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DRAINAGE, SWAMP STRUCTURE AND VEGETATION SUCCESSION AT MELALEUCA PARK, NORTHERN SWAN COASTAL PLAIN

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ABSTRACT

The relationships between water-table, soil drainage, swamp structure and vegetation in Melaleuca Park are examined. Changes likely to occur in the vegetation as a consequence of lowering of the water-table by pumping from bores are suggested.

INTRODUCTION

Melaleuca Park (hereafter referred to as the Park) is situated on the northern Swan Coastal Plain ca. 25 km north-northeast of Perth between Wanneroo and Bullsbrook.

The Park consists of about 3000 ha of natural vegetation bounded on its south and west sides by pine plantations, on its east side by cleared farmland and market gardens and on its north side by natural vegetation (Royal Australian Air Force facilities and bombing range). It is controlled by the Western Australian Forests Department which set aside the land as a reserve "for conservation purposes and for providing a basis for future long term studies of the relative productivity and ecological stability of natural forest" (letter from Forests Department to Western Australian Naturalists Club, 3 December, 1974).

The Park is situated on the Bassendean Sand System, an area of highly leached Pleistocene sand dunes with sandy or peaty swamps in the interdunal depressions. The mean annual rainfall is approximately 840 mm (based on data from Wanneroo and from Pearce Airforce Base, Bullsbrook - Bureau of Meteorology, unpublished data).

The vegetation of the Perth region has been described by Speck (1952) and placed by Beard (1981) in the Bassendean Vegetation System. Havel (1968) used ordination techniques to assess the ecological factors determining the distribution of many plant species in natural vegetation north of Perth including sites in Melaleuca Park. In addition, Havel (1975), and Carbon (1976) have discussed possible changes to flora and fauna of the Bassendean Dune System if changes in water-table depth should occur following water extraction from the Gnangara Water Mound.

The Gnangara Water Mound itself, is a dome-shaped aquifer which owes its form to drainage at the Moore River on the north, the sea on the west, the Swan River on the south, and Ellen Brook on its eastern borders. A programme is underway to extract large quantities of water from the mound to supplement Perth's water supply, and there are fears that the consequent lowering of the water-table may ultimately lead to loss of coastal vegetation in its vicinity.

The study described here was carried out between June and February 1977, with the assistance of members of the Western Australian Naturalists Club.

METHODS

Forty-five sites were studied at the Park (see Fig. 1). The Park was also traversed several times to observe vegetation in areas between sites. Some plant species for the succession study were collected and identified by members of the Western Australian Naturalists Club during 1976; the remainder were collected and identified by the author in 1977.

Canopy cover of the vegetation formations was visually estimated using the categories 2-10%, 10-30%, etc. in conformity with recent vegetation classifications e.g. Beard-Webb (1974), Muir (1977). These estimates were checked by occasional line-transects. Average foliage density was determined using a Spherical Densiometer (type A) as described by Lemmon (1956).

Swamp depth was measured from the margin, where the aquatic or semi-aquatic vegetation gave way to *Banksia* woodland. This transition line was nearly always clearly visible and closely corresponded to a contour around the swamp edge. From at least two points on this transition line sightings were taken into the swamp using an Abney Level. Sightings were made onto a tree or in swamps without trees onto a pole which was place therein. The height of the target point above the swamp floor was then measured.

Swamp areas were calculated from 1:25,000 air photographs (June 1976) by drawing the boundaries of the swamps directly onto the photographs and then superimposing on them a grid of squares of known area.

Soil moisture samples were taken at 0.5 m depth at each site and placed immediately into thick plastic bags and sealed. Samples were weighed in the laboratory, then dried at 100°C in a draight until their weight was constant. Finally, they were cooled to room temperature and weighed again. Water content was expressed as percentage by weight of the original sample.

Soil profiles were examined and described (Appendix 1) to a depth of 2 m or to the water-table (whichever came first) according to the methods of Northcote (1971). Soil pH was determined with a Pye Unicam (Model 293) pH meter. Samples were prepared by mixing 20 grams of soil with 100 c.c. 0.01 M calcium chloride solution and agitating for five minutes before testing. Total soluble salts were determined using a Philips PW9504 conductivity meter fitted with a PW9510 electrode. Samples were prepared in the same way as those for pH, but deionised water rather than calcium chloride solution was used in sample preparation.

