NUTRIENT STATUS Ok MANGROVE SYSTEMS AND SOME POSSIBLE EFFECTS OF EXTRANEOUS INPUTS

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INTRODUCTION

Connections between mangroves and coral reefs have not been investigated in any detail. Indeed, it is difficult to conceive of a direct connection between these systems in the central and southern sectors of the Great Barrier Reef where the majority of the substantial reefs are situated tens of kilometers from the coastal mangroves. Nevertheless. the possible impacts of anthropogenic nutrient inputs into mangroves are of very direct importance to the discussions of this workshop. In practice. most of the resort and other developments in the region are situated on the coast or on coastal islands which contain, or are close to, substantial mangrove forests. Hence. the impact of these developments is likely to be felt first by the mangroves.

This paper briefly discusses some aspects of nutrient flows and seasonal variations in the concentrations of dissolved organic and inorganic forms of the major "macro" nutrients (carbon. nitrogen and phosphorus) in mangrove waters. This information, along with a limited amount of data concerning the capacity of mangroves to absorb nutrient loads. is then used to speculate on the possible effects of extraneous nutrient' inputs into these systems. Specifically, the questions to be addressed are:

(a) What are the ambient concentrations of nutrients in "pristine" mangrove waterways and how do these vary throughout the year?

(b) Are mangroves a source or sink for particular forms of nutrients? (Cf. the controversial "outwelling" concept which has been the subject of considerable attention in studies of, temperate salt marshes and critically reviewed by Nixon (1980)).

(c) Can mangrove forests absorb large nutrient loads and hence ameliorate their potential impact on coastal waters or other perhaps more fragile ecosystems (e.g. fringing reefs)?

RELEVANT DATA AND INFORMATION

Ambient nutrient levels

Most of the following data and discussion. except where otherwise specified'. is taken from a manuscript recently submitted for publication (Boto and Wellington. ms submitted).

The concentrations of some dissolved organic and inorganic materials. in a mangrove tidal channel (Coral Creek. Missionary Bay. Hinchinbrook Is.) have been shown to vary significantly over a 20-month period (Fig. 1). although the concentrations of all species were generally an order of magnitude lower than results reported for temperate salt marshes. Florida 'basin mangroves or an estuarine mangrove system in Malaysia (Nixon. 1980: Twilley. 1985: Nixon et al. 1984). In this regard. Coral Creek provides an interesting comparison with all other wetlands studied to date in that it is influenced' only by tidal action and is virtually free of any terrestrial/freshwater influences via river or groundwater inputs.. This factor alone probably accounts for the much lower ambient nutrient levels in these waters.

The concentrations of dissolved organic carbon (DOC). dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) varied significantly (one-way ANOVA. $p<0.05$) throughout the study period but no seasonal trends were apparent. In the 1982-83 summer period. the inorganic nutrient (ammonium, nitrate: nitrite and phosphate) levels peaked during the period December to March and by July had decreased to levels near or, below

