WATER QUALITY: IS THE EFFLUENT FROM AUSTRALIAN MARICULTURE OPERATIONS A PROBLEM IN MANGROVE COMMUNITIES?

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ABSTRACT

Mangroves are a community under pressure from many sources. Most pressure comes from clearing, in-filling and erosive events. Increasingly there are questions about the effects of long term changes in the quality of the tidal waters that flow through the communities. Estuarine and coastal waters that flow through mangrove communities receive run-off from industrial, domestic and agricultural processes. As well the waters may receive high volumes of pollutants from short term accidental discharges.

In considering the effects of water quality on the mangrove communities we are looking at either short term polluting events or long term alterations in the chemical constituents and contaminants that are found in the water that moves through the communities. These components may be taken up and stored in the sediment or the biomass in the communities or remain in the water column. The fates of these extra inputs are not clearly understood.

Clearly defining what is meant by the term water quality as it applies to these concerns about mangrove communities is a difficult process. While studies on the effects of pollution events eg. oil spills are found in the literature, there has been little published research on the long term effects of changes in water quality on mangrove communities. There are particular examples where research is required.

The difficulties are that the base-line studies to define the chemical and biological constituents of the water have not been carried out. Instantaneous measurements of water, biomass or sediment composition are not enough. What is needed are long term surveys covering as wide a range of chemical and biological parameters as possible.

WATER QUALITY

With the wild catch of seafood at or above a sustainable yield, the world demand for fish or other seafood products will increasingly be satisfied from mariculture production units (Scientific American 1995). The World Bank has suggested that early in the next century, up to 40% of the world demand for fish products will be supplied by aquaculture. While difficult to predict, current developments in Australia are such that by early in the next century it would be expected that between 10,000 and 20,000 hectares of ponds or their equivalent would be in production in tropical Australia. While cage culture of fish is expanding the mariculture production of marine shrimp will be a significant part of total Australian production. The future for shrimp culture is very bright (Weidner and Rosenberry, 1992).

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In Australian conditions the economics of pond based shrimp mariculture demand high production rates per hectare. Often referred to as intensive or semi-intensive operations, such units are planned on yields of at least 5000 to 6000 kg per hectare per crop with two crops per year. A dominant feature of management concerns in mariculture operations in Australia is the maintenance of pond water quality conditions that will allow the maximum growth rate of the organisms being cultured (Boyd, 1986). High water exchange rates and a constant supply of clean good quality sea water are essential management tools. A major concern is the amount of wastes produced (Smith, 1993; Wang, 1990; Williamson, 1989). Per hectare of ponds the total waste produced per crop is difficult to estimate. The dissolved, colloidal and suspended wastes discharged from the ponds are high in Nitrogen, Phosphate and suspended solids (Boyd and Musig, 1992 Pruder, 1992). Robertson and Phillips (1995) give values for intensive shrimp pond effluent compared with pristine mangrove waterways (Table 1).

Table 1: Some Water Quality Variables in Shrimp Pond Effluent (from Robertson and Phillips, 1995)

Water Quality Variable	Intensive Shrimp Pond Effluent	Pristine Mangrove Waterways
NH_3 (μM)	10.0 - 35.0	0 - 37
NO_3 (μM)	1.97 - 73.15	0.10 - 1.42
PO_4 (μM)	0.53 - 4.21	0 - 5.26
TSS (mgl^{-1})	119 - 225	67 - 3312
Chla (μgl^{-1})	20 - 250	0.2 - 5.07
Bacterial Cells ml^{-1}	8.8 - 25.7 x 10^6	0.85 - 4.7 x 10^6

It is the impact of the disposal of effluent near or in mangrove areas that has to be considered. If an average water exchange of 10% per day is used then a 1 hectare pond (average depth 1.2m) will discharge approximately 168 Ml over the 20 week crop cycle.

With the rapid change in biomass in the pond and feeding rates being altered to cope with these changes, average values of effluent materials are not of great value. Mangrove communities, either natural or constructed appear to have a great potential as bio-filtration units for the processing of these discharges from mariculture operations as well as waste-water treatment (Tam and Wong, 1995).

The Australian mariculture industry would regard itself as a strong supporter of any efforts to manage and conserve the mangrove communities of tropical Australia. With a few exceptions, Australian mariculture operations are generally not constructed on or in mangrove communities. Mariculture ponds are generally constructed above high tide levels to ensure rapid draining at any stage of the tide and to avoid any problems with sulfate rich marine sediments. Most of the interference to mangrove communities in Australia from mariculture operations would come from the construction of inlet and outlet structures and access tracks.

