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THE PHYSICAL ENVIRONMENT, FLORISTICS AND PHENOLOGY OF A *BANKSIA* WOODLAND NEAR PERTH, WESTERN AUSTRALIA

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ABSTRACT

The physical environment and floristic composition of 10 ha of mature, undisturbed Banksia *woodland on deep, leached sand are described. The study area covered part of a siliceous dune under a mediterranean climate on the southern outskirts of Perth, Western Australia. The 6 m high tree stratum consisted mainly of* Banksia attenuata *(Proteaceae). The 1 m high shrub stratum comprised 90 perennial species in 25 families. Slight variations in the composition of both strata were found among four study sites in association with small differences in substrate. The period of maximum flowering was October, although a few species flowered in winter or in summer. The times of appearance of an additional 25 species of annuals and herbs, apparent only in winter and spring, are recorded.*

INTRODUCTION

This paper presents data on the physical environment, floristics and phenology of an area of *Banksia* woodland at Jandakot Airport (32°05'S, 115° 53'E) on the southern outskirts of the Perth metropolitan area, Western Australia. The main aim of the study was to provide environmental and floristic data as a counterpart of an intensive study on the reptile, frog and bird communities of this area (Davidge 1979a, 1979b, Milewski unpublished). These data also provide a detailed description of an Australian mediterranean area. It is intended that this description will permit future comparisons of plant and animal communities in Australia with those of other continents with a similar mediterranean climate.

DATA COLLECTION

An area was needed which was large enough to include all plant and animal members of a natural community but which, at the same time, included only one such community. A study area of 10 ha was chosen on the basis of the apparent gross homogeneity of the environment and vegetation, the maturity of the vegetation and a minimum of man-made disturbance or invasion by weedy annuals. Figure 1 is an aerial view of the area and figure 2 illustrates the vegetation.

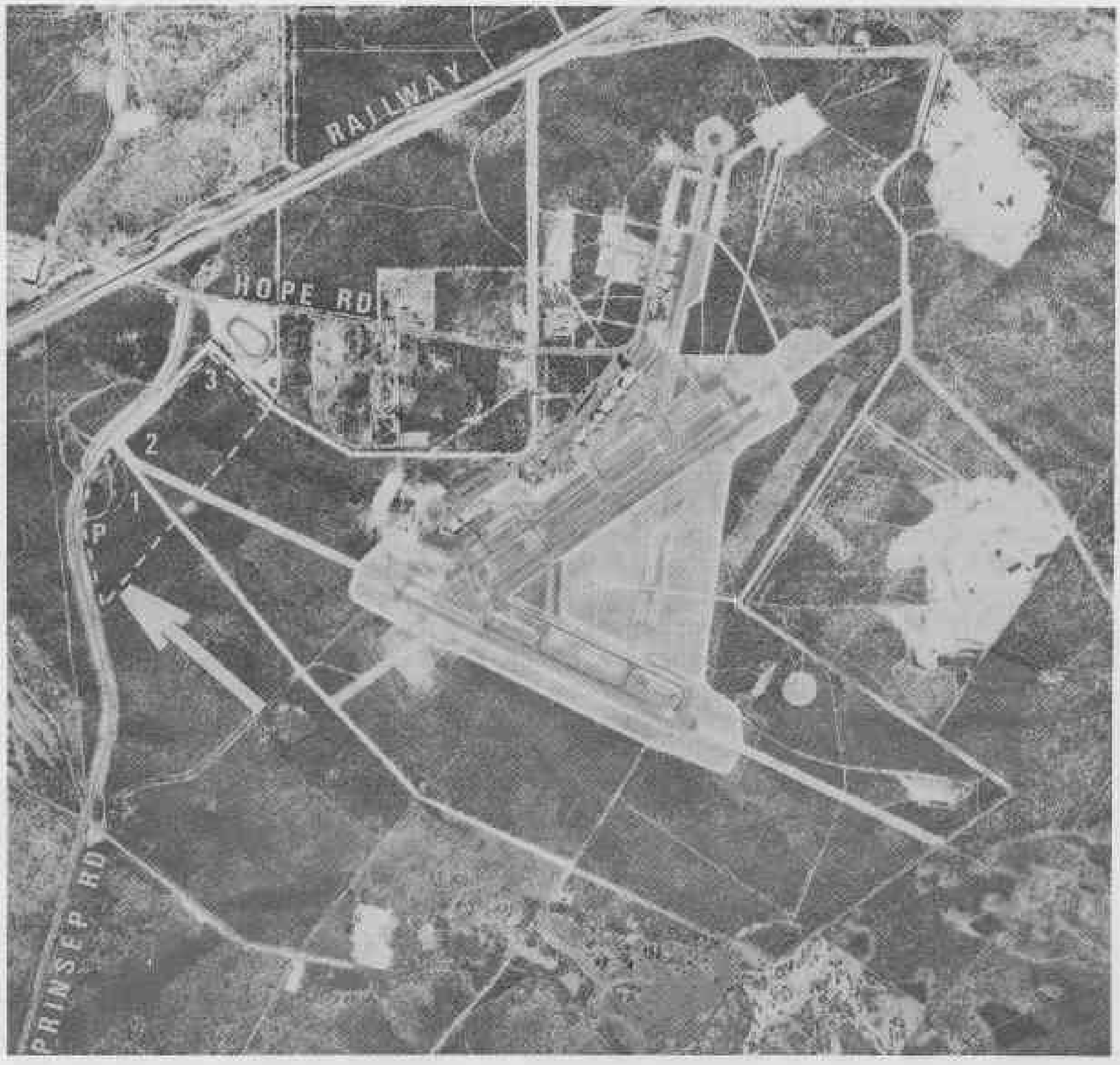

Fig. 1. Aerial view of Jandakot Airport, showing location of study area (arrowed).

