A PRELIMINARY ASSESSMENT OF THE RECENT ENVIRONMENTAL HISTORY OF LAKE GORE – ESPERANCE WESTERN AUSTRALIA

A TECHNICAL REPORT FOR
THE DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
WESTERN AUSTRALIA

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EXECUTIVE SUMMARY

Lake Gore was cored in February 2003 to profile recent environmental changes and determine contemporary and historical rates of sedimentation.

A 35,000-year-old sedimentary archive was retrieved from the lake and the Holocene section (last 10,000 years) of the core was analysed in detail.

During the mid Holocene a relatively salt intolerant flora dominated by *Casuarina* sp gave way to more salt tolerant flora dominated by Chenopods with *Melaleuca* sp becoming progressively more important.

This pattern of vegetation change suggests that the Lake Gore was relativly saline between five and six thousand years ago, a situation which appears to have persisted to the present.

Rates of sediment accumulation were determined for Lake Gore and were found to have increased from historical levels of less than 8 mm per century to a current rate of around 400 mm per century, a 50 fold increase.

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INTRODUCTION

The Dalyup Catchment lies 35 km west of the south-coast town of Esperance and covers an area of 82607 ha. It has been extensively cleared for agriculture and less than 10% of it comprises remnant native vegetation (AgWest 2001). The Dalyup and West Dalyup Rivers are the catchment's main watercourses and drain in a southerly direction to Lake Gore (Figure 1). These rivers are ephemeral and flow in response to winter rains. Some summer flow may also occur due to groundwater seepage (Water and Rivers Commission 2002).

Lake Gore is a saline lake with an area of 738 ha. It is a sub-terminal basin and drains into number of secondary lakes in response to exceptionally large flow events. It is relatively shallow with a maximum-recorded water depth of around 2 m (AgWest 2001). Lake Gore is a Ramsar listed conservation wetland. It supports one third of the world's population of Hooded Plover (*Thinornis rubricollis*) (Rose and Scott 1997), in addition to being an important refuge for many other species of aquatic bird, including global migratory species (Lane et al 1996). It is a conservation estate of international significance (Jaensch and Watkins 1999).

A number of serious land degradation issues affecting the Dalyup Catchment have been identified (AgWest 2001, Water and Rivers Commission 2002). These include secondary soil salinity, wind and water erosion, waterlogging, water repellent soils and siltation of channels and lake basins. These issues impact directly upon the quality and sustainability of agricultural production and the environment, and in particular, the viability of Lake Gore as a conservation wetland.

In recognition of the conservation value of Lake Gore this study intends to examine aspects of the lake's changing environment, and in particular to gain insights into the lake's environment prior to recent agricultural development. Specifically, the objectives are to:

- Analyse and interpret various paleoenvironmental proxies from the lake's sedimentary record.

- Outline recent environmental change, specifically, rates of sedimentation and gross changes in catchment vegetation.

- Determine a chronology of recent environmental change.

- Provide a foundation for further, more-detailed, paleoenvironmental work on Lake Gore and the Dalyup catchment.

To accomplish this sediment cores were retrieved from the lake and analysed using standard techniques for paleoenvironmental reconstruction. Core chronology was established using radiocarbon dating and historical data with associated sedimentary signatures where available.

