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The Great Astrolabe Reef Lagoon (Fiji) : Results of the French-Fijian ASTRO expedition

OCEANOGRAPHIE
Notes et documents n° 46
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General introduction

This work was carried out in Fiji as part of the international cooperation in marine biology between France and Fiji. This cooperation was initiated in 1991 between the Tahiti ORSTOM Center and the Institute of Marine Resources (The University of South Pacific, Suva).

In 1988, a Marine Pollution Research Group was formed at USP to coordinate the work in this field at the University. The group decided to carry out a baseline study of the Astrolabe lagoon and reef. The development of Dravuni as an important center for reef and lagoon research, attracting scientists from around the world was also envisaged (Morrison & Naqasima, 1992).

In 1991, the ORSTOM CYEL program in French Polynesian atolls began, with the object of creating a models for the operating system of atoll lagoons. Contacts were made between USP and ORSTOM scientists and the site of the Great Astrolabe Reef lagoon was choosen for a join study. A preliminary expedition was done in 1993 and a proposal (ASTRO) was drawn up to complete the baseline study of the Great Astrolabe Reef lagoon and to compare the GAR lagoon with French Polynesian lagoons.

The description of the Great Astrolabe Reef and lagoon appears in Morrison & Naqasima (1992) :

The Great Astrolabe Reef (18°45'S, 178°30'E) is situated north-east of Kadavu and south of Viti Levu (Figure 1). The Astrolabe Islands are a group of volcanic islands 3.3 to 3.5 million years old (Howorth & Carman, 1992). The climate is humid tropical with an average temperature of 25°C and rainfall of 2596 mm. Prevailing winds are from the south east. There are 13 islands, 4 of which 4 are inhabited (1000 inhabitants). Fish is the major source of protein for the villagers in the group (Naqasima et al., 1992).

The lagoon surface area is approximately 210 km^2. The maximum depth is about 37.5m and the average depth is 20m (Naqasima et al., 1992). The residence time for the Astrolabe lagoon was estimated 15-25 days in first approximation by MacLeod (1992). Preliminary results on marine biology, water quality, shellfish quality and sediments were published by Naqasima & Bandy (1992), Morrison & Maata (1992), Morrison et al. (1992), Morrison & Naidu (1992).

Thirteen scientists have studied the GAR lagoon in May 1994 (Table 1).

A part of them was based in the field research station of Dravuni Island with the support of the USP APHAREUS research vessel ship and the others in the ORSTOM ALIS research vessel ship.

This volume presents 10 papers redacted by 16 scientists from 9 institutes (Table 1)

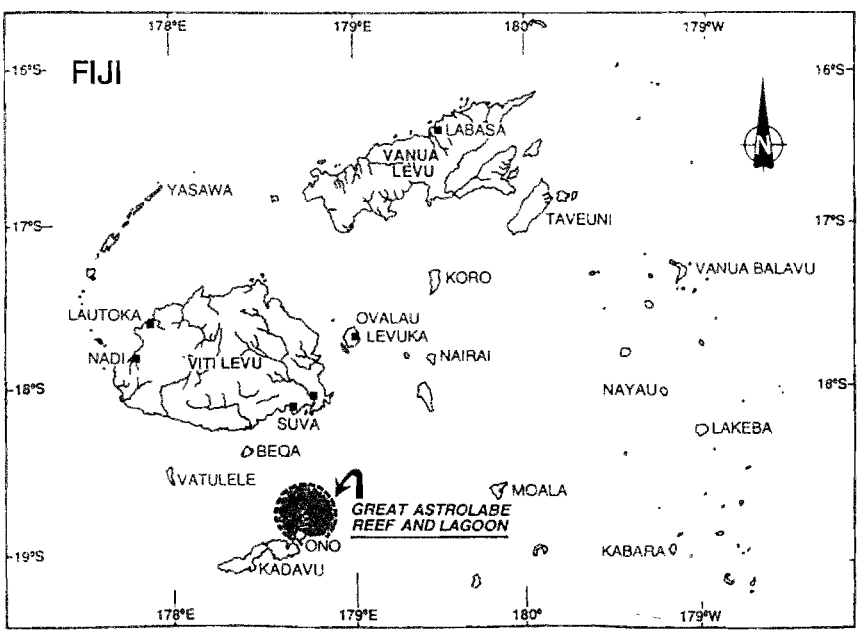

Figure 1 : Location of Great Astrolabe Reef

Table 1: List of the participants in the ASTRO expedition and authors of this volume

Name	Institute		Specialty
Blanchot J.	ORSTOM Nouméa	ASTRO	Picoplankton
Boucher G.	MNHN Paris		Meiofauna
Buscail R.	Univ. de Perpignan		Geochimist
Charpy L.*	ORSTOM Tahiti	ASTRO	Primary production
Charpy-Roubaud C.**	ORSTOM Tahiti	ASTRO	Microphytobenthos
Clavier J.	ORSTOM Brest	ASTRO	Zoobenthos
Di Matteo A.	ORSTOM Nouméa		Zoobenthos
Garrigue C.	ORSTOM Nouméa		Phytobenthos
Harrison N.	USP (Fiji)	ASTRO	Chemistry
Kotta J.	MNHN Paris		Meiofauna
Lo L.	EVAAM Tahiti	ASTRO	Chemistry
Maata M.	USP (Fiji)	ASTRO	Chemistry
Maihota N.	ORSTOM Tahiti	ASTRO	Diver
Manuelli F.	USP (Fiji)	ASTRO	Diver
Newel P.	USP (Fiji)	ASTRO	Zoobenthos
Richer de Forges B.	ORSTOM Nouméa		Zoobenthos
Sarazin G.	Univ. Paris VII	ASTRO	Geochemistry
Torreton J.-P.	ORSTOM Tahiti	ASTRO	Bacteria
Yeo G.	USP (Fiji)	ASTRO	Sediments

* Expedition leader for the water column study

** Expedition leader for the benthos study

Funding support was provided by the French Embassy in Suva, the ORSTOM program CYEL (Tahiti), the ORSTOM program FLUPAC (New Caledonia), the IMR (Suva), the School of Pure and Applied Science (USP, Suva) and the University of Paris VII.

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We thank Pr. R. South, who initiated of the French-Fijian cooperation, M. Bourelon who was in charge of Regional Cooperation at the French Embassy and M. J.-A. Costilhes, French Ambassador in Fiji and M. Boccas, Director of the Tahiti ORSTOM Center.

We also thank the crews of the research vessels ALIS and APHAREUS for their kind and efficient help on board, the leader of the Dravuni field Station.

We also thank very warmly the traditional landowners of Dravuni Island for allowing us to work in the lagoon and all the Inhabitants of the Island for their kind welcome.

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Phytoplankton biomass and productivity in The Great Astrolabe Lagoon

by Loïc Charpy

ORSTOM, Centre d'Océanologie de Marseille, traverse de la Batterie des Lions, F-13007 Marseille, France.

Abstract

Phytoplankton biomass and productivity of the Great Astrolabe Reef lagoon were studied using measurements of chlorophyll concentration and carbon uptake. Average chlorophyll concentration was 0.8 mg m^{-3} with 45% of phytoplankton passing through 3µm. Primary production was 1.3 gC m^{-2} day^{-1} (30m depth) with 47 % due to phytoplankton <3µm.

1. Introduction

Coral reef lagoons can play an important role in Pacific Islands economy when used for aquaculture. However, lagoon productivity studies are necessary to estimate their potential for mariculture.

Here, we present results from primary production experiments carried out in the Great Astrolabe Reef (GAR) lagoon in April and May 1993. The experiments were undertaken with two goals : (1) to estimate the average productivity of the lagoon and (2) using size-fractionation methods, to estimate relative contributions of phytoplankton sub-populations to community productivity.

2. Materials 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 (Figure 1). Water samples were collected with acid-cleaned Niskin bottles at 5m depth intervals between 0 m and 40m (the deepest station). In ocean outside the reef, water samples were collected at 20m intervals to 120m and then at 150m and 200m.

2.2 Primary production measurements

Two to five subsamples of unscreened sea-water (Furnas, 1987) were incubated *in situ* with 2 µCi of ^{14}C-bicarbonate in polycarbonate bottles. Surface irradiance was recorded during incubations with a LI-COR solarimeter. Following incubation, bottles were filtered through 3 µm Nuclepore filters ; pressure heads during fractionation never exceeded 0.004 atm. The filtrates were immediately refiltered onto 1 µm Nuclepore filters and then onto 25 mm Whatman GF/F glass fiber filters. Filters were acidified with 250 µl of 0.5N HCl to remove inorganic carbon. Radioactivity was measured with a liquid scintillation counter. Areal production was calculated by trapezoidal integration and daily production estimated by dividing the production measured during the incubation period by the fraction of total daily irradiance during that period.

2.3 Chlorophyll determination

Chlorophyll concentrations were determined by fluorometry (Yentsch & Menzel, 1963). Water samples for chlorophyll determinations were size fractionated by the same methods as productivity samples : They were successively filtered through a 3 µm filter (Nuclepore), then through a 1 µm filter (Nuclepore) and finally through a GF/F (Whatman) filter.

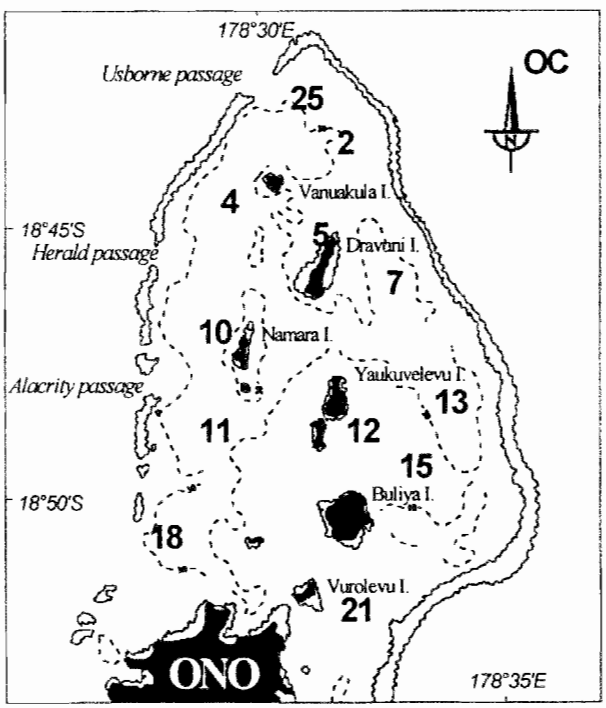

Figure 1: Station locations in GAR lagoon (OC = oceanic station)

3. RESULTS

3.1 Lagoon

Results are summarized in Table 1

Table 1 : Average ± SE of chlorophyll concentrations (Chl) and percentage of biomass and Primary Production (PP) of size classes

	>3µm	3-1µm	<1µm	Total
mg Chl m^{-3}	0.423 ± 0.018 N=47	0.123 ± 0.013 N=47	0.237 ± 0.018 N=47	0.830 ± 0.040 N=53
% Chl	55.2 ± 2.0 N=47	15.2 ± 1.2 N=47	29.6±1.5 N=47	
% PP	47.1 ± 2.1 N=43	22.6 ± 1.4 N=43	30.3±1.4 N=43	

3.1.1

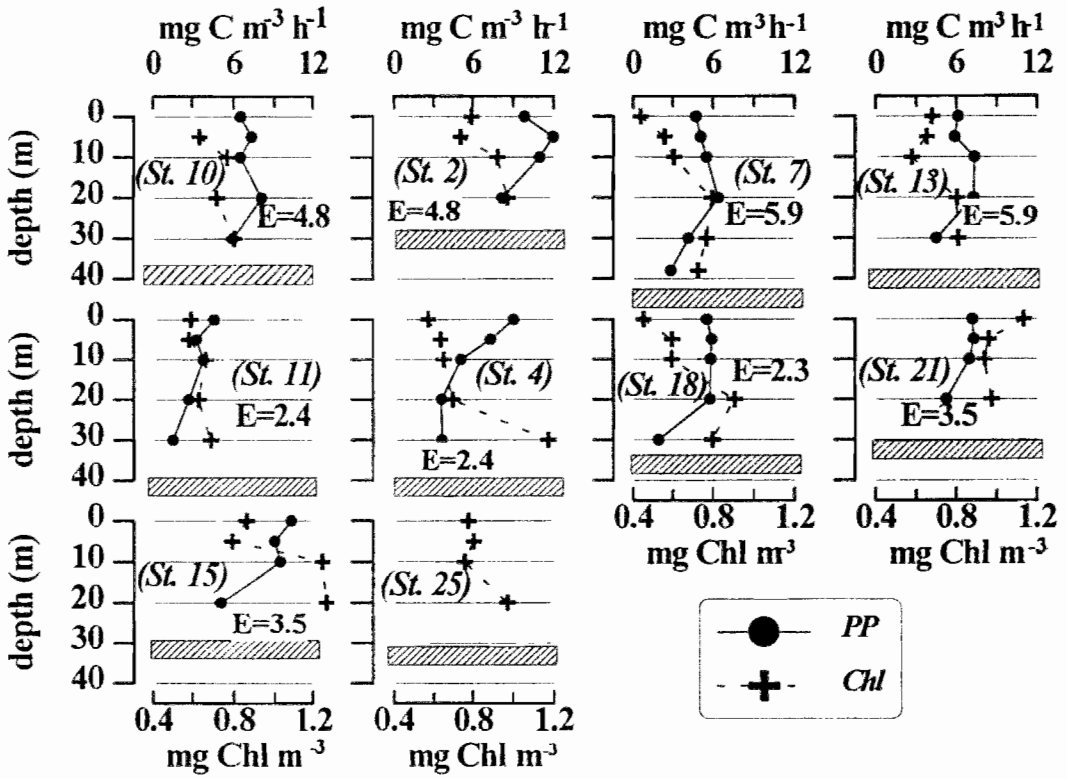

Figure 2: Chlorophyll (*Chl*), primary production (*PP*) and light energy (E : E m^{-2} h^{-1}) in GAR lagoon

3.1.1 Vertical variations

Phytoplankton biomass estimated by chlorophyll concentration ranged from 0.4 to 1.2 mg m^{-3} and generally increased with depth except at station 21 (Figure 2).

Primary production (Figure 2) ranged from 1.6 mg C m^{-3} h^{-1} at 30 m depth (station 11) to 12 mg C m^{-3} h^{-1} at 5 m depth (station 2). Maxima were observed close to the surface.

3.1.2 Horizontal variations

South east stations (15 and 21) presented maxima of chlorophyll and stations 7 and 11 the minima (Figure 3).

Stations 15 and 21 presented highest percentage of cells < 1µm (45%) and stations 10, 2, 7, 4, 18, 25, highest percentage of cells > 3 µm (> 60%) (Figure 4).

To compare station productivity, we calculated the integrated (upper 20m and 30m) plankton production (Table 2). Values vary from 604 (station 11) to 1337 mg C m^{-2} d^{-1} (station 2).