Fifty two sample plots, 2 x 1 m, were placed within a primary study site of 1 ha (corresponding to the site used by Davidge 1979a, and R_1 of Davidge 1979b), using an 8 x 8 m grid. The first pair of numbers from a table of random numbers gave the co-ordinate of a point on the grid. Two more pairs of numbers gave the direction and distance to walk from this point to the first plot. The process was repeated to locate the other plots. The area assessed in this way was 100 m^2 of 1% or the total area of the site.

All shrub species (perennials lower than 3 m), present as living plants in each plot, were recorded between February and May 1978. The foliage projective cover of each species was estimated for each half of each plot. Mean foliage projective cover was then calculated for all species in the primary site. The site was examined thoroughly for species undetected by

Fig. 2. General view of the vegetation in the study area, showing the upper stratum of low trees of *Banksia* spp. (*B. menziesii* left foreground, *B. attenuata* background).

the sampling method (only three were discovered in this manner), and their foliage projective cover over the whole primary site was estimated. The cover of trees was measured from colour and infra-red aerial photographs of the site. The proportion of cover contributed by each tree species was then estimated in the field. The primary site was revisited from the end of August to mid-November to estimate the cover of species of annuals and herbs which lose their foliage seasonally.

The cover of each perennial plant species in three 0.5 ha secondary study sites (1, 2 and 3, corresponding to R_2, R_3 and M_2 respectively of Davidge 1979b) in other parts of the study area was estimated relative to that in the primary study site in order to assess floristic variation within the area.

Soil profiles were obtained when the soil was moist by augering to 1.5 m in all sites and to 4.5 m in the primary site. The exposed soil was described in the field by manual texture assessment and comparison of colours with standard charts.

Species were identified at the Western Australian Herbarium by one of us (AVM) or by herbarium staff. Voucher specimens and photographs were lodged as a permanent record at the School of Environmental and Life Sciences, Murdoch University.

PHYSICAL ENVIRONMENT

The monthly distribution of average annual precipitation and average maximum and minimum temperatures for the study area are given in Table 1. The climate is mediterranean with 57% of the average annual precipitation of 860 mm falling in winter (June-Aug.). This corresponds to various alternative climate types such as Thornthwaite's (1948) sub-humid, warm, great-moisture-deficiency-in-summer (CB's) climate, Köppen's (1936) transition between a warm climate with long hot summer (Csa) and a warm climate with long temperate summer (Csb), and the UNESCO-FAO (1963) Attenuated Thermomediterranean climate.

Winds are usually gentle and temperatures rarely reach freezing point, possibly as seldom as once per year. The mean minimum for the coldest month of the average year is about 9°C, while the difference between mean winter and mean summer temperatures is only about 10°C (Bureau of Meteorology 1966). Annual rainfall is very variable, ranging from 500 mm to more than 1,300 mm. A warm to hot dry season is usual for 7 months of the year (Table 1). In October, precipitation and evapotranspiration are equal (Speck 1952). In the following weeks precipitation decreases rapidly and increasing temperatures raise the evapotranspiration. Although plants initially may draw on water stored in the soil, the upper layers of soil reach wilting point by early December and continue to dry out until the soil water is replenished in May (Speck 1952).

Table 1. The monthly distribution of average annual precipitation and average maximum and minimum temperatures for the study area, after Bureau of Meteorology (1966). Monthly precipitation values were obtained by multiplying the values for Fremantle by a factor (1.1) derived from the total annual precipitation for Fremantle and the isohyet which includes Jandakot (864 mm).

		Temperature (°C)			
Month	Average precipitation (mm)	Average max.	Absolute max.	Average min.	Absolute min.
January	8.0	29.4	43.9	17.5	9.2
February	10.8	29.7	44.4	17.7	8.7
March	19.1	27.7	41.3	16.4	7.7
April	46.7	24.5	37.6	14.0	4.0
May	127.8	20.6	32.4	11.6	1.7
June	186.1	18.1	27.6	8.8	1.6
July	173.0	17.1	24.6	8.8	1.2
August	134.0	17.8	27.8	9.0	1.9
September	77.1	19.3	33.3	10.0	2.6
October	47.8	21.0	37.2	11.3	4.4
November	19.6	24.5	40.3	13.7	5.5
December	13.6	27.2	42.2	15.9	8.6
Year	863.6	23.1	44.4	12.9	1.2

The area lies between the Bassendean and Spearwood Dune Systems (McArthur & Bettenay 1960), in a gently undulating Pleistocene landscape of well-drained, deep, coarse, siliceous, podsolized, white over yellow sand on the Swan Coastal Plain (Tables 2a & b). The altitude is 49-52 m above mean sea level. The average depth of the water table, which is virtually flat here, is 24-28 m below ground surface (water table maps held by the Metropolitan Water Board).

The study area covers part of a single dune and the substrate varies slightly in different sites as regards altitude, slope angle, the presence of a partly organic surface layer and the depth below the surface at which yellow sand and its associated band of soft concretions occurs. In some places the upper, white sand is 4 m deep, while in one site (R_3) the finer yellow sand reaches the surface (Table 2a & b).