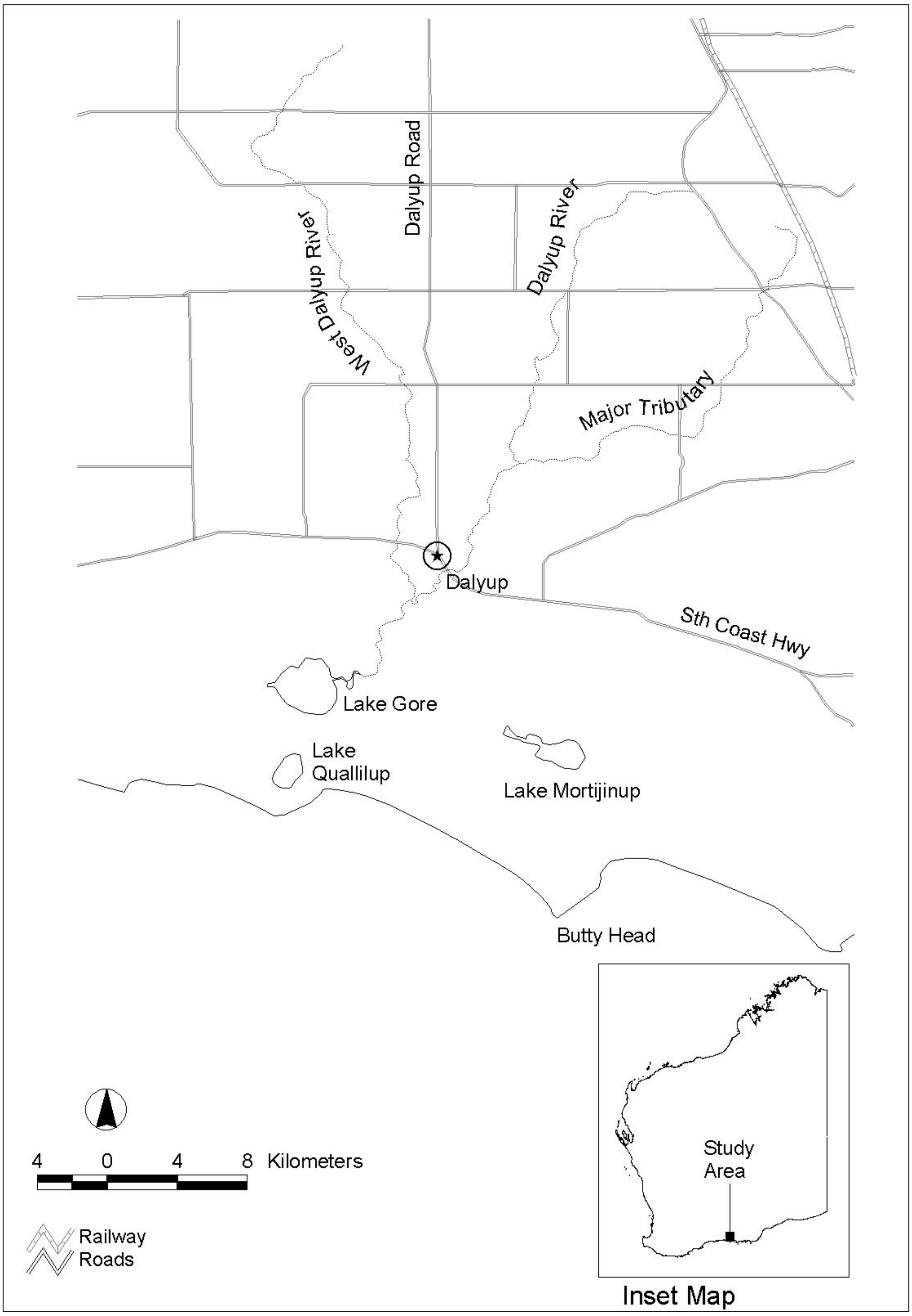

Figure 1. Location of Lake Gore and major watercourses of the Dalyup Catchment.

METHODS

Field Work

The components of lacustrine sediment most useful for environmental reconstruction are deposited as fine-grained sediment that is invariably most concentrated in the deepest part of the lake, well away from basin entrances or exits. The centre of Lake Gore was judged to be its deepest point on the basis of both field observation and aerial photographs and was cored on 27 February 2003. Cores were taken using a top-hammer system to drive 50mm diameter PVC pipes into the lake substrate and were retrieved using a tripod and winch arrangement (Figure 2). This system has been used extensively in environmental and palynological studies of Western Australian lacustrine and fluvial environments (eg, Picket 1997, Wilson and Eliot 2001). Cores were stored at 4°C in a cool room at the School of Earth and Geographical Sciences, UWA. Prior to sampling, cores were split, photographed and described.

Figure 2. Retrieving a core from Lake Gore.

Palynology

Initially, cores were sampled at 10 cm to a depth of 90 cm. This depth was judged sufficient to encompass both European and pre-European depositional regimes. When a clearer understanding of the core's chronology was achieved, finer (1 cm) intervals were sampled to resolve the exact depth that recorded the transition to a European influenced landscape.

Ten cubic centimeter sediment samples were treated with 10% potassium hydroxide, 10% hydrochloric acid and 48% hydrofluoric acid. Resulting pollen concentrates were then acetylised and sieved through 5 μm nylon mesh before dehydration and mounting in silicone oil (2000 centistoke) (Faegri and Iversen 1989).

Pollen preparations were examined using an Olympus BX-60 microscope. Approximately 200 pollen grains were identified at each sample depth. Pollen spectra were constructed using the program Tilia 2.0 and then analysed using the stratigraphicaly constrained cluster analysis package CONYIS (Grimm 1987), which allows objective identification of distinct zones within the pollen stratigraphy.

Total Phosphorous

Sediment samples were digested in perchloric acid. Digests were neutralised to p-nitrophenol endpoint, diluted, and the resulting orthophosphate was spectrophotometricaly determined using the molybdenum blue method (Sommers and Nelson 1972).

