefield	WH,SF,BT,FC
*H. bonariensis**	BT,HT,FC
H. tripartita	HT
Lilaeopsis polyantha	FF
Platysace ericoides	DSF,IDF
P. lanceolata	DSF,DHF,DH,IDF
P. linearifolia	DHF,DH,IDF
Trachymene incisa	DHF,DH,IDF
Xanthosia pilosa	DHF,DH,IDF
APOCYNACEAE	
Parsonsia straminea	WSF,VT
ARALIACEAE	
Astrotricha longifolia	WSF,DSF,SG,
Polyscias sambucifolia	WSF,DSF
ASCLEPIADACEAE	
*Araujia hortorum**	WSF,HT
ASTERACEAE (COMPOSITAE)	
Ageratina adenophora *	WSF,SG
*Aster subulatus**	FF
*Bidens pilosa**	WSF
Cassinia aculeata	DSF,DHF
Chrysanthemoides monilifera ssp. *rotundata**	FC
*Cirsium vulgare**	WSF,DSF
*Conyza canadensis**	WSF,DSF,BT,HT,FC,SG
Cotula coronopifolia	FF
C. longipes	FF
Gnaphalium involucratum	DSF,FC

*G. purpureum**	DSF
Helichrysum bracteatum	SG
*Hypochoeris radicata**	WSF,DSF,DHF,DH,IDF,WH, FF,BT,HT,FC
Melanthera biflora	VT
*Picris hieracioides**	WSF
Pseudognaphalium luteoalbum (L.) Hilliard et Burtt	DSF,FF
Senecio lautus ssp. *dissectifolius*	WSF,DSF,SG
S. lautus ssp. *maritimus*	FC,SG
S. linearifolius	DSF,DHF
Sonchus megalocarpus (Hook.f.) J. M. Black	FC
BAUERACEAE	
Bauera rubioides	WH,WHF
BIGNONIACEAE	
Pandorea pandorana	DSF,BT,HT,FC,VT
BRASSICACEAE (CRUCIFERAE)	
Cakile edentula	FC
CAMPANULACEAE	
Wahlenbergia communis	WSF
W. gracilis	DSF,BT,HT,FC
W. stricta	WSF,DSF,HT
CASUARINACEAE	
Casuarina glauca	FF
C. littoralis	DSF,WSF
C. torulosa	WSF,DSF
CHENOPODIACEAE	
Rhagodia candolleana Moq.	FC
Sarcocornia quinqueflora	FF
CHLOANTHACEAE	
Chloanthes stoechadis	DSF,DHF
Spartothamnella juncea	WH,SF,S
CONVOLVULACEAE	
*Ipomoea cairica**	FC
Polymeria calycina	WH
CUNONIACEAE	
Ceratopetalum apetalum	VT
Schizomeria ovata	VT
DILLENIACEAE	
Adrastaea salicifolia	DSF,DHF,IDF,SG
Hibbertia fasciculata	DHF,DH
H. linearis	DSF
H. nitida	DH
H. obtusifolia	DSF,DHF,IDF,SG
H. scandens	WSF,DSF,WHF,IDF,BT,HT,FC,VT
DROSERACEAE	
Drosera binata	SF,S,FF
D. peltata	DHF,DH,WH
D. pygmaea	VT
ELAEOCARPACEAE	
Elaeocarpus obovatus	WSF
E. reticulatus	DSF
EPACRIDACEAE	
Astroloma pinifolium	DHF,DH
Brachyloma daphnoides	DHF,DH,IDF
Epacris microphylla	WH
E. obtusifolia	WH,S
E. paludosa	WH,S
E. pulchella	DHF,DH,IDF
Leucopogon ericoides	DSF,DHF,DH

L. lanceolatus var. *gracilis*	DSF,DHF,DH,IDF
L. muticus	DHF, DH
L. parviflorus	DSF,DHF,DH,FC
L. virgatus	DHF,DH
L. rodwayi	DHF,DH,IDF
Melichrus procumbens	DSF,IDF
Monotoca elliptica	DSF,IDF,SG
M. scoparia	DSF,DHF
Sprengelia incarnata	WH
