17. MICROBIAL MINERALIZATION

Hopkinson et al. (1987) made a small number of direct measurements of NH_4-N mineralization rates in GBR reef waters using ^{15}N isotope dilution techniques. The lowest microbial NH_4 mineralization rate (0.0013 µmol N l^{-1} hr^{-1} = 0.031 µmol N l^{-1} day^{-1}) was measured in mid-shelf waters collected well to windward of the study reef (Davies Reef, ca. 19°S). Higher rates (to 0.0112 µmol N l^{-1} hr^{-1} = 0.27 µmol N l^{-1} day^{-1}) were measured within cave systems along the backside of the reef, and particularly within narrow crevices with lower flushing rates and higher microbial population levels. These measurements were made during low-biomass winter conditions (August 1984). An extrapolation of these few measured mineralization rates to summer conditions is difficult as mineralization rates are dependent upon temperature, food or substrate levels and nanoplankton standing crop, all of which are highly variable and essentially unquantified. If the Q_{10} value (above) estimated by Ikeda et al. (1982b) also holds for micro-organisms, the measured open water mineralization rates would translate to 0.0023 µmol N l^{-1} hr^{-1} (= 0.054 µmol N l^{-1} day^{-1}). Using the same multiplier, the highest within-reef ammonium mineralization rates would similarly translate to 0.0196 µmol N l^{-1} hr^{-1} (= 0.47 µmol N l^{-1} day^{-1}).

Based on the conditions prevailing at the time, the nitrogen mineralization rate measured by Hopkinson et al., 1987 in shelf waters outside the reef system would be most applicable to low-nutrient, outer shelf waters. The higher nitrogen mineralization rates measured within reef caves, though not verified as such, would more likely typify conditions prevailing in inshore waters characterized by higher phytoplankton and bacteria standing crops, dissolved organic nutrient concentrations and particulate matter loads. Taking Hopkinson et al.'s high and low measured rates as cross-shelf end members, Table 37 presents an annual estimate of microbial nitrogen mineralization within the Cairns and Tully boxes.

Table 37. Estimates of water column nitrogen mineralization by heterotrophic microbes in the Cairns and Tully boxes.

Cairns box		Summer			Winter		
Depth band	Volume m^3	N excretion rate µmol m^{-1} day^{-1}	Days	Total excretion kmol	N excretion rate µmol m^{-1} day^{-1}	Days	Total excretion kmol
0-10 m	1.9E+09	470.00	212	189316	270	153	78489
10-20 m	1.09E+10	330.00	212	762564	190	153	316863
20-30 m	2E+10	190.00	212	805600	110	153	336600
30 + m	1.64E+11	54.00	212	1877472	31	153	777852
		Seasonal Totals		3634952			1509804
					Annual N Mineralized		**5144756**

Tully box		Summer			Winter		
Depth band	Volume m	N excretion rate µmol m day	Days	Total Excretion kmoles	N excretion rate µmol m day	Days d	Total Excretion kmoles
0-10 m	1.5E+09	470.00	212	149460	270	153	61965
10-20 m	8.5E+09	330.00	212	594660	190	153	247095
20-30 m	3.1E+10	190.00	212	1248680	110	153	521730
30 + m	2.71E+11	54.00	212	3102408	31	153	1285353
		Seasonal Totals		5095208			2116143
					Annual N Mineralized		**7211351**

These calculations, though of a first-order nature, clearly suggest that microbial nitrogen mineralization processes in shelf waters (5.1-7.2 x 10^6 kmol per year) are likely to be of far greater magnitude than macrozooplankton and benthic mineralization processes and are of similar order to nitrogen demand by phytoplankton. As with macrozooplankton, much of this mineralization is likely to occur during the warmer and more productive summer months. Because of the rather limited nature of the data from which this estimate was derived, the accuracy and precision of this mineralization estimate is unknown.

Table 38 presents estimates of water column ammonium (NH_4), DIN (NH_4+NO_2+NO_3), DON and PON replacement (turnover) times (Furnas et al., 1986) within the two study boxes. Replacement times for the aggregate inorganic nitrogen (DIN) pool are largely determined by the estimated replacement times for ammonium (NH_4), the predominant constituent.

Ammonium pool replacement times within the two boxes range between 5 hours and 1.5 weeks. The calculated replacement times are largely constrained by the magnitude of the estimated mineralization rates rather than the sizes of the ammonium or DIN pools. The fastest replacement times for ammonium (and DIN) occur in the shallow inshore depth bands where the volume specific mineralization rates are the highest. The estimates suggest that in the Cairns box, ammonium pools in nearshore waters are turning over at least once per day, regardless of season. In the Tully box, estimated inshore turnover times range from < 1 day during summer to 3 days in winter. Offshore turnover times in both boxes are of similar order (≥ 1 week) during the winter.