Radiocarbon Dating

Organic particles extracted from the sediment were submitted to the Rafter laboratory of the New Zealand Institute of Nuclear Sciences for accelerator mass spectrometry dating (AMS). Particles were harvested from the sediment using a 10-micron sieve. Mineral matter was removed with HCl and HF and the remaining material was given an alkali/acid treatment followed by further washing with milliQ water. Particle integrity was checked under a microscope before samples were submitted for AMS analysis.

RESULTS

Coring yielded 3 cores ranging from 1.65m to 2.9m in length. The longest of these, Gore 2, was chosen for analysis.

Core Description

A log of the core is given in Figure 3. The core's lithology comprises 4 distinct elements; an upper marl unit (0-98cm); a middle gypsum-clay unit (98-233cm); a narrow calcium carbonate unit (233-239cm); and a basal marl unit (239-274cm).

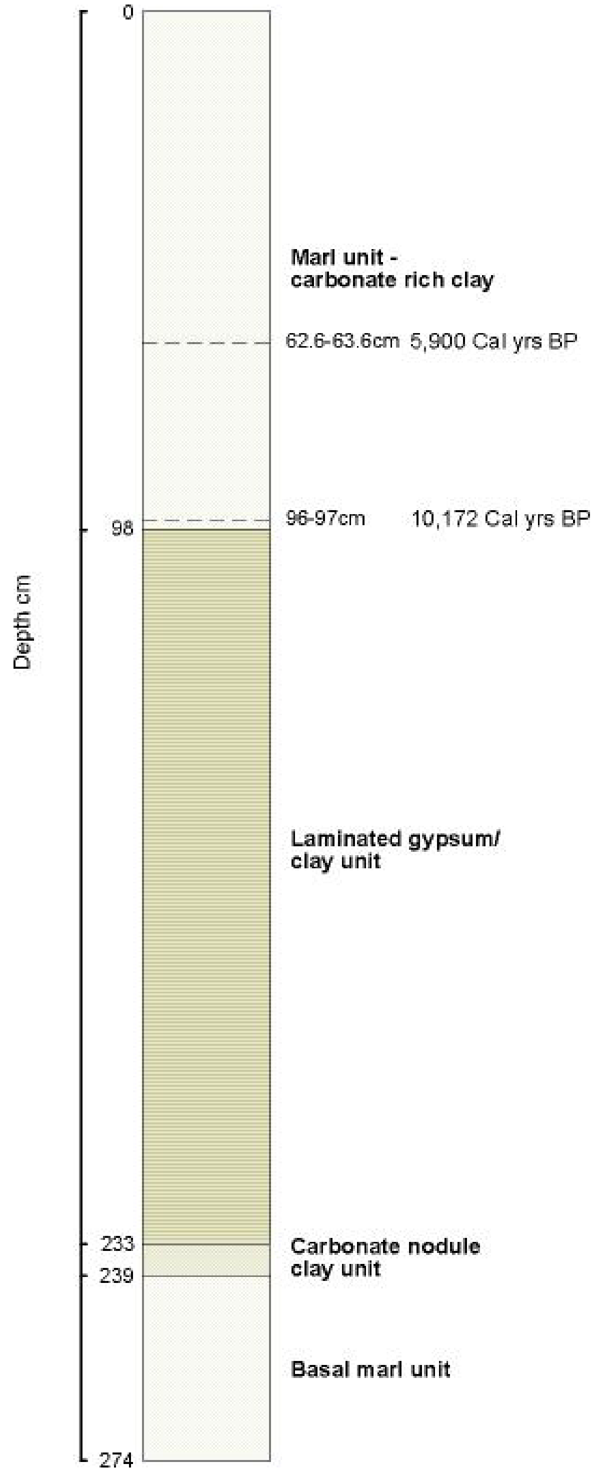

Figure 3: Log of the core Gore 2.

Upper marl unit: Massive, relatively undifferentiated carbonate rich clay. It has a relatively consistent gray color (5B 5/1) with the exception of a paler (5Y 7/1) band extending from 56 to 62cm. Some weak gypsious banding is apparent between 92 and 95cm.

Gypsum-clay unit: This unit comprises an upper laminated sequence of alternating white gypsum and dark clay bands and a lower massive clay sequence.

Calcium carbonate unit: Undifferentiated sequence comprising weakly cemented carbonate nodules and gravel.

Basal marl: Massive, undifferentiated, dark (5G 5/1), carbonate rich clay reminiscent of the upper marl unit.

Palynostratigraphy and Vegetation Dynamics

The pollen spectrum and CONISS dendogram for the top 90 cm of the core is given in Figure 4. The spectrum and dendogram indicate 3 principal pollen zones are present.

