THERMAL POLLUTION AND ALGAL GROWTH IN THE TUGGERAH LAKES*

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Abundant growth of 'weed' and its accumulation and decomposition in inshore waters and on the shoreline are seen as increasing problems in estuaries and lakes in regions of expanding populations. The weed may be visually unacceptable, become malodorous as it decomposes, and can considerably reduce the amenity value of the water-way if it interferes with activities such as swimming and boating. In Australia, the phenomenon has been studied in detail in the Peel-Harvey estuarine system in Western Australia (Hodgkin *et al.* 1985) and the Swan River estuary (John 1987). In New South Wales, Yassini (1985) has provided an overview of the problem of algal growth in Lake Illawarra.

In the Tuggerah Lakes on the central coast of New South Wales, the problem of excessive weed growth is one of the problems being tackled by Wyong Shire Council in relation to the overall management of the lake system. In this case, as elsewhere in Australia, the weed problem is due to macroalgae (seaweeds) and not aquatic angiosperms (seagrasses). There is no evidence of an explosion in seagrass growth in the last 20 or so years, though there have been changes in the overall distributions (see King & Hodgson 1986, and King & Holland 1986 for relevant literature). When the Munmorah Power Station was planned, algal growth was not perceived as a likely outcome of power station operation but seagrasses were studied because of suggestions that the growth of particular 'reeds' would accelerate, thereby reducing the cooling field and potentially offering resistance to the pumping of water through the lakes. This possibility has not been realised in the 21 years of power station operation.

The nuisance algae in Tuggerah Lakes are mostly green algae, baitweed (*Enteromorpha*) and more particularly the finer filamentous types (*Chaetomorpha* and *Rhizoclonium*). These algae are attached, at least initially, to the substratum which is often the leaves of seagrasses. Later they may form large floating surface mats which can be buoyed up by the oxygen produced during photosynthesis. A further macroalga common in the lakes is *Gracilaria verrucosa*. This is a more robust red alga and it is not implicated as a nuisance species. The three green algae are naturally occurring in the Tuggerah Lakes and are otherwise widely distributed in estuarine and marine localities. As elsewhere, e.g. Swan River and the Peel-Harvey estuary, it is their excessive growth and subsequent accumulation and decay with the production of objectionable odours that is a major cause for complaint.

The algal problem is thought to be increasing in severity and there has been a desire to apportion responsibility or pinpoint a major culprit in the saga.

In Tuggerah Lakes the Electricity Commission of NSW is a most conspicuous user of lake water. Munmorah power station (1400 MW) uses steam-driven generating units, and lake water is drawn continuously from Lake Munmorah to cool the condensors, and heated water is discharged into Lake Budgewoi. The overall effect on the temperature in the lakes has been analysed by CSIRO (Siromath 1982). Because of the potential of this heated water to effect the ecology of the lakes system, the role of the power station in contributing to the problem ought to be considered. Also some members of the local community perceive the power station as the villain, and the matter has been aired in the press.....*'Local authority officials largely blame the State Electricity Commission – ELCOM – which operates a power station on Munmorah's shores. The power station at Lake Munmorah pumps huge quantities of hot water into the three interconnecting lakes and this, says Wyong Shire Council, is what has stimulated the weed growth explosion'* [Australian, 24 Dec. 1987, p. 3]. Where 'algal pollution' occurs it is almost always controversial since rarely does it occur in an environment where only a single environmental variable has been altered. In the case of Tuggerah Lakes, with rapid urbanization of the catchment, and increasing recreational use of the waterway, the effects of factors such as eutrophication from point and non-point sources, and siltation accompanied by increased turbidity, will be difficult to separate from one another or from thermal effects.

Leaving aside the fact that heated water affects only Lakes Budgewoi and Munmorah, there are a number of reasons which suggest that it is extremely unlikely that algal growth and biomass accumulation is stimulated by heated effluent in this lake system.