Table 2: Incident light energy (E m^{-2} d^{-1}) during the day (Ed) and during the incubation (Ei) and integrated primary production (IPP: mg C m^{-2} day^{-1}) in GAR lagoon

date	stat	Z st.	Ed	Ei	dt	IPP_{20m}	IPP_{30m}
18/04/1994	10	37	30.85	15.24	3.18	912	1363
18/04/1994	2	28	30.85	15.24	3.18	1337	
19/04/1994	7	43	36.71	18.25	3.09	694	1025
19/04/1994	13	38	36.71	18.25	3.09	852	1221
20/04/1994	11	39	20.8	7.33	3.00	604	788
20/04/1994	4	39	20.8	7.33	3.00	987	1295
21/04/1994	18	34	20.43	9.83	4.27	1036	1378
22/04/1994	21	30	21.18	10.92	3.09	803	
22/04/1994	15	29	21.18	10.92	3.09	1002	
					Average	**914.0**	**1178.3**
					n	**9**	**6**
					SE	**71.5**	**94.0**

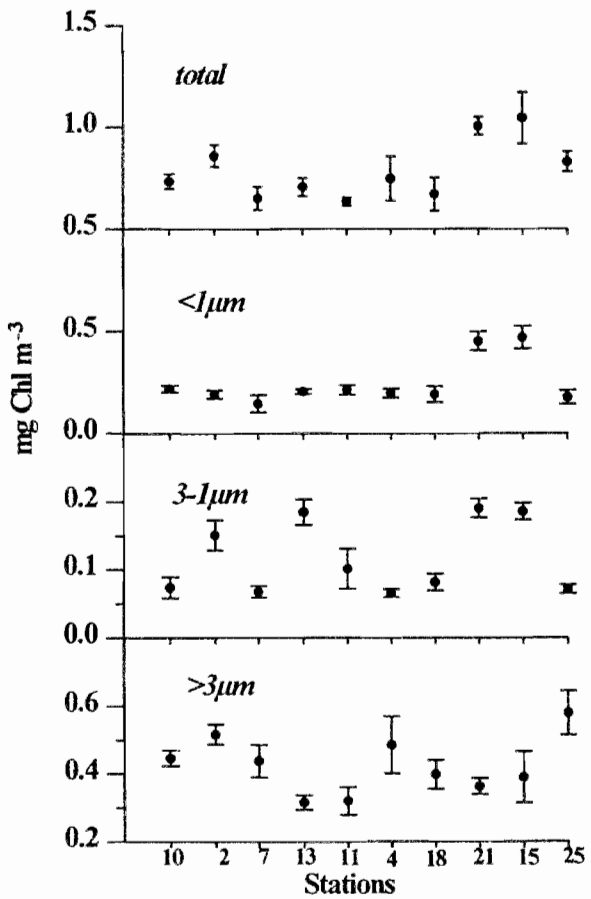

Figure 3: Average ± SE of Chl in different size fractions in GAR lagoon

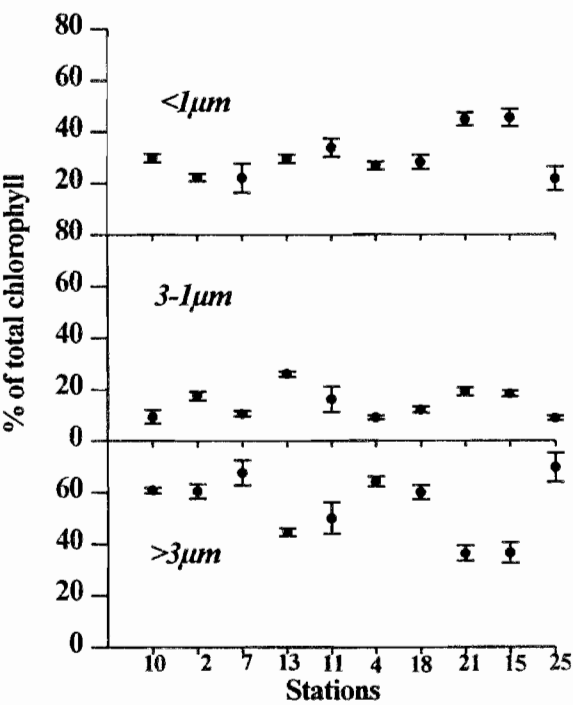

Figure 4: Percentages of Chl in different size fractions in GAR lagoon

3.2 Ocean

The maximum of chlorophyll in ocean was at 30 m depth (0.44 mg m^{-3}) and represented 40 % of the lagoonal Chl. The >3µm size class dominate phytoplankton in the upper 40 m and the <1µm size class below (Figure 5).

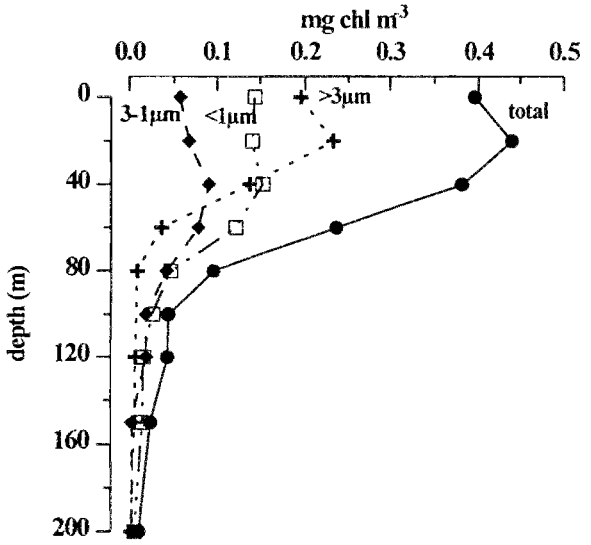

Figure 5: Vertical profiles of chlorophyll at oceanic station

4. Summary conclusions

The GAR lagoon phytoplankton biomass estimated with chlorophyll was 0.8 mg m^{-3}. Four times higher than Tuamotu atoll lagoon (Charpy-Roubaud et al. 1989, Charpy et al. 1992). Differences can be observed according to the station location. The stations located in the south east of the lagoon presented highest biomass. At these stations, we observed a dominance of picoplankton < 1µm. However, in average 55% of phytoplankton cells had a size >3µm. In Tuamotu atoll lagoons, this percentage was only 30% (Charpy & Blanchot 1996).

Primary production in the upper 30m was in average 1.3 g C m^{-2} day^{-1}. This value is 2 to 3 times the values recorded for atoll lagoons (Charpy-Roubaud et al. 1989, Charpy et al. 1992, Charpy & Blanchot 1996) and 100 times higher than the value published by Sorokin (1979) for an other Fijian island : Ngellelevu atoll. The oceanic station sampled, showed a maxim of Chl in the upper 40m. In this layer, phytoplankton size was very similar to lagoon, however, below, the picoplankton <1µm dominated the biomass.

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Nutrients and Particulate organic matter in The Great Astrolabe Reef Lagoon

by Loïc Charpy[1], Nathalie Harrison[2] and Matakite Maata[2]

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[2] The University of the South Pacific Dept. of Chemistry, P.O. Box 1168, Suva Fiji

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.

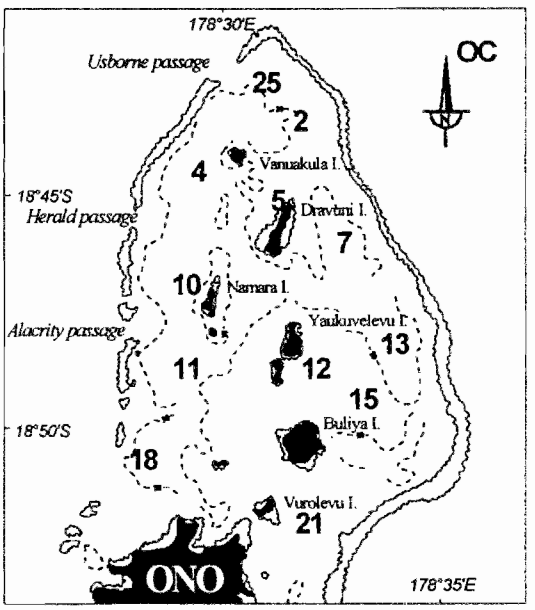

Figure 1: Station locations in GAR lagoon (OC=oceanic station)

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.

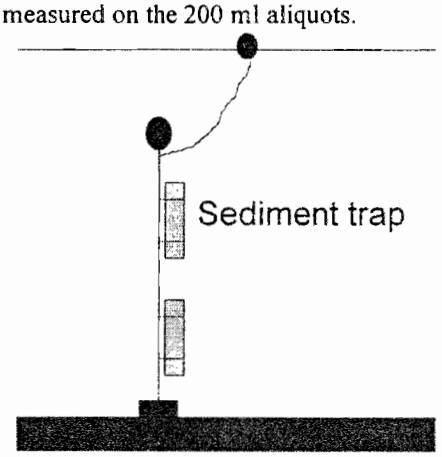

Figure 2: Measurements of Particulate organic matter trapping rate

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) .

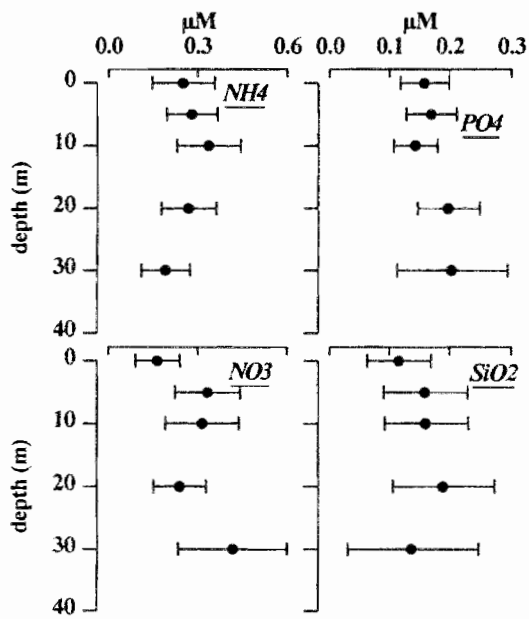

Figure 3: Average ± SE of nutrient concentrations profiles in GAR lagoon

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**

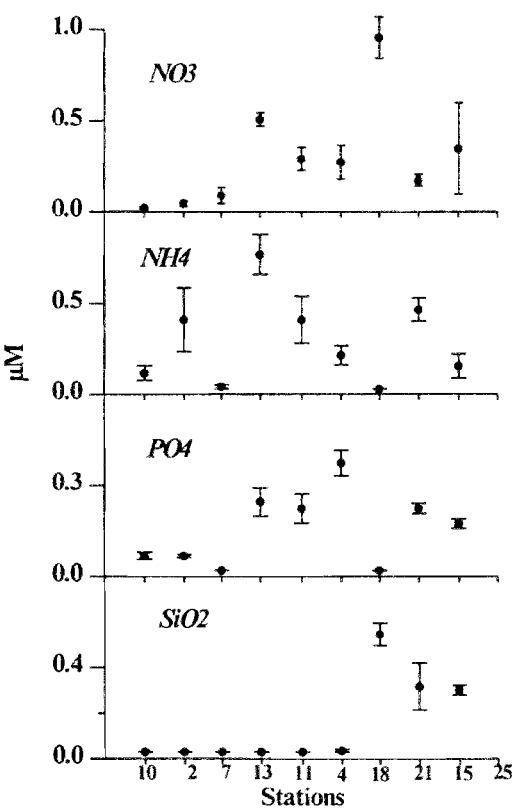

Figure 4: Average ± SE of nutrient concentrations in 9 stations of GAR lagoon

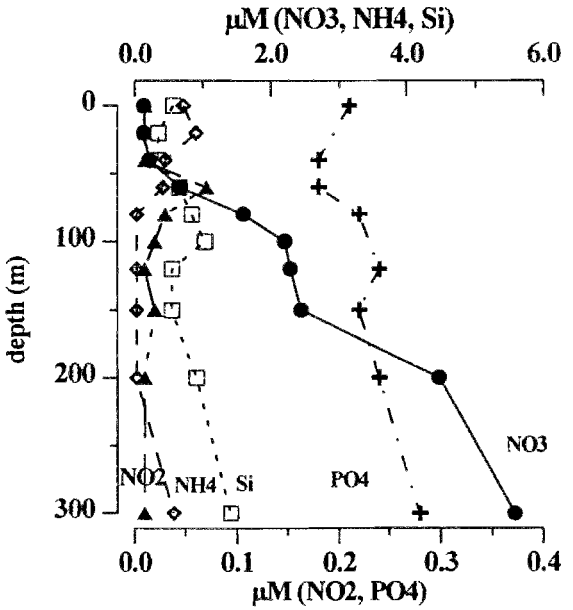

Figure 5: Nutrient concentrations in ocean

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.

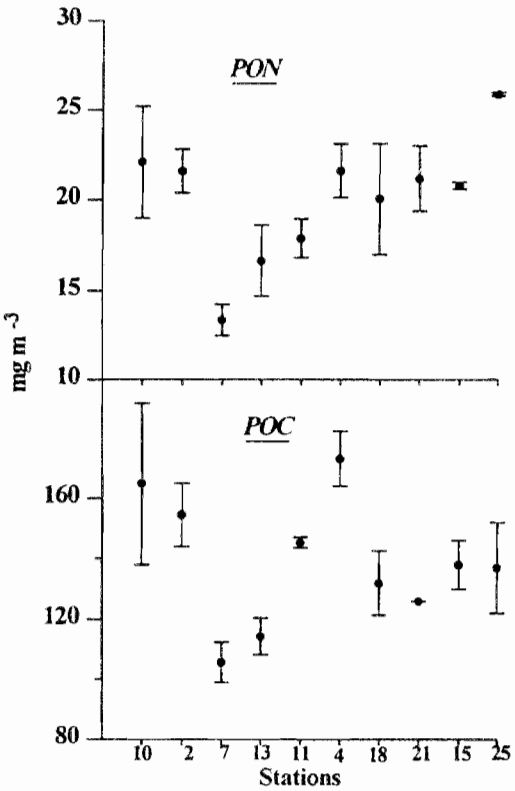

Figure 6: Average ± SE of POC and PON concentrations in 10 stations of GAR lagoon

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

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Sediment constituents in the Great Astrolabe Reef lagoon (Fiji)

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Abstract

Sediments of the Great Astrolabe Reef lagoon were investigated using a Smith-McIntyre grab during the joint Fijian-French ASTRO cruise, in april 1994. This preliminary paper focused on carbonated biophase, wich was studied trough skeletal composition of 25 sediment samples regularly spaced in the lagoon. Counting and identification of the biogenic debris were achieved for each sample on 13 size fractions (3.98, 3, 2, 1, 0, -1, -1.32, -2, -2.32, -3, -3.32, -4 and -4.32 ϕ). The results indicates that the main constituents of the carbonated biophase of the lagoon are, in order of importance, *Halimeda* plates, foraminifers an molluscs. The lagoon as a whole, is characterized by a HALIFOR biofacies and a HaliForPel sub-facies (*Halimeda*-Foraminifers-Pelecypods). Three main types of biofacies are found : *Halimeda* biofacies (HALIMOL and HALIFOR), a foraminifer biofacies (FORAMOL) and molluscs biofacies (MOLHAL and MOLFOR). Coral reefs represent only a small part among the producers of lagoon sediments (7th rank). The excellent state of preservation of the bioclasts suggests a modern or recent sedimentation and a low impact of the hydrodynamic agents at the bottom level. The absence of lithoclasts in the sand fraction indicate a limited terrigenous influence.