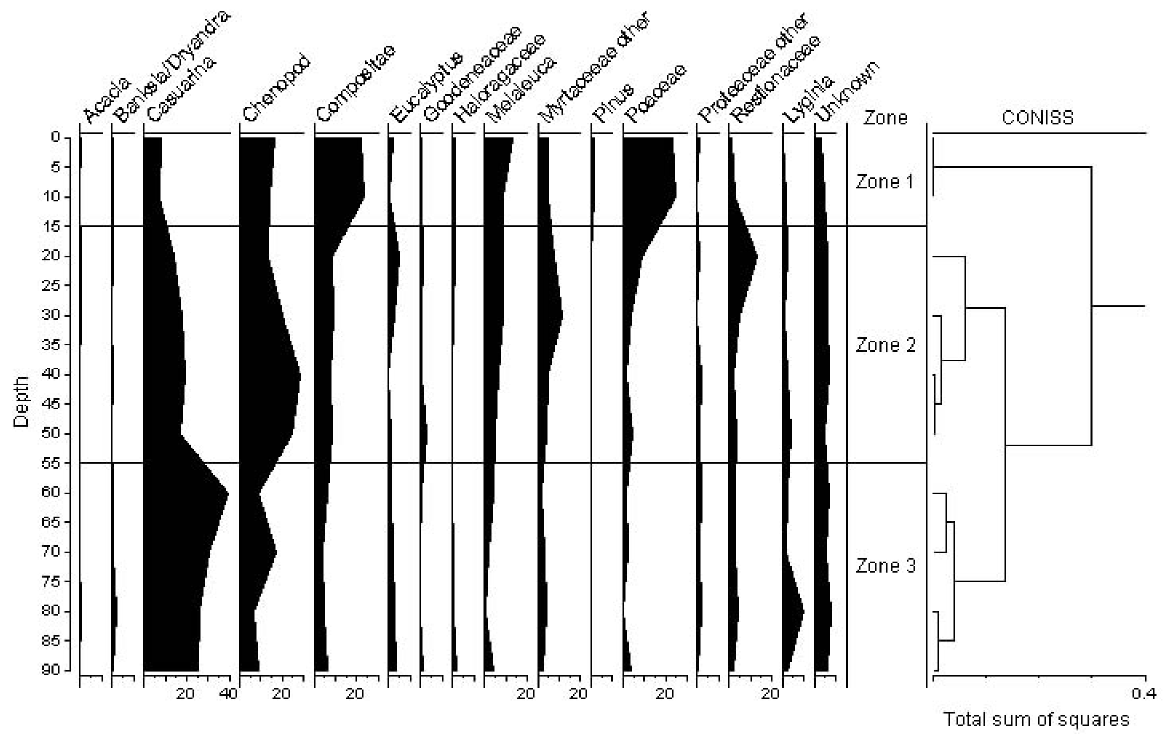

Figure 4. Pollen spectrum (% of total) and CONISS dendogram.

The upper zone (0-15cm) is characterised by an abundance of Compositate and Poaceae pollen and the presence of *Pinus* pollen. The zone is unique, a feature reflected in the total sum of squares statistic differentiating it from the two lower zones. It indicates a disturbed, European influenced landscape; one distinguished by a profusion of pioneer and weed species and the presence of an exotic taxon (*Pinus*).

The second zone (15-55cm) is characterised by native plant assemblages dominated by chenopods. The third zone (55-90cm) is characterised by native plant assemblages dominated by *Casuarina*. Across the three zones there is a suggestion of *Melaleuca* abundance decreasing with depth.

Figure 4 shows that the transition from a pre-European to a European influenced landscape is recorded between 10 cm and 20 cm. To define the transitional depth at a higher resolution, samples were taken at 1 cm intervals between 10cm and 20 cm. The presence or absence of *Pinus* pollen, and the abundance of Poaceae and Compositae pollen, as a proportion of the total pollen count, was determined for these samples.

The deepest occurrence of *Pinus* pollen was observed in the 17-18 cm sample. Data indicating the abundance of Compositae (dasies) and Poaceae (grasses) pollen as a proportion of the total pollen count are given in Figures 5 and 6. Both figures show a dramatic increase in the importance of these taxa occurs at a depth of 19-20cm.