The basis for considering temperature to have a major influence on production is the general observation that the rates of metabolic reactions are temperature dependent (Larcher 1980). Biochemical reaction rates approximately double for each rise in temperature of 10° C but reactions which are enzyme controlled, such as photosynthesis and respiration, have optimum temperatures above which the enzymes are inactivated. The effects of temperature are not identical on the two processes with photosynthesis reaching an optimum at temperatures at which the increase in respiration is still rising exponentially. Figure 1 is a diagram of the temperature dependence of photosynthesis and respiration (Larcher 1980).

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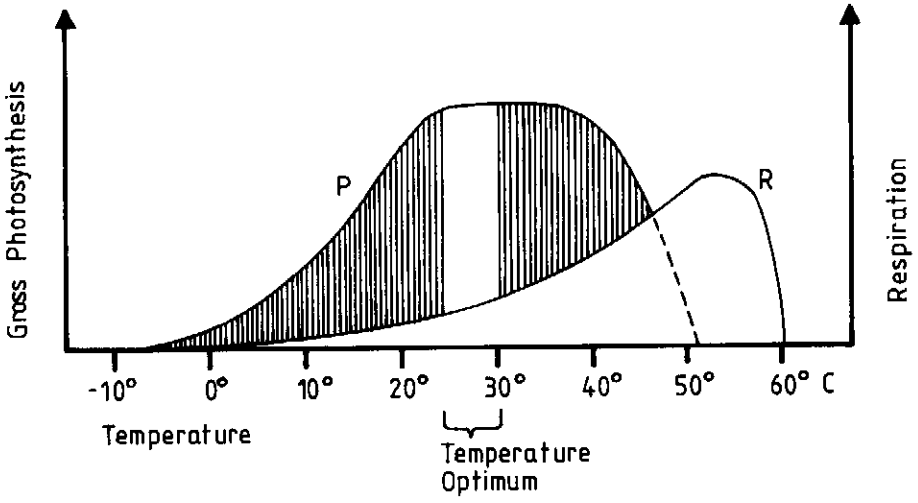
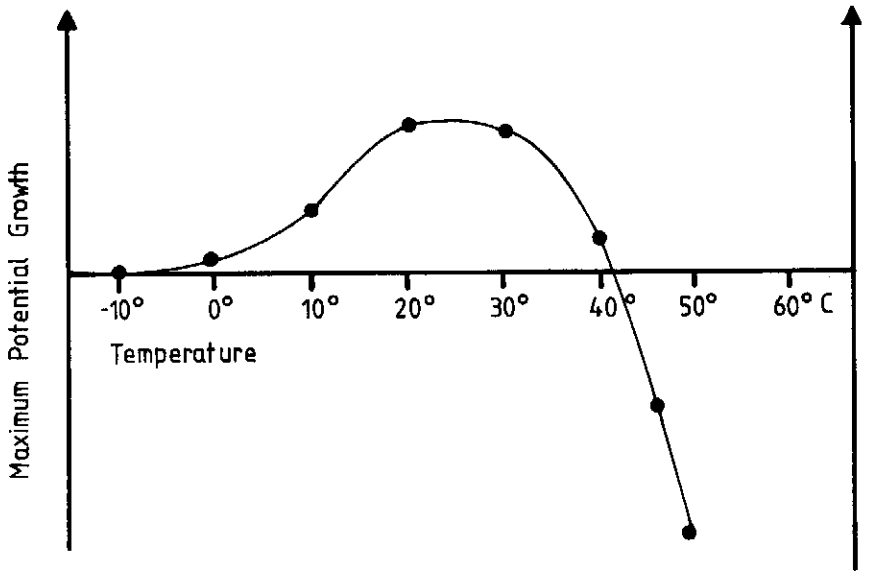
* based on an address prepared for a public meeting held at Wyong Memorial Hall, 17 December 1987

Figure 1.



A. Effect of temperature on photosynthesis (P), and respiration (R). The hatched area represents net photosynthesis (after Larcher 1980).



B. Maximum potential growth (assuming photosynthesis at the maximum rate for 12 h and respiration for 24 h each day) and the effect of temperature.