S. sprengelioides	WH
Styphelia viridis	DHF,DH
Trochocarpa laurina	VT
Woollsia pungens	DSF,DHF,DH,IDF
EUPHORBIACEAE	
Amperea xiphoclada	DSF,DHF,DH,IDF
Baloghia lucida	VT
Breynia oblongifolia	DSF,BT,HT,SG
Euphorbia sparrmanii	FC
Glochidion ferdinandi	SF
Omalanthus populifolius	WSF
Phyllanthus thymoides	DSF,DHF,DH,IDF
Poranthera corymbosa	DSF,SG
P. ericifolia	DSF
P. microphylla	DH,HT
Pseudanthus orientalis	DSF,DHF,DH
P. pimeleoides	DH,WH
Ricinocarpos pinifolius	DSF,DHF,DH,IDF
EUPOMATIACEAE	
Eupomatia laurina	VT
FABACEAE (PAPILIONACEAE)	
Aotus ericoides	DSF,DHF,DH,IDF
Bossiaea ensata	DHF,DH,IDF,SG
B. heterophylla	DSF,DHF,DH,IDF
B. rhombifolia	DHF,DH
Chorizema parviflorum	DSF
Daviesia ulicifolia	WSF
Desmodium brachypodum	WSF
Dillwynia floribunda	WH
D. glaberrima	DHF,DH,WH
D. retorta ssp. *D*	DSF,DHF,DH,IDF
Glycine clandestina	WSF,DSF,DHF,DH,BT,HT
Gompholobium glabratum	DH
G. grandiflorum	DSF
G. latifolium	DSF,DHF
G. pinnatum	WH
G. virgatum ssp. *virgatum*	DSF,DHF,DH,IDF
Hardenbergia violacea	DSF,DHF,IDF
Hovea linearis	DSF,DHF,DH,IDF
H. longifolia	DSF
Indigofera australis	DSF
Kennedia prostrata	WSF,HT,VT,SG
K. rubicunda	WH,SF,S,BT,HT,FC,VT,DSF
Mirbelia rubiifolia	DHF,DH
Oxylobium ilicifolium	WSF
Phyllota phylicoides	DHF,DH,IDF
Platylobium formosum	DSF,HT,SG
Pultenaea blakelyi	DSF
P. daphnoides	VT,SG
P.microphylla var. *microphylla*	WHF
P. paludosa	WH
P. retusa	WHF
P. villosa	WSF
Sphaerolobium vimineum	WH
Viminaria juncea	DHF,WH,WHF,SF,S

GENTIANACEAE	
Centaurium tenuiflorum	WSF
GERANIACEAE	
Geranium homeanum	WSF,HT
G. solanderi	DSF
Pelargonium australe	BT,HT,FC
GOODENIACEAE	
Dampiera stricta	DHF,DH,WH,WHF
D. undescribed sp.	DSF
Goodenia hederacea	WSF,DSF
G. heterophylla	WSF,DSF,DHF
G. paniculata	WH,SF,S,FF
G. stelligera	WH
Scaevola calendulacea	HT,FC
HALORAGACEAE	
Gonocarpus micranthus	WH,SF,S,FF,BT,WHF
G. teucrioides	DSF,DHF,IDF,SG,BT
Myriophyllum aquaticum	sa
M. propinquum	SF,FF
HYPERICACEAE	
Hypericum japonicum	WSF,DSF,DHF
LAMIACEAE (LABIATAE)	
Plectranthus parviflorus	WSF,FC
Westringia fruticosa	HT
LAURACEAE	
Cassytha glabella	DHF,DH,WHF
C. pubescens	WH,SF
Endiandra sieberi	DSF,VT
Neolitsea dealbata	VT
LENTIBULARIACEAE	
Utricularia dichotoma	WH,S
U. exoleta	SF
U. uliginosa	SF
LINACEAE	
Linum trigynum	WSF
LOBELIACEAE	
Lobelia alata	SF,S,FF,VT
Pratia pedunculata	SG
P. purpurascens	WSF
LOGANIACEAE	
Mitrasacme paludosa	WH