The deep sandy soil falls within the Jandakot series (iron-humus podzols) of the Bassendean Association (Bettenay *et al.* 1960), but corresponds to Speck's (1952) Karrakatta Sands, perhaps transitional to his Muchea Sands (part of his Bassendean Association). Speck described both of these as having a pH of 5.7-6.6 near the surface and 7.0-7.9 at depth. These soils have excellent infiltration and drainage and are very leached. They comprise 85% coarse sand, 11% fine sand and 1% clay and silt (Speck 1952). Other details are: $CaCO_3$ = 0.5-1.3% near the surface, decreasing to less than 0.2% at depth; organic carbon = 3.4-3.7% near the surface, decreasing to 1.2-1.8% at depth; P_2O_5 = 0.001% near the surface; K_2O = 0.005%; and N = 0.005% (Speck 1952).

FLORISTIC COMPOSITION

a. General description

The vegetation, in colloquial terms, is "low woodland" (tree height 5-6 m, canopy cover 20%) over "heath" (height 0.5-1.0 m, canopy cover 60%). The tree stratum in the primary study site consists mainly of *Banksia attenuata* (Proteaceae), although five other species are present. *Eucalyptus marginata* (Jarrah) and *Casuarina fraserana* are represented by only two or three trees in this site. The shrub stratum comprises 80 perennial species in 25 families, of which *Beaufortia elegans* (Myrtaceae) and *Leucopogon kingianus* (Epacridaceae) are particularly prominent. Most species occur with low cover values, of less than 2% (Tables 3 & 4).

The 0.5 ha sites differ slightly from the primary site in the composition of both the tree and shrub strata. The same species are generally present but have different cover values (Table 3). In one site (M_3) *C. fraserana* occurs as several large trees; in this and another site (R_2) *E. marginata* is more common than in the primary site. The shrubs *B. elegans* and *L. kingianus* have lower cover in the secondary sites than in the primary site, their place being taken by e.g. *Leucopogon conostephioides*, *Eremaea pauciflora*, *Casuarina humilis*, *Stirlingia latifolia* and *Hibbertia hypericoides*. Several species, e.g. *Mesomelaena stygia*, *Daviesia nudiflora* and *Hibbertia racemosa*, are restricted to one site (R_2), apparently associated with patches where yellow sand reaches ground surface. In addition, secondary site M_3 has a relatively high cover (total 20%) of perennial monocotyledons, mainly *Patersonia* (Iridaceae), *Phlebocarya* (Haemodoraceae), *Lyginia* (Restionaceae) and *Amphipogon* (Poaceae) (Table 3).

Table 2a. Colour of soil to 1.5 m depth in the study area, according to the Munsell colour chart. a to e refer to auger holes dug in different parts of the same site.

	Primary site				
Depth (m)	a	b	c	d	e
0-0.1	10YR 5/2	10YR 6/2	10YR 5.5/2.5	10YR 3/2	10YR 4/3
0.1-0.2	7.5YR 4.5/1.5	10YR 6.5/2	7.5YR 6/2		10YR 6/2.5
0.2-0.3	7.5YR 4.5/2	10YR 6.5/2.5	10YR 6.5/2.5	7.5YR 4.5/2	7.5YR 5.5/2
0.3-0.4		7.5YR 6.5/2	10YR 6.5/2	7.5YR/2.5	10YR 5.5/2.5
0.4-0.5	7.5YR 4.5/2		7.5YR 7/2	7.5YR 5.5/2	7.5YR 5.5/3
0.5-0.6	7.5YR 5/2	10YR 7/2		7.5YR 6.5/2	
0.6-0.7	7.5YR 5.5/2			10YR 6.5/2	10YR 6/3
0.7-0.8	7.5YR 5.5/2	10YR 7.5/2	10YR 7.5/2		
0.9-1.0	10YR 7/2	10YR 8/2	10YR 8/2		10YR 6.5/3
1.0-1.1				10YR 7.5/2	
1.1-1.2	10YR 7.5/2	10YR 7.5/2.5	10YR 8/1.5		
1.2-1.3		10YR 8/2	10YR 8.5/1.5		2.5Y 7.5/3
1.3-1.4	10YR 7.5/2	10YR 8.5/2			10YR 7.5/3
1.4-1.5	10YR 7.5/2		10YR 8.5/1.5	10YR 8/2	2.5Y 7.5/3

	Secondary sites			
	Site 1			
Depth (m)	a	b	Site 2	Site 3
0-0.1	10YR 5/2	10YR 4/1.5	10YR 4.5/2	10YR 3.5/2
0.1-0.2	10YR 3.5/1.5	10YR 3.5/1.5	10YR 4.5/2	10YR 3/1.5

Table 2a (cont.)

Depth (m)	Site 1		Site 2	Site 3
	a	b		
0.2-0.3	10YR 3.5/1.5	10YR 3.5/1	10YR 6/2.5	10YR 3.5/1.5
0.3-0.4	10YR 4/1.5	10YR 3.5/1.5	10YR 6.5/2.5	10YR 4/1.5
0.4-0.5	7.5YR 4.5/2	10YR 4/1.5	10YR 6.5/3	10YR 4.5/1.5
0.5-0.6			10YR 6/3.5	7.5YR 4.5/1.5
0.6-0.7	7.5YR 4.5/2	10YR 5/1.5	10YR 6/3	10YR 5.5/1.5
0.7-0.8	7.5YR 4.5/2	7.5YR 5/1.5	2.5Y 6/3	10YR 6/2
0.8-0.9	7.5YR 5/2		2.5Y 7/3.5	10YR 7/2
0.9-1.0	7.5YR 5/2	10YR 5.5/1.5	2.5Y 7.5/4	10YR 7.5/2
1.0-1.1	7.5YR 5.5/1.5	7.5YR 5.5/1.5	2.5Y 7/5	10YR 7.5/2
1.1-1.2	7.5YR 5.5/1.5		2.5Y 7/5	10YR 7.5/2
1.2-1.3	7.5YR 6/1.5	10YR 6/1.5		10YR 7.5/2
1.3-1.4	7.5YR 6/1.5	7.5YR 6/1.5	2.5Y 7.5/5.5	10YR 8/2
1.4-1.5	7.5YR 7/1.5	10YR 6.5/2	2.5Y 7/6.5	10YR 8/2

Table 2b. Description of soil profile in the primary study site, on the basis of field examination of four auger holes to 4.5 m depth.

