Nutrients and Particulate organic matter in The Great Astrolabe Reef Lagoon

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Abstract

During the joint Fijian-French ASTRO cruise conducted in April 1994 in the Great Astrolabe lagoon and surrounding oceanic waters. Nutrient concentration and particulate organic matter stock and sedimentation rate was quantitatively investigated at 10 sampling stations. Dissolved inorganic nutrient concentrations were low in all the lagoon. Average POC and PON concentrations were respectively 144 and 20 mg m^{-3}. The average sedimentation rate for these elements were 37 and 8 mg m^{-2} day^{-1}.

1. Introduction

The lagoons of the South Pacific Islands play an important role in the country economy: cultured pearls from pearl oyster aquacultures in Tuamotu atoll lagoons are French Polynesia's major export; in addition, lagoon fisheries supply a major part of the local fish requirement.

An estimate of lagoonal productivity is necessary to assess the lagoons' potential for exploitation. Such estimates are difficult to make due to the diversity of lagoonal primary producers: phytoplankton, macrophytes, sand microphytes, and epilitic and symbiotic microphytes. Moreover, the flux of detritus particles flowing from the coral reefs into the lagoon may also be important to lagoon organisms (Gerber & Marshall 1982). The particulate organic matter (POM) content of the water column seems to be a good index of lagoon productivity (Charpy 1985).

Measurements of organic material deposition are very important. Nutrient requirements for lagoonal production may be met through recycling of autochthonous material in the sediments. One of the principal factors which governs rates of nutrient regeneration from sediments is the amount of organic matter incorporated into those sediments from the water above (Koop & Larkum 1987).

We studied the abundance, rate of deposition on the lagoon floor and export rate of POM in an open atoll of the Tuamotu archipelago from 1983 to 1987.

2. Material and Methods

2.1 Water sampling

The ASTRO expedition has studied the lagoon of the Great Astrolabe Reef and the surrounding ocean between April 17th and May 1st. Twenty five station were sampled in the GAR lagoon and one in ocean outside the reef OC (Figure 1). Water samples were collected with acid-cleaned Niskin bottles each 5 meters depth between 0 m and 40 m (in the deepest station). In ocean, water samples were collected each 20m until 120m and at 150m, 200m and 300m.

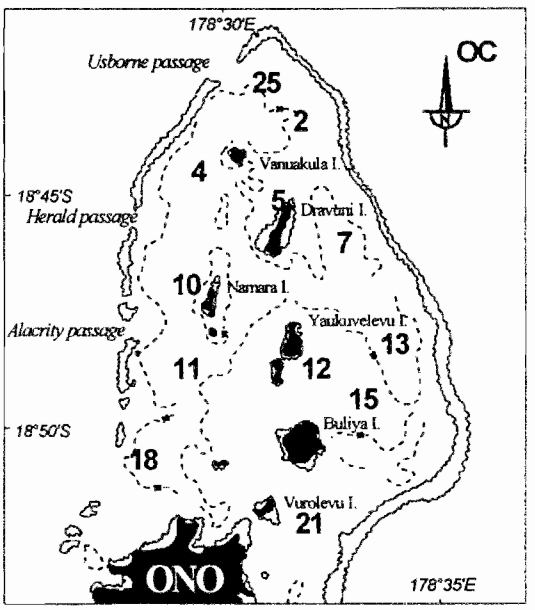

Figure 1: Station locations in GAR lagoon (OC=oceanic station)

2.2 Nutrient analysis

Dissolved nutrient (NH_4, NO_2, NO_3, $Si(OH_4)$, PO_4) concentrations were determined immediately in the field laboratory using the standard techniques described by Strickland and Parsons (1972).

2.3 Particulate organic matter

POC and PON concentrations were determined after rinsing the filter with 20 ml of HCl (0.1 N) with CHN analyzer (Gordon & Sutcliffe 1973).
Concentrations of chlorophyll a (Chl) were determined by fluorescence (Yentsch & Menzel 1963) using a Turner 111 fluorimeter

2.4 Trapping rate (TR)

Ten measurements of trapping rate of particulate matter were performed in 2 stations at 20 and 30m depth. The sediment trap used in this study consisted of a 10 l PVC plastic jar with a trapping surface of 0.08 m^2. (16x40 cm). The ratio of height to width of the jar was 2.5 : 1 as recommended by Gardner (1980). No poisoning was done. The jar was mounted 20m and 30 m below the surface on an anchored nylon rope, and supported by a subsurface float 2 m below the surface. Material was collected for 6 to 20 h. Seston was resuspended by magnetic stirring and split into 8 aliquots of 500 ml and 2 of 200 ml. POC, PON analysis were made in duplicate with the 500 ml aliquots; pigment concentrations were measured on the 200 ml aliquots.

