RELATIONSHIPS BETWEEN TREE SIZE AND MEAN WATER LEVEL IN DUNAL SWAMP FORESTS OF THE LOWER NORTH COAST OF NEW SOUTH WALES

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ABSTRACT

This paper presents the results of a study which measured the depth of the water-table and/or surface water in several swamp forests in the Port Stephens and Lake Macquarie areas over a period of ten months.

Highly significant negative correlations were found between mean water level and size of *Melaleuca quinquenervia*. Hypotheses are suggested to explain large numbers of fallen and/or dead trees at some of the sites sampled.

INTRODUCTION

Melaleuca quinquenervia and, to a lesser extent, *Eucalyptus robusta* dominate swamp forests occurring on coastal sands along the lower north coast of New South Wales. This wetland type typically occurs in dunal swales or in low lying areas along the interface between sand plains and adjoining bedrock where groundwater is at, or close to, the surface.

Although the relationship between a shallow water-table and the occurrence of swamp forest is well identified (e.g. Myerscough & Carolin, 1986), there are few data on the range of water-table depth that typically occurs in swamp forests, with most available data being in the form of single measurements of the depth of groundwater (see examples in Table 1).

Data collected over a longer period would have particular relevance to swamp forests which occur in close proximity to areas subject to increasing urbanisation, where localised changes in surface runoff and groundwater depths can generally be expected to occur, raising the question of the impact of predicted hydrological changes of the swamp forest. This question has been difficult to answer due to the lack of data on the natural hydrological regime of the swamp forests. The present study was initiated to provide some data which could assist in addressing this issue in the future.

METHODS

Sampling was undertaken at 23 sampling points at 11 sampling sites in swamp forests in the Port Stephens and Lake Macquarie areas. The location of sampling sites is shown in Figure 1.

Care was taken to locate most sites where the ground water and/or surface water regimes were not subject to recent substantial disturbances, as would be evidenced by dieback in the trees, implying a degree of stability in the current ground water and/or surface water regimes. Four sampling points (5, 7a, 7b, 11c) were purposefully located in areas where there was evidence of recent disturbance in the form of dead or fallen trees.

At two sites (3 & 4) it was possible to sample a relatively steep environmental gradient. At each of these sites, three sampling points were placed along the gradient.

Measurements of the depth of the water-table and/or depth of surface water were undertaken at each sampling point at weekly intervals between February and December 1994 using piezometric wells at fixed datum points. The number of weekly samples taken at each point ranged from 17 to 40, due to later establishment dates for some sites and some missed weeks due to factors such as vandalism of piezometric tubes.

Data were also collected at each point on the height and diameter (dbh) of at least 25

Site	Brief Description of Vegetation	Date	Groundwater Depth (m)	Reference
Wetland 899a Wyong	*M. quinquenervia 8-10m high, 0.2-0.3 m dbh.* Understorey dom. *Gahnia clarkei, Blechnum indicum.*	Apr-91	0.9	Andrews.Neil (1991)
		May-91	0.86-0.97	Douglas & Partners (1991a)
Wetland 896 Wyong	*M. quinquenervia 8-10m high, 0.2-0.3 m dbh.* Understorey dom. *Gahnia clarkei, Blechnum indicum.*	Apr-91	0.76-1.3	Andrews.Neil (1991)
Wetland 911 Avoca	*M. quinquenervia*	1990	0.7	Andrews.Neil (1990)
Near Salamander Bay	*M. quinquenervia*	Nov-89	0.4	Coffey & Partners (1989); SWC (1989)
Wetland 527 Dunbogan	*M. quinquenervia*	May-90	0.6	Douglas & Partners (1990) Kendall & Kendall (1991)
		May-91	0.92	Douglas & Partners (1990) Kendall & Kendall (1991)

Table 1: Examples of available data on water levels in swamp forests.

trees (stems), being the trees nearest the water sampling point, although the size and shape of the area sampled depended on the density of the trees and the steepness of the environmental gradient.

Soil profile textural data were collected at most sites to assist with site description.

Water (ground or surface) samples were collected from 18 of the sample points and analysed for pH (using a hand-held pH meter) and orthophosphate and nitrate (using a Chemetrics multi-filter photometer and Chemetrics reagents). High turbidity prevented the use of the photometer on some samples.