1. Introduction

The sediments of the Great Astrolabe Reef in Fiji were studied during the joint Fijian-French cruise "ASTRO", conducted in April 1994 on board of ORSTOM R.V. "ALIS". The Great Astrolabe Reef and Lagoon have been the subject of a baseline study by Morrison & Naqasima (1992), but this did not include the study of the sediments.

The sedimentological description of the bottoms contributes to our basic knowledge acquisition on the environment (soft bottoms can represent up to 90 % of the lagoon area) and it is an important factor to explain the distribution of the benthic species as well as the fishes living in tropical lagoons. It allows also to consider the hydrodynamic conditions that prevail at the bottom level. Sedimentology is also a useful tool in the management of the lagoon ressources (close relationships between the nature of the sedimentary environment and some exploitable species, inventory of the areas favourable to the extraction of sand and aggregates for the building industry) and in the preservation of the environment (impact of extractions, coastal and lagoonal development for the tourist industry).

From a more fundamental point of view, the identification and the characterization of the sedimentary environments, and particularly the skeletal composition, on one hand help to understand the sediment genesis process, and on the other hand allow to quantify the respective influences of terrigenous input, reefs, and benthic communities on the development of the lagoon sediments.

The preliminary results presented below thus concern, the sedimentology and more particularly the bioclastic composition of the sediments in the Great Astrolabe Reef lagoon. The same type of sedimentological study has been conducted since 1985 in the lagoons of New Caledonia (Chevillon, *in press* (a); Clavier *et al.*, 1995) and more particularly in the northern lagoon (Chevillon, 1992, 1990; Chevillon & Clavier, 1988; Chevillon *et al.*, *in press* (a); Plunet & Truvant, 1994), in the southern lagoon (Adjas, 1988; Chevillon, 1986, 1985; Chevillon & Poumarède, *in press*; Chevillon & Richer de Forges, 1988; Debenay, 1988a, 1988b, 1988c, 1987, 1986, 1985a, 1985b, 1985c; Dugas & Debenay, 1978, 1980, 1981, 1982; Poumarède, 1994) and the eastern lagoon of the main island (Chevillon, 1989), as well as in the Ouvea (Chevillon, *in press* (b), 1996; Chevillon *et al.*, 1992) and Chesterfield atolls (Chevillon & Clavier, 1990; Chevillon *et al.*, *in press* (b); Richer de Forges *et al.*, 1988; Rico & Sonnier, 1993).
In the Great Astrolabe Reef lagoon, bio-sedimentological analysis were done along a transect of W-E close to Dravuni Island (Schneider et al., 1995).

A more detailed sedimentological study of the Great Astrolabe Reef lagoon and a comparison with the sedimentology of New Caledonia lagoons will be

the subject of a coming publication (Chevillon & Yeo, *in prep.*).

2. Material & Methods

Twenty five samples of sediment, evenly spaced in the Great Astrolabe Reef lagoon (Fig.1 & Table 1) were collected from the R.V. "Alis", using a Smith-McIntyre grab.

Table 1: Depth (m) and position of collected samples

N°	Depth	South Latitude	East Longitude
1	31	18°43.50'	178°29.67'
2	28	18°43.49'	178°31.75'
3	22	18°44.68'	178°31.70'
4	39	18°44.57'	178°29.46'
5	17	18°45.19'	178°31.25'
6	38	18°46.11'	178°29.53'
7	43	18°46.09'	178°32.73'
8	37	18°46.97'	178°33.84'
9	35	18°46.90'	178°31.75'
10	37	18°46.99'	178°29.18'
11	39	18°48.81'	178°29.19'
12	29	18°48.80'	178°32.10'
13	34	18°48.28'	178°33.84'
14	27	18°49.48'	178°34.72'
15	29	18°49.46'	178°33.14'
16	32	18°49.48'	178°31.83'
17	34	18°49.57'	178°29.50'
18	34	18°50.77'	178°26.64'
19	31	18°50.94'	178°31.86'
20	34	18°50.71'	178°33.85'
21	30	18°52.14'	178°31.97'
22	36	18°51.64'	178°29.50'
23	31	18°48.43'	178°30.84'
24	32	18°49.83'	178°30.50'
25	31	18°42.66'	178°30.97'

In the laboratory, the samples, after homogenisation, were dried (72h à 60°C), weighed, and the mud fraction was removed by washing through a 3.98 ϕ sieve (63 µm). The remaining sediment - i.e. sand and gravel fraction (coarser than 3.98 ϕ) - was dried and weighed again, and dried-sieved using the following mesh sizes : 3.98, 3, 2, 1, 0, -1, -1.32, -2, -2.32, -3, -3.32, -4, -4.32 ϕ. We thus obtained 13 size fractions which were weighed and expressed as a percentage of the initial sample. Particle constituents were identified and counted under a binocular microscope using a Stratmann counting dish. This dish has 45 cells of 1 cm² each. For each sample and each size fraction, a cell is chosen at random and all grains within it are identified and counted; another cell is then chosen until at least 100 grains are examined (1 300 grains per sample), knowing that once a cell is started, all the grains it contains have to be examined. The results were converted into weight percentages according to the amount of the considered size fraction (Table 2), so that the total constituent percentages could be calculated (Masse, 1970).

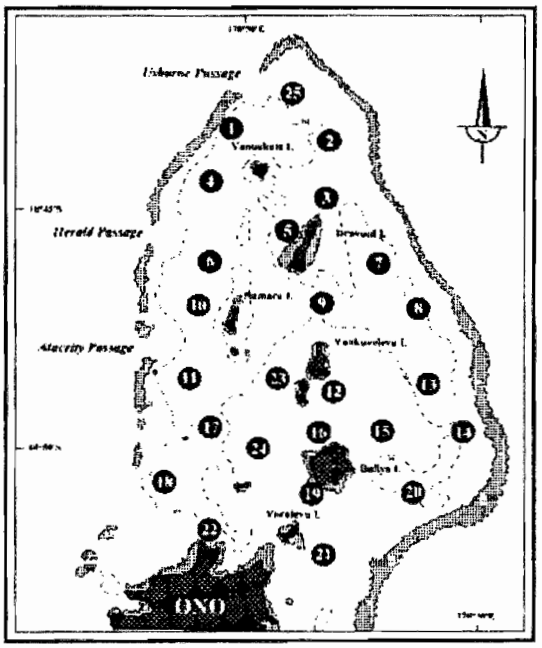

Figure 1: Locations of sampling stations

A biofacies (or facies biogen) name is then attributed to each sample according to an ordered bi-nominal or tri-nominal classification of the main constituents. For instance, if the first three bioclastic constituents are, in order of importance, molluscs, calcareous algaes and foraminifers, the biofacies name would be "MOLALGFOR". In the case of a bi-nominal classification (i.e. MOLALG), a sub-facies can be determined by involving the third constituent and the distinction between the various groups of molluscs, between the *Halimeda* plates and the red calcareous algaes within the calcareous algaes, or between the ostracodes and the other crustaceans (macroforms). For intance, the MOLALG biofacies (molluscs-calcareous algaes) could present a "GastHalFor" (Gastropods-*Halimeda*-Foraminifers) or a "PelRedFor" (Pelecypods-Red calcareous algaes-Foraminifers) sub-facies.

Table 2: Skeletal composition calculation processes

Size fractions		Skeletal constituents A, B, C...	
N°	weighed %	numerical %	weighed %
1	P_1	$A_1, B_1, C_1..$	$P_1A_1, P_1B_1, P_1C_1..$
2	P_2	$A_2, B_2, C_2..$	$P_2A_2, P_2B_2, P_2C_2..$
:	:	:	:
13	P_{13}	$A_{13}, B_{13}, C_{13}...$	$P_{13}A_{13}, P_{13}B_{13}, P_{13}C_{13}..$
		Total :	**A% , B%, C% (Σ = 100%)**

3. Results

3.1 Overall skeletal composition

The main producers of sediment in the Great Astrolabe Reef lagoon are, in order of importance, *Halimeda* (*Halimeda* plates can represent up to 86 % of the sediment constituents), foraminifers and molluscs (pelecypods and gastropods essentially and in equal proportion) (Fig. 2). Other groups of organisms take part, in a more limited way, in the production of the lagoon sediment : crustaceans (macroform), madreporians (coral), calcareous tubes (vermetid molluscs or serpulid worm tubes), echinoderms, bryozoans, scaphopods molluscs, sponges (spicules), alcyonarians (spicules), ostracods and red calcareous algaes (Table 3). In addition there are a certain number of reduced debris (identified or non-identified grey grains), natural agregates and undetermined fragments (generally small grains - <0,5 mm - altered by abrasion, microperforation or diagenesis).

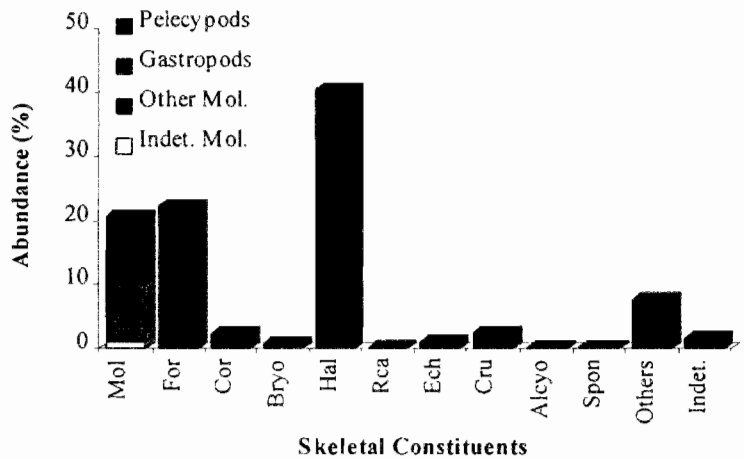

Figure 2 : Mean skeletal composition (n=25) of the sediments of the Great Astrolabe Reef lagoon (Mol : Molluscs, Other Mol. : Scaphopods and Pteropods, Indet. : indeterminates, For : Foraminifers, Cor : Corals, Bryo : Bryozoans, Hal : Halimeda plates, Rca : Red Calcareous Algaes, Ech : Echinoderms, Crus : Crustaceans, Alcyo : Alcyonarian spicules, Spon : Sponge spicules, Others : serpulid worm tubes, altered grains, grain aggregates, lithoclasts)

The small amount of undetermined fragments (an average of 1.65 %) reveals that the bioclasts are in an excellent state of preservation. It may be concluded on one hand that the production of sediments is modern or recent (no relict biophase) and on the other hand, that the hydrodynamic on the bottom is light (no abrasion, little transfer).

Finally, it should be underlined that the absence of lithoclasts (mineral elements of terrestrial origin) indicates a very low terrigenous influence in the sand fraction. The presence of high islands in the lagoon, suggests that terrigenous input exist, but that their influence may be probably detected only on the fine fraction of the sediments (< 63 µm).

3.2 Biogenous facies

The quantitative ordered classification of the biophase main constituents, reveal an important variability of the sediment composition since, not less than 5 biofacies and 10 sub-facies have been counted (i.e. nearly one sub-facies every 2 samples) (Fig. 3 & Table 4). Every sub-facies involves the three main constituents (*Halimeda*, foraminifers and molluscs) and shows hereby, the obvious supremacy of these three groups in the constitution of the sediment biophase. Still, two exceptions stand out : the GasHalCor sub-facies (Gastropod-*Halimeda*-Corals, station 5) and the ForPelCru (Foraminifers-Pelecypods-Crustaceans, station 22).

Table 3: Skeletal composition of samples (%)

	Station																								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Lagoon**
Pelecypods	9.1	16.3	8.9	13.0	13.2	7.9	28.6	22.4	6.7	6.6	7.6	2.9	6.1	13.6	4.4	10.0	8.6	10.5	10.1	9.1	3.8	18.0	2.9	2.9	23.0	**10.6**
Gastropods	9.6	11.2	8.9	7.8	13.6	10.8	8.9	15.6	5.6	15.9	12.3	2.4	4.7	11.7	6.4	5.3	6.6	16.7	5.6	7.5	4.2	7.5	2.7	2.7	16.2	**8.8**
Scaphopods	1.7	0.9				0.3	0.7			0.6				0.6								1.3		0.0	0.8	**0.3**
Pteropods																				0.1						**0.004**
Indet. Molluscs		0.7	3.5	0.7	2.2	3.4		1.1	0.7	0.5	0.3	0.1	1.4	0.5	1.7	0.7	0.3	0.3	1.0	1.4	0.1			0.2	0.6	**0.9**
Foraminfers	64.2	56.0	8.9	9.5	10.7	9.0	42.3	28.3	23.0	36.2	20.9	9.8	11.0	6.5	16.8	23.3	7.4	17.6	62.6	26.1	3.7	41.1	7.0	4.1	13.1	**22.4**
Corals	0.4	0.8	5.4	4.7	20.5	6.4			0.9	0.5	3.0	0.6	0.3	1.4	0.1		4.4	3.6	0.1	1.7	1.5		0.1	1.3	1.2	**2.4**
Bryozoans	0.6	1.0	0.1	2.1		1.5					0.4	2.1	0.2	0.9	1.0	1.0	1.1	2.5	0.2	0.9	0.7	0.2		1.4	1.2	**0.8**
Red Calcareous Algae			0.2											0.7				0.1		0.7	0.1			0.1	2.1	**0.16**
Halimeda	3.1	5.3	24.2	48.1	26.5	40.1	4.2	10.1	58.0	17.5	25.2	78.8	74.4	57.0	57.7	49.0	58.1	36.6	11.3	41.2	83.3	1.2	86.6	82.3	35.5	**40.6**
Echinoderms	1.3	0.4	0.6	2.0	0.8	5.1	1.1	1.9	0.1	3.1	3.6	0.5	0.3	1.5	0.5		1.3	1.2	0.5	0.8				0.2	0.3	**1.1**
Ostracods																					0.3			0.2		**0.02**
Crustaceans	1.2	3.8	2.0	3.5	1.3	1.6	3.4	5.2	0.7	1.5	3.2	1.8	0.3	2.9	3.2	3.4	2.4	4.2	2.4	4.4	1.6	4.2	0.4	1.2	1.3	**2.4**
Alcyonarians	1.1			0.3				0.6									1.7									**0.1**
Sponges		0.9		0.3								0.3			0.2				0.5					0.2	1.6	**0.2**
Serpulid worm tubes			0.4	1.9	1.3	0.9	0.7		0.3	0.1		0.6	1.0	1.2		2.0	0.5	0.5	1.5	0.8	0.8	25.6	0.4		1.4	**1.7**
Reduced grains	5.2	1.5		3.6	4.9	8.4	3.3	9.5	0.2	8.1	15.5				6.8	0.7	4.4	0.9	2.3	1.8		0.4		2.8		**3.2**
Oxidized grains				0.4																						**0.01**
Aggregates	2.6	1.5	1.1	1.9	3.3	3.5	6.9	5.4	2.6	9.2	8.1		0.3	1.5	1.4	4.8	3.2	5.4	1.6	3.5				0.4	1.6	**2.8**
Lithoclasts																										-
Indeterminate			35.8		1.8	1.2			1.0	0.2									0.2	0.4		0.6				**1.6**

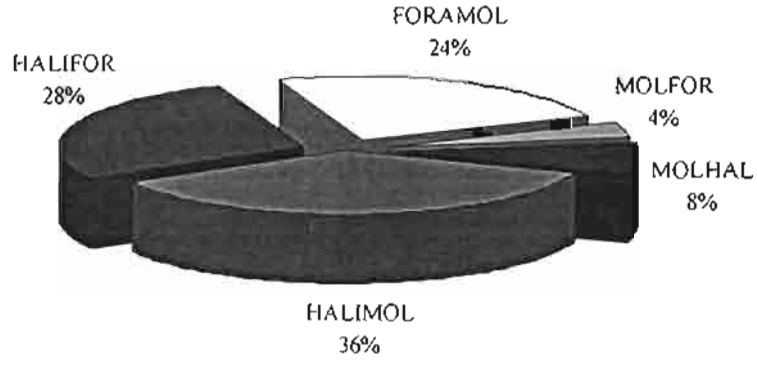

Figure 3: Pie chart showing the proportions of main biofacies

Three types of main biofacies stand out : the *Halimeda* biofacies, which represents 64 % of the samples (HALIMOL : 36 % and HALIFOR : 28%), one foraminifer biofacies (FORAMOL : 24%) and the mollusc biofacies (12% of the samples among which : MOLHAL = 8% and MOLFOR = 4%).