With such construction subject to permitting requirements direct interference with mangrove communities is minimal. This contrasts with many mariculture operations in the Asian region where large scale destruction continues to occur.

Mangrove communities as we have heard, are a major feature of low energy inshore environments in estuarine and coastal areas. A major focus in research in mangrove communities relates to the monitoring of damage and recovery from clearing and in-filling processes which destroy the community or from hydrodynamic changes that cause major erosion of communities. The effects of changes in water quality have not received the same attention from researchers as damage from development or studies of community dynamics. Research has been aimed at explaining these major changes in community structure and the extent of change that has occurred. With few exceptions (and I think Gladstone is one of them) the problem in such studies is that baseline data is slight or non-existent.

A second research focus is studies, of which the work of Australian Institute of Marine Studies is a major example, that attempt to quantify and explain the conditions within what could be termed a 'stable' system. A significant part of this research output has looked at the fluxes of materials into and out of stable mangrove communities that are not under development or pollutant stresses. Of particular interest to those interested in water quality are the studies that explain the effects of reduction in water velocities in the community on the deposition and adsorption processes occurring and those studies that deal with the bio geochemistry of the sediments (Wolanski,1995). Particularly the idea that some elements are relatively mobile between the sediment and water mass and others are relatively immobile.

Although the marine environment is almost the dumping ground of choice for effluents (the run a pipe out to sea and it will be diluted approach) the research into the impacts of waste waters on mangroves are limited. Yet in waste water or effluent studies there has been a lot of research based on the idea that the processes that are involved in the trapping of nutrients in natural communities apply just as much to the pollutants entrained in the water mass (Chamberlain 1988; Dixon and Florian,1993; Folke and Kautsky,1992; Iwama,1991).

There is major interest in using natural or constructed wetlands for waste water treatment. Effectively, waste water is distributed into wetland communities. Pollutants are adsorbed into the sediments, taken up into biomass or stored in the sediments. This increases the turn-over time of the pollutants and the materials are held long enough for microbiological breakdown or remineralisation to occur. Mangrove communities in this view represent a potential 'bio- or nutrient filter' acting to trap and degrade 'pollutants' in the water masses that flow into and out of the communities.

It is over ten years since Clough et al. (1983) looking at previous work of Nedwell, evaluated the potential use of mangrove communities in sewage treatment. A literature search on work published since then reveals that very little research has been carried out on the questions that they started with:

"what is the effect of sewage and waste-water on mangroves and .... how effectively can mangrove systems trap the various components of these effluents which would otherwise enter offshore systems?"

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There are really very few papers addressing this. Robertson and Phillips (1995) do address the question of what effluents contain and the potential use of mangroves in trapping these pollutants. In Australia there is currently a deal of work in process on the distribution and fate of pollutants in the marine environment. Eg Ocean Rescue 2000 and the State Of Marine Environment Report documents and the current Senate Inquiry into Marine Pollution. It is a comment on the development of technologies that much of the information is published on the Internet and readily accessible.

Declining water quality and sedimentation have been identified as key issues in the marine environment, particularly in ecosystems such as estuaries, salt marshes, mangroves, seagrasses, rocky shores and sandy beaches in developed parts of Australia. It is surprising that there is still little published research on the long term effects of these low level but permanent changes in water quality on the dynamics of mangrove communities. It seems to me that one of the most important questions which could be asked about the interaction of mangroves and water quality and extend the ideas of Clough et al is:

"What are the long term implications, for the food chains that originate in the mangroves, of changes in water quality?"

Before we go any further it is best to review what we mean by water quality. Generally we would define the term water quality almost from a human health point of view and this is the approach adopted here. This does not consider 'toxic' events that would destroy mangroves but long term low level changes in the water quality bathing the communities. Estuarine and coastal waters that flow through mangrove communities receive run–off from industrial, domestic and agricultural processes. mangrove communities are receiving:

- run–off of agricultural fertiliser, pesticides, soil and industrial run–off (Mackey et al.,1992)
- domestic sewage and storm water run–off (Tam and Wong, 1993; Wong et al.,1995)
- episodic inputs from disposals of wastes and accidental discharges eg. oil and other products (Burns et al.,1993; Lewis,1983; Scherrer and Mille,1990)

As well the waters may receive high volumes of pollutants from short term accidental discharges. Such changes can be broadly described as long term degradation of the water quality. In considering the effects of these changes in water quality on the mangrove communities we are looking at either short term polluting events or long term alterations in the chemical constituents and contaminants that are found in the water that moves through the communities.