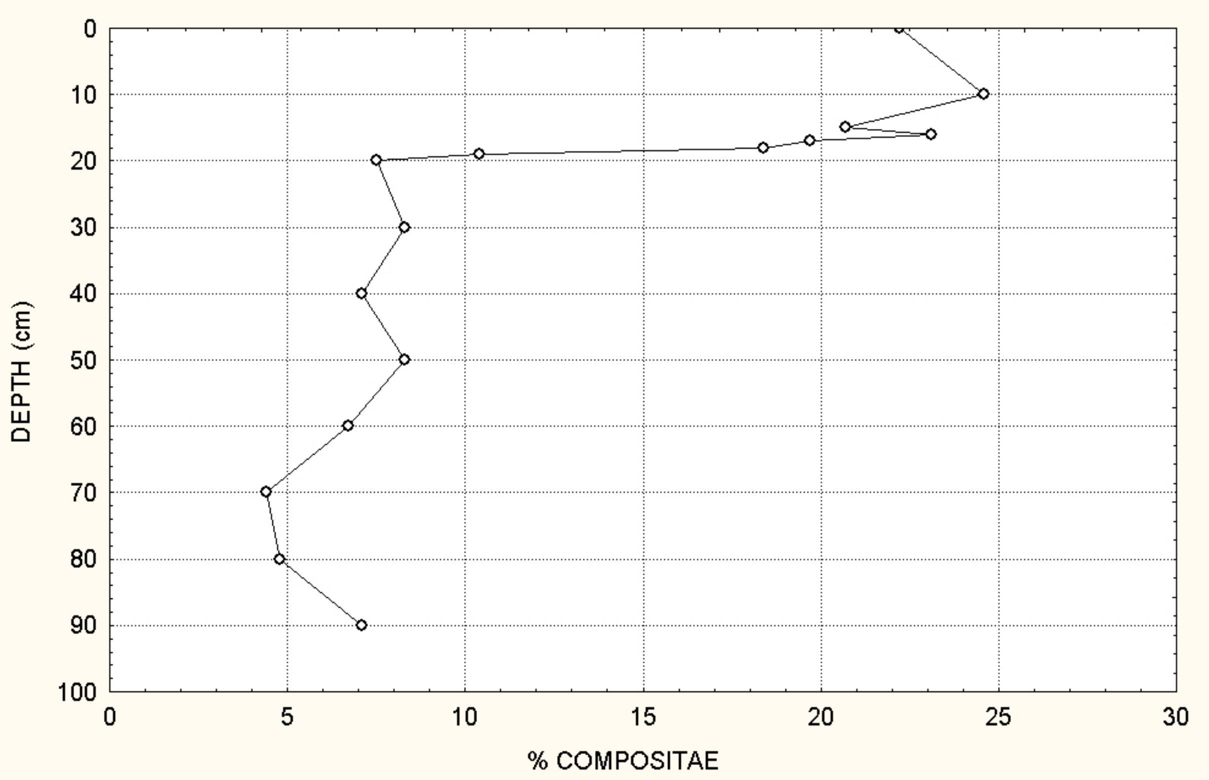

Figure 5. Abundance of Compositae pollen.