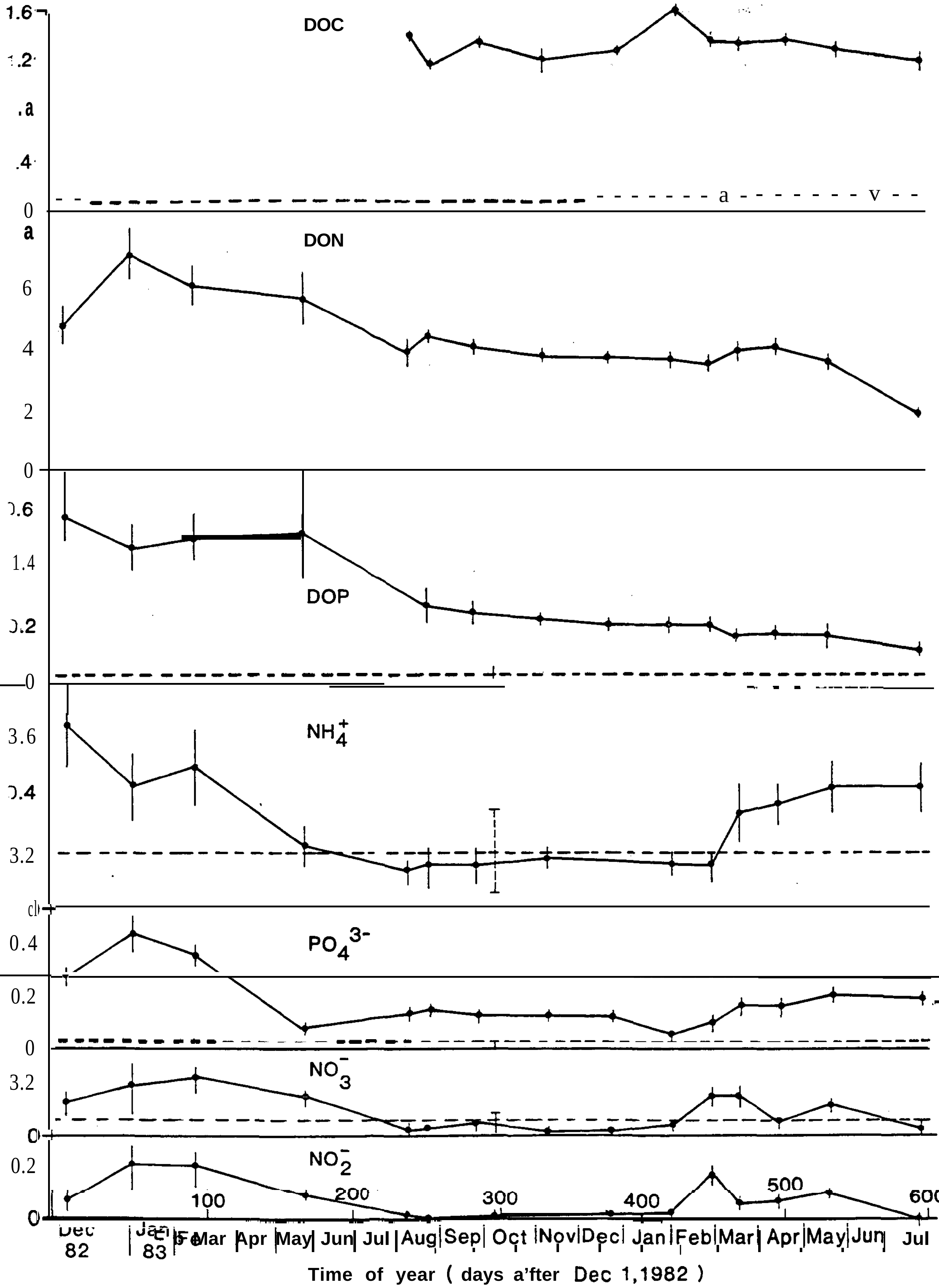

Figure: 1 Variation of the concentration (mean + 95% C.I.) of the dissolved materials in Coral Ck with time of-year. (Dotted lines indicate detection limits for the various entities).

the limits of detection. In the following year. however, the peak was later - February to July - significantly reduced in magnitude (l-way ANOVA, $p<0.05$) and more prolonged, with ammonium and phosphate levels still significantly above detection limits in July.

Correlations between the concentrations of the dissolved materials, and some selected climatic data from a weather station in Coral Creek were examined. Most of the correlations were low ($/r/<0.65$) in absolute terms and it was readily apparent that the concentrations of most of these materials were only weakly (if at all) influenced by the macro-climatic variables examined in this study. A possible exception was foi the case of nitrate + nitrite where a good predictive multiple regression model could be, constructed using' solar radiation and water temperature as predictor variables. The utility of Such a model is questionable, however. as nitrate + nitrite account for only a minor fraction (2-3 %) of the total dissolved nitrogen in these waters,

Dissolved material fluxes

Only a few of the dissolved components gave statistically significant net flux estimates for individual tidal cycles. Further, even these components showed no consistent trend in net fluxes with all components except total dissolved phosphorus showing virtually zero net flux when the results for the 16 cycles studied were integrated over a full year (Table 1). Total dissolved phosphorus gave an annual net **import** amounting to ca. 24% of forest primary production requirements.'These results were consistent with previous studies which indicated that the mid- to high-intertidal areas of the forests in the Coral Creek system are P-limited (Boto and Wellington, 1983).

When these results are coupled with' previous estimates (Boto and' Bunt. 1981 with modifications according to the data of Robertson, 1986) of particulate matter **export** (mainly in the form of intact plant litter) amounting to ca. 35%, 9% and 10% of forest primary production C, N and P requirements respectively. it is immediately obvious that these forests generally export substantial quantities of organic carbon while N and P are almost completely conserved within the system. This tidally-dominated mangrove system therefore appears to be in a very finely balanced state as far as the macronutrients are concerned and, most pertinent to this discussion, there is no evidence to suggest that mangroves act as "sinks" for dissolved nutrients in the water column, except perhaps for total dissolved phosphorus.

Studies (Boto and Wellington. 1983) in which very large N and P fertilizer loadings were applied directly to the soils within the forests nevertheless demonstrated the ability of these forests to absorb high loadings of nitrogen and phosphorus, at least in the short term (one year). In that study. the forests showed either a significant positive growth response over 12 months or no response, depending on position within the intertidal zone. No detrimental effects were noted during that period.