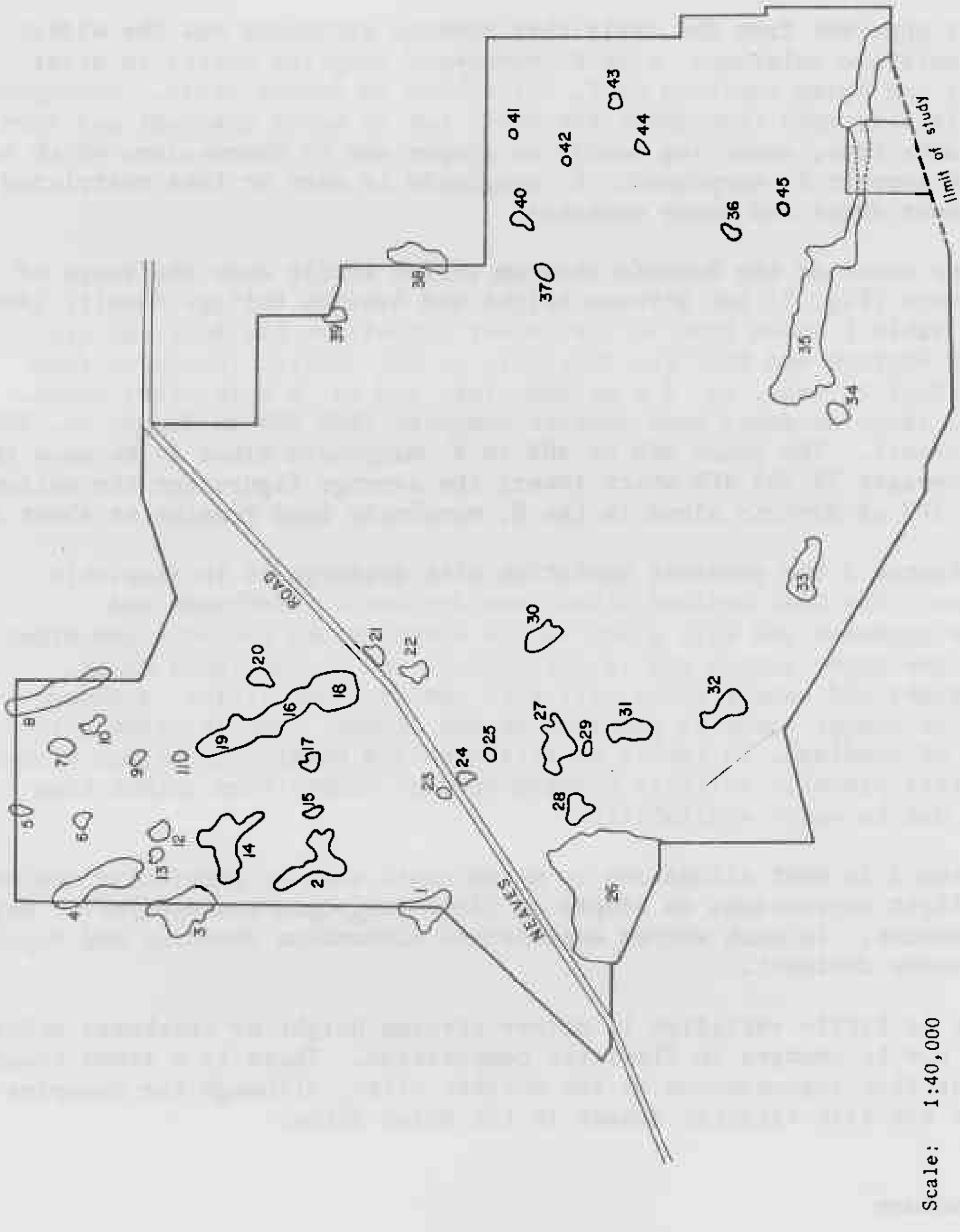

Fig. 1. Melaleuca Park, showing locations of swamps studied.

RESULTS AND DISCUSSIONS

Drainage and woodland physiognomy

About 90% of the Park is woodland of varying composition and structure; the remainder is swampland. Table 1 shows variation in dominance and physiognomy of woodland between the driest, best drained areas (dune tops) and the damper poorly drained areas (interdunal depressions).