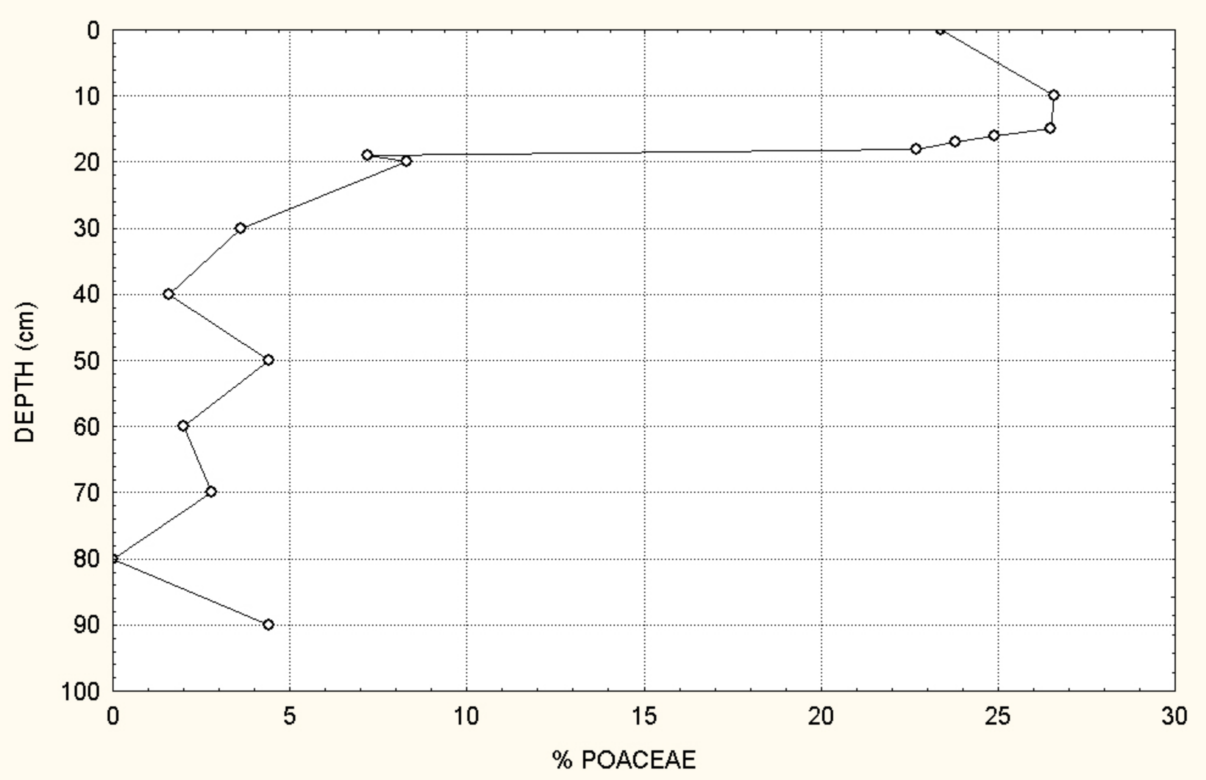

Figure 6. Abundance of Poaceae pollen.

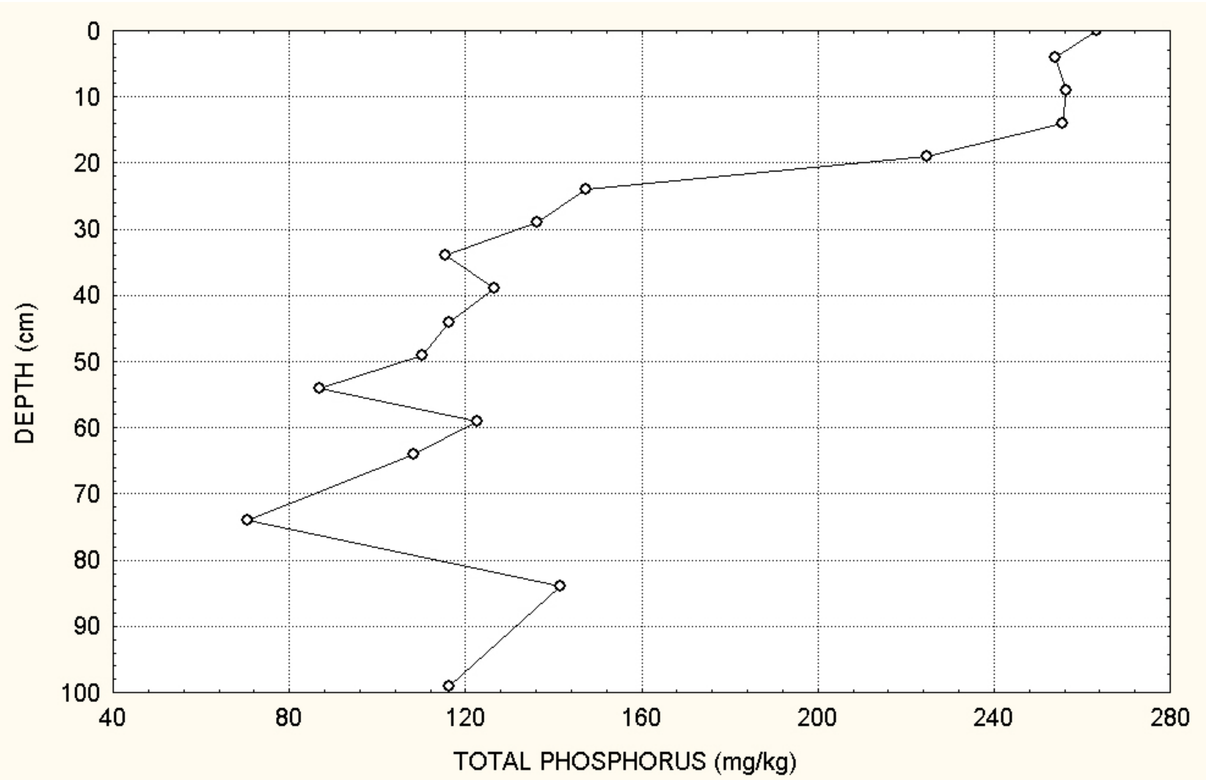

Figure 7. Total phosphorous stratigraphy.

Total Phosphorus Stratigraphy

The total phosphorus stratigraphy is given in Figure 7.