DISCUSSION

It is important to stress at the outset of this discussion that the data obtained for Coral Creek can not be considered to be typical of the estuarine mangroves of the northern coastline in which the nutrient status is probably much more influenced by the associated riverine input than by the presence of the mangroves per se (Boto and Wellington? ms submitted; Nixon et al. 1984). The discussion by Mitchell (this volume) on river inputs of nutrients is therefore more relevant to the estuarine mangroves where the presence of the 'mangrove vegetation may act as a "sink" to reduce somewhat the impact of river-borne nutrients on coastal waters (e.g. see Kennedy. 1984) although this latter feature has never been effectively demonstrated.

The Missionary. Bay mangroves (including Coral Creek) are. however, typidal of some of the larger mangrove forests of this region e.g. those situated at the, southern end. of Hinchinbrook channel. Bowling Green Bay. Trinity, Inlet. Port Douglas. Lockhart River (mouth) and Newcastle Bay. Because of their considerable areal extent. therefore. these

tidally-dominated systems can be considered to exert a significant influence on the coastal. and perhaps shelf. waters of the GBR lagoon.

It is reasonable to propose. from the information gained in the Coral Creek studies, that the effects of extraneous nutrient inputs to the mangrove systems, and their ability to absorb and hence ameliorate subsequent impacts on surrounding waters, will depend strongly on the placement, timing and quantities of such inputs.

For example, the consistently very low levels of dissolved organic and inorganic nutrients in the waters would suggest that major direct inputs of nutrient-laden effluents to the waters would be expected to be very detrimental to the water column nutrient status. Relatively minor loadings would have a significant effect on the dissolved nutrients in the waters and the potential for eutrophication must be considerable. Other discussions at this workshop may' focus on such effects and some local case history studies. Placement of the effluent directly into mangrove waterways may have less impact if carried out during flood tides. preferably spring tides. In this situation? the waters have a greater chance of coming into contact with the mangrove forest sediments and to be taken up by the trees, before the waters are then dispersed into the surrounding coastal waters during the ebb cycle.

Fairly obviously. the preferred mode of input would be directly onto the mangrove forest sediments and at an elevation high in the intertidal zone. This would give the greatest chance for the nutrients to be taken up by the trees and sediments and would enhance forest growth in the usually hypersaline high intertidal zone by lowering the soil salinities as well as increasing the phosphorus status of the soils which are likely to be P-deficient in this zone.

Even if the most efficient input mode can be achieved, it would be crucial to minimize the loadings and to monitor the nature of the effluent. There are definite limits to the long term ability of the trees and soils to absorb inorganic nutrients. This will be mainly determined by the forest growth rate i.e. if nutrient supply chronically exceeds the rate at which the trees can incorporate them, the excess must eventually leach into the mangrove waterways. There are also limits on the ability of even Fe-rich soils to chemically fix phosphate. While very heavy P loadings can be tolerated in the medium term (e.g. up to 400 $kgP.ha^{-1}.y^{-1}$ for the first year - Boto and Wellington? 1983) owing to the phosphate-. fixing capacity of clay and silts in particular. this capacity will significantly diminish in the longer term (Holford and Patrick. 1978).

Organic-rich effluents with high biological oxygen demand probably present the greatest threat to the long-term viability of the forests. Many mangrove forests are likely to be at or near the limits of their ability to cope with soil anaerobiosis (Boto and Wellington, 1984; Smith, unpublished data) and increased organic loads are highly likely to significantly intensify soil anaerobiosis which will not only effect the trees but probably also the burrowing infauna which play such a crucial role in the mangrove ecosystem (Robertson, 1986; Smith, 1987; Smith, unpublished data). It would therefore be strongly recommended that effluents be subjected to preliminary treatment to reduce the organic matter content before addition to a mangrove forest. More details of the probable response of mangroves to sewage effluent are given in a review by Clough et al (1984).

In summary. the ability of mangroves to absorb nutrient inputs will be heavily dependent on the placement, timing. quantity and nature of the effluent, WHile mangrove trees and soils have a capacity to absorb fairly substantial inputs of inorganic nutrients. at least in the short to medium term. their waterways contain very low levels of dissolved nutrients. There is also 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 waterways could lead to rapid and substantial eutrophication. particularly where tidal flushing may be limited.

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Table 1

Estimated net annual exchanges-of the dissolved components in Coral Creek and the proportion of net forest primary production requirements (Boto and Bunt, 198 1, 1982) represented by each (negative sign denotes net export).

Component	Net annual exchange (kg C. N or $P.ha^{-1}.yr^{-1}$)	Proportion of primary production (%)
DOC	73.1	0.8
DON	12.6	4.7
DOP	3.7	17.9
NH^4	1.5	0.6
$NO^3 + NO^2$	-0.3	-0.1
PO^4	1.3	6.3
Total dissolved N	13.8	5.1
Total dissolved P	5.0	24.2