Table 4: Composition and abundance of the sub-facies

SUB-FACIES	Abundance	Stations
HalPelFor	24%	3, 4, 13, 14, 17, 24
HalGasFor	12%	6, 18, 21
HalForPel	20%	9, 12, 16, 20, 23
HalForGas	8%	11, 15
ForGasHal	8%	1, 10
ForPelHal	12%	2, 7, 19
ForPelCru	4%	22
PelForHal	4%	8
GasHalCor	4%	5
PelHalFor	4%	25

From the average composition of the biophase, the lagoon is globally characterized by the main HALIFOR biofacies and the association of *Halimeda*-Foraminifers-Pelecypods (HalForPel sub-facies)

4. Conclusion

In the Great Astrolabe Reef lagoon, *Halimeda*, foraminifers, and gastropod and pelecypod molluscs are ranked first among the producers of the sedimentary biophase. Corals, which bioclasts are specific of reef and lagoon environments, represent only a small part of the sediment composition (7th rank of the constituents). Coral reefs contribution to the lagoon sedimentation is consequently, extemely weak. Recent sedimentation and weak hydrodynamic conditions at the bottom level are strongly suggested by the small proportion of indetermined debris and by the excellent state of preservation of the bioclasts observed from the binocular microscope examination. The absence of lithoclasts (mineral elements of terrestrial origins) reveals, despite the presence of high islands in the lagoon, a weak terrigenous influence. Even though the Great Astrolabe Reef lagoon can be characterized by three types of main biofacies - the *Halimeda* facies (HALIMOL and HALIFOR), the foraminifers facies (FORAMOL) and the molluscs facies (MOLHAL and MOLFOR) - not less than 10 sub-facies have been identified (i.e. nearly one sub-facies every 2 samples), proving hereby, an important variability in the bioclastic composition of the samples. At a more general level, the biophase average composition allows a description of the Great Astrolabe Reef lagoon by the HALIFOR main biofacies and the *Halimeda*-Foraminifers-Pelecypods sub-facies.

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Soft substrate macrobenthos of Fiji's Great Astrolabe Reef lagoon. List of taxons, densities and their biomass

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Abstract

During the joint Fijian-French ASTRO cruise conducted in April 1994 in the Great Astrolabe lagoon, the soft bottom macrobenthos was quantitatively investigated at 25 sampling stations, using a 0.1 m² Smith-McIntyre grab. At each station, sediment was sampled with a total 1 m² area (10 replicate grabs) and washed through a set of 20, 5 and 2 mm sieves to retain flora and fauna. A total of 207 taxa was identified. This paper presents methods and raw data obtained from the study expressed for each taxon as numbers of individuals, dry weight and ash free dry weight per m².

Résumé

Au cours de la mission franco-fidjienne réalisée en avril 1994 dans le lagon du Grand récif de l'Astrolabe, le macrobenthos des fonds meubles a été échantillonné quantitativement sur 25 stations, à l'aide d'une benne Smith-McIntyre. Sur chaque station, le sédiment a été prélevé sur une superficie totale de 1 m² (10 coups de benne) et passé sur des tamis de 20, 5 et 2 mm pour isoler la flore et la faune. Un total de 207 taxons a été identifié. Le présent document regroupe un exposé des méthodes mises en oeuvre et une liste des résultats bruts issus de l'étude. Pour chaque taxon, ces derniers portent sur le nombre d'individus, le poids sec et le poids de matière sèche sans cendre.

1. Introduction

Quantitative studies on the benthic fauna of the sediments behind coral reefs are surprisingly sparse, and no such studies have previously been made in Fijian waters. The Great Astrolabe Reef and Lagoon have been the subject of a baseline study (Morrison and Naqasima, 1992) but this did not include the fauna and flora of the lagoonal sediments, concentrating limited analysis and collecting resources on the reef (Naqasima and Brandy, 1992).

Quantitative studies on the marine benthos of soft substrate have been made in the South West Pacific, centred on the work of the ORSTOM team based in Nouméa, New Caledonia. These include work on the South West lagoon of New Caledonia (Chardy *et al.*, 1988; Chardy and Clavier, 1988), Chesterfield Lagoon (WNW of New Caledonia, Clavier and Garrigue, 1990) and Uvea Lagoon (Loyalty Islands, NE of New Caledonia; Clavier *et al.*, 1992).

Sampling soft sediments has been reviewed by Hartley and Dicks (1987) and the methods used in this study are described below. The protocol followed is the one that has been developed by the ORSTOM team operating from Nouméa, New Caledonia, and was followed in this study to facilitate comparisons between this and the earlier work done in New Caledonia.

2. Materials and methods

The study focused on subtidal sediments. Macrobenthic communities were sampled at 25 sites located between 17 and 43 m depth over the lagoon (Table 1 and Figure 1). Sampling was carried out with the RV 'ALIS' in April 1994.

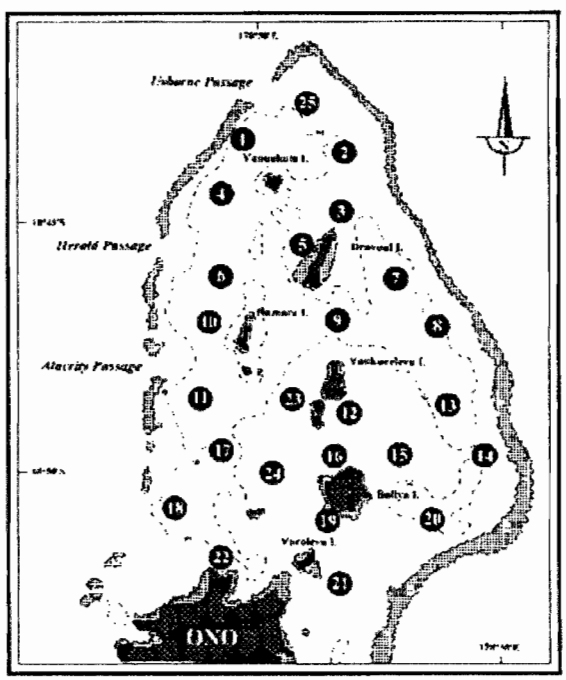

Figure 1: Location of sampling stations

Macrofauna and macroflora were sampled using a 0.1 m² Smith McIntyre grab weighed down with an additional 60 kg lead ballast (Figure 2). The sampling unit was a 1m² area, i.e. ten 0.1 m² grabs. The total collected volume of sediment was about 60 l. The boat was moored with a bow anchor and was free to swing under the influence of wind. The probability of a bite coincidence between samples was consequently very low. The samples from the same station were mixed and passed through 20, 5 and 2 mm stacked sieves. On board, organisms were separated from the substrate, sorted by major taxonomic groups and preserved in 10 % formalin neutralised with borax.

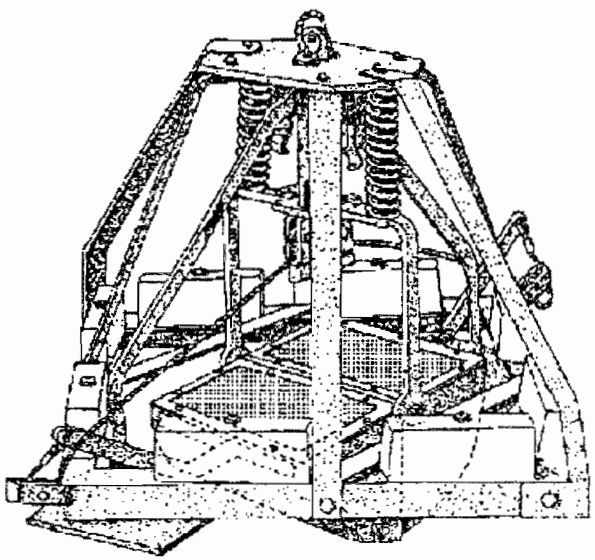

Figure 2: The Smith-Mc-Intyre grab

In the laboratory, taxonomic determinations were carried out as precisely as possible using the available literature. The results per station have been expressed as the number of individuals per m² for each identified taxon for macrofauna. Dry weights were measured after oven-drying (60°C) until constant weight and the ash weight by further heating at 550°C for 3 hours. The ash free dry weight is the difference between these two values. The biomasses have been expressed in grams of dry weight and ash free dry weight per m² for macrofauna and macroflora. Taxonomic biomasses have been summed to obtain the total macrobenthic biomass per station.

Table 1 : Depth (m) and position of the sampling stations

N	Depth	Latitude	Longitude
	31	18°43.50' S	178°29.67' E
	28	18°43.49' S	178°31.75' E
	22	18°44.68' S	178°31.70' E
	39	18°44.57' S	178°29.46' E
	17	18°45.19' S	178°31.25' E
	38	18°46.11' S	178°29.53' E
	43	18°46.09' S	178°32.73' E
	37	18°46.97' S	178°33.84' E
	35	18°46.90' S	178°31.75' E
1	37	18°46.99' S	178°29.18' E
1	39	18°48.81' S	178°29.19' E
1	29	18°48.80' S	178°32.10' E
1	34	18°48.28' S	178°33.84' E
14	27	18°49.48' S	178°34.72' E
15	29	18°49.46' S	178°33.14' E
16	32	18°49.48' S	178°31.83' E
17	34	18°49.57' S	178°29.50' E
18	34	18°50.77' S	178°26.64' E
19	31	18°50.94' S	178°31.86' E
20	34	18°50.71' S	178°33.85' E
21	30	18°52.14' S	178°31.97' E
22	36	18°51.64' S	178°29.50' E
23	31	18°48.43' S	178°30.84' E
24	32	18°49.83' S	178°30.50' E
25	31	18°42.66' S	178°30.97' E

3. Taxonomic list

3.1 Phytobenthos

CHLOROPHYTA

1 *Avrainvillea amadelpha* (Montagne) Gepp & Gepp
2 *Avrainvillea* sp.
3 *Caulerpa bikinensis* Taylor
4 *Caulerpa brachypus* Harvey
5 *Caulerpa racemosa* var. *clavifera* (Turner) Weber van Bosse
6 *Caulerpa sertularioïdes* (Gmelin) Howe
7 *Caulerpa taxifolia* (Vahl) C. Agardh
8 *Caulerpa urvilliana* Montagne
9 *Halimeda cylindracea* Decaisne
10 *Halimeda discoidea* Decaisne
11 *Halimeda incrassata* (Ellis) Lamouroux
12 *Halimeda macroloba* Decaisne
13 *Halimeda opuntia* (L.) Lamouroux
14 *Tydemania expeditionis* Weber van Bosse
15 *Udotea flabellum* (Ellis & Solander) Howe
16 *Udotea glaucescens* Harvey
17 *Halicystis* sp.

18 *Valonia aegagropila* C. Agardh
19 *Valonia fastigiata* Harvey

PHAEOPHYTA
20 *Dictyota* sp.

CYANOPHYTA
21 Cyanophyceae indet.

3.2 Zoobenthos

SPONGES
22 Sponge indet. 1
23 Sponge indet. 2
24 Sponge indet. 3
25 Sponge indet. 4
26 Sponge indet. 5
27 Sponge indet. 6

CNIDARIANS
28 *Edwardsia* sp.
29 *Trachyphyllia geoffroyi* (Audouin, 1926)

PLATYHELMINTHS
30 Platyhelminth indet.

NEMERTEANS
31 Nemertean indet.

NEMATODES
32 Nematode indet.

ANNELIDS
33 *Amphicteis* sp.
34 *Arabella iricolor* (Montagu, 1804)
35 *Armandia* sp. cf. *leptocirrus* (Grube, 1878)
36 Chaetopteridae indet.
37 *Chloeia* sp.
38 *Cirriformia* sp.
39 *Dasybranchus* sp.
40 *Drilonereis* sp.
41 *Euclymene* sp.
42 *Eunice complanata* (Grube, 1877)
43 *Eunice* sp.
44 *Eupolymnia* sp.
45 *Glycera* sp.
46 *Goniada* sp. *1*
47 *Goniada* sp. *2*
48 *Laonome* sp.
49 *Leiochrides australis* Augener, 1814
50 *Linopherus* sp.
51 *Loimia ingens* (Grube, 1878)
52 *Lumbrineris* sp. *1*
53 *Lumbrineris* sp. *2*
54 *Lysilla pacifica* Hessle, 1917
55 *Lysippe* sp.
56 *Malacoceros* sp.
57 *Marphysa* sp.
58 *Mastobranchus trinchesii* Eisig, 1887
59 Nereidinae indet.
60 *Notomastus* sp.
61 *Pareulepis* sp.
62 *Pectinaria* sp
63 *Phyllochaetopterus* sp.
64 *Phyllodoce* sp.
65 *Pista* sp. cf. *australis* Hutchings & Glasby, 1988
66 *Poecilochaetus* sp.
67 *Polydora* sp.
68 *Polyodontes* sp.
69 *Prionospio (Aquilaspio) aucklandica* Augener, 1923
70 *Prionospio (Aquilaspio)* sp..
71 *Prionospio (Prionospio) lineata* Imajima, 1990
72 *Prionospio* sp.
73 *Psammolyce antipoda* (Schmarda, 1861)
74 *Rhinothelepus* sp.
75 *Samytha* sp.
76 *Samythella* sp.
77 *Sigalion mathildae* Audouin & Milne-Edwards, 1832
78 *Spio* sp.
79 *Sthenelais laevis* Kinberg, 1858
80 *Sthenelais zeylandica* Wiley, 1905
81 *Sthenolepis yhleni*(Malmgren, 1867)
82 *Streblosoma* sp.
83 *Syllis (syllis)* sp.
84 *Terebellides stroemi* Sars, 1835

SIPUNCULIDS
85 *Aspidosiphon* sp. *1*
86 *Aspidosiphon* sp. *2*
87 *Aspidosiphon* sp. *3*
88 Sipunculid indet. 1
89 Sipunculid indet. 2

LOPHOPHORIANS
90 Phoronidian indet.
91 Brachiopod indet.
92 *Lingula* sp.

