EXECUTIVE SUMMARY

In response to a perceived problem regarding nutrient levels at localised sites in the Great Barrier Reef Marine Park, GBRMPA held a Workshop on Nutrients in the Great Barrier Reef Region on 26 and 27 November 1987. Over forty participants attended the Workshop, including researchers in the disciplines of biology, chemistry, engineering, geology and oceanography as well as State and Commonwealth government water quality and marine park managers.

The Nutrient Workshop provided a forum for examination of roles and responsibilities regarding water quality; an opportunity for discussion and interchange of ideas on a technical level regarding research undertaken; and guidance to the Marine Park Authority in relation to management of enhanced nutrients in the Marine Park.

Nineteen papers were presented on the first day of the Workshop in relation to: coastal processes, effect of nutrients on coral reef communities, nutrient distribution and fluxes, movement and chemical processes.

On the second day participants were divided into three working groups to discuss management issues and the need for research and monitoring in: the Green Island area, the Whitsunday area, and the inshore GBR Region. These working groups were valuable in consolidating ideas on the need for. concern about nutrients in the GBR Region and for advising on the future direction that management should take.

ROLES AND RESPONSIBILITIES

Two main organisations are concerned with water quality management in the GBR Region: GBRMPA under the Great Barrier Reef Marine Park Act 1975 (Cwlth) and Queensland Water Quality Council (QWQC) under the Queensland Clean Waters Act 1971-82.

The Great Barrier Reef Marine Park Act provides for the regulation or prohibition of acts (whether in the Marine Park or elsewhere) which may pollute water in a manner harmful to plants or animals in the Marine Park. Those wishing to discharge household, commercial or industrial waste into the Marine Park need to apply for a permit. To date, in the absence of alternative acceptable standards, GBRMPA has accepted Queensland Water Quality Council guidelines for waste discharge in relation to point source discharges from tourist resorts. The Marine Park Authority also recognises a need to address non-point sources of nutrients in the future.

The Queensland Clean Waters Act seeks to protect all waters (underground, surface, and the sea, within Queensland) by controlling discharge of all kinds of waste capable of causing pollution, through two separate provisions: licensing discharges and "duty of care" provisions. Licensing is based on effluent standards, and provides exceptions for septic tanks serving less than 100 persons, stormwater run-off uncontaminated by domestic

sewage, and agricultural run-off. To date, the approach taken by QWQC has been a problem-oriented response. As with the Marine Park Authority, regulation of non-point sources has not been attempted." Nutrient removal from waste occurs only in highly populated areas of south-east Queensland.

COASTAL PROCESSES

A number of participants discussed the input of nutrients from mainland sources.

Rasmussen established a relationship between nutrients in the Barron River discharge and the Low Isles environment by analysing coral cores.

Nitrogen appears to be the nutrient limiting phytoplankton biomass in pelagic shelf waters. The total 11-year, monthly mean flows from all major rivers from the Barron to the Burdekin were summed in Mitchell's studies, estimating that "10,000 tonnes of NO_3^-N is released annually along this coastal area. The need to monitor flood events was stressed. Since much of the river water is constrained within the near-shore region (20 kilometres offshore) by long-shore currents, Mitchell estimated that the nitrogen flux from river inputs in nearshore regions could account for as much as 50 per cent of the total N, significantly affecting phytoplankton productivity in the inshore GBR.

While dissolved nutrients may be dispersed further from the shore, Johnson's work indicates that most nutrients attached to suspended materials are deposited initially close to shore, within 15 kilometres offshore in water depths of less than 20 metres.

Alongi indicated that nutrient fluxes from GBR sediments are naturally enhanced during periods of extensive river run-off and storm surges (cyclones) which generate sediment resuspension. It has been predicted that resuspension of 1 centimetre of GBR inshore sediment leads to moderate increases in water column nutrient concentrations, particularly for nitrogen species.