Profile zone	Munsell Colour	Texture	Depth from surface (m)
1.	Light brownish-grey to very dark greyish-brown, darkest near surface owing to organic matter	Sand, tending to loamy sand near the surface where the coarse grains are bound by humus and fine roots	0 to 0.2
2.	Light brownish-grey becoming gradually paler with depth (to white)	Coarse sand	0.2 to between 0.6 and 4.2
3.	Grading yellower, to pale brown or brownish-yellow	Sand	variable, depending on depth of zone 2, e.g. 0.6 to 3.2, 1.6 to 2.3 or 4.2 to 4.5
4.	Grades darker and richer, to brownish-yellow with darker mottles (strong brown)	Coarse sand or sand with up to 20% by volume of concretions (up to small gravel size) of coarse cemented sand, generally breakable between finger and thumb	variable, depending on depth of zones 2 & 3, e.g. 2.3 to 2.8, 3.3 to 3.8, or not reached by 4.5
5.	Loses the mottles and grades paler, to yellow (similar to but slightly brighter than in zone 3)	Coarse sand or sand	remainder of profile, continuing beyond 4.5

Table 3. Average foliage projective cover of perennial plant species, in order of decreasing cover, in the primary study site (1 ha of *Banksia* woodland). + = cover of less than 0.1%. Also given are the plant species found in three 0.5 ha secondary study sites (1, 2 and 3 corresponding to sites R_2, R_3 and M_2 respectively of Davidge 1979b). For these sites, foliage projective cover was only estimated and is given for those species which either (i) have cover greater than 2% in at least one site, or (ii) are absent from at least one site; the presence of other species is denoted by an asterisk. The tree stratum was defined as all plants taller than 3 m. Total foliage projective cover in the primary site was estimated to be 60-65% from aerial photographs and field assessment.

Species	Primary site	Secondary sites 1	Secondary sites 2	Secondary sites 3
TREE STRATUM				
1. *Banksia attenuata* R.Br.	6.9	6.0	6.0	4.5
2. *Banksia menziesii* R.Br.	2.9	2.5	4.0	4.5
3. *Eucalyptus todtiana* F. Muell.	1.2	1.5	0.5	0.5
4. *Nuytsia floribunda* (Labill.) R.Br.	0.5	0.5	0.8	0.6
5. *Eucalyptus marginata* Sm.	0.1	0.5	1.5	1.5
6. *Casuarina fraserana* Miq.	+	-	-	2.0
7. *Banksia ilicifolia* R.Br.	-	-	+	+
SHRUB STRATUM				
8. *Beaufortia elegans* Schau.	10.8	6.0	2.5	0.6
9. *Leucopogon conostephioides* DC.	6.8	7.0	5.5	7.5
10. *Leucopogon kingianus* (F. Muell.) C.A. Gardn.	4.6	2.0	+	+
11. *Hibbertia hypericoides* (DC.) Benth.	2.7	3.0	6.8	5.5
12. *Stirlingia latifolia* (R.Br.) Steud.	2.5	3.0	4.0	2.5
13. *Eremaea pauciflora* (Endl.) Druce	2.0	4.0	7.5	3.0
14. *Scholtzia involucrata* Endl.	1.8	2.0	5.2	3.5
15. *Hibbertia subvaginata* (Steud.) F. Muell.	1.7	1.8	2.3	1.3
16. *Melaleuca thymoides* Labill.	1.3	1.5	1.5	4.5
17. *Lyginia barbata* R.Br.	1.1	1.0	0.8	2.5
18. *Acacia pulchella* R.Br.	0.8	-	-	-
19. *Conostephium pendulum* Benth.	0.8	1.0	1.5	2.4
20. *Dasypogon bromeliaefolius* R.Br.	0.8	1.0	1.5	2.4
21. *Calytrix flavescens* A. Cunn.	0.7	0.8	2.0	3.5
22. *Eremaea* sp. aff. *fimbriata* Lindl.	0.6	-	-	-
23. *Petrophile linearis* R.Br.	0.5	-	-	-
24. *Daviesia juncea* Sm.	0.4	-	-	-
25. *Bossiaea eriocarpa* Benth.	0.3	-	-	-
26. *Hemiandra pungens* R.Br.	0.3	-	-	-
27. *Lomandra caespitosa* (Benth.) Ewart	0.3	-	-	-
28. *Loxocarya flexuosa* (R.Br.) Benth.	0.3	-	-	-

Table 3 (cont.)

