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Nutrients from sediments

Implications for algal blooms in Myall Lakes

D Palmer, DJ Fredericks, C Smith & DT Heggie

During April and October 1999, the Myall Lakes experienced blue green algae blooms that persisted until August 2000.[1] The bloom conditions had considerable impact on the local tourism and fishing industry. In response to community outcry and political pressure to find solutions to the problem, the managing authorities developed monitoring and assessment programs in an attempt to discover the cause of the algal blooms. An important component of the assessment was to understand the nutrient dynamics and sediment–water interactions within the Bombah Broadwater.

AGSO conducted an 11-day survey in Bombah Broadwater within the Myall Lakes system, measuring fluxes of nutrients from the sediments using benthic chamber instrumentation. The results showed that denitrification, a natural microbial process which removes nitrogen from estuaries as nitrogen gas, was operating inefficiently. As a consequence, a high proportion of the nitrogen recycled in the sediments was being returned to the water column as biologically available ammonia, potentially enhancing algal growth in the water column.

The Myall Lakes region is on the central coast of New South Wales approximately 280 kilometres north of Sydney. The Myall Lakes drain a catchment approximately 780 square kilometres in area, of which about 25 per cent is cleared and under agricultural production; the remainder is relatively undisturbed vegetation within state forest, national park or uncleared private land holdings.[2]

Bombah Broadwater (figure 1) is the southern most lake within the Myall Lake system. It is a relatively shallow, flat-bottomed lagoon, approximately 22 square kilometres in size. Bombah Broadwater receives the main freshwater input to the lake system (Myall and Crawford Rivers and Boolambayte Creek via Boolambayte Lake) and drains out via the lower Myall River which flows south, approximately 20 kilometres into Port Stephens. There is very little tidal flushing of the Myall Lakes as marine water only moves up the lower Myall River into Bombah Broadwater during extended periods of low rainfall.[2]

The distribution of sediment facies within the lake corresponds closely with water depth. The outer margins and a broad shoal in the centre of the lake consist of medium to coarse sand, dominantly quartzose in composition. Areas greater than two metres in water depth are dominated by mud with a total organic carbon content of around five to seven per cent.[3]

Benthic flux measurements

The flux of nutrients and metabolites between the sediments and the overlying water was measured using benthic chambers.[4] The chambers were deployed on the sediments of the lake and captured approximately nine litres of seawater. Data loggers recorded dissolved oxygen concentrations both within the confined chamber waters and in bottom waters outside the

Map: AUSLIG

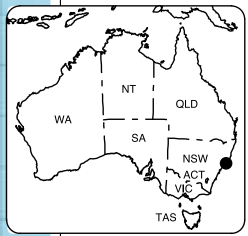

Figure 1. Bombah Broadwater site map

chamber. Samples were drawn from within the chamber at predetermined intervals and analysed for dissolved inorganic nutrients (NO_x^-, NH_4^+, HPO_4^{2-}, SiO_4^{2-}), pH, TCO_2, alkalinity, N_2 and Cs concentrations. The flux of nutrients and metabolites across the sediment water interface was determined from the rate of change in concentration within the chamber, during the course of each incubation.

Benthic chambers were deployed at three sites as selected by the New South Wales Department of Land and Water Conservation (figure 1). One site was located on the sand facies (site 3); the other two were on the mud facies (sites 1 and 2).

Sediment denitrification

Nitrogen is delivered to coastal lake and estuarine environments in dissolved and particulate forms. Nitrogen added to the estuary is either captured by primary producers—including phytoplankton, various seagrass species and mangroves—or is flushed out to the sea. In most Australian barrier estuaries (those separated from the ocean by a sand barrier) most nitrogen is trapped or/and recycled within the coastal lake or estuary. The dominant, naturally occurring, self-cleansing mechanism for these lakes and estuaries is denitrification. Denitrification is a bacterially-mediated process that occurs within sediments. It converts nitrates, and nitrites generated from the breakdown of organic matter, into nitrogen gas, which is subsequently lost to the atmosphere. The identification of this denitrification process and the efficiency to which it is occurring are key sedimentary indicators of environmental condition.

Denitrifying bacteria are ubiquitous in nature and require an organic substrate, a supply of nitrate, and a sub-oxic to anoxic environment or niche within the sediments for metabolism. When denitrifying bacteria are operating efficiently, the majority of dissolved inorganic nitrogen (DIN) generated via the breakdown of organic matter is converted to gaseous N_2. However, when denitrification is operating inefficiently, most DIN is returned to the water column, thus remaining available for plant growth.

Denitrification efficiency, expressed as a percentage, was calculated using

$$\textit{Denitrification Efficiency} = \frac{(\text{N Predicted} - \text{DIN Measured})}{\text{N Predicted}} * 100$$

N Predicted is the calculated flux of DIN from the measured Total CO_2 flux assuming a Redfield stoichiometry of 106C:16N.