Not surprisingly, estimated replacement times for DON stocks in both boxes are quite long, ranging from ca. 1.5 weeks at inshore stations during summer to 2-5 months in the offshore (>30 m depth) band during winter. These times do not reflect the likely turnover times of some biologically active constituents of the DON pool, such as dissolved amino acids, which are only present at low (nM) concentrations and are known to have turnover times on the order of hours in some systems (Fuhrman and Ferguson, 1986). Calculated PN pool replacement times on the basis of microbial mineralization ranged from ca. 3 days to four weeks, depending on the season and depth band.

No measurements of microbial phosphorus mineralization have been made to date in open shelf waters of the GBR. Dunlap (1985) measured potential enzymatic mineralization rates of DOP in waters flowing over shallow reef flat habitats in the central GBR, but it is difficult to extrapolate these results to the wider shelf environment. Nonetheless, his results indicated that on reef flats at least, enzymatic mineralization of DOP could be a major source of inorganic phosphorus to benthic algal communities. Laboratory studies of phosphorus remineralization by pelagic microflagellates and bacteria have yielded conflicting results. Both nitrogen and phosphorus mineralization rates are strongly dependent upon the physiological state of microbial populations involved and the C:N:P composition ratios of their food source (e.g. Goldman et al., 1987). As a result, microbial populations can either act as sources or sinks for nitrogen and phosphorus. The data most useful for deriving insights about microbial phosphorus cycling rates in GBR waters comes from field studies which were largely carried out near Hawaii (Smith et al., 1985; Harrison and Harris, 1986; Orrett and Karl, 1987). While measured mineralization rates were shown to vary with time over the course of a day, for time periods on the order of 24 hours, water column phosphorus uptake and mineralization rates appear to be balanced. As a result, the estimates of phosphorus demand derived from primary production rates and the Redfield ratio can supply a first-order estimate of water column phosphorus mineralization.

Table 38. Estimates of mean seasonal replacement times (days) for water column stocks of ammonium, DIN, DON, and PON in the Cairns and Tully boxes based on *in situ* mineralization rates of Hopkinson et al. (1987). Summer mineralization rates are estimated to be 1.75 times winter rates and are not adjusted for seasonal differences in biomass.

	Concentration (μM)				Replacement Time (days)			
Depth Range (m)	0-10 m	10-20 m	20-30 m	30 m +	0-10 m	10-20 m	20-30 m	30 m +
Cairns box								
Summer								
Mineralization Rate (μM day^{-1})	*0.47*	*0.33*	*0.193*	*0.054*				
NH_4	0.21	0.29	0.17	0.18	0.4	0.9	0.9	3.3
DIN	0.25	0.33	0.20	0.21	0.5	1.0	1.0	3.9
DON	5.45	4.68	6.14	6.17	11.6	14.2	31.8	114.3
PON	1.60	1.10	0.99	0.80	3.4	3.3	5.1	14.8
Winter								
Mineralization Rate (μM day^{-1})	*0.27*	*0.19*	*0.110*	*0.031*				
NH_4	0.26	0.33	0.33	0.23	1.0	1.7	3.0	7.4
DIN	0.30	0.36	0.39	0.27	1.1	1.9	3.5	8.7
DON	5.00	5.21	4.99	4.97	18.5	27.4	45.4	160.3
PON	1.63	1.12	1.06	0.72	6.0	5.9	9.6	23.2
Tully box								
Summer								
Mineralization Rate (μM day^{-1})	*0.47*	*0.33*	*0.193*	*0.054*				
NH_4	0.17	0.10	0.05	0.09	0.4	0.3	0.3	1.7
DIN	0.27	0.10	0.05	0.09	0.6	0.3	0.3	1.7
DON		4.21	3.68	4.65		12.8	19.1	86.1
PON		1.37	1.16	1.20		4.2	6.0	22.2
Winter								
Mineralization Rate (μM day^{-1})	*0.27*	*0.19*	*0.110*	*0.031*				
NH_4	0.89	0.56	0.30	0.32	3.3	2.9	2.7	10.3
DIN	1.14	0.91	0.40	0.42	4.2	4.8	3.6	13.5
DON								
PON	2.19	2.69	1.27	0.91	8.1	14.2	11.5	29.4