Plant scientific names used in the text follow Harden (1990-3).

DESCRIPTION OF SITES

Tomago-Stockton Sandbeds

Sites 1 & 2
These two sites were located in two separate swamp forests on sand near Fern Bay, in the northern suburbs of Newcastle. They occur close to the interface between the Newcastle Bight sand dunes and estuarine alluvium associated with Fullerton Cove.

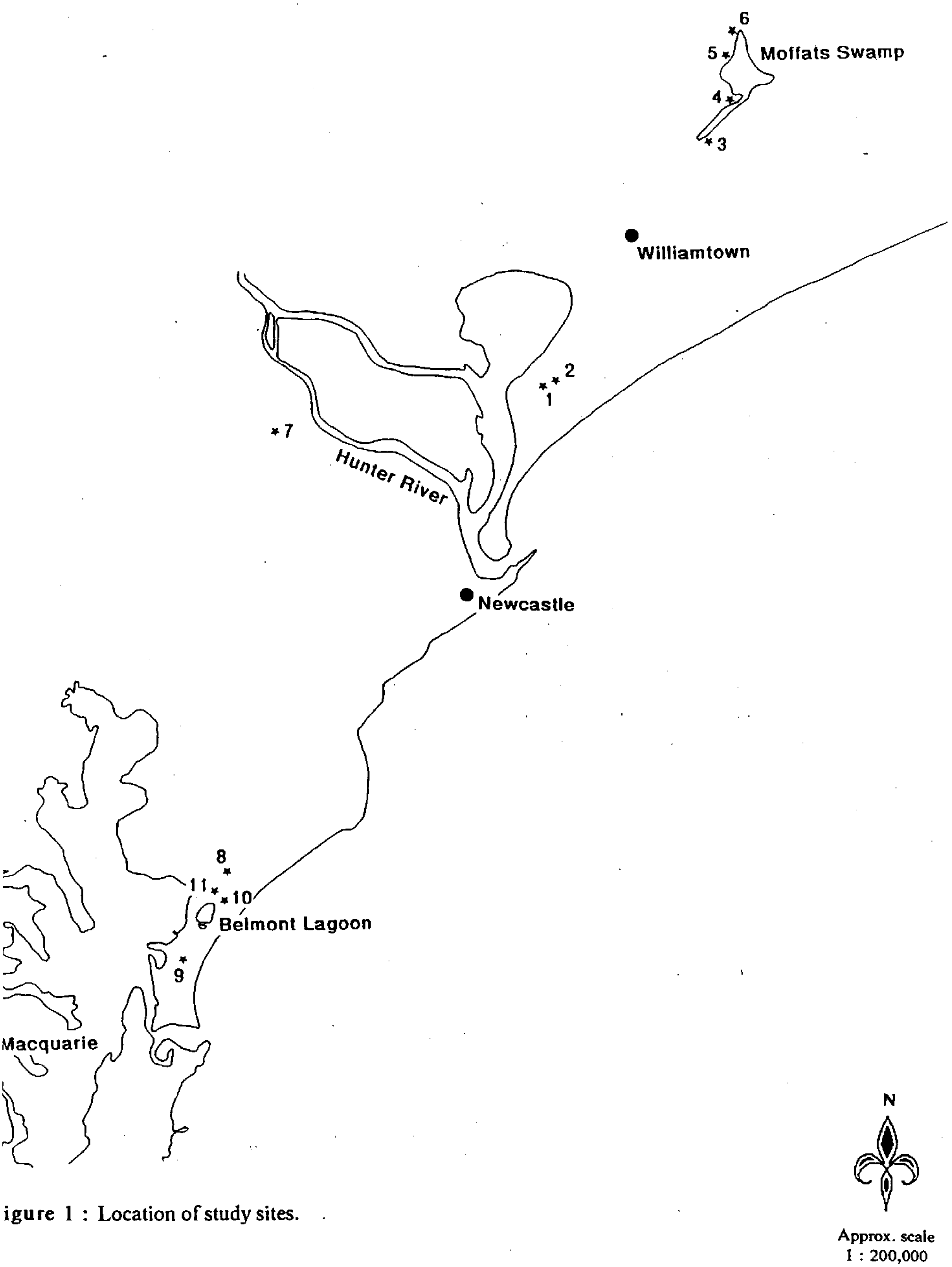
Two sampling points were established at site 1 and one point at site 2. In addition to *Melaleuca quinquenervia* some *Eucalyptus robusta* was present at points 1a (20% of sampled trees being *E. robusta*) and point 2 (16% *E. robusta*). *Casuarina glauca* was present at point 1a (24%).