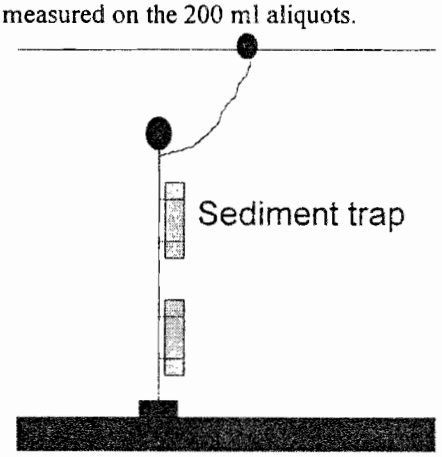

Figure 2: Measurements of Particulate organic matter trapping rate

Concentrations of Chl, POC and PON were measured at 20m and 30m, at the beginning of the experiment.

The trapping rate (TR) was calculated by the equation:

$$TR\ (mg\ POM\ m^{-2}\ d^{-1}) = V\ (C_T - C_w)\ /\ t\ S$$

where

C_T = POM concentration in the trap (mg m^{-3}); C_w = POM concentration in the water at 20m or 30m (mg m^{-3}); V = trap volume (m^3); t = time interval (d); S = collecting surface area of the trap (m^2).

3. RESULTS

3.1 Nutrients

3.1.1 Lagoon

Depth seems to have no influence onto the nutrient concentration variations (Figure 3). Nitrate concentrations were below 0.5 µM except at station 21 where the average was 1 µM. NH_4 concentrations varied between 0 and 0.7 µM according to the stations (Figure 4). PO_4 concentrations were very low (<0.1µM) at stations 2, 7, 10, 18. In the 5 other stations PO_4 concentrations were > 0.2µM. Silicate concentrations were very low <0.1µM in all stations except stations in the 3 stations located at the south of the lagoon (18, 21 and 15) .

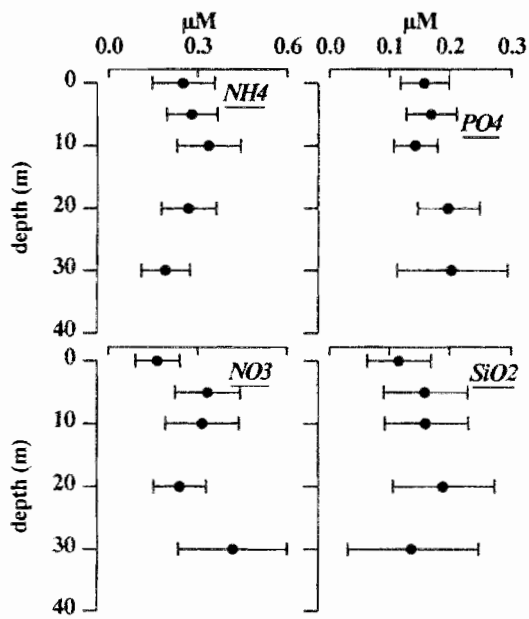

Figure 3: Average ± SE of nutrient concentrations profiles in GAR lagoon

3.1.2 Ocean

Nitrate concentration was very low in the upper 60m and increase below, reaching 6 µM at 300m. Phosphate concentrations were between 0.2 and 0.3µM. Silicate concentrations varied between 0 and 1 µM

Table 1: Nutrients and particulate organic C and N concentrations in the GAR lagoon