Concern regarding input of nutrients from mainland agricultural lands were confirmed by Prove's research. Soil erosion rates in a cane growing area of between 50 and 500 t/ha/year using conventional cultivation techniques were found. Preliminary results indicate that concentrations in run-off water from farm plots range from 84 to 1000 mg/L of total inorganic nitrogen and 1.6 to 34 mg/L of inorganic phosphorus. Erosion can be significantly affected by zero tillage and residue retention practices, but there is little evidence to suggest that nutrient concentrations would vary by adoption of conservative farming practices.

Boto suggested that the ability of a mangrove system to absorb and ameliorate nutrient inputs will depend on placement, timing, quantities, and nature of such input. There is little evidence to suggest any appreciable net exchange between mangroves and surrounding coastal waters in the tidally dominated systems, and it is suggested that direct inputs of nutrients into these mangrove waterways could lead to rapid and substantial eutrophication, particularly where tidal flushing may be limited.

A paper by Cosser included in the proceedings, but not presented at the Workshop, summarises the inputs from two different sources: point sources as continuous, insignificant quantities overall, but high loading in limited areas; and run-off which is episodic, quantitatively significant, but generally low loading per unit area. In order to evaluate the relative importance of respective sources, information as to quantities, real and temporal loading characteristics, sinks, and the pathways of biological assimilation is required for each. He stressed the importance of storm flow in nutrient flux and attempted to estimate riverine phosphorus loading to the Cairns Section of the Great Barrier Reef Marine Park based on export coefficients observed in southern Queensland, yet to be verified.

NUTRIENT MOVEMENT

A major source of enhanced nutrients is thus seen to be from mainland sources and processes such as cyclones in the GBR Region which cause resuspension of nutrients. Within the system, nutrient movement can be predicted to some extent.

Three main types of nutrient movement were discussed by Wolanski: through river floods, of a baroclinic coastal boundary layer of width increasing northward and breaking up in patches; circulation around reefs of non-buoyant nutrients which may become trapped in lagoons and near separation points such as illustrated by the CORSPEX model; and buoyant nutrients like sewage where waste is concentrated along topographically-controlled fronts.

Furnas discussed how nutrients are dispersed by water movement and transformed by planktonic organisms. Inputs of nitrogenous nutrients lead to increases in phytoplankton and can develop into blooms within 2-3 days if sufficient nutrients are available. However additions of nutrients to GBR waters may not necessarily be observed as an increase in dissolved nutrient levels. Rather, local or regional increases in phytoplankton biomass would be an obvious sign. Such enhanced phytoplankton biomass levels would affect coral reefs either through increases in 'surplus' water column phosphate concentrations, or indirectly in community changes resulting from shading, sedimentation, and proliferation of benthic filter feeders.

EFFECT ON CORAL REEF COMMUNITIES

A large proportion of the papers dealt with effects of nutrients on coral reef communities. It has been established, primarily in overseas studies, but also in research undertaken on the GBR, that corals have a low tolerance to elevated nutrients.

Kinsey's experiments at One Tree Island illustrated that addition of nutrients N and P on a daily basis over 8 months increased primary productivity but had no visible effects on the community structure. However, coral calcification rates had reduced by 50 - 60 per cent. Suppressed community calcification will result in decreased real growth and structural maintenance. It seems that

reefs may tolerate elevated nutrient levels well above the natural range for significant periods of time. In this situation the nutrients, and the organic loading (phytoplankton) which they, generate, impose a chronicstress leaving the reef vulnerable to non-recovery after an acute event such as freshwater input, crown of thorns kill and coral bleaching events.

Coral 'cores were analysed by Rasmussen for phosphate levels on an historical basis. Through laboratory experiments she has shown that increased phosphate flux contained in mainland run-off hindered the ability of corals to operate at equilbrium resulting in alteration to the crystal morphology of the coral skeleton, decrease in skeletal density, and increase in skeletal fragility.

Morrissey described the nutrient history of the Coral Reef Tank at the GBR Aquarium by following temporal changes in nitrate concentrations. High mortality rates of scleractinian corals, especially Acropora, occured at times of elevated nitrates, with widespread death at above 2.5 μM (of nitrate). When corals are at their temperature tolerance limits, they are more susceptible to stress by high nutrient levels.