Species	Primary site	Secondary sites 1	2	3
29. *Phlebocarya ciliata* R.Br.	0.3	0.3	0.3	1.5
30. *Schoenus curvifolius* (R.Br.) Benth.	0.3	-	-	-
31. *Stylidium repens* R.Br.	0.3	-	-	-
32. *Cassytha* sp. indet.	0.2	-	-	-
33. *Casuarina humilis* Otto et Dietr.	0.2	4.0	5.0	4.5
34. *Conostylis aculeata* R.Br.	0.2	-	-	-
35. *Gompholobium tomentosum* Labill.	0.2	-	-	-
36. *Hypocalymma robustum* Endl.	0.2	-	-	-
37. *Hypolaena exsulca* R.Br.	0.2	-	-	-
38. *Jacksonia furcellata* (Bonpl.) DC.	0.2	-	-	-
39. *Laxmannia ramosa* Lindl.	0.2	-	-	-
40. *Leucopogon strictus* Benth.	0.2	-	-	-
41. *Lomandra endlicheri* (F. Muell.) Ewart	0.2	-	-	-
42. *Macrozamia riedlei* (Gaud.) C.A. Gardn.	0.2	-	-	-
43. *Phlebocarya filifolia* (F. Muell.) Benth.	0.2	-	-	-
44. *Restio* sp. indet.	0.2	-	-	-
45. *Schoenus brevisetis* Benth.	0.2	-	-	-
46. *Stylidium brunonianum* Benth.	0.2	-	-	-
47. *Acacia stenoptera* Benth.	0.1	-	-	-
48. *Amphipogon turbinatus* R.Br.	0.1	0.2	0.3	0.3
49. *Calytrix fraseri* A. Cunn.	0.1	-	-	-
50. *Eriostemon spicatus* A. Rich.	0.1	-	-	-
51. *Hibbertia aurea* Steud.	0.1	-	-	-
52. *Hibbertia huegelii* (Endl.) F. Muell.	0.1	-	-	-
53. *Hibbertia pachyrrhiza* Steud.	0.1	+	-	+
54. *Hovea trisperma* Benth.	0.1	-	-	-
55. *Laxmannia squarrosa* Lindl.	0.1	-	-	-
56. *Lechenaultia floribunda* R.Br.	0.1	-	-	-
57. *Lepidosperma angustatum* R.Br.	0.1	-	-	-
58. *Lysinema ciliatum* R.Br.	0.1	-	-	-
59. *Melaleuca seriata* Lindl.	0.1	0.1	0.6	1.3
60. *Oxylobium capitatum* Benth.	0.1	-	-	-
61. *Patersonia occidentalis* R.Br.	0.1	0.3	1.0	1.6
62. *Platysace compressa* (Labill.) Norman	0.1	+	-	-
63. *Xanthosia huegelii* (Benth.) Steud.	0.1	-	-	-
64. *Acacia huegelii* Benth.	+	-	-	-
65. *Arnocrinum preissii* Lehm.	+	-	-	-
66. *Calectasia cyanea* R.Br.	+	-	-	-
67. *Conostylis aurea* Lindl.	+	-	-	-
68. *Conostylis juncea* Endl.	+	-	+	-
69. *Conostylis setigera* R.Br.	+	-	-	-
70. *Dampiera linearis* R.Br.	+	-	-	-

Table 3 (cont.)

Species	Primary site	Secondary site 1	Secondary site 2	Secondary site 3
71. *Drosera paleacea* DC.	+	-	-	-
72. *Hensmania turbinata* (Endl.) W.V. Fitzg.	+	-	-	-
73. *Leptomeria empetriformis* Miq.	+	-	-	-
74. *Leucopogon pulchellus* Sond. or *L. polymorphus* Sond.	+	-	+	-
75. *Leucopogon racemulosus* DC.	+	-	-	-
76. *Lomandra preissii* (Endl.) Ewart				
77. *Melaleuca scabra* R.Br.	+	-	-	-
78. *Persoonia saccata* R.Br.	+	+	-	0.7
79. *Pithocarpa pulchella* Lindl.	+	-	-	-
80. Poaceae sp. indet. 1	+	-	-	-
81. Poaceae sp. indet. 2	+	-	-	-
82. *Scaevola paludosa* R.Br.	+	-	-	-
83. *Stylidium junceum* R.Br.	+	-	+	-
84. *Stylidium piliferum* R.Br.	+	-	-	-
85. *Stylidium schoenoides* DC.	+	-	+	-
86. *Thysanotus triandrus* (Labill.) R.Br.	+	-	-	-
87. *Tricoryne elatior* R.Br.	+	-	+	-
88. *Burtonia conferta* DC.	-	-	*	-
89. Cyperaceae sp. indet.	-	-	+	0.3
90. *Daviesia nudiflora* Meisn.	-	-	0.5	-
91. *Hibbertia racemosa* (Endl.) Gilg.	-	+	0.5	+
92. *Mesomelaena stygia* (R.Br.) Nees	-	-	+	-
93. *Pimelea sulphurea* Meisn.	-	-	*	-
94. *Regelia inops* Schau.	-	-	-	*
95. *Schoenus* sp. indet.	-	-	+	-
96. *Synaphea spinulosa* (Burm.f.) Merrill	-	-	*	*
97. *Xanthorrhoea preissii* Endl.	-	-	*	*

Table 4. Estimated relative perennial cover for all plant families occurring in the study area, in order of decreasing cover. Numbers in parentheses refer to species as listed in Table 3. Total foliage projective cover was obtained by adding cover values of species; no account was taken of overlap between canopies in the calculation.