M. polymorpha	DHF,DH
MALVACEAE	
Hibiscus diversifolius	BT
H. heterophyllus	WSF
*H. mutabilis**	BT
*Sida rhombifolia**	WSF
MELIACEAE	
Synoum glandulosum	HT,BT,VT
MENISPERMACEAE	
Sarcopetalum harveyanum	BT,HT,FC
Stephania japonica var. *discolor*	BT,HT,FC,VT,SG
MENYANTHACEAE	
Villarsia exaltata	SF,S,LS
MIMOSACEAE	
Acacia baueri spp. *baueri*	DHF,DH
A. binervata	WSF
A. elongata	WH,S,WHF,SF

A. floribunda	DSF,DH,WH
A. genistifolia	DHF,DH
A. implexa	WSF,SF
A. longifolia var. *longifolia*	DHF,IDF,BT,VT,HT
A. longifolia var. *sophorae*	FC,HT,BT
A. maidenii	DSF
A. myrtifolia	WSF
A. parramattensis	WSF,VT
A. suaveolens	DSF,DHF,DH,IDF,WH
A. trinervata	SF
A. terminalis	DSF,DH,IDF,WH
A. ulicifolia	DSF,DHF,DH,IDF
MORACEAE	
Ficus rubiginosa	WSF
Maclura cochinchinensis	DSF
MYRSINACEAE	
Rapanea variabilis	BT,DSF
MYRTACEAE	
Acmena smithii	VT,SG,HT,BT
Angophora costata AAADA	DSF,DHF,IDF,WHF,BT,DH
A. floribunda AAABB	WSF
A. subvelutina AAABA	WSF
Backhousia myrtifolia	VT,SG
Baeckea brevifolia	WH
B. imbricata	DH
Callistemon citrinus	SF,S
C. rigidus	SF,S
Calytrix tetragona	DSF,DH,IDF,DHF
Darwinia leptantha	DH,WH
Eucalyptus acmenoides MAG:C	WSF,DHF,DH
E. canaliculata SECEDC	WSF
E. grandis SECAB	WSF
E. gummifera CAFUF	DSF,DHF,DH,IDF
E. maculata CCC:B	WSF
E. microcorys SWA:A	WSF,DSF
E. paniculata SUV:D	WSF
E. pilularis MAIAA	WSF,DSF,DHF,IDF,DH
E. piperita ssp. *piperita* MATHAA	WSF
E. propinqua SECEA	WSF
E. resinifera SECCC	WSF
E. robusta SECAF	SF,WHF
E. signata MATKD	DHF
E. tereticornis SNEEB	WSF
Kunzea capitata	DHF,DH,IDF,WHF
Leptospermum attenuatum	DHF,DH,IDF
L. flavescens	DHF,DH,WH,WHF,SF
L. juniperinum	WH,SF,S
L. laevigatum	BT,HT,SG
L. liversidgei	WH,S
Lophostemon confertus (R.Br.) Peter G. Wilson & J. T. Waterhouse	WSF
Melaleuca armillaris	HT
M. nodosa	DHF,DH,WH,WHF
M. quinquenervia	DHF,WHF,SF,S,FF
M. sieberi	WH,WHF
M. styphelioides	WSF
M. thymifolia	DHF,DH,WH
Rhodomyrtus psidioides	DSF,VT
Syncarpia glomulifera	WSF
Syzygium oleosum (F. Muell.) Hyland	WSF
NYMPHAEACEAE	
*Nymphaea capensis**	sa,S
OLACACEAE	
Olax stricta	DHF,DH

OLEACEAE	
Notelaea longifolia	WSF,DSF
N. ovata	SG
ONAGRACEAE	
Ludwigia peploides ssp. *montevidensis*	FF
OXALIDACEAE	
Oxalis corniculata s. lat.	WSF,FC,SG
PASSIFLORACEAE	
*Passiflora subpeltata**	WSF
PEPEROMIACEAE	
Peperomia leptostachya	SF
PITTOSPORACEAE	
Billiardiera scandens	DSF,DHF,DH,IDF,BT,FC
Pittosporum undulatum	WSF,DSF,VT,BT