The understorey vegetation comprised a wide range of species but was relatively homogeneous between all points, with characteristic species including *Blechnum indicum, Gahnia clarkei, Persicaria strigosa, Carex neurochlamys* and *Omalanthus populifolius*.

Sites 3 to 5
These sites were located on sands around Moffats Swamp, which occurs along the interface of the Tomago sand beds and bedrock-derived soils around Medowie.

Sites 3 and 4 each comprised three sampling points placed along a relatively steep topographical and environmental gradient. This was evidenced by the decrease in size (height and diameter) of *Melaleuca quinquenervia* with the drop in height of the land surface along this gradient.

In addition to large *Melaleuca quinquenervia,* sampling point 3a supported a high proportion of *Eucalyptus robusta* (32%) as well as a small number of *Angophora costata* (12%). *Blechnum indicum* clearly dominated the understorey with other common species including *Entolasia marginata* and *Lepidosperma*



igure 1 : Location of study sites.

longitudinale.

Trees of *Melaleuca quinquenervia* were smaller and denser at points 3b and 3c. These points remained inundated during the study period and supported little emergent vegetation.

Sampling Point 4a had an understorey dominated by *Blechnum indicum* with other common species including *Baumea rubiginosa* and *Villarsia exaltata*. Points 4b and 4c supported dense stands of small *Melaleuca quinquenervia* and were inundated throughout the study period, with little emergent vegetation.

Site 5 was located in close proximity to Medowie wastewater treatment works. This site was flooded throughout the survey period, possibly as a result of localised changes in the groundwater height resulting from the discharge from the wastewater treatment works. Many fallen *Melaleuca quinquenervia* trees were evident in the vicinity of the sampling point (Shortland Wetlands Centre, 1992), and a number of trees were observed during the study period to have fallen after periods of strong winds (J. Clarke, pers. obs.), although no supporting data were collected. Due to the constant inundation during the study period understorey vegetation comprised aquatic plant species, with characteristic species including *Triglochin procerum* and *Lemna minor*.

Medowie

Site 6
This site was located on the northwestern edge of Moffats Swamp on loam to clay soil (sampled to a depth of 1.1 m). Sampling point 6a had an understorey dominated by *Ischaemum australe, Baumea articulata* and *Blechnum indicum.* Scattered *Acacia elongata* and *Acacia longifolia* were also present at this point. The dominant understorey species at point 6b were *Baumea rubiginosa* and *Baumea articulata* with *Blechnum indicum* being much less common than at point 6a.

Shortland Wetlands

Site 7
This site was located within a swamp forest at Shortland Wetlands Centre which has been subject to a range of historical impacts, including increase in permanence of inundation. This change in water regime could be attributed to a build up of a relatively impervious layer of fine sediment over the original sandy soil, which has promoted a ponding effect. Increased runoff from the surrounding urban catchment would also be a major contributory factor (pers. obs.).
Many of the larger *Melaleuca quinquenervia* trees in the centre of the swamp have fallen and/or died. When flooded, this site has little understorey vegetation apart from scattered aquatic herbs, especially *Triglochin procerum,* but when dry supports a dense cover of *Paspalum distichum* and other amphibious herbs.

Belmont Sands

Sites 8 to 11
These sites were located within the barrier dunes between Lake Macquarie and the Pacific Ocean in the vicinity of Belmont, a highly urbanised area.

Sampling points at site 8 included a proportion of *Eucalyptus robusta* (40% at 8a and 4% at 8b). The understorey was diverse, with typical understorey species included *Blechnum indicum, Gahnia clarkei* and *Omalanthus populifolius*.