For an example of the water quality parameters that may impact on mangrove communities the table is a listing of the parameters that was defined the STEWARD system (Support Technology for Environmental, Water, and Agricultural Resource Decisions), by The Pennsylvania State University (Centre for AI Applications in Water Quality).

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From a water quality point of view there is not so much a debate about how to measure as rather what to measure. Currently there are several excellent works covering the methods of water quality assessment. There have been for some time extensive Water Quality Assessment Databases with tested methods. The question is whether over a long term where there is a change in these inputs there are major effects on water and sediment quality, marine bio-diversity and commercial and recreational users of the resource.

From a mariculture management point of view the studies that are needed to assess the impact of pollutants, land use or water use on mangrove communities are both general scientific questions (Table 3) and more specific questions (Table 4).

Table 2: Some Parameters for the Analysis of Water Quality in Mangrove Communities (Based on the STEWARD System)

Acidity	Cyanide	Ozone
Alkalinity	Dissolved Oxygen	pH
BOD	Fluoride	Phosphate
Boron	Hardness	Salinity
Bromide	Heavy Metals	Silica
Carbon,	Herbicides	Suspended Solids
- organic	Insecticides	Sulfate
- total	Iodine	Sulfide
Carbon Dioxide	Nitrogen (all forms)	Taste
COD	Odor	Temperature
Chlorine, residual	Oil and Grease	Turbidity
Chlorophyll	Organic Compounds	
Colour		
Conductivity		

The table doesn't include those microbiological components that are more clearly of interest to those people working on sewage treatment and control.

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Table 3: Assessing the impact of pollutants on mangroves

1. Baseline studies to provide information:
   - on the presence and levels of pollutants
   - comparisons between impacted and non–impacted areas
2. Sampling programs of plant material to provide a regular monitoring program. Advantages of using plants are:
   - Usually present before and after any polluting event
   - Represent long term exposure to problem unlike animals
   - Tissue collection and analyses may be standardised and there are fewer ethical clearance problems
3. Toxicity and bio–assays to link the pollutants to observed effects
4. Studies of bio–concentration and bio–accumulation to assess the effects along the food chain

Table 4: Particular questions that are relevant to the interaction of mangroves and mariculture effluents

- What is the fate of pathogenic micro organisms entrained in effluents and deposited in mangrove systems, particularly, do they enter the food chains?
- With continual input from pollutants can the sedimentary Phosphorus and/or Nitrogen pool be saturated? If this occurs what is the sedimentary concentration of Phosphorus and/or Nitrogen at which the sediment release becomes equal to uptake?
- What is the interaction between algal blooms in estuaries and mangroves? Already in many estuarine and inshore areas world wide we are seeing nuisance blooms of toxic algae.
- Can aquaculture effluents be processed through the mangrove communities without causing significant damage?
- Are heavy metals trapped in the sediment, entrained in the food chain?
- What are the effects of oils spills in mangroves?

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The central question in discussions on the effects of mariculture effluents in mangroves is whether there will be any environmental changes and the rates of environmental change. Rates of environmental changes are as important to decision makers as are the magnitudes of those changes over the long term. Much confusion and controversy surrounds the estimates of the rates of slow-onset, low-grade, long-term changes that are possibly seen as noise in the ecological process. Almost by definition the long term changes will only become evident when their reversal will be difficult and expensive. Unfortunately the low level of effluent produced from mariculture operations may be in this class.

The difficulties are that sufficient base-line studies to define the chemical and biological constituents of the water have been carried out in mangrove communities. Instantaneous measurements of water, biomass or sediment composition are not enough. What is needed are long term surveys covering as wide a range of chemical and biological parameters as possible.

It is important to emphasise therefore that while discharges from mariculture operations in Australia do not currently pose a major threat to mangroves, as in many other countries this may change. The problem for the Australian industry is to justify the exploitation of the mangrove communities where many people see these overseas experiences as being indicative of potential problems in Australia. The mariculture industry looks to research and development outcomes that will support the exploitation but maintain conservation of the natural resource.

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