It is apparent from the table that *Banksia attenuata* has the widest range of moisture tolerance, with *B. menziesii* adapting better to drier conditions and being replaced by *B. ilicifolia* in damper soils. *Eucalyptus todtiana* is scattered throughout the Park, but is never dominant and rarely found on dune tops, occurring mostly on slopes and in depressions which are too dry to support *E. marginata*. *E. marginata* is more or less restricted to the damper areas and swamp ecotones.

Canopy cover of the *Banksia* stratum varies little over the range of soil moisture (Fig. 2) but stratum height and Average Foliage Density (AFD) do vary. Table 1 shows that in the driest situations the Banksias are shorter in stature and that the thickness of the stratum (distance from bottom to top) is less, ca. 3 m on dune tops and ca. 8 m in other areas. Similarly, trees on dunes have sparser canopies (AFD 30% on dunes, ca. 50% in other areas). The lower AFD of 40% in *E. marginata* areas is because this species averages 25-30% AFD which lowers the average figure for the entire stratum. AFD of *Banksia* alone in the *E. marginata* zone remains at about 50%.

In stratum 2 the greatest variation with drainage is in floristic composition. The best drained sites have *Jacksonia floribunda* and *Adenanthos cygnorum* and this gives way to *Xanthorrhoea preissii* and other shrubs on the upper slopes and in depressions and *E. marginata* areas. Stratum height and canopy cover vary with species composition, although variation in canopy cover is greatest on the slopes. AFD in stratum 2, like that of woodland, is lowest on hill tops and marginally higher elsewhere, although this probably reflects changed species composition rather than variation due to water availability.

Stratum 3 in most situations is mixed heath with no particular dominants. In very slight depressions on slopes or flats *Dasypogon bromeliifolius* may become dominant. In much wetter depressions *Adenanthos obovatus* and *Regelia ciliata* become dominant.

There is little variation in either stratum height or thickness other than that due to changes in floristic composition. There is a trend towards denser post-fire regeneration in the moister sites, although the canopies themselves are also slightly denser in the drier sites.

Swamp Structure

Ten percent of the area of the Park is wetland of various types, from open swamps to damp depressions. The majority of swamplands are interdunal depressions. Figure 3 illustrates that in 35 of the 45 (78%) wetlands examined there is a direct relationship between depth and area. This would be expected where interdunal depressions are saucer-shaped and the swamp floors are of slightly varying height above the water-table.

Table 1. Variation in characteristics of vegetation at sites varying from highest to lowest points.

Character	Stratum	Dunes & tops of Rises	Slopes & Flats	Depressions within woodlands	Eucalyptus marginata areas
Dominants	1.	Banksia attenuata B. menziesii	B. attenuata B. menziesii Scattered B. ilicifolia	B. attenuata B. ilicifolia Scattered B. menziesii	B. attenuata B. ilicifolia E. Marginata
Height of bottom of stratum		4 m	2 m	2 m	2 m Jarrah 3 m
Height of top of stratum		7 m	10 m	10 m	10 m Jarrah 14 m
Canopy Cover		2-10%	2-10%	2-10%	2-10%
Average Foliage Density		50%	50%	50%	40%
Dominants	2.	Jacksonia floribunda Adenanthos cygnorum	Xanthorrhoea preissii or X. preissii - mixed shrubs	X. preissii	X. preissii
Height at bottom of stratum		0.5 m	0-0.5 m	0 m	0 m
Height at top of stratum		4 m	0-5.2 m	1.5 m	1.5 m
Canopy Cover		2-10%	0-20%	2-10%	2-10%
Average Foliage Density		10%	15%	15%	15%
Dominants	3.	Mixed shrubs	Mixed or mixed shrubs Dasypogon bromeliifolius	Adenanthos obovata, Regelia ciliata mixed shrubs	Mixed shrubs
Height at bottom of stratum		0 m	0 m	0 m	0 m
Height at top of stratum		0.5 m	0.5 m	1 m	1 m
Canopy Cover		30%	2-30%	30-70%	70-80%
Average Foliage Density		40%	30%	30%	30%

