An account of the decline of Lake Towerrinning, a wheatbelt wetland

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Abstract

Lake Towerrinning, a wetland in the wheatbelt of Western Australia, is valued for both recreation and conservation. Water quality, however, has decreased dramatically in recent years, threatening its value for water sports and as a waterbird refuge. A preliminary investigation of water quality and vegetation decline was conducted to determine the sequence of events that led to the current levels of degradation. Turbidity, salinity, and water nutrients were found to be very high. Reduced stabilization of the sediment due to the demise of the fringing rush vegetation, and algal blooms caused by nutrient-rich runoff from agricultural land, were seen to be the major contributors to high turbidity. The decline in the fringing rush (around the lake) and tree vegetation (around lake and within the catchment) due to clearing and increased salinity is thought to be the turning-point in the sequence of events which lead to a reduction in water quality.

Introduction

Lake Towerrinning, situated 32 km south of Darkan (lat. 33°20′, long. 116°44′), is typical of degraded wetlands in the wheatbelt of Western Australia. Catchment clearing has resulted in the mobilization of salts from subsurface soils and eventual salinization of what was once a freshwater lake. Although secondary salinity has been well recorded for the Wheatbelt (Burvill 1950; Conacher and Murray 1973; Henschke 1980), there is little documentation of its effects on wetland ecosystems. Lake Toolibin is an exception where monitoring programs and research have been conducted since 1977; this has provided a valuable case history for the gradual decline of a wetland habitat and associated flora and fauna due to secondary salinity (Mattiske, 1978; Froend *et al.* 1987; Halse 1987; NARWRC, 1987; Bell & Froend, 1990). The Toolibin studies emphasised the importance of historical information and monitoring in determining the sequence of events which lead to environmental change and degradation.

Unlike Lake Toolibin, Lake Towerrinning (Fig. 1) is a permanent lake with a long history of recreational activity such as picnicking, swimming, sailing, and water skiing. Because it contains water permanently, it is also of critical importance as a drought refuge for waterbirds (Jaensch 1988). However, there has been a pronounced decline in the fringing rush and tree vegetation which is vital for waterbird habitat. The West Arthur Shire and the Department of Conservation and Land Management (CALM) expressed concern over the decline in water quality of the lake since 1973, and whether or not the present level of boating activity is having an adverse effect on the lake, its waterbirds, turbidity and marginal vegetation. A gradual increase in salinity, turbidity, and odour threatens the future of the lake both as a waterbird refuge and recreation area.

This study aimed to describe the sequence of events which led to the degradation of Lake Towerrinning, and deduce the mechanisms of this degradation through a quantitative assessment of current water quality.

Methods

Records for salinity and lake levels have been collected at bimonthly intervals as part of the South West Wetland Monitoring Program conducted by J Lane and D Munro of CALM, since November 1979. Maps of the fringing vegetation and estimates of rate of vegetation decline were also provided by CALM. Historical information regarding the use of the lake and catchment was provided by the West Arthur Shire.

Field investigations were limited to two days (26 July, 20 September, 1986) concentrating on salinity and turbidity aspects. Eight sampling sites were located around the lake on a grid pattern (Fig. 1). At sites 1, 3, 6, and 8 water samples were taken at intermediate depth and analysed for concentration of total phosphorus, ammonia, nitrate-nitrite, organic nitrogen, total nitrogen, and total suspended solids (inorganic and organic components) using standard techniques. At each site Secchi depth was measured and light attenuation measured with a Licor Li-186B integrated quantum photometer. Salinity and temperature were measured with a Yeo-Cal Electronics salinity/temperature meter, and a known quantity of water filtered through Whatman GF/C filter paper to extract phytoplankton for chlorophyll *a* analysis and total suspended solids. Bathymetry was determined by measuring water depth along the grid lines (Fig. 1) at approximately 50m intervals using a weighted, graduated rope.

Results

Clearing of the Catchment, Lake Levels and Salinity

Personal communication with West Arthur Shire councillors and landowners has provided historical information regarding water quality decline. More than 90% of the catchment of Lake Towerrinning has been cleared, the last major removal of native vegetation being carried out in about 1970. The lake was still considered fresh in 1966 but estimates suggest it became saline during the early 1960s. Vegetation surrounding the lake declined rapidly in the years 1966-1972. Obvious decline in the water quality has been noticed since 1973. During the last ten years, many bores sunk in the catchment have returned saline water, and the water in many dams has also become saline.