date	stat	Z st.	Z sam	NO_2	NO_3	NH_4	PO_4	SiO_2	POC	PON	C/N
18/04/1994	10	37	0	0.02	0.02	0.21	0.05				
18/04/1994	10	37	5	0.01	0.02	0.03	0.10	0.03			
18/04/1994	10	37	10	0.01	0.02	0.21	0.05		138	19	7.3
18/04/1994	10	37	20	0.01	0.02	0.1	0.09				
18/04/1994	10	37	30	0.01	0.02	0.03	0.05	0.03	192	25.2	7.6
18/04/1994	2	28	0	0.01	0.07	0.07	0.06	0.03	165	20.4	8.1
18/04/1994	2	28	5	0.01	0.07	0.29	0.06	0.03			
18/04/1994	2	28	10	0.05	0.02	0.38	0.07	0.03	144	22.8	6.3
18/04/1994	2	28	20	0.04	0.02	0.90	0.08	0.03			
19/04/1994	7	43	0	0.04	0.02	0.03	0.02	0.03	104	14.1	7.4
19/04/1994	7	43	5	0.03	0.23	0.03	0.02	0.03			
19/04/1994	7	43	10	0.03	0.23	0.03	0.02	0.03	95	11.6	8.2
19/04/1994	7	43	20	0.02	0.02	0.04	0.02	0.03			
19/04/1994	7	43	30	0.02	0.02	0.03	0.02	0.03	118	14.4	8.2
19/04/1994	7	43	38	0.02	0.02	0.09	0.02	0.03			
17/04/1994	13	34	0	0.03		1.09	0.16	0.03	112	15.8	7.1
17/04/1994	13	34	5	0.04	0.49	0.69	0.18	0.03			
17/04/1994	13	34	10	0.06	0.61	0.95	0.21	0.03	126	20.4	6.2
17/04/1994	13	34	20	0.06	0.49	0.59	0.25	0.03			
17/04/1994	13	34	30	0.03	0.44	0.52	0.42	0.03	105	13.8	7.6
20/04/1994	11	39	0	0.01	0.23	0.27	0.25	0.03	148	19.3	7.7
20/04/1994	11	39	5	0.01	0.19	0.66	0.18	0.03			
20/04/1994	11	39	10	0.01	0.54	0.77	0.11	0.03	146	18.6	7.8
20/04/1994	11	39	20	0.01	0.23	0.08	0.39	0.03			
20/04/1994	11	39	30	0.02	0.27	0.27	0.18	0.03	142	15.8	9.0
17/04/1994	4	39	0	0.01	0.06	0.32	0.43		164	18.8	8.7
17/04/1994	4	39	5	0.04	0.06	0.31	0.44				
17/04/1994	4	39	10	0.03	0.02	0.31	0.4		164	22.3	7.4
17/04/1994	4	39	20	0.03	0.08	0.32	0.48				
17/04/1994	4	39	30	0.07	0.54	0.28	0.53		192	23.8	8.1
20/04/1994	4	39	0	0.01	0.23	0.03	0.18	0.06			
20/04/1994	4	39	5	0.01	0.35	0.03	0.25	0.03			
20/04/1994	4	39	10	0.02	0.31	0.03	0.18	0.03			
20/04/1994	4	39	20	0.01	0.12	0.03	0.32	0.03	182	24.3	7.5
20/04/1994	4	39	30					0.03	123	30	4.1
17/04/1994	4	39	37	0.07	0.97	0.48	0.53				
21/04/1994	18	34	0	0.01	0.72	0.03	0.02	0.4	128	18.4	7.0
21/04/1994	18	34	5	0.01	0.72	0.03	0.02	0.49			
21/04/1994	18	34	10	0.01	1.22	0.03	0.02	0.53	116	15.8	7.3
21/04/1994	18	34	20	0.02	0.9	0.03	0.02	0.63			
21/04/1994	18	34	30	0.02	1.22	0.03	0.02	0.68	152	26	5.8
22/04/1994	21	30	0	0.01	0.13	0.44	0.22	0.03	126	23	5.5
22/04/1994	21	30	5	0.01	0.13	0.54	0.27	0.51			

Table 1 (suite) : Nutrients and particulate organic C and N concentrations in the GAR lagoon

date	stat	Z st.	Z sam	NO_2	NO_3	NH_4	PO_4	SiO_2	POC	PON	C/N
22/04/1994	21	30	10	0.01	0.17	0.59	0.2	0.34	126	19.4	6.5
22/04/1994	21	30	20	0.01	0.27	0.3	0.2	0.39			
22/04/1994	15	29	0	0.01	0.02	0.03	0.2	0.32	146	20.6	7.1
22/04/1994	15	29	5	0.01	1.08	0.2	0.18	0.26			
22/04/1994	15	29	10	0.01	0.02	0.07	0.18	0.27	130	21	6.2
22/04/1994	15	29	20	0.01	0.27	0.32	0.13	0.35			
23/04/1994	12	29	10						118	18.8	6.3
23/04/1994	10	37	20						187	22.4	8.3
23/04/1994	10	37	30						169	28.8	5.9
25/04/1994	10	37	20						204	13.6	15.0
25/04/1994	10	37	30						187	23.8	7.9
29/04/1994	25	31	0						152	26	5.8
29/04/1994	25	31	5								
29/04/1994	25	31	10						122	25.8	4.7
29/04/1994	25	31	20								
				NO_2	**NO_3**	**NH_4**	**PO_4**	**SiO_2**	**POC**	**PON**	**C/N**
			Average	**0.02**	**0.30**	**0.27**	**0.18**	**0.15**	**144.5**	**20.4**	**7.3**
			n	**48**	**47**	**48**	**48**	**40**	**32**	**32**	**32**
			SE	**0.00**	**0.05**	**0.04**	**0.02**	**0.03**	**5.2**	**0.8**	**0.3**