MOLLUSCS
Gastropods
93 *Acteon virgatus* Reeve, 1842
94 *Atys cylindricus* (Helbling, 1879)
95 *Cantharidus* sp.
96 Cerithidae indet. 1
97 Cerithidae indet. 2
98 *Dentalium sp*
99 *Lophiotoma* sp.
100 *Malea pomum* (L., 1758)
101 *Nassarius glans* Röding, 1798
102 *Nassarius* sp.
103 *Natica onca* Röding, 1798
104 *Natica* sp.
105 *Oliva carneola* (Gmelin, 1791)
106 *Oliva miniacea* (Röding, 1798)
107 *Pupa solidula* (L., 1758)
108 *Rhinoclavis aspera* (L., 1758)
109 *Strombus fragilis* (Röding, 1758)
110 *Subcancilla interlirata* (Reeve, 1844)
111 *Terebellum terebellum* L., 1758
112 *Terebra* sp.
113 *Terebra subulata* (L., 1767)
114 *Terebra undulata* Gray, 1834
115 Turridae indet. 1
116 Turridae indet. 2
117 *Vexillum sanguisugum* (L., 1758)
118 *Vexillum* sp. *1*

119 *Vexillum* sp. *2*
120 *Vexillum* sp. *3*
121 *Vexillum* sp. *4*
122 *Viriola interfilata* (Gould, 1861)

Bivalves

123 *Anodontia* sp.
124 *Arca navicularis* Bruguière, 1789
125 *Arcopagia (Pinguitellina) robusta* (Hanley, 1844)
126 *Barbatia* sp.
127 *Codakia* sp.
128 *Ctenodardia victor* (Angas, 1872)
129 *Fimbria fimbriata* (L., 1758)
130 *Gari maculosa* (Lamarck, 1818)
131 *Laevicardium* sp.
132 *Lima* sp.
133 *Lioconcha castrensis* (L., 1758)
134 *Lioconcha ornata* (Dillwynn, 1817)
135 Lucinicae indet. 1
136 Lucinidae indet. 2
137 *Modiolus philippinarum* Hanley, 1843
138 *Pinna* sp.
139 Pinnidae indet.
140 *Tellina rastella* Hanley, 1844
141 *Tellina* sp.
142 Tellinidae indet.
143 *Timoclea (Glycydonta) marica* (L., 1758)
144 *Vasticardium pulicarium* (Reeve, 1845)

CRUSTACEANS

145 Stomatopod indet. 1
146 Stomatopod indet. 2
147 *Ampelisca* sp.
148 Melitidae indet.
149 *Arcania* sp.
150 *Calappa* sp.
151 *Dacryopilumnus* sp.
152 *Hephthopelta* sp.
153 *Hexapus (Lambdophattus) anfractus* Rathbun, 1909
154 *Hexapus (Lambdophattus)* sp.
155 *Hexapus* sp.
156 *Leucosia* sp.
157 *Macrophthalmus convexus* Stimpson, 1858
158 *Micippa philira* (Herbst, 1803)
159 *Nursia* sp.
160 *Palicus* sp.
161 *Parthenope (Aulacolambrus) hepatus* (Adams & White, 1848)
162 *Phymodius* sp.
163 *Pilodius* sp.
164 *Pilumnus* sp.
165 *Podophthalmus nacreus* Alcock, 1899
166 *Portunus longispinosus* (Dana, 1852)
167 *Portunus* sp.
168 *Psaumis cavipes* (Dana, 1852)
169 *Tetrias fischeri* (A. Milne Edwards, 1867)
170 *Thalamita* sp. *1*
171 *Thalamita* sp.*2*
172 *Thalmitoides tridens* (A. Milne Edwards, 1869)
173 *Typhlocarcinodes* sp.
174 Galatheidae indet.
175 Paguridae indet.
176 Alpheidae indet. 1
177 Alpheidae indet. 2
178 Natantia indet.
179 Palaemonidae indet.
180 Pasiphaeidae indet.
181 Penaeidae indet.
182 Processidae indet.
183 Sergestidae indet.
184 *Parribacus* sp.
185 Callianassidae indet.
186 *Upogebia* sp.

ECHINODERMS

187 Asterid indet.
188 *Astropecten polyacanthus* Müller et Troschel, 1842
189 Brissidae indet.
190 *Brissopsis luzonica* (Gray, 1851)
191 *Laganum depressum* Agassiz, 1841
192 *Maretia planulata* (Lamarck, 1816)
193 *Metalia sternalis* (Lamarck, 1816)
194 Holothurid indet.
195 Amphiuridae indet.
196 Ophionereidae indet.
197 *Ophiopteron elegans* Ludwig, 1888
198 Ophiuridae indet.

CHORDATES

199 Enteropneusta indet.
200 Ascidian indet.
201 Acranian indet.

VERTEBRATES

202 *Callionymus* sp.
203 Gobiidae indet.
204 Labridae indet.
205 *Muraenichthys* sp.
206 Scorpaenidae indet.
207 Syngnathidae indet.

4. Results by station

Number of individuals (Nb), dry weight (DW) and ash free dry weight (AFDW) in grams, are expressed per m².

STATION 1

Taxon	*Nb*	*DW*	*AFDW*
Annelids			
Eupolymnia sp.	1	0.0009	0.0006
Loimia ingens	1	0.0075	0.0044
Marphysa sp.	1	0.0069	0.0052
Nereidinae indet.	1	0.0011	0.0007
Notomastus sp.	1	0.0008	0.0005
Pectinaria sp	2	0.0027	0.0004
Phyllochaetopterus sp.	1	0.0008	0.0006
Pista sp. cf. *australis*	1	0.0075	0.0038
Terebellides stroemi	1	0.0172	0.0108
Sipunculids			
Aspidosiphon sp. *3*	2	0.0091	0.0069
Sipunculid indet. 1	1	0.0159	0.0044
Sipunculid indet. 2	1	0.0983	0.0236
Molluscs			
Dentalium sp	2	0.0624	0.0138
Oliva carneola	1	1.3447	0.0987
Oliva miniacea	1	5.9760	0.5760
Vexillum sp. *1*	1	0.2405	0.0215
Anodontia sp.	1	0.2614	0.0304
Laevicardium sp.	10	1.1941	0.1345
Modiolus philippinarum	1	0.2070	0.0437
Tellina sp.	6	0.5382	0.0651
Crustaceans			
Paguridae indet.	1	0.0087	0.0061
Echinoderms			
Amphiuridae indet.	1	0.0189	0.0108
Ophiuridae indet.	2	0.0191	0.0090
Vertebrates			
Gobiidae indet.	1	0.0119	0.0085

Number of taxons :	**25**
Number of individuals :	**42**

STATION 2

Taxon	*Nb*	*DW*	*AFDW*
Annelids			
Chloeia sp.	1	0.0049	0.0039
Dasybranchus sp.	2	0.0146	0.0107
Glycera sp.	1	0.0006	0.0003
Lysippe sp.	1	0.0005	0.0003
Pista sp. cf. *australis*	1	0.0068	0.0032
Polyodontes sp.	1	0.0098	0.0074
Prionospio (Prionospio) lineata	1	0.0083	0.0057
Sigalion mathildae	3	0.0056	0.0035
Terebellides stroemi	13	0.4230	0.2665
Sipunculids			
Sipunculid indet. 2	1	0.0391	0.0218
Molluscs			
Nassarius sp.	1	0.0965	0.0224
Oliva miniacea	1	2.2658	0.2096
Pupa solidula	1	0.8794	0.1527
Terebra sp.	1	0.2973	0.0270
Terebra undulata	1	0.1327	0.0211
Lioconcha ornata	1	0.0892	0.0721
Modiolus philippinarum	5	0.8568	0.1389
Tellina sp.	1	0.0170	0.0073
Crustaceans			
Calappa sp.	1	0.0420	0.0260
Hexapus (Lambdophattus) anfractus	2	0.0681	0.0414
Hexapus (Lambdophattus) sp.	4	0.0680	0.0372
Hexapus sp.	2	0.0343	0.0202
Paguridae indet.	1	0.0148	0.0054
Thalamita sp. *1*	1	0.0352	0.0146
Echinoderms			
Laganum depressum	1	0.1285	0.0219
Ophiuridae indet.	2	0.0116	0.0058

Number of taxons :	**28**
Number of individuals :	**51**

STATION 3

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Halimeda cylindracea		27.8357	3.0890
Cnidarians			
Edwardsia sp.	1	0.0472	0.0185
Annelids			
Lysippe sp.	1	0.0008	0.0006
Nereidinae indet.	1	0.0009	0.0007
Sipunculids			
Aspidosiphon sp. *3*	1	0.0090	0.0048
Lophophorians			
Brachiopod indet.	1	0.5000	0.0200
Molluscs			
Natica onca	1	0.0627	0.0296
Oliva miniacea	1	2.7920	0.5454
Pupa solidula	1	0.0615	0.0118
Arca navicularis	1	0.1207	0.0067
Laevicardium sp.	1	0.0658	0.0058
Lioconcha ornata	4	3.1597	0.9740
Tellina sp.	10	1.3451	0.1362
Crustaceans			
Portunus longispinosus	1	0.1381	0.0642

Number of taxons : 16
Number of individuals : 26

STATION 4

Taxon	*Nb*	*DW*	*AFDW*
Nemerteans			
Nemertean indet.	1	0.0068	0.0059
Annelids			
Dasybranchus sp.	2	0.0056	0.0041
Eunice complanata	1	0.0015	0.0011
Eunice sp.	1	0.0018	0.0010
Glycera sp.	1	0.0006	0.0003
Goniada sp.1	1	0.0008	0.0005
Lysippe sp.	4	0.0019	0.0014
Phyllochaetopterus sp.	1	0.0064	0.0051
Poecilochaetus sp.	2	0.0018	0.0012
Prionospio (Prionospio) lineata	2	0.0021	0.0012
Rhinothelepus sp.	3	0.0736	0.0442
Sigalion mathildae	1	0.0034	0.0029
Sthenolepis yhleni	1	0.0042	0.0036
Terebellides stroemi	41	0.7604	0.4791
Molluscs			
Nassarius sp.	1	0.1524	0.0652
Subcancilla interlirata	2	0.3436	0.0292
Terebellum terebellum	1	0.0300	0.0062
Arca navicularis	1	0.2405	0.0222
Barbatia sp.	1	0.2678	0.0356
Laevicardium sp.	5	0.3224	0.0408
Lioconcha ornata	3	0.4147	0.0289
Modiolus philippinarum	45	0.6456	0.2184
Tellina sp.	1	0.0199	0.0053
Tellinidae indet.	7	0.2860	0.1324
Crustaceans			
Alpheidae indet. 2	2	0.0242	0.0184
Ampelisca sp.	1	0.0002	0.0001
Callianassidae indet.	4	0.0503	0.0343
Hexapus sp.	3	1.1161	1.0790
Echinoderms			
Amphiuridae indet.	2	0.0454	0.0149
Ophiuridae indet.	11	0.0895	0.0130

Number of taxons : **35**
Number of individuals : **152**

STATION 5

Taxon	*Nb*	*DW*	*AFDW*
Nemerteans			
Nemertean indet.	3	0.0168	0.0148
Annelids			
Eupolymnia sp.	1	0.0008	0.0006
Linopherus sp.	1	0.0005	0.0004
Lysippe sp.	5	0.0112	0.0090
Malacoceros sp.	1	0.0014	0.0009
Nereidinae indet.	1	0.0011	0.0007
Samythella sp.	1	0.0008	0.0006
Sipunculids			
Aspidosiphon sp. *3*	1	0.0159	0.0110
Molluscs			
Terebra subulata	1	11.3325	0.4073
Fimbria fimbriata	2	0.1842	0.0228
Laevicardium sp.	2	0.4121	0.0389
Lioconcha castrensis	2	0.3867	0.0645
Lioconcha ornata	2	7.4660	0.5032
Modiolus philippinarum	1	0.2535	0.1227
Tellina sp.	2	0.3018	0.1434
Timoclea (Glycydonta) marica	1	0.0396	0.0243
Crustaceans			
Dacryopilumnus sp.	1	0.0084	0.0052
Pasiphaeidae indet.	1	0.0018	0.0017
Portunus sp.	1	0.0882	0.0546
Stomatopod indet. 2	1	0.0401	0.0267
Echinoderms			
Astropecten polyacanthus	1	0.2312	0.0340
Laganum depressum	1	0.0404	0.0183
Ophiuridae indet.	1	0.0327	0.0159
Chordata			
Acranian indet.	8	0.0260	0.0219
Vertebrates			
Gobiidae indet.	1	0.0657	0.0559

Number of taxons : 27
Number of individuals : 43

STATION 6

Taxon		*Nb*	*DW*	*AFDW*
Algae				
	Cyanophyceae indet.		0.0450	0.0060
	Udotea glaucescens		0.0190	0.0020
Nemerteans				
	Nemertean indet.	1	0.0095	0.0065
Annelids				
	Eunice complanata	1	0.0018	0.0013
	Glycera sp.	1	0.0014	0.0008
	Goniada sp.*1*	2	0.0134	0.0107
	Lysippe sp.	3	0.0012	0.0009
	Mastobranchus trinchesii	1	0.0005	0.0002
	Polyodontes sp.	1	0.0086	0.0071
	Prionospio (Prionospio) lineata	2	0.0128	0.0088
	Sthenolepis yhleni	1	0.0056	0.0041
	Terebellides stroemi	12	0.2413	0.1520
Molluscs				
	Cerithidae indet. 1	1	0.0624	0.0289
	Lophiotoma sp.	1	0.3770	0.0336
	Nassarius glans	2	0.2132	0.0396
	Nassarius sp.	1	0.1520	0.0205
	Terebellum terebellum	1	0.1010	0.0233
	Terebra sp.	1	0.2903	0.0242
	Ctenodardia victor	1	0.1037	0.0630
	Laevicardium sp.	5	0.2834	0.0634
	Lioconcha ornata	1	0.0491	0.0026
	Modiolus philippinarum	45	1.0480	0.1037
	Pinnidae indet.	1	0.0372	0.0056
	Tellinidae indet.	2	0.0632	0.0205
Crustaceans				
	Alpheidae indet. 2	2	0.0149	0.0104
	Calappa sp.	1	0.0084	0.0052
	Callianassidae indet.	1	0.0343	0.0206
	Hexapus (Lambdophattus) sp.	1	0.0907	0.0560
	Hexapus sp.	1	0.0185	0.0110
	Leucosia sp.	1	0.0096	0.0019
	Macrophthalmus convexus	1	0.0081	0.0048
	Paguridae indet.	2	0.0120	0.0085
	Parthenope (Aulacolambrus) hepatus	1	0.0657	0.0354
	Thalmitoides tridens	1	0.0882	0.0546
Echinoderms				
	Maretia planulata	1	0.0994	0.0148
	Ophiuridae indet.	3	0.0299	0.0143
Vertebrates				
	Gobiidae indet.	1	0.0130	0.0096

