20. SUMMATION

This report presents the first quantitative estimates of nutrient pool sizes and nutrient fluxes for a shelf-scale section of the Great Barrier Reef. The region between Cape Tribulation and Dunk Island, adjoining Cairns, is characterized by the close proximity of outer-shelf reefs to the coast, the highest regional level of reef-based tourism and a high level of agricultural, urban and hinter-land development. The budgets developed indicate that instantaneous nutrient availability within central Great Barrier Reef shelf waters is still largely controlled by natural input and recycling processes. Human-related inputs remain at low incremental levels. This is almost always the case for large natural ecosystems. What we wish to learn is how systems of this scale and type respond to such incremental inputs and where the perceived desirable qualities of the ecosystem become endangered by them.

The budgets for the nutrient elements nitrogen (N) and phosphorus (P), as presented, are not complete or balanced. The magnitude of several important system fluxes remain to be verified by direct measurement or other means. In particular, rates of cross shelf diffusion (turbulent mixing), lateral exchanges between outer shelf waters and the East Australian Current (EAC), denitrification in shelf sediments and microbial mineralization in the water column need to be measured or estimated in a manner which will allow a more fully verified description of system-scale fluxes to be made. Of the above, sediment denitrification rates and water column mineralization rates are open to direct measurement. In contrast, lateral mixing and exchange fluxes will almost certainly have to be modelled to estimate their magnitude. It is essential that cross-shelf mixing rates be determined as this process will be a major determinant of shelf water quality, particularly within the nearshore zone.

The high intrinsic growth, nutrient uptake and production potential of phytoplankton in well-lit, warm tropical seas will almost always ensure that concentrations of dissolved inorganic nutrients remain low in central Great Barrier Reef waters. If pronounced increases in dissolved nutrient levels occur for some reason, these increases will be ephemeral as phytoplankton rapidly take up the nutrients. Changes is water quality will therefore be most apparent through regional increases in phytoplankton biomass and suspended particulate materials. Monitoring programs need to focus on collecting high quality estimates of phytoplankton biomass and population status over periods long enough to cancel biases arising from short-term variability.

A significant proportion of both the nitrogen and phosphorus in the water column was present in particulate and dissolved organic form. The high sedimentation fluxes of particulate nitrogen and particulate phosphorus measured in both inner and outer shelf waters relative to external inputs imply equally large resuspension fluxes and indicates that a substantial proportion of the particulate nitrogen and particulate phosphorus within the water is detrital in nature. The general correlation between particulate nitrogen, particulate phosphorus and chlorophyll clearly suggests that almost all of this material is of marine origin (Gagan et al., 1987). The dynamics of particulate detrital materials form a back-drop against which biological flux measurements must be made. Very little is known regarding the composition of dissolved and particulate organic nutrient pools in Great Barrier Reef waters or of their internal dynamics. It is likely that the mineralization of water column and sediment organic nitrogen and phosphorus pools substantially buffers fluctuations in phytoplankton biomass and dissolved inorganic nutrient concentrations.

Putting the very large uncertainty in nitrogen fixation by *Trichodesmium* aside, considerable disparity between the magnitude of external inputs from the land, atmosphere and sea and the likely magnitude of internal recycling fluxes of nitrogen and phosphorus in shelf waters is evident. The largest proportion of these internal recycling fluxes are mediated by water column microbial populations. The estimates presented herein are derived from a very tenuous base as

the dynamics of microbial populations in Great Barrier Reef waters are virtually unknown. Much of what is known about water column microbial dynamics in tropical marine waters is based upon experiments in "clear water" oceanic systems. The limits to the extrapolation of such results to a shelf and coastal system with extensive coral reefs and resuspension fluxes is uncertain. Research activities by the Biological Oceanography group over the next few years will focus upon quantifying local recycling fluxes and putting reasonable bounds on their magnitude.

It is tempting to conclude that the water quality status of the central Great Barrier Reef is not at immediate risk and that at current nutrient input rates, external sources will have little future impact on water quality within the central Great Barrier Reef region. For the moment, this may be the case. Human related nutrient inputs comprise only a few percent of the total nutrient (nitrogen, phosphorus) fluxes which sustain the Great Barrier Reef ecosystem. Dissolved and particulate nutrient concentrations will remain low in outer shelf waters and will continue to be largely controlled by natural processes. However, the estimates of stocks and fluxes given herein are strongly weighted toward the larger areas and volumes of the outer shelf. The initial impact of changes in water quality will be most apparent in the near-shore zone and inner Great Barrier Reef lagoon and will be most strongly felt by the coastal fringing reefs. These nutrient-related changes in water quality will be closely connected to alterations in coastal sediment inputs and sedimentation dynamics. The magnitude of terrestrial inputs of sediments and nutrients are directly linked to regional populations levels, economic activity and development patterns. It is still unresolved to what extent water quality and sediment related factors control the cross-shelf distribution of reefs and of biological communities on reefs. Deleterious changes in water quality on the mid- and outer shelf, much like the rise in global human populations will happen imperceptibly at first. When changes to mid-shelf reefs that can be clearly related to water quality become evident, they will be difficult to arrest. Unlike parts of the well-studied Kaneohe Bay system (Smith et al., 1981), significant human-related nutrient inputs to the central Great Barrier Reef cannot be reduced by turning off or diverting one or a few discrete sources. The largest external inputs, mainly from river runoff, are diffuse in nature with multiple sources within watersheds which are largely unmanaged and therefore difficult to identify and control.

If the lessons from the experience in Kaneohe Bay, Hawaii are transferable to the Great Barrier Reef, incremental increases in nutrient inputs to the Great Barrier Reef will progressively increase stocks of nutrients in both nearshore waters and sediments. Increases in sediment nutrient pools will subsequently be reflected in increased stocks of detrital nitrogen and phosphorus being resuspended into the water column to be come available for mineralization by bacteria and zooplankton. Nutrient-related changes in water quality will therefore represent a balance between resuspension mediated sediment-water column exchanges, mineralization by water column populations making use of this resuspended material, phytoplankton demand and physical cross-shelf dispersion processes.

The challenge for oceanographers is to delve into the natural variability which characterizes shelf systems like the Great Barrier Reef, both to understand its magnitude and causitive mechanisms and to tease out definitive trends in the state of waters, sediments and biological communities. In parallel, it is essential that coral reef scientists work to understand how nutrient concentrations, supply rates, speciation and mineralization processes directly and indirectly affect the structure and function of coral reefs. Both efforts will require a long-term commitment of time and resources.

The challenge for reef managers is to turn this information into sound programs for the conservation of the Great Barrier Reef that have broadly based community and political support. In the first instance, there is a great need to educate the public and the political/bureaucratic system about the magnitude of changes in water quality which will

ultimately lead to a degradation of the Great Barrier Reef and its value to Australia, the time scales over which such changes occur, the mechanisms involved and the long-term dynamics of the process. The changes will initially be subtle, localized and easy or tempting to ignore.

The alternative is a Great Barrier Reef that is less than the Great Barrier Reef we have now.