PART 3

PRIMARY PRODUCTION AND NITRATE UPTAKE

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1 - METHODS

1.1. - Primary production

Measurements of carbon uptake have been carried out by the standard ^{14}C method (Steeman Nielsen 1952). The ^{14}C used was provided by the CSIRO (Australia) as $Na_2\ ^{14}CO_3$ (10 µCi in 1 ml sterile aqueous solution). Each inoculum was from 200 or 400 µl of ^{14}C solution, giving an activity from 4.4×10^6 dpm to 8.8×10^6 dpm, and was added in a 280 ml flask sample.

Two kinds of experiments have been carried out during the cruise :

a) Simulated in situ incubations :

The sample bottle were wrapped in neutral density screens in order to simulate light intensities from depth to which 100,50,25,10,5, 3 and 1 % of the incident light penetrated, and placed in a deck incubator. The flasks were filled with surface water filtered on 125 µm plankton net to discard the largest living zooplankters.

b) In situ incubations :

The samples were taken with Niskin bottles at depths determined by the Secchi disk to which 100,50,25,10,5 and 1 % of the incident light penetrated ; after filling up the incubation flasks with filtered water on 125 µm plankton net, these ones were immersed for incubation at the predetermined depths.

In the two cases immediately after sampling, the nutrients were measured according to Strickland and Parsons(1968).

Seston was uptaken after pre-filtration on 125 µm plankton net and filtration on silver filters (0.8 µm ; Selas Flotronics) and preserved at -20°C for further determination for particulate carbon and nitrogen at the laboratory (CHN Hwelett-Packard 185 B). Incubations times ranged from 4 to 10 hours.

After incubation and filtration, filters were washed with HCl N/100 and preserved in a freezer (-20°C), and counted later on a Packard Tri-Carb scintillation counter.

The CO_2 concentrations of the waters were estimated by the relation established for brackish waters (Lemasson and Pages 1980). Uptake rates from carbon are expressed in $\mu mol.h^{-1}C$ (ρ_c) and specific uptake rates in h^{-1} (V_c, in $\mu mol\ C.\ (\mu mol\ C_p)^{-1}.h^{-1}$).

1.2. - Nitrate uptake

Inorganic nitrogen uptake was measured by the ^{15}N method by two ways :

a) In situ incubations :

The water sample is was prefiltered on a 125 µm plankton net and is enriched of about 10 % of the ^{15}N labelled compound compared with the ambient concentration of the unlabelled compound. The labelled nitrate was $(^{15}NO_3)_2Ca$ at 99 %. Bottles (2.580 liters) were incubated for 12 hours, from dawn to sunset, under in situ light conditions by suspending bottles vertically in the water column at the depths corresponding to 100,50,25,10,5 and 1 % level of incident light.

b) Simulated in situ incubations :

When dealing with low ambient concentrations of nutrients (near the minimum limit of detection), an addition of labelled nutrient quantitatively equivalent to the minimum limit of detection would lie between 50 and 100 per cent of the nutrient pool, and the calculated rate of uptake would vary accordingly. But it is possible to extrapolate with assumed parameters for uptake kinetics from rates measured at high and saturating concentrations of labelled substrate to rates for uptake at ambient nutrient concentrations (MacIsaac and Dugdale, 1972).

By using the Michaelis-Menten kinetic expression :

$$V = \frac{V_{max} \cdot S}{K_t + S}$$

if we know V_{max} (maximal velocity of uptake) and K_t (substrate concentration at which $V = V_{max}/2$) called "transport constant", it is theoretically possible to calculate V, the velocity of uptake of substrate (in this paper, units of NO_3-N taken up per unit time per unit N_p, i.e. t^{-1}).

Incubations were made with enrichments of 0.2, 0.5, 1, 5 and 10 $\mu mol.l^{-1}$ KNO_3, and incubations were carried out at 100 % of incident light in on deck incubator. The kinetics constants were computed by the Sakoda and Hiromi (1976) method. Incubation times were about 6 hours.

In the two cases the filters were filtered under low depression (100 mm Hg vacuum), preserved at -20°C and analyzed at the laboratory on shore by optical emission spectrometry (Lemasson et al. 1982).