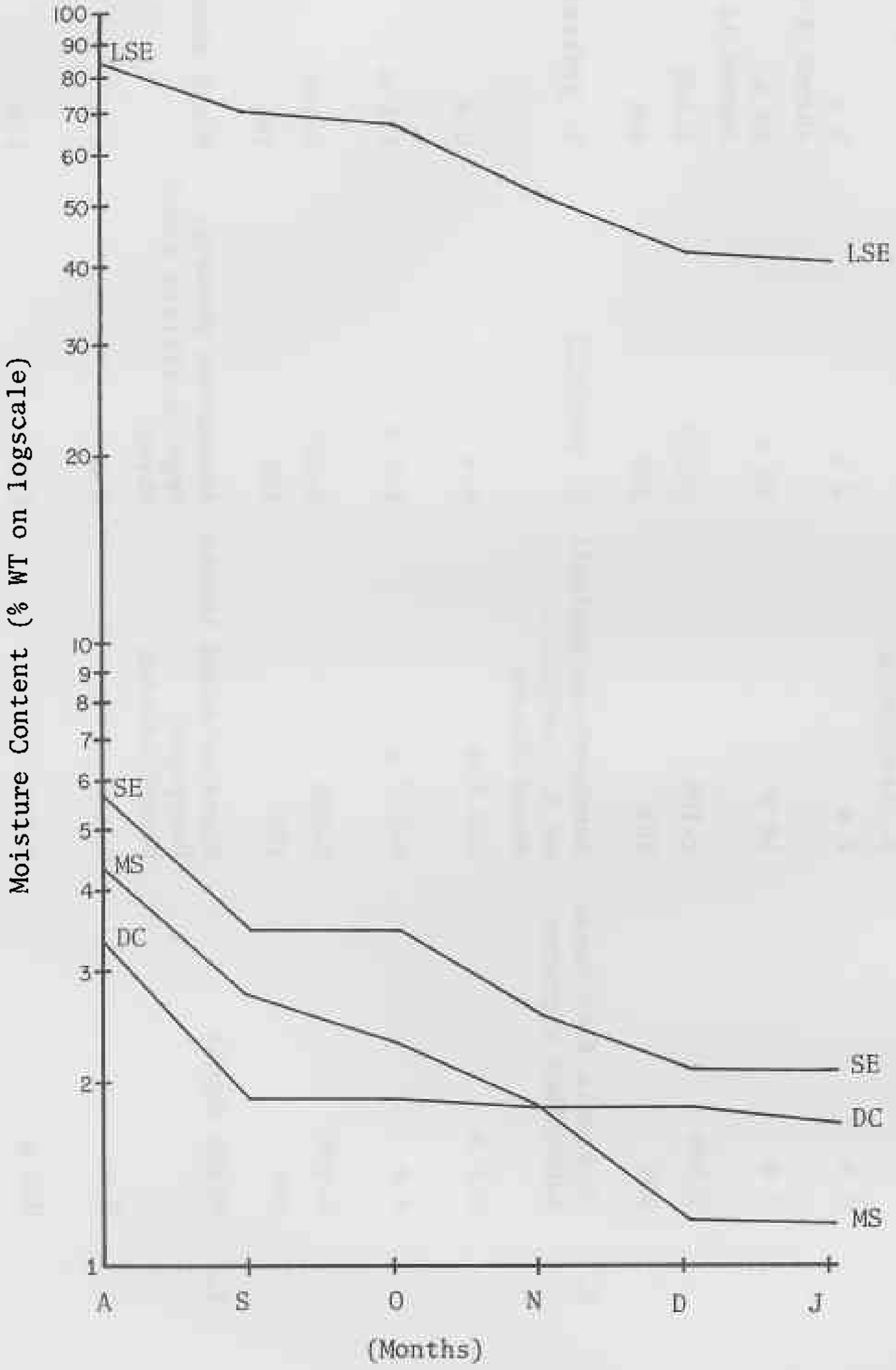

Fig. 2. Variation in soil moisture content over spring and early summer.