Salinity varies with lake level, due to the concentrating effects of evaporation (Fig. 2). During the drought years of 1979-81 lake levels were low and salinity levels correspondingly very high. Unseasonal rains in January 1982, caused by cyclonic activity, ended the dry weather pattern and lake levels have since remained above 2.0 m. There are many dead tree stumps submerged in the lake, some of which had to be removed for boating safety in certain areas (Shire councillors pers. comm.); this indicates that lake levels have increased over the years.

Having determined the bathymetry (Fig. 1), it is possible to calculate the total salt load of the lake water from the lake level and water salinity data. Figure 3 shows changes in salt load during 1981-1986. Values during the dry period of 1979 - May 1981 are very high and are likely to be exaggerated due to the very low water levels (< 0.5 m) and consequent inaccuracy of volume determinations; these have not been included in the figure. The trend in salt load since January 1981 shows increasing amounts of salt stored in the lake until significant rainfall and subsequent outflow events occur; for example, from January 1981 to early January 1982 salt load increased to 28 200 t but decreased to 13 860 t in March 1982 after the lake overflowed from cyclonic rainfall. This trend continues up to July 1983 (28 300 t) until heavy rainfall and subsequent outflow again reduced the salt load in September 1983 (22 930 t). It is likely that continued input of saline surface and groundwater adds to the salt load during years of no outflow. Apart from these events, the salt load of the lake is increasing by approximately 6500 t per year.

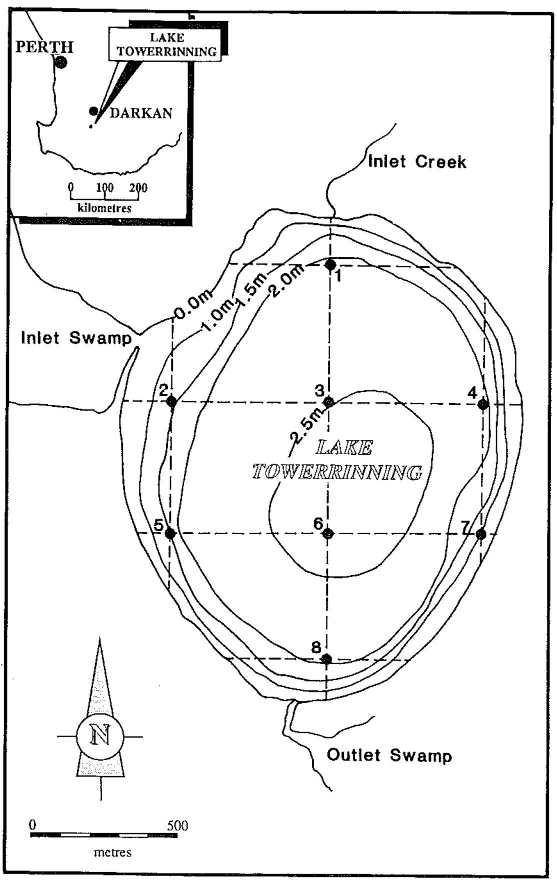

Figure 1 Lake Towerrinning showing location, sampling sites (1-8), and lake bathymetry (in metres).

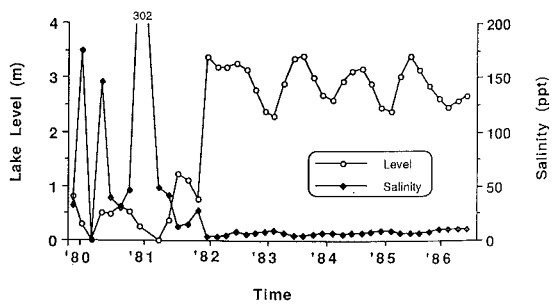

Figure 2 Lake level and salinity measurements taken at bimonthly intervals from November 1979 to September 1986 at Lake Towerrinning.

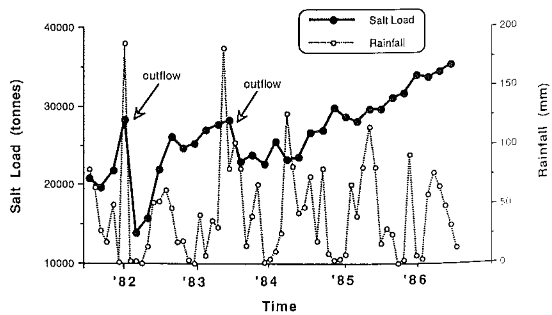

Figure 3 Total salt load for the period July 1981 to September 1986 at Lake Towerrinning. Outflows occurred during January 1982 and July - August 1983.