The temperature curve for growth in the field is the result of numerous metabolic interactions and field results are not always predictable from laboratory results (Lobban *et al.* 1985). An important consideration is the fact that respiration continues throughout 24 hours whereas photosynthesis occurs only during daylight hours.

The conclusion reached here is consistent with the general observation that in global terms the greatest production by marine algae occurs in temperate regions. In tropical regions, biomass accumulation is reduced due to respiratory drain, whereas in polar regions low temperature ensures a low rate of photosynthesis. This can be understood in relation to figure 1. Thus there is no general increase in algal growth with decreasing latitude (and increasing temperature) in the coastal lagoons along the eastern Australian seaboard.

There are at least two further reasons why, in this particular case, it is unlikely that the power station cooling water discharge is the cause of the present excessive algal growth.

a) The problem is by no means limited to those areas which lie within the cooling field of the power station. Biomass data so far collected from Chittaway Point in Tuggerah Lakes, and well outside the direct influence of the thermal plume from the power station, show similar values to those from San Remo, near the station outfall.

b) Munmorah power station has been operating for just over 20 years, yet the increase in algal growth is supposedly a comparatively recent phenomenon. Unfortunately, as is often the case, retrospective construction of the history of algal pollution is fraught with problems (see for example, Hodgkin & Vicker 1987).

It may be argued that temperatures *per se* may not be directly controlling algal production but may alter other conditions, and therefore be indirectly responsible for increases in algal biomass. For example, increased temperature could perhaps increase the rate of release of nutrients from sediments and thus stimulate growth.

If one assumes that it is the balance between respiration and photosynthesis only that determines net biomass accumulation then we can re-examine the temperature optimum illustrated in figure 1. Assuming photosynthesis at the maximum rate for 12 hours per day, the resulting curve for biomass accumulation shows a significant drop-off at higher temperatures.

This is probably the main reason why tolerance limits in the field are significantly lower than is predicted on the basis of the temperature optimum for photosynthesis determined from short term experiments (Lobban *et al.* 1985). Certainly this must be taken into account when extrapolating from laboratory measurement to the field situation.

Temperatures in the lake shallows where the algae grow are to some extent independent of those in the lake proper. Except in the small area immediately adjacent to the discharge from the power station, the thermal enhancement is minimal (see Siromath data), and less than 2° C. Temperature data are currently being collected in both inshore sites and outside the weed beds in south-eastern Lake Tuggerah at Chittaway Point, and at San Remo near the outfall of Munmorah power station in Lake Budgewoi as part of our vegetation studies in coastal saline lagoons. As an extreme example, the temperature in weed beds at San Remo during a hot summer day (18 Jan. 1987) was recorded in the range 22-33° C, whereas just outside the weed beds the range was reduced to 25 - 33° C. Comparable figures for Chittaway Point were 22-36° C and 25-32° C. Such temperatures are well above those at which algal growth would be enhanced: on the contrary, growth rates would be reduced. The most likely effect of thermal enhancement in shallow inshore regions would be to alter the time of the period of peak growth, but not to prolong it. Such ideas would need to be coherently argued taking cognisance of pertinent issues raised in the foregoing.

Perhaps none of the points discussed here would, taken alone, convince anyone that temperature increase due to power station operations has not caused an increase in algal growth in the Tuggerah Lakes. However, taken together (and in the absence of any demonstrated link) it seems appropriate in this case to investigate other more likely causes especially nutrient availability. Hodgkin & Vicker (1987) reviewed the history of algal pollution in the Swan River estuary, W.A., and their comments are particularly apposite here. They noted that history .....'*shows a readiness to ignore well documented facts in favour of a popular myth that blamed a favourite villain, and records a fair amount of buck passing that postponed effective action for a long time.*' Practical management of aquatic resources, and indeed the science on which management decisions are sometimes based, is expensive: but nothing is quite so expensive in the long run as not taking appropriate action as soon as possible.

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