Number of taxons : 38
Number of individuals : 104

STATION 7

Taxon	*Nb*	*DW*	*AFDW*
Nemerteans			
Nemertean indet.	2	0.2144	0.1631
Annelids			
Euclymene sp.	1	0.0006	0.0002
Lumbrineris sp.*1*	2	0.0007	0.0004
Phyllochaetopterus sp.	1	0.0005	0.0003
Prionospio (Aquilaspio) aucklandica	2	0.0218	0.0150
Molluscs			
Cerithidae indet. 1	3	0.2546	0.0215
Tellina sp.	1	0.0736	0.0112
Crustaceans			
Alpheidae indet. 2	1	0.0074	0.0049
Hexapus (Lambdophattus) anfractus	3	0.4085	0.2338
Macrophthalmus convexus	2	0.3654	0.1871
Podophthalmus nacreus	1	0.0399	0.0247
Stomatopod indet. 2	1	0.1603	0.1083
Echinoderms			
Astropecten polyacanthus	1	0.1489	0.0242
Chordata			
Enteropneusta indet.	1	0.2325	0.1284
Vertebrates			
Callionymus sp.	1	0.0080	0.0060
Muraenichthys sp.	1	0.7100	0.5325

Number of taxons : 17
Number of individuals : 24

STATION 8

Taxon	*Nb*	*DW*	*AFDW*
Cnidarians			
Edwardsia sp.	1	0.0277	0.0135
Annelids			
Lysilla pacifica	1	0.0063	0.0040
Phyllochaetopterus sp.	1	0.0092	0.0074
Polyodontes sp.	1	0.0123	0.0107
Prionospio (Aquilaspio) aucklandica	3	0.0113	0.0078
Samytha sp.	5	0.0163	0.0098
Sigalion mathildae	2	0.0044	0.0028
Terebellides stroemi	3	0.0579	0.0365
Sipunculids			
Sipunculid indet. 1	1	0.0482	0.0220
Molluscs			
Cerithidae indet. 1	1	1.0852	1.0059
Nassarius sp.	1	0.3213	0.0493
Terebellum terebellum	1	0.4152	0.1887
Lioconcha castrensis	2	0.8847	0.1292
Tellina sp.	1	0.0425	0.0098
Crustaceans			
Alpheidae indet. 2	1	0.0061	0.0042
Hexapus (Lambdophattus) sp.	1	0.0347	0.0190
Hexapus sp.	3	0.0805	0.1215
Macrophthalmus convexus	1	0.3671	0.1612
Portunus longistylosus	1	0.3549	0.2197
Stomatopod indet. 2	1	0.0239	-0.8245
Echinoderms			
Maretia planulata	1	0.1187	0.0075
Ophiuridae indet.	1	0.0113	0.0057
Chordata			
Enteropneusta indet.	1	0.3129	0.1378
Vertebrates			
Gobiidae indet.	2	0.0291	0.0209

Number of taxons :	**28**
Number of individuals :	**37**

STATION 9

Taxon	*Nb*	*DW*	*AFDW*
Nematodes			
Nematode indet.	2	0.0199	0.0179
Annelids			
Dasybranchus sp.	1	0.0935	0.0683
Glycera sp.	1	0.0012	0.0008
Lysippe sp.	1	0.0006	0.0003
Prionospio (Aquilaspio) sp.	1	0.0047	0.0029
Terebellides stroemi	6	0.1059	0.0667
Sipunculids			
Sipunculid indet. 1	1	0.0220	0.0100
Crustaceans			
Hexapus sp.	1	0.0191	0.0117
Stomatopod indet. 2	1	0.1706	0.1219
Echinoderms			
Asterid indet.	1	0.0204	0.0030
Laganum depressum	1	0.3629	0.0409
Maretia planulata	4	0.3617	0.0222
Metalia sternalis	1	14.7044	2.1924
Ophiuridae indet.	3	0.0168	0.0038

Number of taxons : 15
Number of individuals : 25

STATION 10

Taxon	*Nb*	*DW*	*AFDW*
Cnidarians			
Edwardsia sp.	1	0.0118	0.0065
Nemerteans			
Nemertean indet.	2	0.2523	0.1373
Annelids			
Arabella iricolor	1	0.0082	0.0068
Dasybranchus sp.	1	0.0013	0.0007
Euclymene sp.	1	0.0008	0.0004
Goniada sp.*1*	1	0.0009	0.0007
Lysilla pacifica	2	0.0146	0.0084
Lysippe sp.	1	0.0005	0.0003
Poecilochaetus sp.	1	0.0008	0.0006
Prionospio (Prionospio) lineata	1	0.0007	0.0005
Rhinothelepus sp.	2	0.0839	0.0210
Sigalion mathildae	2	0.0320	0.0272
Terebellides stroemi	18	0.4068	0.2563
Sipunculids			
Aspidosiphon sp. *2*	3	0.0169	0.0113
Sipunculid indet. 1	6	0.0894	0.0226
Molluscs			
Nassarius glans	1	0.1401	0.0215
Subcancilla interlirata	2	0.0569	0.0045
Vexillum sp. *2*	1	0.1625	0.0150
Vexillum sp. *3*	1	0.0640	0.0058
Vexillum sp. *4*	1	0.0585	0.0054
Ctenodardia victor	1	0.1638	0.0141
Laevicardium sp.	1	0.0481	0.0059
Lioconcha castrensis	1	0.7527	0.3002
Lioconcha ornata	3	0.1908	0.0133
Pinna sp.	2	0.1248	0.0494
Tellina sp.	1	0.0241	0.0050
Crustaceans			
Callianassidae indet.	1	0.0116	0.0083
Pasiphaeidae indet.	2	0.0030	0.0025
Portunus longispinosus	1	0.0079	0.0044
Stomatopod indet. 2	1	0.1221	0.0923
Echinoderms			
Laganum depressum	3	0.3581	0.0501
Maretia planulata	2	0.0822	0.0076
Metalia sternalis	1	4.1810	0.8050
Amphiuridae indet.	2	0.0365	0.0106
Ophiuridae indet.	14	0.1213	0.0595

Number of taxons :	**41**
Number of individuals :	**85**

STATION 11

Taxon	*Nb*	*DW*	*AFDW*
Nemerteans			
Nemertean indet.	1	0.0280	0.0234
Nematodes			
Nematode indet.	4	0.0331	0.0298
Annelids			
Dasybranchus sp.	4	0.0637	0.0465
Euclymene sp.	1	0.0691	0.0484
Linopherus sp.	2	0.0017	0.0013
Loimia ingens	2	0.0980	0.0591
Polyodontes sp.	1	0.0097	0.0083
Prionospio (Prionospio) lineata	1	0.0119	0.0082
Rhinothelepus sp.	1	0.0458	0.0275
Terebellides stroemi	26	0.6077	0.3829
Sipunculids			
Sipunculid indet. 1	2	0.0674	0.0287
Molluscs			
Atys cylindricus	1	0.1820	0.0162
Pinnidae indet.	1	0.0367	0.0150
Tellina rastella	1	0.1815	0.1263
Tellina sp.	1	0.0356	0.0162
Crustaceans			
Alpheidae indet. 1	1	0.0686	0.0457
Alpheidae indet. 2	1	0.0058	0.0035
Leucosia sp.	1	0.0503	0.0252
Stomatopod indet. 2	1	0.0184	0.0143
Echinoderms			
Brissopsis luzonica	1	4.5859	0.9461
Laganum depressum	1	0.1952	0.0693
Maretia planulata	3	0.2126	0.0148
Metalia sternalis	1	17.6416	7.2719
Amphiuridae indet.	2	0.1345	0.0286
Ophiuridae indet.	10	0.1003	0.0500
Vertebrates			
Gobiidae indet.	1	0.0212	0.0164

Number of taxons : 31
Number of individuals : 72

STATION 12			
Taxon	***Nb***	***DW***	***AFDW***
Algae			
Caulerpa racemosa var.*clavifera*		0.3120	0.1490
Halicystis sp.		0.0230	0.0080
Halimeda incrassata		0.8650	0.0640
Halimeda opuntia		3.9880	0.2060
Udotea glaucescens		0.2090	0.0450
Valonia aegagropila		0.0960	0.0220
Sponges			
Sponge indet. 2	1	3.3362	0.1744
Sponge indet. 4	5	7.4655	1.5818
Annelids			
Chaetopteridae indet.	1	0.0009	0.0007
Eunice sp.	1	0.0008	0.0006
Laonome sp.	1	0.0141	0.0109
Terebellides stroemi	1	0.0253	0.0159
Sipunculids			
Sipunculid indet. 1	1	0.0952	0.0495
Molluscs			
Acteon virgatus	1	0.2600	0.0232
Natica sp.	3	0.3180	0.1224
Rhinoclavis aspera	1	3.0029	0.1289
Terebellum terebellum	1	0.7486	0.1011
Arcopagia (Pinguitellina) robusta	1	0.0300	0.0102
Ctenodardia victor	2	3.2533	1.1311
Gari maculosa	2	0.4317	0.0635
Gari squamosa	1	0.0091	0.0062
Laevicardium sp.	15	3.7839	1.3467
Lima sp.	4	0.1158	0.0515
Lioconcha ornata	3	5.5766	2.4012
Lucinicae indet. 1	1	0.0419	0.0312
Modiolus philippinarum	153	5.4497	0.6229
Tellina sp.	10	0.8186	0.3350
Crustaceans			
Alpheidae indet. 2	3	0.0223	0.0163
Callianassidae indet.	2	0.2501	0.1864
Hexapus (Lambdophattus) sp.	1	0.0101	0.0058
Macrophthalmus convexus	5	0.0632	0.0431
Nursia sp.	1	0.0168	0.0104
Palaemonidae indet.	1	0.0110	0.0093
Palicus sp.	1	0.0672	0.0416
Thalamita sp. *1*	3	0.0408	0.0238
Echinoderms			
Astropecten polyacanthus	1	2.2960	0.3807
Maretia planulata	1	0.2687	0.0554
Amphiuridae indet.	1	0.0063	0.0024
Chordata			
Ascidian indet.	1	0.8046	0.1043
Vertebrates			
Gobiidae indet.	1	0.0289	0.0202
Number of taxons : **44**			
Number of individuals : **231**			

STATION 13

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Caulerpa taxifolia		0.0190	0.0090
Sponges			
Sponge indet. 1	1	1.2109	0.4328
Sponge indet. 2	1	0.2167	0.0107
Cnidarians			
Edwardsia sp.	2	0.0645	0.0177
Annelids			
Armandia sp. cf. *leptocirrus*	1	0.0002	0.0001
Dasybranchus sp.	2	0.3756	0.2742
Lumbrineris sp.*2*	1	0.0006	0.0004
Lysilla pacifica	2	0.0241	0.0171
Polydora sp.	1	0.0006	0.0003
Polyodontes sp.	1	0.0108	0.0089
Prionospio (Prionospio) lineata	1	0.0016	0.0009
Sipunculids			
Sipunculid indet. 2	1	0.1136	0.0615
Molluscs			
Viriola interfilata	1	0.0650	0.0060
Crustaceans			
Alpheidae indet. 2	2	0.0227	0.0161
Arcania sp.	1	0.0105	0.0065
Callianassidae indet.	1	0.0133	0.0080
Hexapus sp.	1	0.0240	0.0103
Pilodius sp.	1	0.0252	0.0156
Stomatopod indet. 1	1	0.3816	0.2544
Echinoderms			
Ophiopteron elegans	1	0.0060	0.0021
Ophiuridae indet.	1	0.0402	0.0198

Number of taxons :	**22**
Number of individuals :	**24**

STATION 14

Taxon		*Nb*	*DW*	*AFDW*
Algae				
	Caulerpa urvilliana		0.1930	0.1190
	Halimeda cylindracea		9.4810	1.4330
Annelids				
	Loimia ingens	1	0.0622	0.0367
	Notomastus sp.	2	0.0075	0.0063
	Sigalion mathildae	2	0.0156	0.0133
	Terebellides stroemi	5	0.1301	0.0820
Molluscs				
	Malea pomum	1	0.3359	0.2515
	Nassarius glans	1	0.8699	0.3249
	Nassarius sp.	1	0.1170	0.0348
	Natica onca	1	0.0732	0.0346
	Terebellum terebellum	1	0.3705	0.0331
	Terebra sp.	1	0.0585	0.0054
	Vexillum sanguisugum	1	2.7604	0.1977
	Arcopagia (Pinguitellina) robusta	3	0.0116	0.0054
	Ctenodardia victor	2	0.2242	0.0957
	Laevicardium sp.	5	0.5597	0.0969
	Lioconcha ornata	4	0.8623	0.3098
	Tellina sp.	8	0.4723	0.1825
Crustaceans				
	Hexapus (Lambdophattus) anfractus	2	0.0298	0.0121
	Hexapus (Lambdophattus) sp.	1	0.0401	0.0215
Echinoderms				
	Maretia planulata	1	0.0655	0.0067
Chordata				
	Enteropneusta indet.	1	0.0240	0.0110

Number of taxons :	**24**
Number of individuals :	**44**

STATION 15

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Avrainvillea sp.		0.0100	0.0020
Caulerpa brachypus		0.1230	0.0660
Caulerpa racemosa var. *clavifera*		0.1720	0.0730
Halimeda opuntia		0.3700	0.0190
Udotea glaucescens		0.1480	0.0450
Annelids			
Glycera sp.	1	0.0006	0.0003
Laonome sp.	1	0.0133	0.0106
Loimia ingens	2	0.0576	0.0340
Polyodontes sp.	1	0.0085	0.0071
Prionospio (Prionospio) lineata	1	0.0018	0.0010
Streblosoma sp.	1	0.0032	0.0013
Sipunculids			
Sipunculid indet. 1	1	0.0277	0.0080
Molluscs			
Acteon virgatus	1	0.2525	0.0292
Natica onca	1	0.8402	0.0633
Pupa solidula	1	0.1752	0.0102
Terebellum terebellum	3	1.4233	0.1933
Laevicardium sp.	7	1.8816	0.7778
Lioconcha ornata	4	2.0265	0.4047
Modiolus philippinarum	1	0.3088	0.1585
Tellina sp.	4	0.4641	0.0494
Crustaceans			
Callianassidae indet.	1	0.0161	0.0111
Portunus longispinosus	1	0.0160	0.0091
Stomatopod indet. 2	1	0.0237	0.0149
Thalamita sp. *1*	1	0.1405	0.0834
Echinoderms			
Holothurid indet.	1	0.1901	0.0982
Chordata			
Ascidian indet.	1	0.4956	0.0502