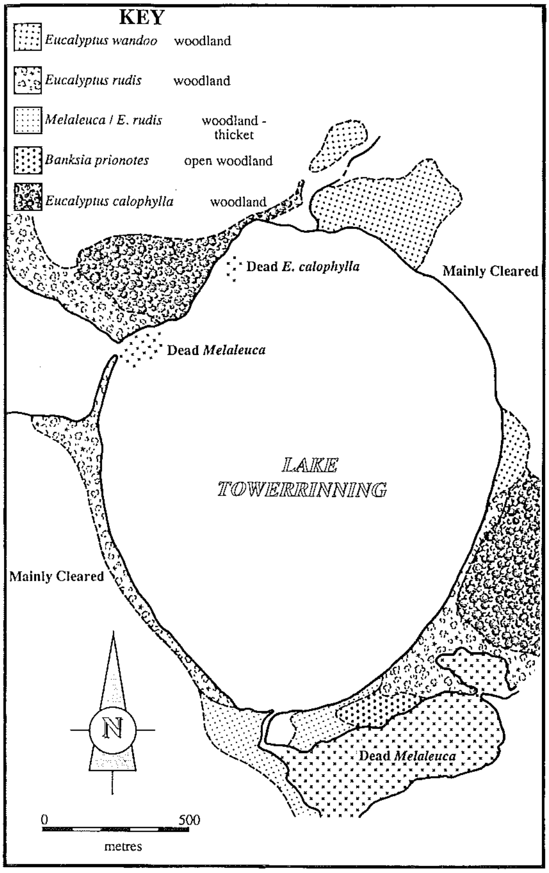

Figure 4 Vegetation formations surrounding Lake Towerrinning. Mapped during 1985 and provided by CALM.

Loss of wetland vegetation

Clearing for agriculture has left a narrow peripheral band of vegetation 100—400 m wide. This peripheral vegetation has been severely affected by increasing soil salinity and flooding. Adjoining landowners noticed that most of the tree vegetation of the inlet swamp (Fig. 4) was dead by 1973, and that decline in tree vigour commenced during the early 1960's.

The vegetation surrounding the lake was mapped in 1985 by CALM (Fig. 4). Almost all of the remaining *Eucalyptus wandoo* and *E. rudis* woodlands to the north have no understorey. Stock have access to the north-east, south-west and southern perimeter of the lake, and the understorey there is heavily disturbed and limited to introduced weeds and grasses. Woodlands to the south-east are more extensive and protected from grazing, and have a more intact understorey. Partially-submerged dead *Melaleuca rhaphiophylla* and *E. calophylla* at the north-west perimeter of the lake indicate increased lake levels and salinity. *Melaleuca / E. rudis* woodland is the main vegetation type at or near both lake inlet and overflow and along the overflow route to Arthur River. The woodland is in varying states of degradation. Most of the *M. rhaphiophylla* in the lake overflow is dead, and weed invasion and heavily-grazed native understorey is seen in most unreserved areas.

Mapping of the distribution of *Baumea articulata* by aerial photograph interpretation (Fig. 5) shows the rush vegetation has dramatically declined since 1964. Virtually all the *Baumea articulata* had died by 1973 and by 1985 only about a dozen small (1-4 m^2) remnants remained. Both local farmers and CALM officers have commented on the presence of a benthic "carpet" of aquatic plants on the lake bed before the late 1970s. The "carpet" occurred throughout the deeper portions of the lake, always beneath mean lake level, but was lost when the lake substantially dried-out during the drought years, probably between 1979-81.

Water quality assessment

The Secchi disc transparency depths averaged 0.5 m with negligible variation between sites, and the mean attenuation coefficient was 0.60. These results show relatively poor light penetration attributed to high water turbidity.

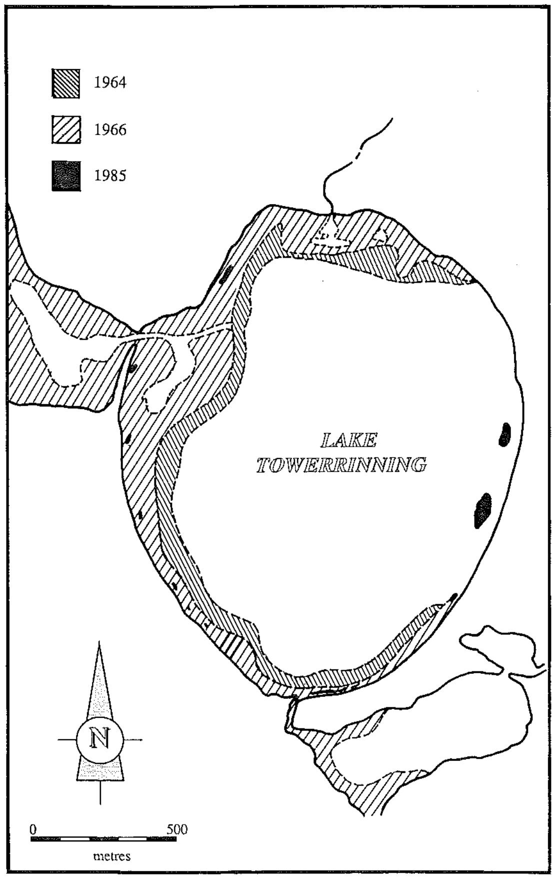

Figure 5 Distribution of *Baumea articulata* at Lake Towerrinning during 1964, 1966, and 1985.