The two sampling points at site 9 were vegetatively similar in character with an understorey comprising an almost monospecific stand of *Blechnum indicum.*

The two sampling points at site 10 were also similar to each other in character with typical understorey species including sparse *Phragmites australis, Hydrocotyle bonariensis* and *Persicaria strigosa.*

Site 11 was placed within a large area of standing dead *Melaleuca quinquenervia* trees. Sampling point 11c was flooded for almost the whole study period and supported no understorey vegetation. The other two points (11a & 11b) supported understorey vegetation which varied with degree of inundation, with typical species being *Persicaria strigosa* giving way to *Paspalum distichum* as the swamp dried up.

WATER LEVELS

The lowest and highest water levels recorded at each sampling point during the study period are presented in Table 2 and shown graphically in Figure 2.

which remained inundated for the duration of the study (exhibited a range between 0.53 m and 1.29 m above ground level). With a few exceptions, the water level at each point varied approximately 0.8 m. Substantially different ranges were recorded at three sites (6,7 &8).

	Sample Point	WATER LEVEL (datum=ground level) (m)			MELALEUCA TREES Height (m)		dbh (m)	
		Lowest	Highest	Mean	Mean	SE	Mean	SE
Tomago- Stockton Sandbeds	1a	-0.55	0.28	-0.29	16.52	0.93	0.36	0.03
	1b	-0.53	0.18	-0.11	17.49	0.97	0.29	0.02
	2	-0.53	0.29	-0.09	17.69	1.26	0.25	0.02
	3a	-0.49	0.45	-0.10	22.48	2.46	0.47	0.04
	3b	0.26	1.00	0.51	13.69	0.42	0.20	0.02
	3c	0.53	1.29	0.80	4.91	0.17	0.06	0.01
	4a	-0.27	0.66	0.16	10.41	0.78	0.23	0.03
	4c	0.30	1.06	0.55	4.14	0.15	0.04	0.00
	4b	0.16	0.91	0.43	5.14	0.11	0.08	0.01
	5	0.21	0.95	0.46	14.12	0.82	0.16	0.01
Medowie	6a	-1.50	0.41	-0.40	12.71	1.58	0.31	0.05
	6b	-0.71	0.52	0.03	16.03	0.85	0.26	0.02
Shortland Wetlands	7a	0.29	0.50	0.42	8.99	0.44	0.22	0.02
	7b	0.09	0.33	0.23	7.35	0.28	0.16	0.01
Belmont Sands	8a	-1.50	-1.37	-1.41	18.79	0.35	0.27	0.02
	8b	-0.38	-0.05	-0.20	18.14	0.77	0.29	0.02
	9a	-0.82	0.01	-0.46	17.04	0.92	0.33	0.02
	9b	-0.75	-0.02	-0.40	20.24	0.85	0.41	0.02
	10a	-0.81	0.05	-0.42	14.50	0.65	0.17	0.01
	10b	-0.85	0.03	-0.43	14.06	0.62	0.15	0.01
	11a	-0.67	0.65	-0.23	7.83	0.85	0.14	0.02
	11b	-0.60	0.30	-0.02	9.60	0.75	0.12	0.01
	11c	0.00	0.66	0.40	8.08	0.60	0.12	0.01

Table 2- Summary of water level and *Melaleuca* tree size data

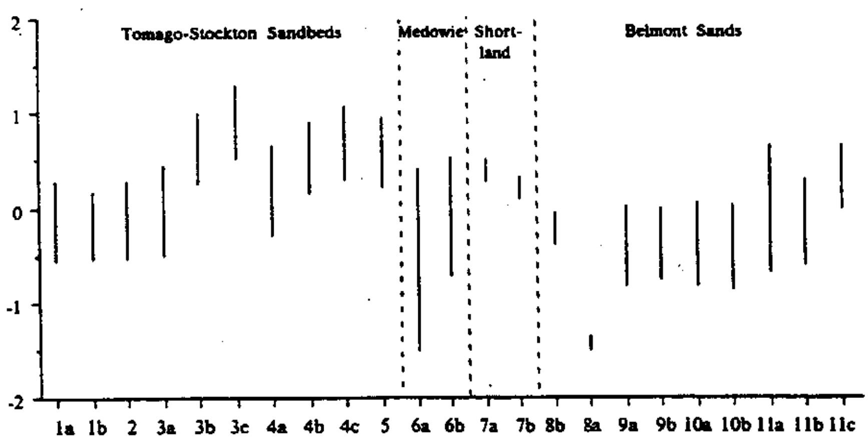


Figure 2: Range of water level (m) recorded for each sampling point (datum = ground level).