DC = dune crest
MS = midslope
SE = swamp edge
LSE = lower swamp edge

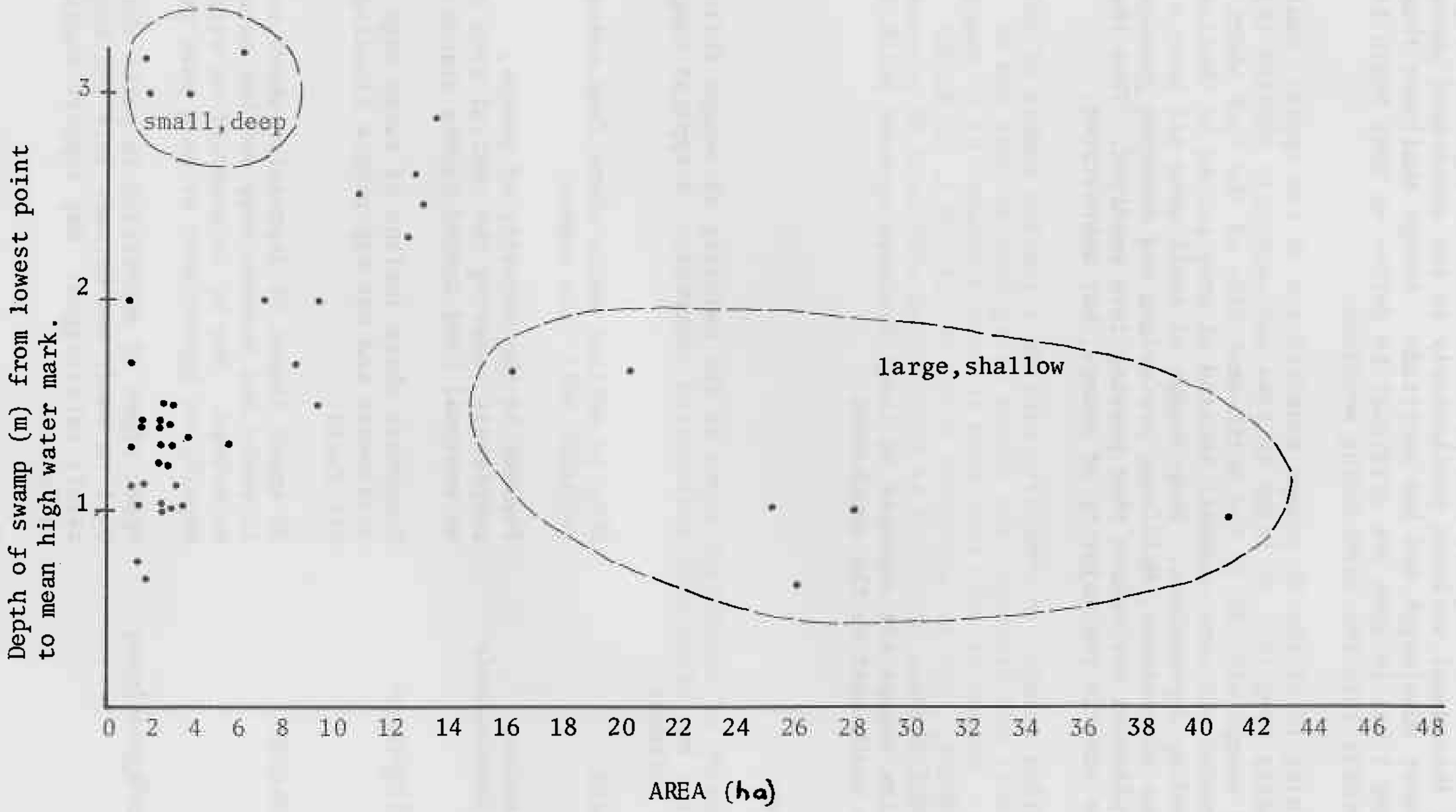

Fig. 3. Relationship between swamp depth (lowest point to mean high water mark) and area as determined from air photographs. Note the almost linear relationship, except for a few small, very deep swamps, and a few large, shallow ones.

This proposition is supported by observations that 25 of the 45 (56%) swamps are less than 3 ha in area, and that 10 of these are in the south-east corner of the Park. Regular dune patterns would be expected to produce numerous small interdunal wetlands particularly to the south-east where dunes are of short wavelength and low amplitude. Swamps shallower than 1 m and smaller than 1 ha. in area are difficult to define as they begin to merge imperceptably into the surrounding woodland.

The remaining 10 of the 45 swamps examined are of two types: small in area and unusually deep (4), or large in area and unusually shallow (6). The small deep swamps are all in the north-west side of the Park where dunes are more pronounced and were commonly located at deep points in shallower north-west-trending depressions. Deep swamps of small area all have a similar sequence of ecotones, *Melaleuca preissiana* and *Astartea fascicularis* passing into *Pultenaea reticulata* then passing into woodland. Thus the sequence is the same as the majority of swamps, but abbreviated.