Table 1

Inorganic, organic component of total suspended solids (TSS) and chlorophyll *a* concentrations of Lake Towerrinning. Data collected on 26 July 1986

Site	Inorg.Solids mg/L	Org.Solids mg/L	TSS mg/L	Chlorophyll *a* µg/L
1	21.6	54.4	76.0	37.4
2	—	—	—	48.1
3	13.0	15.8	28.8	48.2
4	17.0	50.8	67.8	42.7
5	8.0	46.8	54.8	42.8
6	6.0	12.8	18.8	48.1
7	37.4	56.4	93.8	42.7
8	3.6	8.2	11.8	26.7
Mean	15.2	35.0	50.3	42.1

The lake had a uniform salinity of 10 parts per thousand (ppt) with no detectable change with depth. This value is high for winter; Lake Towerrinning can be considered brackish during winter and saline-hypersaline during the drier summer months. Water temperature was constant at 12 °C, with no stratification.

Both the organic and inorganic components of total suspended solids (TSS) and chlorophyll *a* levels are shown in Table 1. A high proportion of organic solids was present in the water column, and could be accounted for by high levels of suspended detritus and/or the high levels of algae as indicated by the chlorophyll *a* concentrations. In general the suspended solids were not high, but turbidity can be attributed to the high concentrations of chlorophyll *a* obtained. This indicates that an algal bloom was occurring at the lake. Differences in TSS between sites could be attributed to water turbulence increasing the suspension of sediment/detritus in shallow water close to the shore (sites 1, 4, 5, 7, and 8). Chlorophyll *a* concentrations showed negligible variation between sites.

Results of the nutrient analyses performed on the water samples collected are shown in Table 2. Total phosphorus levels were very high but inorganic nitrogen concentrations were low. This is attributed to the high proportion of organic nitrogen, indicating that most of the nitrogen entering the lake is taken up by algae in the water column. Total nitrogen concentrations are significantly higher during September. This is primarily due to higher organic nitrogen and, to a lesser extent, ammonia concentrations. The algal bloom observed in July was chiefly comprised of a species of *Anacystis*, a blue-green algae able to fix atmospheric nitrogen. This may account for the increase in both organic nitrogen and ammonia during September when higher temperatures and longer light periods promote increased rates of algal reproduction and metabolism. Although chlorophyll *a* concentrations were not determined in September, it was observed that the algal bloom was still occurring.

Discussion

The mechanisms which brought about the decrease in water quality can be deduced from the historical information and records of the lake and its catchment. The reduction in fringing vegetation of the lake (and catchment) is a milestone in the series of events leading to poor water quality. The reasons for the decline in vegetation could be increased flooding or salinity. Fringing rush and tree vegetation requires a particular inundation regime and if the depth and duration of inundation are increased, vegetation of lower elevations may die and the margin will retreat to a higher elevation of suitable inundation regime. If the change in inundation is rapid and combined with increasing salinity, then the result may be local extinction rather than changes in distribution. Although increased surface water (and probably groundwater) input from the catchment due to clearing may be responsible for the initial decline of the fringing vegetation, increasing salinities would have severely limited recruitment. *Baumea articulata* is adapted to freshwater conditions and has a low tolerance to saline water, and so the salinity of Lake Towerrinning is considered the major cause of the decline and failure of re-establishment of the fringing sedges. The drought period during the late 1970s and early 1980s would have compounded the problem, because of high soil surface salinities. Data indicate that outflow events significantly reduce the salt load of the lake, implying that artificially increasing outflow frequency and controlling lake levels is a means of reducing water salinity.

It is possible that a large proportion of the suspended organic matter is derived from the comparatively sudden senescence and decomposition of the fringing *Baumea articulata* due to the increase in salinity; this would have caused the following problems:

a) An increase in the detritus input to the water column and sediment due to decomposing plant material, causing an increase in the nutrient load and turbidity.