Family	Total foliage projective cover (%)
Myrtaceae (3,5,8,13,14,16,21,22,36,49,59,77,94)	19.0
Proteaceae (1,2,7,12,23,78,96)	15.0
Epacridaceae (9,10,19,40,58,74,75)	12.6
Dilleniaceae (11,15,51,52,53,91)	4.7
Restionaceae (17,28,37,44)	1.6
Fabaceae (24,25,35,38,54,60,88,90)	1.3
Xanthorrhoeaceae (20,27,41,66,76,97)	1.3
Casuarinaceae (6,33)	1.1
Mimosaceae (18,47,64)	0.9
Haemodoraceae (29,34,43,67,68,69)	0.8
Loranthaceae (4)	0.7
Cyperaceae (30,45,57,89,92,95)	0.6
Stylidiaceae (31,46,83,84,85)	0.6
Lamiaceae (26)	0.4
Liliaceae (39,55,65,72,86,87)	0.4
Poaceae (48,80,81)	0.2
Apiaceae (62,63)	0.1
Goodeniaceae (56,70,82)	0.1
Iridaceae (61)	0.1
Lauraceae (32)	0.1
Rutaceae (50)	0.1
Zamiaceae (42)	0.1
Asteraceae (79)	+
Droseraceae (71)	+
Santalaceae (73)	+
Thymelaeaceae (93)	+

A species present in the study area but absent from all study sites is *Adenanthos cygnorum*, which occurs as a stand of tall shrubs between secondary sites M_3 and R_2.

The vegetation of the study area does not correspond precisely to any previously described community, although it has been described in a general sense by Diels (1906), Seddon (1972) and Heddle, Loneragan and Havel (1979, "Bassendean - central and south" vegetation complex) and corresponds to Speck's (1952) "Banksia, Casuarina, Eucalyptus Association", and Beard's (1979) Bassendean System: southern or Perth section. The vegetation differs slightly from that north of Perth, e.g. type F of Havel (1976), in lacking e.g. *Jacksonia floribunda* and members of the genera *Boronia*, *Astroloma* and *Conospermum*. The *Banksia* woodland described by Bell *et al.* (1979) occurs on weakly leached sand associated with limestone outcrops and differs in the composition of the shrub stratum.

Eastwards from the Karrakatta/Bassendean transition, "as the Muchea (Bassendean) sands become more typical the Jarrah trees become fewer, are reduced to stunted trees and finally are absent altogether" (Speck 1952). It is as part of this "Jarrah-Banksia ecotone" Speck 1952) that the study area can best be described, transitional as it is between stands with a canopy of *E. marginata* and *Casuarina fraserana* over smaller trees of *Banksia*, and those containing only *Banksia* and *E. todtiana* (Speck 1952, Beard 1967, Seddon 1972). The shrub stratum appears to represent a similar transition from yellow to white sand, as shown by the rare local occurrence of yellow sand species such as *Mesomelaena stygia* (Havel 1976).

b. Homogeneity

The primary study site (1 ha) appears to represent a single plant community, as shown by a species-area curve (Fig. 3). The very small variations in floristic composition here may be attributed to the chance occurrence of locally rare species in certain parts of the site (Table 3).

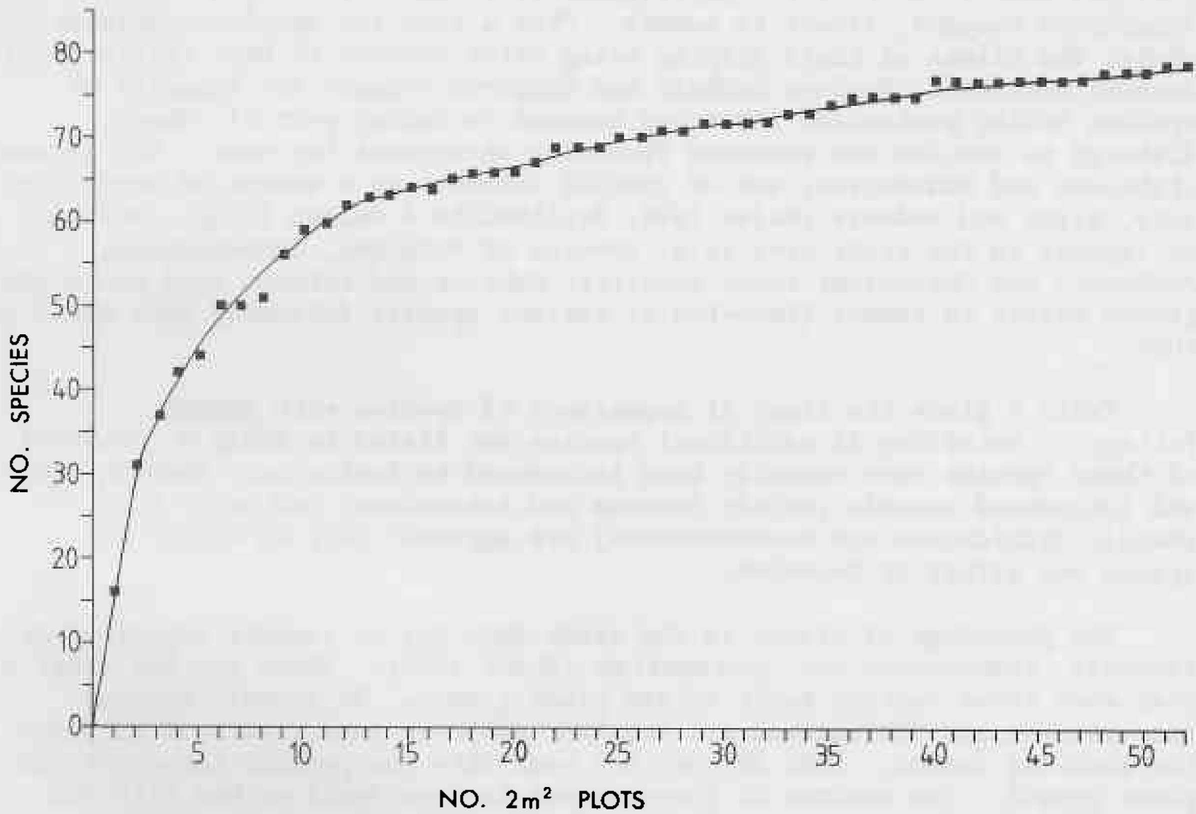

Fig. 3. Cumulative total number of shrub species found in consecutive 2 m^2 sample plots in the 1 ha primary site. Note that the sample plots were not adjacent, but scattered through the site.