Chronostratigraphy

Radiocarbon Chronology: Details of the radiocarbon chronology are given in Table 1.

Depth (cm)	$\delta^{13}C$ per mille	CRA BP	Cal Age BP
62.6-63.6	-23.9	5130±40	5906
96-97	-24.6	8968±50	10172
200-201	Failed		
239.5-240.5	-24.4	33980±490	n/a

Table 1. Radiocarbon dates for Gore 2 core.

Chronologies derived from the historical record: Pollen of exotic plants such as pines can be used as chronostratographic markers provided the time of their initial cultivation can be established (eg, Hancock et al 2001). Landscape disturbance may perturb plant community structure which will ultimately be recorded in the palynostratigraphy. Again, this can provide a chronometric device provided the time of disturbance can be established (eg, Brooks and Grenier 2001).

Total phosphorous stratigraphy can also used as a chronometric tool. Dodson and Lu (2000) demonstrated phosphorous enrichment in the surface sediment of Byenup Lagoon in response to agricultural practices. Other chemical species, such as heavy metals, exhibit patterns of enrichment in sediment profiles that correlate with their emission chronology. (Forstner and Wittman 1981).

Agricultural development of the Esperance sandplain did not prove to be economically viable until after the discovery of local trace element deficiencies the 1950's (Murray 1985, Water and Rivers Commission 2002). Large scale clearing of the Dalyup catchment with concomitant application of superphosphate started around 1955 (Murray 1985, Water and Rivers Commission 2002, Joy Marold *pers comm*, Murray Richter *pers comm*, Tom Button *pers comm*). Pine trees were supplied to farmers in the Dalyup catchment throughout the 1960's by the WA Forestry Department for use as wind breaks (Joy Marold *pers comm*, Murray Richter *pers comm*, Tom Button *pers comm*). Joy Marold and her father planted pine trees along McCalls Rd, adjacent to Lake Gore, in 1968 (Joy Marold *pers comm*). This information is summarised in Table 2.

Stratographic Attribute	Depth (cm)	Date
Appearance of *Pinus* pollen	17-18	1960
Plant Community Perturbation	18-19	1955
Elevated Total Phosphorous	19	1955

Table 2. Historically derived chronologies for Gore 2 core.

Rates of Sediment Accumulation

Sediment accumulation rates were calculated from the chronostratigraphy and are given in Table 3.

Depositional Regime	**Chronometer**	**Sediment Accumulation Rate (mm/100 years)**
Pre European (late Holocene)	^{14}C	7.4
Pre European (early Holocene)	^{14}C	7.9
European	*Pinus* pollen	407
European	Community Perturbation	385
European	Total Phosphorus	395

Table 3. Sediment accumulation rates for Gore 2 core.

DISCUSSION

Each unit represented in Figure 3 reflects the operation of distinct depositional processes. The upper, massive and undifferentiated marl unit encompasses the climatically moderate Holocene. Here the sediment is characterised by medium to high levels of calcium carbonate, a virtual absence of gypsum and no indication of deflationary processes. Rates of sediment accumulation are essentially identical for the early and late Holocene. This suggests similar sedimentary processes operated consistently across the Holocene until the 1950's when the rate of sediment accumulation accelerated dramatically. These observations suggest a relatively consistent climatic and hydrological regime operating at a catchment scale during the Holocene.

The environmental stability suggested by the Holocene unit contrasts markedly with the volatility implicit in the complex lithostratigraphy of the second unit, which spans the late Pleistocene, including the recovery from the Last Glacial Maximum. The unit consists of alternating gypsum and clay laminae which are suggestive of rapidly alternating arid and temperate phases. The absence of carbonates and the importance of sulphates suggests that late Pleistocene water chemistry was different to that of the Holocene; perhaps in response to shifts in the balance of groundwater verses surface water inputs with increased aridity. The unit's lithostratigraphy is possibly punctuated with deflationary phases. Detailed palaeoenvironmental reconstruction of this section of core will ultimately be predicated on high-resolution ^{14}C or similar chronostratigraphy, and interpretation of gypsum-crystal morphology and the depositional context of gypsious facies.

Underlying the laminated sequence is a narrow carbonate-nodule unit. It is possible to attribute the occurrence of this unit to heightened aridity associated with the LGM. The failure of the 200 cm radiocarbon date however makes interpretation difficult. The core's basal unit comprises massive, undifferentiated, calcium carbonate rich clay which is reminiscent of the Holocene sequence. It is suggestive of a climatically moderate period at 35,000 ybp.