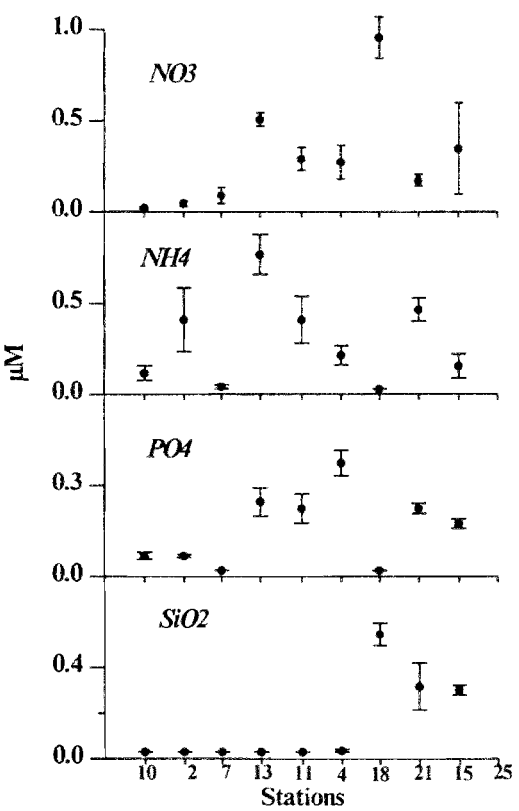

Figure 4: Average ± SE of nutrient concentrations in 9 stations of GAR lagoon

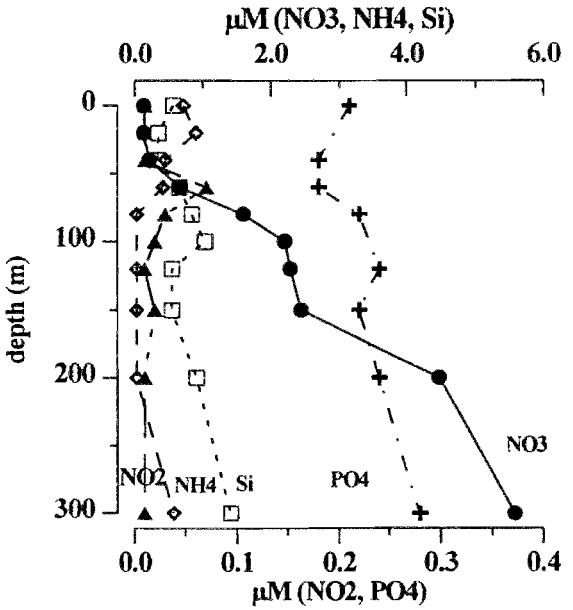

Figure 5: Nutrient concentrations in ocean

3.2 Particulate organic matter

POC and PON concentrations were in the ranges 95 - 204 mg C m^{-3} and 12 - 30 mg N m^{-3}.

Stations 7 and 13, both located in the east part of the lagoon, presented lowest POM concentrations (Figure 6). Richest stations were located at the north-west of the lagoon.

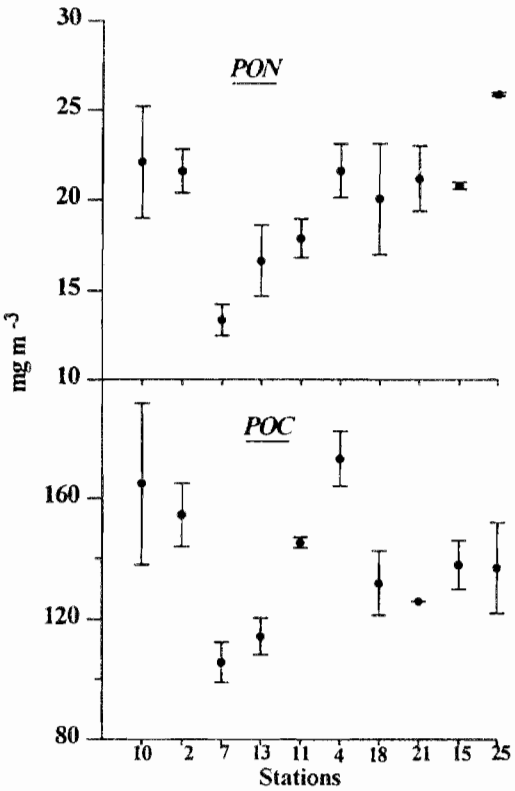

Figure 6: Average ± SE of POC and PON concentrations in 10 stations of GAR lagoon