Number of taxons : 26
Number of individuals : 36

STATION 16

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Avrainvillea amadelpha		4.3470	0.9280
Halimeda incrassata		0.4440	0.0550
Halimeda opuntia		1.6680	0.1280
Udotea glaucescens		0.0400	0.0090
Sponges			
Sponge indet. 2	1	0.2768	0.0237
Nemerteans			
Nemertean indet.	1	0.0530	0.0451
Annelids			
Dasybranchus sp.	1	0.0299	0.0218
Glycera sp.	1	0.0009	0.0005
Polydora sp.	1	0.0005	0.0003
Sthenelais zeylandica	1	0.0167	0.0156
Terebellides stroemi	5	0.1068	0.0673
Lophophorians			
Lingula sp.	1	0.1300	0.0780
Molluscs			
Cerithidae indet. 1	1	0.1051	0.0102
Barbatia sp.	2	1.3043	0.3270
Crustaceans			
Hexapus sp.	1	0.0082	0.0039
Palaemonidae indet.	3	0.1002	0.0843
Sergestidae indet.	1	0.0020	0.0019
Stomatopod indet. 2	2	0.0654	0.0414
Tetrias fischeri	1	0.0882	0.0546
Thalamita sp. *1*	2	0.0690	0.0397
Typhlocarcinus sp.	2	0.0929	0.0575
Echinoderms			
Brissidae indet.	1	0.0140	0.0029
Ophionereidae indet.	1	0.0005	0.0001

Number of taxons :	**26**
Number of individuals :	**29**

STATION 17

Taxon		*Nb*	*DW*	*AFDW*
Algae				
	Caulerpa taxifolia		0.0050	0.0020
	Dictyota sp.		0.0470	0.0180
	Halimeda macrophysa		0.0410	0.0060
	Halimeda opuntia		0.2770	0.0150
	Valonia fastigiata		0.0400	0.0160
Sponges				
	Sponge indet. 5	1	0.6586	0.3012
Annelids				
	Cirriformia sp.	1	0.0003	0.0002
	Euclymene sp.	2	0.0021	0.0010
	Eunice complanata	1	0.0018	0.0013
	Glycera sp.	1	0.0011	0.0008
	Leiochrides australis	2	0.0015	0.0009
	Lumbrineris sp.*2*	1	0.0006	0.0004
	Phyllodoce sp.	1	0.0052	0.0011
	Prionospio sp.	1	0.0006	0.0004
	Sthenelais laevis	1	0.0018	0.0010
Molluscs				
	Cantharidus sp.	1	0.1300	0.0116
	Cerithidae indet. 2	1	0.1950	0.0180
	Tellina sp.	1	0.0082	0.0037
Crustaceans				
	Alpheidae indet. 2	2	0.0019	0.0015
	Macrophthalmus convexus	3	0.0188	0.0103
	Paguridae indet.	3	0.0710	0.0377
	Thalamita sp. *1*	1	0.1024	0.0623
	Thalamita sp.*2*	1	0.0065	0.0007
	Upogebia sp.	2	0.0104	0.0071
Echinoderms				
	Holothurid indet.	1	0.1098	0.0656
	Ophiuridae indet.	2	0.0073	0.0021
Vertebrates				
	Gobiidae indet.	3	0.1590	0.1212

Number of taxons :	**29**
Number of individuals :	**33**

STATION 18

Taxon	*Nb*	*DW*	*AFDW*
Annelids			
Dasybranchus sp.	1	0.0015	0.0009
Euclymene sp.	5	0.0054	0.0037
Lumbrineris sp.*2*	1	0.0006	0.0004
Polydora sp.	1	0.0006	0.0003
Sigalion mathildae	2	0.0043	0.0029
Spio sp.	1	0.0012	0.0008
Terebellides stroemi	5	0.0909	0.0573
Sipunculids			
Aspidosiphon sp. *3*	1	0.0238	0.0157
Sipunculid indet. 1	1	0.0118	0.0050
Molluscs			
Oliva carneola	1	0.2158	0.0208
Terebra sp.	1	0.0846	0.0092
Terebra undulata	3	0.3808	0.0461
Turridae indet. 1	1	0.1170	0.0108
Ctenodardia victor	1	0.2036	0.0314
Laevicardium sp.	6	0.4515	0.0567
Lioconcha castrensis	2	0.6349	0.1696
Lioconcha ornata	1	0.0287	0.0050
Modiolus philippinarum	9	0.1216	0.0227
Tellina sp.	1	0.0102	0.0046
Vasticardium pulicarium	1	0.0621	0.0457
Crustaceans			
Paguridae indet.	2	0.0329	0.0139
Parthenope (Aulacolambrus) hoplonatus	2	0.0283	0.0159
Portunus longispinosus	1	0.0270	0.0117
Typhlocarcinodes sp.	1	0.0650	0.0580
Echinoderms			
Maretia planulata	3	0.2215	0.0133
Metalia sternalis	1	6.9581	0.6832
Amphiuridae indet.	2	0.0375	0.0196
Ophiuridae indet.	2	0.0114	0.0058
Chordata			
Enteropneusta indet.	2	0.0735	0.0353

Number of taxons :	**33**
Number of individuals :	**61**

STATION 19

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Avrainvillea amadelpha		0.6610	0.1740
Caulerpa racemosa var. *clavifera*		0.9900	0.5030
Halimeda incrassata		0.4140	0.0450
Udotea glaucescens		0.2490	0.0450
Nemerteans			
Nemertean indet.	2	0.0552	0.0388
Annelids			
Amphicteis sp.	1	0.0009	0.0006
Drilonereis sp.	1	0.0543	0.0378
Euclymene sp.	1	0.0010	0.0005
Loimia ingens	1	0.1101	0.0650
Lumbrineris sp.*1*	1	0.0007	0.0005
Lysilla pacifica	2	0.0203	0.0081
Lysippe sp.	4	0.0018	0.0012
Pareulepis sp.	2	0.0091	0.0080
Polydora sp.	14	0.0146	0.0101
Sigalion mathildae	2	0.0095	0.0076
Terebellides stroemi	13	0.3560	0.2243
Sipunculids			
Sipunculid indet. 1	9	0.3593	0.0489
Molluscs			
Terebellum terebellum	2	0.4880	0.2477
Crustaceans			
Alpheidae indet. 2	2	0.0173	0.0137
Galatheidae indet.	2	0.0373	0.1089
Hexapus (Lambdophattus) anfractus	2	0.0694	0.0429
Hexapus (Lambdophattus) sp.	2	0.0778	0.0464
Macrophthalmus convexus	4	0.1920	0.0826
Parthenope (Aulacolambrus) hepatus	1	0.4076	0.1313
Penaeidae indet.	1	0.0141	0.0022
Stomatopod indet. 2	2	0.0848	0.0632
Thalamita sp. *1*	1	0.0115	0.0070
Echinoderms			
Metalia sternalis	2	18.2651	1.4802
Chordata			
Ascidian indet.	1	0.0123	0.0020

Number of taxons : 36
Number of individuals : 75

STATION 20

Taxon	*Nb*	*DW*	*AFDW*
Annelids			
Dasybranchus sp.	1	0.0245	0.0179
Glycera sp.	3	0.0079	0.0063
Goniada sp.*1*	2	0.0017	0.0012
Lumbrineris sp.*1*	1	0.0005	0.0003
Lysilla pacifica	1	0.0057	0.0032
Lysippe sp.	1	0.0006	0.0003
Poecilochaetus sp.	2	0.0021	0.0014
Sigalion mathildae	1	0.0019	0.0011
Terebellides stroemi	11	0.1184	0.0746
Sipunculids			
Sipunculid indet. 1	1	0.1255	0.0130
Molluscs			
Tellina sp.	1	0.0959	0.0279
Crustaceans			
Alpheidae indet. 2	2	0.0390	0.0246
Hephthopelta sp.	1	0.0756	0.0468
Hexapus (Lambdophattus) sp.	4	0.3085	0.1419
Echinoderms			
Ophiuridae indet.	1	0.0107	0.0053
Chordata			
Enteropneusta indet.	3	0.1693	0.1027
Vertebrates			
Gobiidae indet.	1	0.0300	0.0225

Number of taxons : 21
Number of individuals : 37

STATION 21

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Halimeda cylindracea		1.2560	0.1600
Sponges			
Sponge indet. 5	1	1.9348	0.2854
Sponge indet. 6	1	2.6146	0.2821
Annelids			
Dasybranchus sp.	1	0.0087	0.0064
Loimia ingens	1	0.0166	0.0051
Samythella sp.	1	0.0007	0.0006
Streblosoma sp.	1	0.0087	0.0053
Terebellides stroemi	1	0.0245	0.0154
Sipunculids			
Sipunculid indet. 2	1	0.0720	0.0384
Molluscs			
Subcancilla interlirata	1	0.3639	0.0778
Ctenodardia victor	1	2.0577	0.5103
Lioconcha ornata	1	3.1727	1.0538
Tellinidae indet.	1	0.5892	0.0374
Crustaceans			
Alpheidae indet. 2	3	0.0302	0.0226
Macrophthalmus convexus	1	0.0053	0.0024
Pilumnus sp.	1	0.0147	0.0091
Thalamita sp. *1*	1	0.0146	0.0091
Echinoderms			
Holothurid indet.	1	0.4250	0.2210
Vertebrates			
Gobiidae indet.	1	0.1123	0.0857

Number of taxons : 19
Number of individuals : 20

STATION 22

Taxon	*Nb*	*DW*	*AFDW*
Cnidarians			
Edwardsia sp.	1	0.0240	0.0082
Nemerteans			
Nemertean indet.	1	0.0238	0.0205
Annelids			
Lysilla pacifica	3	0.0221	0.0157
Pareulepis sp.	1	0.0024	0.0016
Phyllochaetopterus sp.	2	0.0011	0.0007
Prionospio (Prionospio) lineata	1	0.0009	0.0005
Rhinothelepus sp.	1	0.0097	0.0061
Terebellides stroemi	2	0.0141	0.0089
Sipunculids			
Sipunculid indet. 1	2	0.0571	0.0190
Molluscs			
Cerithidae indet. 1	2	0.3587	0.0355
Terebellum terebellum	1	0.1314	0.0315
Laevicardium sp.	2	0.1590	0.0437
Crustaceans			
Alpheidae indet. 1	1	0.0096	0.0071
Alpheidae indet. 2	1	0.0131	0.0086
Callianassidae indet.	1	0.0115	0.0071
Macrophthalmus convexus	1	0.4836	0.2872
Natantia indet.	17	0.0790	0.0722
Stomatopod indet. 2	2	0.0753	0.0569
Echinoderms			
Amphiuridae indet.	1	0.0151	0.0030
Ophionereidae indet.	1	0.0049	0.0015
Chordata			
Enteropneusta indet.	1	0.0957	0.0430
Vertebrates			
Gobiidae indet.	1	0.0385	0.0272

Number of taxons :	**25**
Number of individuals :	**46**

STATION 23

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Caulerpa bikinensis		0.4950	0.2850
Caulerpa sertularioides		0.0630	0.0410
Caulerpa taxifolia		0.1310	0.0840
Halimeda discoidea		13.1140	3.0080
Halimeda incrassata		68.7700	7.5500
Halimeda macroloba		0.2540	0.0720
Halimeda opuntia		71.7900	3.6820
Udotea glaucescens		0.8820	0.2210
Sponges			
Sponge indet. 2	3	4.9770	0.4182
Sponge indet. 3	2	0.1883	0.0770
Sponge indet. 4	1	1.4781	0.3127
Sponge indet. 5	1	0.5990	0.1339
Cnidarians			
Trachyphyllia geoffroyi	1	117.0475	5.2972
Platyhelminths			
Platyhelminth indet.	1	0.0648	0.0545
Nemerteans			
Nemertean indet.	2	0.1317	0.1066
Annelids			
Arabella iricolor	4	0.0228	0.0185
Armandia sp. cf. *leptocirrus*	25	0.0755	0.0589
Dasybranchus sp.	1	1.2093	0.8828
Euclymene sp.	1	0.0012	0.0005
Eunice sp.	2	0.0013	0.0009
Eupolymnia sp.	1	0.0011	0.0008
Leiochrides australis	6	0.0178	0.0130
Linopherus sp.	7	0.0461	0.0420
Lumbrineris sp.*2*	5	0.0009	0.0007
Lysilla pacifica	3	0.0239	0.0104
Prionospio (Prionospio) lineata	6	0.0238	0.0164
Psammolyce antipoda	1	0.0525	0.0176
Syllis (syllis) sp.	3	0.0015	0.0012
Sipunculids			
Sipunculid indet. 1	1	0.0091	0.0017
Molluscs			
Strombus fragilis	3	3.5612	0.2275
Codakia sp.	5	7.1363	1.2397
Ctenodardia victor	1	0.3424	0.0494
Lioconcha ornata	1	3.8089	1.2570
Modiolus philippinarum	1	0.3770	0.0863
Crustaceans			
Alpheidae indet. 1	2	0.1937	0.1322
Alpheidae indet. 2	16	0.2312	0.1647
Callianassidae indet.	3	0.0664	0.0441
Hexapus sp.	1	0.0112	0.0053
Melitidae indet.	4	0.0085	0.0065
Micippa philira	1	0.8253	0.5109
Parribacus sp.	1	0.0594	0.0396
Pasiphaeidae indet.	2	0.0402	0.0321
Penaeidae indet.	2	0.0336	0.0248
Phymodius sp.	8	0.7288	0.3242
Processidae indet.	2	0.1195	0.1027
Stomatopod indet. 1	1	0.8412	0.5668
Stomatopod indet. 2	10	0.9962	0.7036
Thalamita sp. *1*	1	0.2016	0.1182
Typhlocarcinus sp.	3	0.1646	0.0912
Echinoderms			
Ophionereidae indet.	1	0.0969	0.0521
Vertebrates			

Gobiidae indet.	3	0.1196	0.0889
Labridae indet.	1	0.0820	0.0615
Muraenichthys sp.	1	0.1637	0.1370
Scorpaenidae indet.	1	0.1227	0.0888
Syngnathidae indet.	1	0.0120	0.0090