PLANTAGINACEAE	
Plantago debilis	HT
*P. lanceolata**	WSF,DSF
POLYGALACEAE	
Comesperma defoliatum	WH
C. retusum	DHF,DH
C. volubile	DH
POLYGONACEAE	
Polygonum strigosum	FF
Rumex acetosella L.*	WSF
PRIMULACEAE	
*Anagallis arvensis**	WSF,FF
Samolus repens	S,FF,HT
PROTEACEAE	
Banksia aemula R.Br.	DHF,DH,IDF,WHF
B. integrifolia	DSF,DHF,BT,HT,FC,VT,SG
B. oblongifolia Cav.	DHF,WH,WHF
B. robur	WH,WHF,S
B. serrata	DSF,IDF,BT
B. spinulosa	WHF
Conospermum taxifolium	DHF,DH,IDF
Hakea teretifolia	WH
Isopogon anemonifolius	DH,WH
Lomatia silaifolia	WSF
Persoonia hirsuta	DH,IDF
P. lanceolata	DH,IDF,WH,WHF
P. laurina	DSF,IDF,WHF
P. levis	WSF,DSF,IDF,WHF
P. linearis	WSF,VT
Petrophile sessilis	DSF,DHF,DH
Symphionema paludosum	WH
Xylomelum pyriforme	DSF
RANUNCULACEAE	
Clematis aristata	WSF,FF,VT
Ranunculus lappaceus	WSF
R. inundatus	FF
RHAMNACEAE	
Alphitonia excelsa	VT
Pomaderris ferruginea	WSF,SG
ROSACEAE	
Rubus parvifolius	WSF,HT
RUBIACEAE	
Opercularia varia	DSF,DHF,DH,BT,HT
Pomax umbellata	DSF,DHF,IDF,WHF,BT,HT,FC

RUTACEAE	
Acronychia wilcoxiana	DSF;BT,VT
Boronia falcifolia	DHF,DH,WH
B. parviflora	WH
B. pinnata	DSF,DHF,DH,IDF
Correa alba	BT,HT,FC,SG
C. reflexa	DSF,DHF,IDF,SG,BT
Eriostemon australasius	DSF,DHF,DH,IDF
Phebalium squameum	VT,DH
Zieria laevigata	DHF,DH
SANTALACEAE	
Exocarpos cupressiformis	WSF,DSF
E. strictus	DHF,WHF
Leptomeria acida	DSF,DHF
SAPINDACEAE	
Cupaniopsis anacardioides	WSF,DSF,FF,BT,HT,VT,SG
Dodonaea triquetra	WSF,DSF,VT,BT
SCROPHULARIACEAE	
Bacopa monnieri	DH
Euphrasia collina	DHF,DH
Gratiola pubescens	FF
SOLANACEAE	
Duboisia myoporoides	BT
Solanum campanulatum	WSF
S. cinereum	BT
S. nodiflorum ssp. *nutans*	WSF
S. pungetium	WSF
S. stelligerum	WSF
STACKHOUSIACEAE	
Stackhousia nuda	DH
S. spathulata	FC
S. viminea	DHF,DH
STERCULIACEAE	
Commersonia fraseri	VT,SG
Lasiopetalum ferrugineum	BT
STYLIDIACEAE	
Stylidium debile	SF,S
S. graminifolium	DHF,DH,IDF,WHF
S. lineare	WH
THYMELAEACEAE	
Pimelea linifolia	DSF,DHF,DH,IDF,BT,HT
Wikstroemia indica	HT,FC
TREMANDRACEAE	
Tetratheca ericifolia	DHF,DH,IDF
T. thymifolia	DSF,IDF,BT
ULMACEAE	
Trema aspera	HT,VT
VERBENACEAE	
Clerodendrum tomentosum	BT
*Lantana camara**	WSF
Verbena officinalis	WSF,HT
*V. rigida**	WSF
VIOLACEAE	
Viola hederacea	WSF,SF,BT,HT
V. sieberiana	SG
VITACEAE	
Cayratia clematidea	WSF,VT
Cissus antarctica	WSF,HT
C. hypoglauca	VT,SG
WINTERACEAE	
Tasmannia insipida	VT