Broad shallow swamps, in contrast, provide a greater number of subtle variations in soil and drainage, the slopes being much broader and of lesser incline. Swamps of this type tend to have dominatns or co-dominants not found elsewhere, such as *Eucalyptus rudis* in stratum 1, or *Agonis linearifolia, Calothamnus lateralis* or *Leptocarpus scariosus* in stratum 2. The broad shallow swamps are remnants of large drainage systems which formerly drained to the south-east or the south-west.

Swamp Succession

The succession of vegetation types in the majority of swamps follows a difinite pattern, but often with abbreviated sequences. A typical complete sequence is as follows:

Baumea articulata	Only in wettest areas where free water persists well into summer.
Melaleuca preissiana over *Astartea fascicularis*	Present in the majority of swamps, completely covering the central area or as an ecotonal band around *Baumea* stands.
Leptospermum ellipticum	Commonest where incline of swamp edge is shallowest and may experience flooding in wet years.
Pultenaea reticulata	On upper slopes of depression where soil is peaty and becomes very wet but rarely waterlogs. May be in association with *Regelia* or *Hypocalymma* or as a pure stand.
Regelia ciliata/Hypocalymma angustifolium	Upper edges of depression in parts where soil is sandy and becomes very wet but rarely waterlogged. May support *Eucalyptus rudis*.
Banksia woodland	The transition from *Regelia/Hypocalymma* to *Banksia* woodland may have complex sub-ecotones of *Eucalyptus marginata, Dasypogon bromeliifolius Xanthorrhoea preissii.*

This basic sequence has numerous subtle variations, some of which are:

1. *Baumea articulata* is more or less restricted to the wettest swamps which are commonly also the best for peat development. As a consequence the two largest of the six swamps with *Baumea* have already been mined and their *Baumea* stands all but destroyed.

2. *Melaleuca rhaphiophylla* may replace *M. preissiana* in some swamps or occur together with it. In all cases *M. rhaphiophylla* frequents the wettest soils, usually those where the water-table lies above the surface during winter.

3. *Leptospermum ellipticum* is absent from many of the swamps, the majority passing more or less directly from *M. preissiana/Astartea fascicularis* stands directly into *Pultenaea*, *Regelia* or *Hypocalymma*. I believe its limited distribution is due to a preference for broad shallow swamp edges. Such a habitat is, of course, easily altered by minor changes in water level.

4. Occasionally, on the steepest sides (usually western) of swamps, or in swamps which are passing rapidly into woodland and have almost lost their identity, *Adenanthos cygnorum* and *Verticordia nitens* are abundant. These species do not form part of the swamp succession but grow opportunistically in the best drained locations where water is freely available. Where they occur in deep depressions in *Banksia* woodland they occupy sites of old swamps now filled with sand. This sand is well drained but abundant water is available at depth. For the same reasons, these species (particularly *A. cygnorum*) are very abundant on dune tops and in areas of regrowth following clearing of road verges. In all these situations water is available at depth (with additional runoff on road verges), and yet the topsoil is disturbed or otherwise very well drained.

5. *Banksia ilicifolia* penetrates further into the swamp than any other species of *Banksia*. The *Banksia* woodland on swamp edges may be of the form discussed in "*Eucalyptus marginata* areas" or "Depressions within woodland" in Table 1 above.

6. *Kunzea ericifolia* may be present as scattered plants or as a dominant throughout any of the drier ecotones.

7. *Pultenaea reticulata* appears to be very dependent on the depth of the water-table. The dry winters of 1976 and 1977 caused very high mortality on swamp margins throughout the Park.

Changes in Water Level

McComb and McComb (1967) state that the water level in Loch McNess (situated ca. 22 km north-west of the Park) could possibly have risen in the past, and that there appears to be a succession from open water, through sedge communities, to woodland. Records show that water levels in Lake Jandabup, ca. 6 km to the south-west of the Park, have risen slowly over the last 100 years, presumably as a result of clearing of surrounding vegetation and the increased runoff from roadways and buildings (A. Douglas, pers. comm.)