Over the entire area, as represented by the secondary sites, floristic composition varies slightly from place to place in association with substrate differences. In view of the large area studied, this variation is relatively small, being found mainly in the cover of species rather than in their presence or absence. Such variation seems unavoidable in view of the requirement of an area large enough to achieve a minimally acceptable sample for studies of vegetation structure and the animal community as well as for the floristic study.

PHENOLOGY

Table 5 gives 1 year's observations on the flowering and fruiting times of 81 perennial plant species found in the study area. These data were collected from March 1978 to February 1979, an unusually dry year. The previous summer (1977-78) was extremely hot and dry and the rains arrived about a month later than usual (Met. Bureau records). Thus the phenological data presented do not refer to an average year. For instance, in the following year many plants were observed flowering in the study area at least a month earlier than recorded in 1978. However, the data do allow some generalizations to be made.

The period of maximum flowering, i.e. when the most species are in full bloom, is October. However, some species flower at the cold time of year and others, such as the physiognomically dominant *Banksia attenuata* and *Beaufortia elegans*, flower in summer. "For a time the epacrids dominate the whole, the climax of their display being often reached in May" (Diels 1906). *Banksia menziesii*, *Lyginia barbata* and *Calytrix fraseri* are examples of species having protracted flowering seasons including part of summer, although no species was recorded flowering throughout the year. The legumes (Fabaceae and Mimosaceae) are of special interest as a source of seeds for ants, birds and rodents (Majer 1978, Braithwaite & Gullan 1978). The pods of legumes in the study area (e.g. species of *Bossiaea*, *Gompholobium*, *Jacksonia* and *Oxylobium*) reach maturity, dehisce and release seed on to the ground mainly in summer (Dec.-Feb.), various species following each other in turn.

Table 6 gives the times of appearance of species with annual foliage, totalling 25 additional species not listed in Table 3. Several of these species have recently been introduced to Australia. Both indigenous and introduced annuals (mainly Poaceae and Asteraceae) and other herbs (mainly Orchidaceae and Haemodoraceae) are apparent only in winter and spring and wither by December.

The phenology of plants in the study area may be largely explained by rainfall, temperature and photoperiod (Speck 1952). There are two times of year when these factors might retard plant growth. In winter, minimum temperatures and photoperiod are reached, while in summer lack of moisture is the limiting factor. This divides the year into two periods favourable to plant growth. The shorter of these starts in late April or May with the first rains, and the longer period includes October. Possibly species flowering during the long summer drought are able to do so because of deep root systems which penetrate to the underground water (Speck 1952). However, the physiological adaptations which allow the tiny, shallow-rooted perennial herb, *Stylidium repens*, to flower in summer remain a puzzle.

The only other studies in Australia of plant phenology in areas of similar climatic and edaphic conditions are those of Patton (1933), Specht and Rayson (1957) and Groves and Specht (1965). The October peak of flowering in the study area agrees with that found by Patton (1933) and Groves and Specht (1965) for heath in coastal Victoria, but is a month earlier than that observed by Specht and Rayson (1957) for heath in eastern South Australia. Fewest species flower in April and May in the Victorian heath, agreeing with

Table 5. Flowering and fruiting times of plant species at Jandakot in alphabetical order. 1 = in bud, 2 = in initial flower, 3 = in full bloom, 4 = in waning flower, 5 = in green fruit, 6 = categories 1 and 5 simultaneously, * = record incomplete. Each month was divided into three equal and consecutive periods, denoted a, b and c.

Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc
Acacia huegelii					11	112	345					
Acacia pulchella		111	233	445	555	555	5					
Acacia stenoptera	333	344	445	55							112	222
Adenanthos cygnorum					1	122	233	344	444	555		
Amphipogon turbinatus				12	345	5						
Arnocrinum preissii					12	345						
Banksia attenuata					1	222	333	333	444	455		
Banksia ilicifolia					*3*							11
Banksia menziesii	444	444	445	555	5				122	222	333	
Beaufortia elegans						122	233	334	444	55		
Bossiaea eriocarpa			12	334	455	5						
Calectasia cyanea	222	233	344	444	445						1	111
Calytrix flavescens						111	112	233	444	55		
Calytrix fraseri					1	122	222	333	333	333	444	455
Cassytha sp. indet.						12	233	45				
Casuarina humilis		12	223	333	444	445	555					
Conostephium pendulum	233	333	334	445	5				111	111	112	222
Conostylis aculeata			1	122	333	445	5					
Conostylis aurea				122	333	444	55					
Conostylis juncea				12	345							
Conostylis setigera				122	333	445	5					
Dampiera linearis			1	112	233	444	55					
Dasypogon bromeliaefolius					11	233	455					
Daviesia juncea	222	333	444	555	55							
Daviesia nudiflora	12*											
Eremaea sp. aff. *E. fimbriata*				12	234	455	5					

Table 5 (cont.)