Connell proposed a preliminary set of tolerance levels of corals to nutrients, suggesting that a 20 per cent decrease in growth rate should be deemed the threshold level for coral. Primarily based on overseas studies, he indicated that an increase in total phosphorus and nitrogen of 2 to 3 times background levels can lead to increased plankton productivity, higher sedimentation rates, benthic algal enhancement, and coral death.

A conservative approach to tolerance levels of corals due to the synergistic effects of phosphorus and nitrogen were espoused by Bell and Greenfield. Levels corresponding to a 10 per cent increase in background $P^{-}PO_4$ and inorganic N were recommended performance standards.

Their evidence implies that denitrification and phosphorus removal are necessary treatment requirements if acceptable levels of waste discharge after dilution are to be achieved in the vicinity of coral reefs. Management strategies are discussed, however, significant effort is required to gather relevant evidence on both microscale and macroscale effects of nutrients in the Great Barrier Reef Marine Park before major changes in management are implemented.

Richards has monitored a reef that is being used by a tourist operation and expressed concern that, observed increased algal growth may have been related to enhanced nutrient levels:

Coral and algae are not the only reef'biota affected by enhanced nutrients. Rasmussen, for example, is investigating a link between 'crown of thorns and enhanced nutrients.

Zann's multidisciplinary study of the ecology, hydrography and fisheries of a lagoon in Tonga illustrated the catastrophic effects of recentgeologic uplifting, intensive fishing and, particularly, increased-nutrient discharge directly and through the groundwater. resulting from urbani'sation and changes in land use.

Work by Risk looked at the relationship between increased coastal productivity at nearshore reefs, and accelerated bioerosion leading to weakening of the coral community. Isotopic tracer methods appear to be powerful tools in the study of coral metabolism.

Jones' work concerned mobilisation of toxic metal ions in inshore GBR caused by the planktonic community. He highlighted processes involving Trichodesmium blooms; input of sediment (through erosion or dredging); sewage; and metal wastes. In comparison with discharge from tourist resorts, waste discharge into the Marine Park from the mainland was seen as a major input, with particular reference to waste water discharge from Townsville and Thuringowa.

McConchie explained that nutrients can be transported in the natural environment as ions adsorbed onto colloids and clay minerals. Colloids that influence the rate of increase of adsorbed chemicals to other parts of the systems were described.

WORKING GROUP RECOMMENDATIONS

Each Working Group was asked to work to similar guidelines and allow for discussion on the need for concern regarding enhanced nutrients in the Great Barrier Reef Marine Park, management recommendations, research and monitoring strategy.

There was general concern that inshore waters of the Great Barrier Reef appear to have elevated nutrient levels, and in localised areas may be reaching an undesirable threshold.

It was felt that main geographical areas of concern were the inshore reefs close to mainland sources and subject to additional stresses from tourism activities. Of particular mention were waters north of Cairns where the Reef is close to shore and there is a northerly flow of water concentrating nutrients inshore; the Townsville - Magnetic Island area where sewage discharges reaching the Great Barrier Reef are likely to be significant; and the Whitsunday area where there are a number of tourist resorts and intensive tourism activity in a small area with a complex circulation pattern.

As a result it was recommended that an appropriate monitoring strategy be'established. Research and monitoring programs need to address the ambient water quality of inshore waters, and differentiate between input from the mainland (urban discharge and agricultural run-off) and input from island resorts and other tourist activities. Priority should be given to data collection in areas of major geographical concern.

In terms of management, it is suggested that standards of waste discharge to be adopted could be based on achieving not more than a 20 per cent decrease in coral growth or 10 per cent increase in nutrients over ambient levels. These standards would have to be applied with caution in different sections of the reef recognising that natural variation will be appreciable.

Two other recommendations worthy of consideration are that GBRMPA should have a representative on the Queensland Water Quality Council, and an advisory committee should be set up to advise GBRMPA oh the'nutrient problem.