In the Park there is strong evidence to indicate that the water-table has fallen and that sand from adjacent dunes has begun to move into some swamps. *Melaleuca preissiana* sometimes occurs in two distinct belts separated by dense

Leptospermum ellipticum stands: an outer belt of large, very old trees, and and inner belt of much younger ones. A similar sequence sometimes occurs where there is an outer belt of *Melaleuca rhaphiophylla* (to 10 m tall and up to 1 m in girth) outside a belt of *M. preissiana* (6 m tall and mostly less than 15 cm in girth). As *M. rhaphiophylla* prefers waterlogged winter conditions and *M. preissiana* prefers drier sites, this sequence indicates that the stands of *M. rhaphiophylla* are probably remnants from a period with a much higher water-table. A decline in the water-table has allowed *M. preissiana* to establish itself within the *M. rhaphiophylla* band. Presumably the water-table declined so quickly that a slow advance of *M. rhaphiophylla* was not possible.

Such successions suggest a decline in water-table as well as a filling in of swamps with sand. In a few places in the Park, scattered senescent or dead *M. preissiana* trees are visible in areas of woodland, suggesting that a swamp was once present which has now been totally reclaimed by woodland and the depression completely filled in. Matiski (per. comm.) has also noted such sand filled swamps at Tick Flat, 15 km north of the Park.

Some swamps show sand fill gradually moving in from the edges, although they may be well vegetated at present. Swamps may have peat at depth as much as 10 m outside the present peat to sand transition area (see profiles, Appendix 1).

CONCLUSIONS

Assuming that the water-table will undergo severe local lowering near boresites as pointed out by Havel (1975), it is unlikely that the vegetation will be able to cope with the proposed water extraction programme at the Gnangara Water Mound and many plants will die. Havel's figure 13 shows death of Marri (*Eucalyptus calophylla*) trees near such a bore. Havel points out however that there should also be a moderate, slow decrease in the overall water-table. The data presented here indicates some of the changes in vegetation which may occur.

Specifically, *Banksia menziesii* can be expected to replace *B. attenuata* on dune slopes, being better adapted to drier conditions. *Banksia attenuata* will probably persist in damper areas but *B. ilicifolia*, being very dependent on moisture availability, may succumb completely. It has been observed by myself, by J. Dell (pers. comm.) and by R. Hunt (pers. comm.), that many species of insects and some birds may be dependent for food on the nectar of these *Banksias*. The flowering times of the three species overlap very little, one ceasing to flower when another is beginning. This provides an almost continuous nectar supply throughout the year. Either the loss of *B. ilicifolia* or a reduction in the abundance of *B. attenuata* could seriously affect dependent fauna.

Other changes to be expected are decreases in stratum height and average foliage density as sites become drier. The significance of stratum height and density to bird utilisation of habitats is well recognised (Cody 1965; Hilden 1965; MacArthur and MacArthur 1961).

Changes in floristic composition occur concurrently with changes in structure. The loss of particular plant species may be important to the habitat of ground fauna. For example *Dasypogon bromeliifolius*, which is likely to be lost, except perhaps in the remnants of swamps, is thought to provide shelter for reptiles (G. Barron, pers. comm.; G. Harold, pers. comm.).

Adenanthos obovatus, which exists only in damp (not swampy) locations, is likely to decline as such sites dry out following a fall in water table. This species in the Park has been observed by J. Dell (pers. comm.) to be a major food source for the Western Spinebill (*Acanthorhynchus superciliosus*).

Leptospermum ellipticum and *Astartea fascicularis* could also be expected to decline. The significance of these species to native fauna is not known, but they both have been observed to attract many species of insects, including Jewel Beetles (Astereidae). Some of these insects could be important in the diet of insectivorous fauna.

The observations that *Melaleuca preissiana* replaces *M. rhaphiophylla* in some swamps suggest a decline in water-table in relatively recent times. It is not known if this decline is a consequence of a natural change in climate or of alteration of the environment by man. It is however an indication that changes to drier conditions have occurred and it increases the likelihood that any future man-induced changes to the water-table may have further drastic effects.