Considering all points collectively, extremes of water level occurred at points 8a, which was not inundated during the study (exhibited a range between 1.50 m and 1.37 m below ground level), and 3c,

The larger ranges in water level recorded at site 6 (1.91 m for point 6a and 1.23 m for point 6b) are attributed to the clay soil which effectively prevented infiltration and caused ponding of rainwater at the surface.

The earlier measurements, which were taken when the site was not flooded recorded the depth of groundwater whereas later measurements recorded the depth of surface water only. Unlike sites in sandy soils, on clay soils the surface can be inundated without necessarily a rise in groundwater.

The smaller water level ranges at site 7, which were surface water only, (0.21 m for point 7a and 0.24 m for point 7b) are also attributed to the clay soil. This site remained inundated throughout the study period and the measurements represented the depth of ponded water rather than any fluctuations in groundwater.

No hypothesis is suggested for the smaller ranges recorded at site 8 (0.14 for point 8a and 0.33 for point 8b).

A comparison of rainfall data for 1994 with monthly average rainfall for Williamtown (see Figure 3) indicates that rainfall during the study period approximated the average (the Tomago-Stockton Sandbeds are in close vicinity to Williamtown; a similarly close station is not available for the other sites). The water levels recorded during the study are assumed to approximate long term average water levels at the sites. However, it is acknowledged that a number of other factors can influence groundwater depth.

WATER LEVEL AND TREE SIZE

Empirical observations have suggested that the size (height and diameter) of *Melaleuca quinquenervia* varies with average depth of water / groundwater (G. Winning, pers. obs.).

The data from the sampling sites within the Tomago-Stockton Sandbeds produced a highly significant correlation between mean water level and mean tree height ($r = -0.788$, $p<0.01$, $n=10$, $df=8$) as well as between mean water level and tree diameter ($r = -0.860$, $p<0.01$, $n=10$, $df=8$). This correlation was weaker for sites on the Belmont Sands, being significant for height ($r = -0.699$, $p<0.05$, $n=9$, $df=7$) but not statistically significant for diameter ($r = - 0.461$, $p>0.05$, $n=9$, $df=7$). For all of the sites combined, the correlations remained highly significant for both height ($r = -0.639$, $p<0.01$, $n=23$, $df=21$) and for diameter ($r = -0.541$, $p<0.01$, $n=23$, $df=21$).

The data suggests a correlation between water level and tree size on sandy soils, although this does not necessarily reflect a direct cause and effect relationship.

It is important to note that the correlation was not consistently strong at all study sites. It is possible that anthropogenic influences on water regime have affected

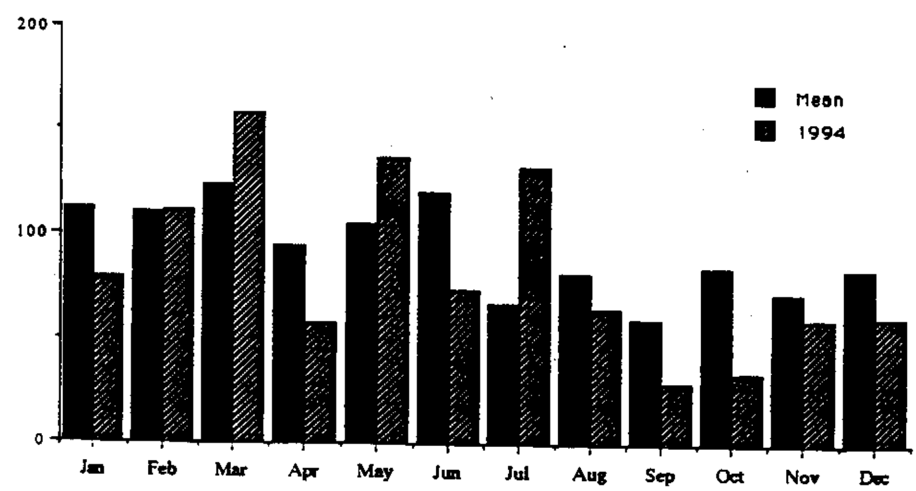


Figure 3: Average (39 year) and 1994 rainfall (mm) for Williamtown. (source: Bureau of Meteorology)

the relationship at some sites. This hypothesis would need to be tested by more extensive collection of tree size and water level data.