3.3 Trapping rate

The sediment trap was placed at a depth thought to be far enough from the bottom (at less 5 m) to collect only material sinking from the surface layer. Current speeds below 5 m depth in the lagoon were not detectable. Therefore we assume that resuspension rate = 0 and that the trapping efficiency was maximum. So sedimentation rate (SR) = trapping rate (TR). Results appear in Table 2. The vertical flux of POC lies within the range 20 - 200 mg C m^{-2} day^{-1}. However, except at station 10 the April 24th, SR_{POC} was between 20 and 50 mg C m^{-2} day^{-1}. The average SR calculated without this data were 0.20 mg Chl m^{-2} day^{-1}, 37.3 mg C m^{-2} day^{-1} and 8.2 mg N m^{-2} day^{-1}.

The average POC:PON ratio (mass) in the trapped material was 5.3:1 (i.e. C:N = 13.8, molar basis); in suspended material, during the time of trapping experiments, the POC:PON ratio (mass) was 7.4:1 (i.e. C:N = 17.2:1, molar basis). The trapped material had a lower ratio C:N (5.3) than the suspended particles (7.4).

Table 2: Particulate organic matter trapping rate (TR; mg m^{-2} d^{-1})

date	stat	$depth_{bottom}$	$depth_{trap}$	dt (h)	TR_{Chl}	TR_{POC}	TR_{PON}	C/N
20/04/1994	4	39	20	21	0.08	20.1	3.9	5.17
			30	21	0.45	41.4	6.7	6.15
21/04/1994	4	39	20	24	0.31	35.9	6.6	5.45
			30	24	0.34	49.0	5.1	9.62
23/04/1994	10	37	20	24	0.10	33.3	11.6	2.88
			30	24	0.00	54.3	18.1	3.01
24/04/1994	10	37	20	23	0.32	189.2	87.3	2.17
			30	23	0.26	200.4	34.4	5.83
25/04/1994	10	37	20	47	0.11	27.4	5.4	5.10

4. Summary and conclusions

If we compare POC content of GAR lagoon with other coral reef lagoons (**Erreur! Source du renvoi introuvable.**), we observe that POC are largely higher in GAR than in Enewetak and Fanning atolls and also than in the Great Barrier Reef lagoon (Lizard Island). POC level in GAR lagoon was very similar to POC level observed in Tuamotu Archipelago. However, the highest POC value is from Houtman Abrolhos Atoll (Western Australia). The windward reef slopes of this atoll support extensive beds of macroalgae, exporting large amounts of algal fragments.

Table 3: Particulate organic carbon (POC; mg C m-3) in coral reef lagoon waters. RT = Residence time in days. Taken in part from Hatcher (1983) and Marshall et al. (1975)

Lagoon	RT	POC		Source
		Lagoon	**Ocean**	
Enewetak Atoll	20-200	20-50	18-30	Gerber & Marshall (1982)
Fanning Atoll	30	80		Gordon (1971), Smith & Pesret (1974)
Canton Atoll	50-95	160[a]		Smith & Jokiel (1975a, b)
Kavariti Atoll		349	240	Quasim & Sankaranarayanan (1970)
Houtman Atoll		1560-3660	14-42	Hatcher (1983)
South Caicos		130	40	Marshall et al. (1975)
Kanohe Bay		420		Coles & Strathman (1973)
Lizard Island		82-16	185-243	Moriarty (1979)
New Caledonia		222 (SD=19)		Clavier et al. (1995)
Tikehau Atoll	176	192 ± 7	52 ± 3	Charpy & Charpy-Roubaud (1991)
Rangiroa Atoll		270 ± 17		non publ. data
Tairao Atoll		210 ± 11		non publ. data
Toau Atoll		140 ± 23		non publ. data
Takapoto		119 ± 5		non publ. data
GAR lagoon		145 ± 5		This study

5. References

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