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APPENDIX 1 - TYPICAL SOIL PROFILES

Soil profiles were examined in a number of sites and are set out in some detail below. The soils were of two types: almost pure quartz sand, strongly leached, on dune tops and slopes (woodland areas); and peat with various proportions of sand in depressions and swamps. Sandy soils were all acid, dune tops averaging pH 3.8 and woodland flats and slopes pH 4.2 (average of 30 cm and 1 m samples taken March and July). The acid pH on slopes is probably due to a higher organic content (see profiles). Total dissolved salts (TDS), was very low on both dune tops and slopes, averaging 25 ppm and 30 ppm respectively.

Swamp vegetation is on soils of peaty origin. The centre of open swamps examined averages pH 4.9 and 200 ppm TDS. The higher pH than woodland soils is probably the result of some sort of buffering effect by the peat. The higher TDS may reflect a "sink" effect for salts from surrounding dunes. If this is so, one would expect higher salt content in the swamps than is apparent.

It was noted that surface water appeared in swamp B Fig. 1 in late March although there had been no rainfall for several weeks previously. Corresponding to this rise in water-table was the appearance of a white or yellow efflorescence on the peat surface about 0.5-1 m outside the advancing edge of the water surface. This efflorescence dissolved completely in 10 cc distilled water and gave pH 3.2 and 12000 ppm TDS. The efflorescence is assumed to be a soluble organic salt derived from peat together with inorganic salts.

Water samples in swamps 1, A and B were taken at time of highest water level (August) and averaged pH 4.4 and 200 ppm TDS.

Typical Soil Profiles

Top of dunes

0-50 cm non-pedal, structureless, poorly coherent, excessively drained, white, sand with ca. 5% organic dust and numerous fine plant roots. Average pH March 4.0, July 3.7.

50-200 cm as for 0-50 cm horizon above but organic dust and plant roots virtually absent. Average pH March 3.8, July 3.7. Average TDS March 20 ppm.

Slopes and flats

0-5 cm as for 5-200 cm sample but with ca. 5-10% organic dust and some plant roots.

5-200 cm non-pedal, structureless, poorly coherent, well to excessively drained, white, sand with organic dust virtually absent but some plant roots. Average pH 30 cm March 4.1, July 3.7, 150 cm March 4.2, July 3.7. Average TDS March 150 cm 30 ppm.

Pultenaea reticulata band

0-1 cm as for 20-200 cm horizon.

2-20 cm as for 20-200 cm horizon with traces of peat and some decomposing litter. This horizon may represent a period of exceptionally high water-table and temporary inundation of this ecotonal band.

20-200 cm slightly pedal, slightly structure, moderately coherent, well drained, white, sand with ca. 10% organic dust and numerous fine plant roots. Average pH 30 cm March 3.8, July 3.5, 100 cm March 3.3, July 3.0 Average TDS March 100 cm 60 ppm.

Astartea fascicularis band

0-4 cm white sand with ca. 5% organic dust.

5-10 cm white sand with decomposed litter and traces of peat.

10-14 cm slightly pedal, structured (finely layered), moderately coherent, well to poorly drained, white sand with ca. 20-25% peaty dust and particles to 2 mm.

14-15 cm as for 5-10 cm horizon with slightly less organic matter. This horizon may represent a period of high water-table preceding that (and slightly less high) indicated in 2-20 cm horizon of *Pultenaea reticulata* band above.

15-35 cm pedal, structureless, coherent, poorly drained, fibrous peat with some sand. Average pH 25 cm March 3.8, July 3.9 Average TDS March 25 cm 90 ppm.

35-200 cm highly pedal, slightly structured, finely layered, very coherent, poorly drained, indurated fibrous dark brown peat. Average pH 100 cm sample March 4.0, July 3.9. Average TDS March 100 cm 90 ppm.

Melaleuca parviflora band

0-35 cm pedal, structureless, very coherent, non-fibrous, black peat. Poorly drained (very damp, March). Average pH 25 cm March 4.9, July 4.5.

40-50 cm pedal, structureless, very coherent, sand with very high peat content. Soil wet. Average pH 50 cm March 5.2, July 4.9. Average TDS March 180 ppm.

50 cm onwards saturated.

Centre of Swamp

0-5 black peat as for 18 cm onwards.

6-18 cm white flocculent material, probably ash from burnt peat.

18-100 cm highly pedal, structureless, very coherent greasy, non-fibrous, black, peat. Very poorly drained, very wet. Average pH 50 cm March 5.0, July 4.8. Average TDS March 200 ppm.

102 cm onwards, below water-table.

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