2 - RESULTS

Tables 2,3 and 4 and figures 48 and 49 summarize the productivity data for carbon and nitrogen-nitrate. The conditions are typical of coastal waters, and the stations in the outer Ambon bay are highly productive. C/N composition ratios (at:at) of the particulate matter (lower than 125 µm) range between 4.8 to 11.4 in the whole water column in Ambon bay. Assimilation ratios ($\Delta C/\Delta N$: $\mu mol.h^{-1}$ C/$\mu mol.h^{-1}$ N-NO_3) are high in the range of 36.3 to 68.7 ; these numbers, higher than the "Redfield" ratio (106/16 ; Redfield 1958) are showing that nitrate seems to be only a few part of the nitrogenous taken up nutrition. Ammonium, preferentially taken up in comparison to nitrate, must be present in abundance in these Ambon bay waters where urban waste products are thrown.

Integrated uptake rates for carbon range from 10.8 $mg.m^{-2}.h^{-1}C$ in open sea to 85.8 $mg.m^{-2}.h^{-1}C$ in the bay near Ambon city. The specific uptake rates for nitrate (V_{NO3}) range from 0.0005 h^{-1} in open sea to 0.023 h^{-1} in the bay near Ambon City.

In the inner bay the primary productivity is lower than that in the external bay ; the data for nutrients and primary productions in the whole bay are those of mesotrophic waters, likewise in the coastal waters of Banda Sea. Nitrogen is likely the limiting element as it is suggested by the often undetectable values of nitrate concentrations in the waters.

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Table 2 - Integrated values of primary production (^{14}C) on the water column between 100 % and 1 % incident light.

N° Station	Prod ($mg.m^{-2}.h^{-1}c$)	C_{p/N_p}	100 % light		C_p $\mu mol.l^{-1}$
			ρ_c ($\mu mol.l^{-1}h^{-1}$)	V_c (h^{-1})	
2	30.4	11.4	0.242	0.0121	19.97
10	85.8	13.6	0.291	0.0184	15.78
20	25.9	16.5	0.054	0.0086	5.71
23	26.1	10.0	0.092	0.0144	6.37
30	10.8	7.7-8.3	0.012	0.0019	5.4-15.5
31	62.1	7.5-9.9	0.167	0.0136	7.7-16.3
32	49.2	4.8-8.2	0.624	0.0295	13.3-21.1

St. 30 and 32 : in situ

St. 2,10,20,23 : in situ simulated

C_p : particulate carbon : limit values on the water column between 1 % and 100 % incident light.

Table 3 - Nitrate uptake. Specific uptake rate (V_{NO3}) and uptake rate (ρ_{NO3}) calculated from kinetics constants for surface water.

N° Station	V_{max} (h^{-1})	K_t ($\mu mol.l^{-1}$)	$V_{NO3}(h^{-1})$	N_p ($\mu mol.\ l^{-1}$)	NO_3-N ($\mu mol.l^{-1}$)	ρ_{NO3} ($\mu mol.l^{-1}$)
2	0.0014 *	0.408 *	0.0004 *	1.75	0.15	0.00023
10	0.0408	0.248	0.0230	1.16	0.32	0.0267
20	0.0051	0.954	0.0000(5)	0.605	(0.01)**	0.00003
23	0.0041	0.370	0.0001(1)	0.634	(0.01)**	0.00007

* Uncertain values.

** Undetectable. This value is an estimation and was used in calculations.

Table 4 - Summary of results of nitrate uptake (in situ incubations)

N° Station	Z	Im %	N_p	P_{NO_3} ($\mu mol.l^{-1}h^{-1}$)	V_{NO_3} (h^{-1})	C_{p/N_p}	$\Delta C/\Delta N$
30	0 15 26	100 50 25	0.81 1.96 0.05	0.00048 0.00013 0.00002	0.00059 0.00007 0.00003	7.7 7.9 8.3	36.3
31	0 16 27 40	100 25 10 5	1.63 0.91 1.34 1.30	0.00332 0.00214 0.00116 0.00022	0.00204 0.00234 0.00086 0.00017	7.2 9.9 7.5 8.1	58.2
32	0 5 10 17 25	100 50 25 10 5	2.21 1.85 2.36 1.93 1.55	0.00783 0.00249 0.00127 0.0051 0	0.00354 0.00135 0.00054 0.00026 0	8.2 5.3 4.8 6.2 7.2	68.7

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