Table 2

Water nutrient concentrations of Lake Towerrinning on 26 July (JUL) and 20 September (SEP)

Site	Total P µg/L		Ammonia µg/L		Nitrate-Nitrite µg/L		Organic N µg/L		Total N µg/L	
	JUL	SEP	JUL	SEP	JUL	SEP	JUL	SEP	JUL	SEP
1	73	86	54	89	14	6	373	2091	442	2186
3	73	84	58	100	10	5	482	2119	549	2224
6	72	69	57	103	10	7	994	1494	1061	1604
8	72	79	83	97	11	8	835	1966	929	2071
Mean	72.5	79.5	63	97.2	11.2	6.5	671	1917.5	745.2	2021.2

Table 3

Comparison of Lake Towerrinning nutrient levels, Secchi depth and chlorophyll levels with some Western Australian freshwater lakes

	Total P µg/l	Inorganic N µg/l	Secchi depth m	Chlorophyll *a* µg/l	Trophic Class (Rast and Holland, 1988) P	Chl *a*
Loch McNess	13	220	100%[1]	0.44	Meso.	Ultra Oligo.
Lake Monger	49	440	100%[1]	1.54	Eutro.	Oligo.
Lake Joondalup	44	890	0.8	3.94	Eutro.	Meso.
Lake Towerrinning	72	74	0.5	42.02	Eutro.	Eutro.

[1]: Secchi depth exceeds lake depth.

b) A reduced or absent fringing vegetation permitting greater amounts of nutrients from the surrounding pasture (and catchment) to enter the lake water and sediments.

c) A reduction in the stabilizing effect of rushes on the sediment; in the absence of rushes the sediment can be disturbed and re-suspended in the water column, causing turbidity and increased nutrient load of the water.

d) Increased wind mixing due to a reduction in the sheltering effect of fringing rush vegetation causing suspension of particulate matter.

The rush and tree vegetation is also an important habitat for waterbirds, and loss of this habitat must have considerably altered the potential of the lake for supporting bird populations. Increased water salinities will also affect submerged macrophytes, phytoplankton, and macroinvertebrate fauna, a further limitation on waterbird habitat. Regrowth of the benthic 'carpet' since the drying of the lake would have been restricted due to higher salinity and turbidity, adding to the destabilization of the sediment.

As indicated by the total suspended solids and chlorophyll *a* results, both living and dead particulate matter contribute to the turbidity. Although the high proportion of organic solids suggests large amounts of organic particulate matter in suspension, a large percentage of the suspended organic matter would be phytoplankton. The total suspended solids levels would account for the low Secchi depths obtained. Even at low windspeed, mixing of the water column occurs due to the shallow depth of the lake and large fetch, which is supported by the lack of salinity and temperature stratification. It is likely therefore that wind mixing rather than occasional use of power boats is responsible for the maintenance of turbidity.

High total phosphorus concentrations indicate that nutrient-rich runoff from the surrounding agricultural land has led to increased primary productivity. Input of nutrients from the surrounding land could be in the form of nitrate from legume pastures and phosphate from applied fertilizers. A high proportion of the nitrogen is organic, suggesting that nitrate entering the system is rapidly consumed by phytoplankton, or that the suspended organic particulate matter is rich in nitrogen. The former explanation is supported by the high chlorophyll *a* concentrations. Increased nutrients may also be due to input from the death and decomposition of fringing rush vegetation. Removal of the rush vegetation may have also resulted in the re-suspension of nutrients stored in the sediments.

Although field sampling for water quality was limited, an indication of trophic status can be deduced. A comparison of Lake Towerrinning with freshwater lakes in Western Australia whose trophic status has been documented more extensively (Gordon *et al* 1981; Table 3) shows that Lake Towerrinning has much greater phosphorus and chlorophyll *a* concentrations, suggesting a comparatively advanced state of eutrophication. Turbidity of Lake Towerrinning is also greater than Lake Joondalup, as indicated by the shallow Secchi depth. When the classification of trophic status by Rast and Holland (1988) is applied, Lake Towerrinning is classified as eutrophic based on total phosphorus and chlorophyll *a* (Table 3). If the trophic probability classification scheme based only on chlorophyll *a* concentration is applied (Rast and Holland, 1988), Lake Towerrinning is classed as hypertrophic. However, it should be emphasised that these comparisons are not based on annual average chlorophyll *a* and nutrient concentrations, as for the other lakes used for comparison.

In conclusion, increased inputs of water, salt and nutrients from the cleared agricultural land within the lake catchment have resulted in a decline in the wetland vegetation and an increase in phytoplankton. Algal blooms and the destabilisation of the sediment are the major causes of the high turbidity currently experienced.

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