15. PHYTOPLANKTON NUTRIENT DEMAND

Algal blooms are a regular and particularly noticeable feature of aquatic ecosystems with enhanced nutrient inputs (Anderson, 1989). To date, few direct measurements of phytoplankton demand for nitrogen or phosphorus have been made in waters of the GBR (e.g. Furnas, 1988). Virtually all of the inorganic nitrogen and phosphorus being added to GBR shelf waters will be taken up by phytoplankton before being recycled to other components of the ecosystem by feeding, sedimentation and mineralization processes. In the well-studied Kaneohe Bay system (Smith et al., 1981), the nutrients added were rapidly taken up by phytoplankton. Water column concentrations away from the immediate site of addition were not greatly elevated. The added nutrients produced a well defined plume (Kimmerer et al., 1980) as phytoplankton rapidly grew downstream of the addition site. Once incorporated into phytoplankton, the nutrients sedimented onto both reefs and the flat benthos, producing long-lived pools of carbon, nitrogen and phosphorus which took a number of years to disperse (Smith et al., 1981).

In the absence of direct uptake data, indirect estimates of demand can be made using daily and seasonally averaged estimates of primary production and C:N:P ratios (106:16:1) in natural phytoplankton (Redfield et al., 1963). The interpretation of such estimates must be restrained, however, in that the carbon uptake, nutrient uptake and growth kinetics of phytoplankton can be unbalanced over daily and shorter time periods (e.g. Goldman et al., 1981). Despite their limitations, primary-production based estimates of nutrient demand place first-order constraints on estimates of time averaged nutrient demand.

Furnas and Mitchell (1987) made measurements of water column primary production rates within the reef matrix on the outer half of the shelf in Palm Passage. Mean daily production rates during summer on the mid and outer shelf were 550 mg C m^{-2} day^{-1} (45.7 mmol m^{-2} day^{-1}) and 412 mg C m^{-2} day^{-1} (34.3 mmol m^{-2} day^{-1}). During the winter season primary production rates for the mid and outer shelf averaged 390 mg C m^{-2} day^{-1}. Both experimental sites in Palm Passage would fall into the outer shelf depth band of the Cairns and Tully boxes (depth >30 m). It is realistic to expect that the production rates measured in Palm Passage are directly extrapolatable to conditions in the outer-shelf regions of the Cairns and Tully boxes.

Based on the Redfield ratios quoted above, the summer [winter] primary production rates on the outer shelf would translate to demand fluxes of 5.2 [4.9] mmol N m^{-2} day^{-1} and 0.32 [0.31] mmol P m^{-2} day^{-1}. For the mid-shelf production measurements, the estimated summer [winter] nitrogen and phosphorus demands are 6.9 [4.9] mmol N m^{-2} day^{-1} and 0.43 [0.31] mmol P m^{-2} day^{-1}, respectively. When weighted seasonally, annual outer shelf nitrogen and phosphorus demand fluxes in Palm Passage are calculated to be 1850 and 115 mmol m^{-2}. For the mid-shelf measurements, the estimated annual nitrogen and phosphorus demand fluxes are 2210 and 139 mmol m^{-2}. The average of the outer shelf nitrogen demand estimates, when multiplied by the outer shelf areas (>20 m) of the Cairns and Tully boxes, translate to overall nitrogen demand fluxes of 8.3 and 11.5 x 10^6 kmol per year, respectively, into phytoplankton (and pelagic bacterial) biomass. For phosphorus, the corresponding annual demand fluxes for the Cairns and Tully boxes would be 5.2 and 7.2 x 10^5 kmol.

Seven measurements of water column primary production were made off Cairns during November-December 1990 (Figure 8, Table 32). With areal weighting, these summer primary production rates translate to estimated annual phytoplankton nitrogen and phosphorus demand fluxes of 26.9 x 10^6 and 1.65 x 10^6 kmol, which are 3.2 times the rate extrapolated from the outer-shelf production measurements made over an annual cycle in Palm Passage. This is likely a high estimate as it is based upon a single summer series of measurements when production is normally high. Based on the Redfield C/N ratio (6.6 by atoms), the estimated nitrogen demand associated with above production estimates ranges between 58 and 272 mmol

N m^{-2} day^{-1}. Phosphorus demand would range between 3.6 and 17 mmol m^{-2} day^{-1} based on the Redfield C/P ratio (106). Calculated depletion times for depth integrated water column DIN stocks ranged from 33 to 163 hours (1.4-6.7 days). With one exception, water column averaged DIP depletion times were longer than DIN depletion times, ranging between 48 and 143 hours (2-6 days). The difference is largely due to the relatively larger size of the water column PO_4 pool. Both DIN and DIP depletion times are long relative to the potential growth rates of phytoplankton populations in GBR waters (Furnas, 1991). Most of the primary production occurs at isolume depths above 20 percent of surface irradiance, while in many cases, particularly at outer-shelf stations, most of the DIN and DIP stocks exist at depths below this time-averaged isolume. Care should therefore be taken about drawing conclusions that turnover times of water column stocks of DIN and DIP are relatively slow in GBR waters. In surface waters where the highest rates of primary production occur, depletion (turnover) times for both DIN and DIP are likely to be on the order of hours, if not less. Under these circumstances, nutrient availability is likely determined by coupling to water column mineralization processes.

That being said, there was no clear differentiation between depletion times calculated for integrated water column DIN and DIP stocks in inshore and offshore experiments. No primary production measurements have been made in the Cairns region during the winter season. If the seasonal difference between mean water column production rates observed in Palm Passage holds for the Cairns region, the seasonal variation in turnover times are also likely to be less than 2-fold.

For comparison, the box-averaged, area-specific annual benthic DIN and DIP fluxes (194.3 kmol km^{-2} and 26.8 kmol km^{-2}), as calculated from the data of Alongi (1989), account for only 13 percent of the nitrogen and 29-30 percent of the phosphorus demand derived from primary production estimates for the Cairns and Tully boxes.

Table 32. Water column primary production rates off Cairns during November - December 1990. Daily primary production is estimated as eight times the mid-day (1000-1400) hourly carbon uptake rate.

Station	Location	Depth m	Hourly C uptake mg C m^{-2} hr^{-1}	Daily Primary Production g C m^{-2}	N Demand (C / 6.6) mmol m^{-2} day^{-1}	P Demand (C / 106) mmol m^{-2} day-1	DIN Stock mmol m^{-2}	DIN Depletion Time hrs	DIP Stock mmol m^{-2}	DIP Depletion Time hrs
CNS196	Outer Shelf	45	100.5	0.8	10.2	0.6	31.5	74.4	3.2	121.5
CNS198	Outer Shelf	62	224.5	1.8	22.7	1.4	45.9	48.6	3.1	52.7
CNS201	Inshore	21	63.0	0.5	6.4	0.4	17	64.2	1.5	90.9
CNS204	Inshore	23	48.0	0.4	4.8	0.3	19.3	95.6	1.8	143.1
CNS207	Midshelf	33	61.5	0.5	6.2	0.4	41.9	162.0	2.3	142.8
CNS209	Inshore	23	126.9	1.0	12.8	0.8	17.7	33.2	1.6	48.1
CNS214	Inshore	17	100.0	0.8	10.1	0.6	15.6	37.1	1.2	45.8
				0.83				73.6		92.1