Species	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc
Eremaea pauciflora				1	123	344	555					
Eriostemon spicatus		111	223	333	445	55						
Eucalyptus marginata					111	122	334	5*		*16	66	666
Eucalyptus todtiana					666	666	*			6		
Gompholobium tomentosum					123	334	444	555	5			
Hemiandra pungens				12	333	445	5					
Hensmania turbinata			1	234	55							
Hibbertia huegelii			1	222	334	555						
Hibbertia hypericoides		2	333	333	334	444	555					
Hibbertia pachyrrhiza			1	223	344	55						
Hibbertia subvaginata		1	122	333	444	55						
Hibbertia aurea			12	333	455	5						
Hovea trisperma	233	344	555	555	55							12
Hypocalymma robustum		1	112	233	344	555	5					
Hypolaena exsulca					123	445						
Jacksonia furcellata					1	111	123	333	344	444	555	
Laxmannia ramosa	444	555	5							1	122	333
Laxmannia squarrosa				1	233	445	5					
Lepidosperma augustatum					*5*						*2*	
Leptomeria empetriformis				1	234	55						
Lechenaultia biloba					1	233	455					
Leucopogon conostephioides	333	344	455	555	55					1	122	223
Leucopogon kingianus		1	111	223	334	445	555					
Leucopogon pulchellus polymorphus		1	233	345	5							
Leucopogon racemulosus	445	555	55								12	333
Leucopogon strictus	333	444	455	5							12	233
Lomandra caespitosa			122	334	55							
Lomandra endlicheri	334	5										12
Loxocarya flexuosa				1	123	455						

Table 5 (cont.)

	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Arpil	May
	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc	abc
Lyginia barbata			33	344	444	444	444	444	444	445	5	
Lysinema ciliatum		12	233	333	444	455	555					
Melaleuca scabra						122	334	45				
Melaleuca seriata					111	233	344	55				
Melaleuca thymoides				111	233	344	55					
Mesomelaena stygia										*	333	445
Nuytsia floribunda						112	233	444	455			
Oxylobium capitatum	11	223	344	555	555							
Patersonia occidentalis				1	233	445	55					
Persoonia saccata						1	123	344	455	555	55	
Petrophile linearis				11	123	345	5					
Phlebocarya ciliata				112	233	445	5					
Phlebocarya filifolia					123	334	55					
Pithocarpa pulchella										1	234	5
Regelia inops					111	233	455	5				
Restio sp. indet.	333	344	444	55						1	122	223
Scaevola paludosa					123	345						
Schoenus curvifolius		12	233	345	55							
Scholtzia involucrata							112	333	334	455	5	
Stirlingia latifolia		1	111	233	455	55						
Stylidium brunonianum				111	233	445	5					
*Stylidium junceum**				1	234	5						
*Stylidium piliferum**				112	234	5						
Stylidium repens						12	222	333	334	444	444	455
Thysanotus triandrus					11	233	45					
*Xanthosia huegelii**			1	112	233	445	5					

* foliage largely withers after November

Table 6. Phenology of annuals and herbs bearing foliage only in winter and spring and wilting by December. The maximum cover of each species was less than 0.1% of the study area. * indicates perennial species.

Family and species	Time of peak flowering
APIACEAE	
Trachymene pilosa Sm.	late Sept.
ASTERACEAE	
Hypochoeris sp. indet. (introduced)	late Sept.
Millotia tenuifolia Cass.	early Oct.
Podotheca chrysantha Benth.	early-mid Oct.
Podolepis spp. indet.	early-mid Oct.
Ursinia anthemoides (L.) Gaertn. (introduced)	early Oct.
CENTROLEPIDACEAE	
Centrolepis drummondii (Nees) Hieron	mid Sept.
CRASSULACEAE	
Crassula sp. indet.	---------
CYPERACEAE	
Scirpus sp. indet.	mid Sept.
DROSERACEAE	
**Drosera erythrorhiza* Lindl.	---------
**Drosera menziesii* R.Br. ex DC.	Sept.
HAEMODORACEAE	
**Anigozanthos humilis* Lindl.	early Oct.
**Anigozanthos manglesii* D. Don	early Oct.
IRIDACEAE	
**Gladiolus caryophyllaceus* (Burm.f.) Poir. (introduced)	early Oct.
LILIACEAE	
**Burchardia umbellata* R.Br.	early Oct.
**Sowerbaea laxiflora* Lindl.	early Oct.
ORCHIDACEAE	
**Caladenia flava* R.Br.	early Oct.
**Caladenia discoidea* Lindl.	early Oct.
**Pterostylis recurva* ? Benth.	early Sept.
**Pterostylis vittata* Lindl.	early Sept.
**Thelymitra campanulata* Lindl.	mid Oct.
POACEAE	
Aira caryophyllea L. (introduced)	early Oct.
Briza maxima L. (introduced)	early Oct.
Stipa sp. indet.	mid Oct.
Poaceae, sp. indet.	Sept.-Oct.

the present study. In Victoria, where there is a more even distribution of rainfall through the year than in the study area, a slightly higher proportion (33% compared with 14%) of perennial species flower in summer, including several which flower throughout the year (Patton 1933, Groves & Specht 1965). However, Myrtaceae flower mainly in spring in Victoria (Groves & Specht 1965), although those in the study area (e.g. species of *Melaleuca, Calytrix* and *Scholtzia*) reach their peak in summer. These genera have also been found flowering in summer elsewhere on the Swan Coastal Plain (Diels 1906).

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