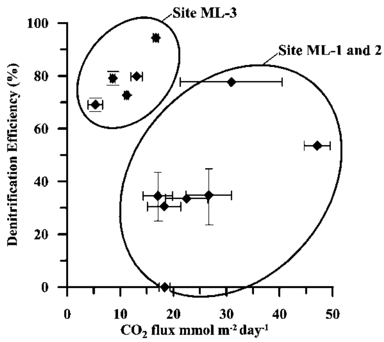

Figure 2. Calculated denitrification efficiency

Calculated denitrification efficiencies were greatest at site ML-3 (average 79% ± 4%) (figure 2). This suggests that the sand facies at ML-3 is very efficient at converting nitrogen from degrading organic matter into N_2. Calculated denitrification efficiencies for mud facies sites, ML-1 and 2 (figure 2) varied over a wider range (30% to 78%), yet had a considerably lower average (38% ± 9%). These efficiencies are low by comparison to muddy sites within other Australian estuaries such as the central portion of Port Philip Bay (~60% to 100%) and Wilson Inlet (~50% to 80%).

In Myall Lakes, the majority of nitrogen recycled from organic matter is being returned to the water column as ammonia at sites 1 and 2. In contrast, the small amount of organic matter being recycled at site 3 is

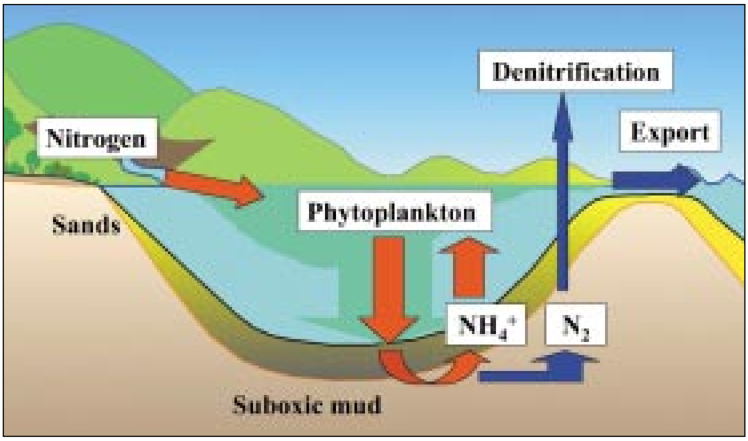

Figure 3. Schematic of nitrogen cycling in Bombah water

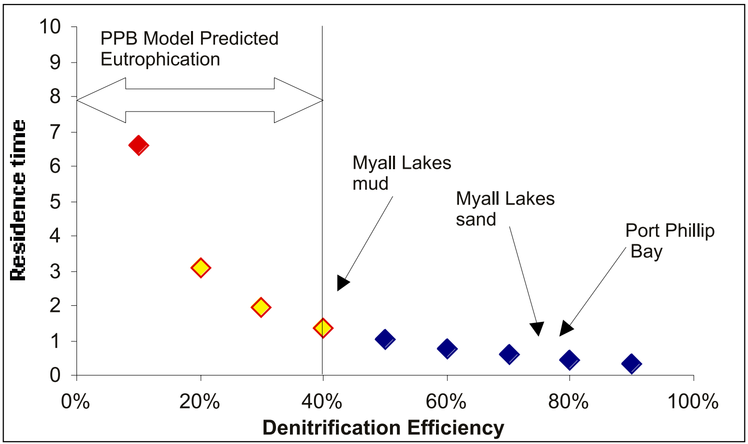

Figure 4. Relationship between residence time of nitrogen in an ideal estuary and sediment denitrification. In this figure, residence time is defined as the number of times added nitrogen is recycled between sediments and the overlying water column before 50% of it is lost as nitrogen gas.

efficiently converting organic nitrogen into nitrogen gas (figure 3).

It is important to consider the significance of low denitrification efficiency. Recycling of nitrogen from sediments is known to have a non-linear impact on productivity[5]— that is, a small decrease in denitrification efficiency may have a disproportionately large impact on primary production.

The impact of denitrification efficiency on the residence time of nitrogen in an estuary with limited flushing is illustrated in figure 4. It shows that the residence time of nitrogen in the estuary increases rapidly when the denitrification efficiency decreases below about 40 per cent. A similar effect was found in the Port Phillip Bay Environmental Study where primary production was predicted to increase rapidly when denitrification effeciencies fell below about 40% (equivalent to a doubling of the N load).[5,6]

Conclusion

It is difficult to assess the system-wide denitrification rate from the data available for Myall Lakes. However, the limited measurements of sediment denitrification in Myall Lakes indicate that denitrification efficiency is low, at least during the winter month of June at the mud sites. Furthermore, the data suggest that Bombah Broadwater may be close to a state in which feedback of labile nitrogen from the sediments may fuel plant growth. It is possible that the extended cyanobacteria bloom experienced in Myall Lakes over the summer of 1999–2000 was sustained by poor sediment denitrification. Any further decline in sediment denitrification is likely to result in more extensive phytoplankton production, though not necessarily cyanobacteria.

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