Figure 5 and 6 indicate that the two dominant components of the pollen spectra are *Casuarina* and Chenopod species (salt bushes). In the early Holocene (Zone 3) salt sensitive *Casuarina* is the dominant taxon and chenopods are less important. Also of significance is the presence of *Lyginia* which is also salt sensitive. This pattern suggests that in the early Holocene, catchment salinity was significantly lower than today.

Between five and six thousand years ago (Zone 2) Chenopods began to dominate and *Casuarina* assumed a secondary role. In addition, *Melaleuca* abundance started to increase, a trend that has persisted into historical times. This pattern suggests that landscape salinisation had its genesis at this time. This timing corresponds with the occurrence of sea levels significantly higher than today's (Playford and Leech 1977).

The floral composition of Zone 1 characterises a landscape disturbed by European agricultural practices. Clearing for agricultural production provides an opportunity for pioneer and weed species (Krebs 1997) and consequently Zone 1 is well represented with taxa such as Compositae and Poaceae, as well as exotic taxa such as *Pinus*. The continued strong representation of native plant taxa is a consequence of the lake's buffer zone as well as the large area of uncleared coastal heath to the south combined with dominant southerly winds.

Table 3 indicates that the rate of sediment accumulation in the basin centre has increased by about 50 times since widespread land clearing occurred. Field observation and aerial photographs show a delta on the eastern side of the lake where the Dalyup River flows in. Significantly higher sedimentation rates are likely to be associated with the delta. A study involving systematic coring of the lake to assess rates of accumulation across the basin should be undertaken as a matter of priority. Such a study could be based upon the proxies established in this study.

The Gore 2 core is a 35,000-year archive of past climates and environments. Field observations suggest that Lake Gore has the potential to provide substantially longer records. This is important because the majority of Australian lakes are much younger than this – usually less than 10000 years old (Williams 1983). Consequently, Lake Gore has the potential to make a significant contribution to the understanding of late Quaternary climatic and vegetation evolution. A clearer understanding of Lake Gore as the culmination of a complex historical interplay of evolutionary, geological and climatic processes will have practical applications in interpreting contemporary processes and informing management strategies and responses.

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REFERENCES

AgWest. 2001. Dalyup Catchment 2000. Miscellaneous Publications No 005/2001

Brooks, G. Grenier, A. 2001 Late Holocene pollen stratigraphy of Lake Louise, Manitoba. Geological Survey of Canada.

Dodson, J. Lu, J. 2000. A Late Holocene Vegetation and Environment Record from Byenup Lagoon, South-western Australia. Australian Geographer. 31.

Faegri, K. Iversen, J. 1989. Textbook of Pollen Analysis. John Wiley & Sons New York 328 p.

Forstner, U. Wittman, G. 1981. Metal pollution in the aquatic environment. Springer-Verlag.

Grimm, E., 1987. CONISS: a fortran 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares.*Computers & Geosciences* 13, 13-35.

Hancock, G. Olley, J. Wallbrink, P. 2001. Sediment transport and accumulation in Western Port. CSIRO Technical Report 47/01

Jaensch, R.P. and Watkins, D. 1999. Nomination of additional Ramsar wetlands in Western Australia. Unpublished technical report by Wetlands International - Oceania for the Department of Conservation & Land Management, Perth.

Krebs, C., 1985. Ecology: The Experimental Analysis of Distribution & Abundance. Harper International.

Lane, J., Jaensch, R. Lynch, R. 1996. Western Australia. In, ANCA. A Directory of Important Wetlands in Australia. Second edition. Australian Nature Conservation Agency, Canberra.

Murray, I. 1985. Agricultural Settlement Experiments in Western Australia – The Esperance Sandplain, 1956-1975. Rural Systems V3, 1. 41-62.

Picket 1997, The late pleistocene and holocene vegetation history of three lacustrine sequences from the Swan Coastal plain, Southwestern Australia. Unpublishe PhD Thesis. The University of Western Australia.

Playford, P,. Leech, R., (1977) Geology and hydrology of Rottnest Island. Geological Survey of WA.

Rose, P.M. Scott, D.A. 1997. Waterfowl population estimates. Second edition. Wetlands International Publication 44, Wageningen, The Netherlands.

Sommers, L., Nelson, D,. 1972. Determination of total phosphorus in soils: A rapid perchloric acid digestion procedure. Soil Sci. Soc. Amer. Proc., 36.

Water and Rivers Commission. 2002. Dalyup and West Dalyup Rivers Action Plan. Water Resource Management Series Report No WRM 34

Williams, W.D. 1983 *Life in Inland Waters.* Blackwell, Melbourne.

Wilson, W. Eliot, I. 2000. Sediments of the Moore River Estuary. Unpublished Technical Report for the Water and Rivers Commission of WA.