TREE DIEBACK

At two of the sites (5 and 7) a number of large *Melaleuca quinquenervia* trees have fallen, and at another sampling point (11c) there were numerous dead standing trees. Although this study did not aim to identify the causes of these problems, observations made during the study have raised hypotheses which may explain them.

Prolonged inundation by water results in all soils pores being filled with water at the expense of air, leading to soil anoxia. This anoxia and associated increased levels of reduced minerals in wetland soils creates a hostile environment for most plants. Those species which thrive in wetlands have structural adaptations which enable them to transport oxygen to their roots directly from the air or from some other aerobic environment in times of inundation. Many wetland tree species develop root adaptations which allow the roots to take oxygen from the air or from the relatively aerobic water inundating the soil on which they grow (Mitsch & Gosselink, 1993).

Melaleuca quinquenervia responds to flooding by developing a dense mat of fine adventitous roots from lateral roots just below the soil surface, with tips protruding above the surface (Sena Gomes & Kozlowski, 1980). These roots would allow respiration in the plant's root system using oxygen taken from the overlying water. These fine roots would be expected to die back during a prolonged dry period, although this is not mentioned in the literature.

The study by Sena Gomes and Kozlowski (1980) showed that short term inundation (up to 60 days) did not substantially affect the vigour of the overall root system in seedlings of *Melaleuca quinquenervia*. However, it is suggested here that prolonged inundation would affect the vigour of deeper roots, especially in larger plants.

At the Shortland Wetlands site, fallen live *Melaleuca quinquenervia* trees typically exhibit a dense growth of fine surface roots but larger, deeper-penetrating roots are dead. This observation suggests a hypothesis that may, at least in part, explain tree fall in hydrologically modified wetlands. Structural stability of large trees in strong winds is provided by deep roots, which could establish and survive under the previously inferred intermittent water regime. The change to more prolonged flooding and the resulting soil anoxia has resulted in the death of deeper roots and their replacement by small shallower roots, which are less able to support the trees in strong winds.

A similar scenario is assumed for site 5 where effluent discharge from the Medowie wastewater treatment works into the wetland is likely to have caused localised changes in groundwater levels. In addition, removal of part of the eucalypt forest surrounding Moffats Swamp to allow construction of the wastewater treatment works has exposed the *Melaleuca quinquenervia* stand to strong westerly winds (Shortland Wetlands Centre, 1992).

Numerous dead standing trees were present at the Belmont site 11. The death of these trees is considered unlikely to be a result of prolonged inundation involving a water regime as documented by the data collected by this study. Trees at other sites appear to survive similar degrees of inundation. It is not known whether the current water regime at site 11 differs from that which prevailed at the time the trees died. Based on the available data it is not possible to suggest a hypothesis which might explain the many dead trees at site 11.

WATER CHEMISTRY

Limited opportunistic sampling of water chemistry was undertaken as part of this study, although not all sites were sampled (sites 8 and 10 were not sampled). Of the samples taken, the mean pH was 6.7 with a range of 5.4 to 8.9.

Orthophosphate for most samples was below or close to the detection limit of 0.01 mg/L, with the exception of sites 5 (4.52 mg/L) and 7 (1.71 & 0.27 mg/L). Site 5 is adjacent to the effluent discharge point of

Medowie wastewater treatment works, which would provide a source of nutrients. Site 7 is subject to periodic sewerage overflows and is the location of a seasonal egret breeding colony, faeces from which would provide an additional source of nutrients.

Nitrate levels were also low with the highest record being 0.19 mg/L (point 4a) and most samples being below or close to the detection limit of 0.01 mg/L.

IMPLICATIONS FOR DEVELOPMENT NEAR *MELALEUCA* SWAMPS

Although the data from this study have shown that *Melaleuca quinquenervia* is capable of surviving in a range of water regimes, there is evidence that substantial changes to water regimes, especially increased permanency of inundation, can weaken the tree's root structure resulting in dieback and tree fall.

Large urban developments on sandy soils have the potential to alter groundwater and surface runoff regimes, thereby altering the water regime in adjacent swamps forests. If such alterations are substantial enough, they are likely to lead to dieback of the swamp forest.

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