Number of taxons : 64
Number of individuals : 153

STATION 24

Taxon	*Nb*	*DW*	*AFDW*
Algae			
Caulerpa bikinensis		5.2310	3.6580
Caulerpa brachypus		0.0440	0.0340
Caulerpa taxifolia		0.4540	0.3280
Halimeda discoidea		16.0380	4.4820
Halimeda incrassata		94.8050	10.9880
Halimeda opuntia		64.6390	3.7470
Udotea flabellum		0.3290	0.0500
Udotea glaucescens		0.1380	0.0260
Sponge			
Sponge indet. 4	1	2.4284	0.4830
Nemerteans			
Nemertean indet.	1	0.0281	0.0241
Annelids			
Arabella iricolor	2	0.0119	0.0100
Armandia sp. cf. *leptocirrus*	35	0.0981	0.0764
Dasybranchus sp.	1	0.0021	0.0013
Euclymene sp.	1	0.0014	0.0008
Eunice sp.	2	0.0015	0.0011
Goniada sp.2	1	0.0095	0.0084
Leiochrides australis	2	0.0085	0.0062
Linopherus sp.	6	0.0154	0.0137
Lysilla pacifica	1	0.0064	0.0042
Mastobranchus trinchesii	3	0.0340	0.0238
Notomastus sp.	1	0.0009	0.0006
Syllis (syllis) sp.	5	0.0023	0.0002
Sipunculids			
Sipunculid indet. 1	1	0.0464	0.0135
Molluscs			
Nassarius glans	1	0.2478	0.2110
Strombus fragilis	1	0.3603	0.0486
Turridae indet. 2	1	0.0910	0.0081
Codakia sp.	10	16.9091	5.1683
Lioconcha ornata	1	0.0467	0.0040
Lucinidae indet. 2	2	0.1065	0.0484
Modiolus philippinarum	4	1.1802	0.4306
Crustaceans			
Alpheidae indet. 1	2	0.1461	0.1106
Alpheidae indet. 2	9	0.0653	0.0491
Arcania sp.	2	0.0790	0.0383
Leucosia sp.	1	0.0924	0.0572
Melitidae indet.	1	0.0003	0.0001
Paguridae indet.	1	0.0147	0.0065
Phymodius sp.	2	0.9164	0.5254
Portunus longispinosus	1	0.4294	0.2227
Processidae indet.	2	0.1060	0.0734
Psaumis cavipes	1	0.0126	0.0078
Stomatopod indet. 2	7	0.2917	0.2038
Thalamita sp. *1*	2	0.1443	0.0885
Thalamita sp.*2*	2	0.0160	0.0108

Thalmitoides tridens	2	0.0324	0.0196
Typhlocarcinus sp.	2	0.4998	0.2594
Upogebia sp.	2	0.0052	0.0036
Echinoderms			
Ophionereidae indet.	1	0.0061	0.0027
Chordata			
Ascidian indet.	1	0.5295	0.0944
Vertebrates			
Gobiidae indet.	3	0.0792	0.0606
Scorpaenidae indet.	1	0.2060	0.1545

Number of taxons : 62
Number of individuals : 128

STATION 25

Taxon	*Nb*	*DW*	*AFDW*
Plants			
Tydemania expeditionis		0.5250	0.0800
Sponges			
Sponge indet. 3	1	0.0500	0.0239
Annelids			
Dasybranchus sp.	1	0.0018	0.0010
Lysippe sp.	1	0.0005	0.0003
Nereidinae indet.	1	0.0008	0.0006
Sthenelais laevis	1	0.0012	0.0008
Syllis (syllis) sp.	1	0.0008	0.0006
Sipunculids			
Aspidosiphon sp. *1*	1	0.1620	0.0864
Aspidosiphon sp. *3*	1	0.0101	0.0051
Molluscs			
Dentalium sp	1	0.0250	0.0070
Terebellum terebellum	1	0.1233	0.0156
Tellina sp.	4	0.4252	0.1120
Vasticardium pulicarium	1	0.4679	0.1022
Crustaceans			
Alpheidae indet. 2	1	0.0091	0.0065
Thalamita sp. *1*	1	0.0051	0.0029
Typhlocarcinodes sp.	1	0.0070	0.0037
Echinoderms			
Ophiuridae indet.	1	0.0180	0.0088

Number of taxons : 18
Number of individuals : 19

5. Summary of biomasses per station

	dry weight			Ash free dry weight		
Station	**Plants**	**Animals**	**Total**	**Plants**	**Animals**	**Total**
1	0.000	10.052	10.052	0.000	1.080	1.080
2	0.000	5.550	5.550	0.000	1.147	1.147
3	27.836	8.304	36.139	3.089	1.818	4.907
4	0.000	4.920	4.920	0.000	2.295	2.295
5	0.000	20.959	20.943	0.000	1.599	1.584
6	0.064	3.569	3.633	0.008	0.869	0.877
7	0.000	2.647	2.647	0.000	1.462	1.462
8	0.000	4.282	4.282	0.000	1.370	1.370
9	0.000	15.904	15.904	0.000	2.563	2.563
10	0.000	7.631	7.631	0.000	1.981	1.981
11	0.000	24.506	24.506	0.000	9.324	9.324
12	5.493	38.664	44.157	0.494	9.109	9.603
13	0.019	2.608	2.627	0.009	1.163	1.172
14	9.674	7.090	16.764	1.552	1.762	3.314
15	0.823	8.367	9.190	0.205	2.016	2.221
16	6.499	2.464	8.963	1.120	0.876	1.996
17	0.410	1.494	1.904	0.057	0.650	0.707
18	0.000	9.906	9.906	0.000	1.366	1.366
19	2.314	20.670	22.984	0.767	2.679	3.446
20	0.000	1.018	1.018	0.000	0.491	0.491
21	1.256	12.722	13.978	0.160	2.828	2.988
22	0.000	1.631	1.631	0.000	0.706	0.706
23	155.499	146.317	301.816	14.943	13.630	28.573
24	181.678	25.309	206.987	23.313	8.575	31.888
25	0.525	1.308	1.833	0.080	0.377	0.457
Mean	15.684	15.516	31.199	1.832	2.869	4.701
SE	9.500	5.888	14.172	1.100	0.697	1.643

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Composition et diversité de la méiofaune du lagon de « Great Astrolabe Reef » (Fiji)

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Abstract

During the joint Fijian-French ASTRO cruise in the Greatv Astrolabe Reef (GAR) lagoon, meiofauna of soft bottom sediments has been investigated at seven stations. Abundance of the higher level taxa, and taxa composition and diversity of nematode has been studied. This paper presents methods and raw data obtained at different level of taxonomic or functional aggregation. As a first ecological contribution of the Fijian meiofauna, it will provide the basic knowledge for biogeographical comparisons in the South Pacific.

1. Introduction

La répartition de la méiofaune du Pacifique SW n'est connue que par quelques travaux réalisés en Australie sur la Grande Barrière de Corail (Alongi, 1986; 1989; Tietjen 1990). Aux Iles Fiji ce compartiment faunistique n'a fait l'objet que de quelques prospections taxonomiques fragmentaires (Cobb,1893 ; Kito, 1989 pour les nématodes). Dans le cadre d'une prospection de la diversité écologique des nématodes du Pacifique SW (Nouvelle-Calédonie : Boucher, soumis ; Ouvéa : en préparation) et central (Moorea : Kotta & Boucher, soumis), les récoltes de méiofaune effectuées durant la campagne ASTRO ont été l'occasion d'une approche globale de la composition du méiobenthos et de la diversité du groupe dominant des nématodes. L'objectif a été de déterminer les groupes zoologiques constitutifs du méiobenthos et la composition en familles, genres et catégories morphofonctionnelles des nématodes collectés dans quelques prélévements du lagon de Dravuni. Ce recensement doit permettre de préciser les caractéristiques de la biodiversité à l'échelle des grands océans (Boucher, 1990; Boucher et Lambshead, 1995; Kotta & , soumis).

2. Materiel et Méthodes

Sept carottages manuels de la couche superficielle du sédiment sur une surface de 2.7 cm ont été réalisés en plongée dans le lagon de Dravuni aux stations prospectées pour le métabolisme benthique et les expériences de " peepers " par Charpy-Roubaud et Sarazin (Figure 1). Le sédiment a été centrifugé trois fois au Ludox TM pour isoler les organismes des grains de sable. Le surnageant a ensuite été lavé sur des tamis de 250 et 40 µm, puis dilué dans une boite de Motoda afin de réduire les temps de tri (dilution 1/2 à 1/4). Les différents groupes taxonomiques présents ont été comptés à la cuve de Dollfus et leur densité exprimée par 10 cm^{-2} dans chaque prélévement. Un échantillon de 100 nématodes, représentatif des deux fractions dimensionnelles obtenues, a été identifié au niveau de la famille, du genre et de la catégorie morphofonctionnelle (catégories trophiques de Wieser, 1953). Les proportions de mâles, femelles et juveniles ont été établies. Les données ont été traitées sous une base de données Access 2 comportant un dictionnaire des genres, familles et catégories morphofonctionnelles.

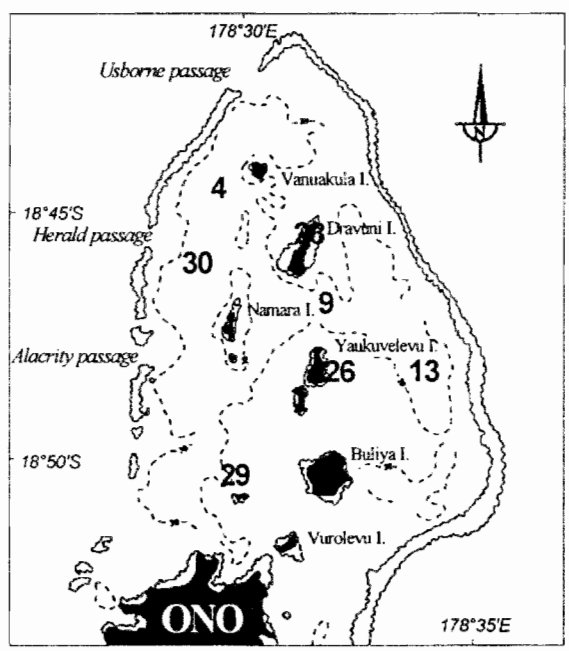

Figure 1: Positions des stations prospectées

Divers indices de diversité, pondérés pour leur richesse en espèces et leur équitabilité, ont été calculés : Richesse en espèces de Margalef (1958): SR=(S-1)/Loge(n) ; indice de Fisher et al. (1943) : S= Loge(1+N/) ; indice de Shannon-Wiener H'= -$p_i(\log 2 p_i)$; Equitabilité : E= H'/Log2 S (Pielou, 1975). L'équitabilité a aussi été calculée par le modèle de Ewens-Caswell qui exprime la déviation de la diversité (V) de l'échantillon au modèle neutre

: V=[H'-E(H')]/Sd(H'), où Sd(H') est la déviation standart de la diversité et E(H') la diversité prédite par le modèle neutre (Lambshead and Platt, 1988).

3. Résultats et discussion

Densité du méiobenthos

Le tableau 2 fournit les abondances des taxa dominants du méiobenthos (organismes franchissant la barrière d'un tamis de 2mm et retenus par un tamis de 40 µm). Les nématodes constituent le groupe dominant avec 66.4% des organismes recensés, suivis par les Copépodes Harpacticoides (18%) et les Polychétes interstitiels (5.5%). Les Kinorhynches sont curieusement absents. Les Ciliés sont rares comme en Nouvelle-Calédonie.

Tableau 2 : Abondance des taxa du meiobenthos dans les sept prélévements étudiés. Moy.: Moyenne; E.t. : écart-type ; I.t.: intervalle de confiance de la moyenne. Le premier code station correspond à celui utilisé dans les autres contributions de ce volume. Le nouveau code correspond au code station utilisé dans Kotta & Boucher (soumis).

Table 2 : Density of the different meiobenthic taxa in the seven investigated stations. Moy.: mean; E.t. : standard error; Int. conf : confidence of the mean. The first code " code station " corresponds to the labelling of the stations used in other contributions to this volume. The new code corresponds to the labelling used in Kotta & Boucher (in press).

Code station	**29**	**28**	**26**	**9**	**4**	**13**	**30**	**Moy.**	**E.t**	**I.t.**
Nouveau Code	**FI1**	**FI2**	**FI3**	**FI4**	**FI5**	**FI6**	**FI7**			
Nematodes	348	531	377	363	1104	353	1034	1356	442	249
Copepodes	12	175	122	287	91	199	231	381	135	68
Nauplii	0	10	7	14	7	28	42	32	15	11
Polychétes	10	45	122	35	28	38	63	119	54	27
Oligochétes	33	10	3	21	0	24	14	38	18	9
Archiannélides	0	0	0	0	0	7	0	3	4	2
Gastrotriches	86	45	17	0	7	0	0	61	46	24
Kinorhynches	0	0	0	0	0	0	0	0	0	0
Turbellariés	2	0	0	0	7	3	0	5	4	2
Tardigrades	0	0	3	7	0	10	0	8	6	3
Ostracodes	0	3	0	0	7	10	0	8	6	3
Cumacées	0	0	0	0	0	0	0	0	0	0
Amphipodes	0	0	0	0	0	0	0	0	0	0
Crustacés divers	0	0	3	0	0	0	0	1	2	1
Insectes	0	0	0	0	0	0	0	0	0	0
Halacariens	7	0	0	3	0	0	0	4	4	17
Mollusques	0	0	0	0	0	0	0	0	0	0
Protozoaires	21	45	7	3	21	63	0	63	33	17
Divers	0	3	0	0	0	3	0	3	3	1
TOTAL	**519**	**870**	**664**	**734**	**1272**	**741**	**1384**	**2082**	**456**	**239**

Le tableau 3 fournit la composition des familles de Nématodes présents dans les prélévements étudiés. Comme dans tous les sédiments lagonaires, les Desmodoridae dominent (26.1%). Ils sont suivis par les Comesomatidae (11.9%), beaucoup plus abondants qu'en Nouvelle-Calédonie, puis par les familles des Chromadoridae et Xyalidae habituellement recensées en milieu tropical.

Table 3 : Dominance par prélévement et dominance générale moyenne des familles de nématodes.
Table 3 : Sample dominance and mean general dominance of the nematode families.

	Code station	**29**	**29**	**26**	**9**	**4**	**13**	**30**	
	FAMILLE	**FI1**	**FI2**	**FI3**	**FI4**	**FI5**	**FI6**	**FI7**	**DG**
1	DESMODORIDAE	61	15	41	13	15	22	16	26.1
2	COMESOMATIDAE		10		7	22	33	11	11.9
3	CHROMADORIDAE	2	4	20	18	14		19	11
4	XYALIDAE	10	9	5	9	10	12	19	10.6
5	CYATHOLAIMIDAE	6	18	6	18	10	3	8	9.9
6	ETHMOLAIMIDAE	2	16	2	6	3	9	4	6
7	LINHOMOEIDAE	4	12	1	1	5	3	2	4
8	AXONOLAIMIDAE	1	2	5		7		2	2.4
9	LEPTOLAIMIDAE	1	6	4			3	2	2.3
10	ANTICOMIDAE		1	3	5	3	1	2	2.1
11	SELACHINEMATIDAE	3	3		3	1	1		1.6
12	ONCHOLAIMIDAE	3		2	3	1	1		1.4
13	OXYSTOMINIDAE				1	2	4	1	1.1
14	DESMOSCOLECIDAE		1		1	2	3		1
15	MONOPOSTHIIDAE	4		3					1
16	APONCHIIDAE			5				1	0.9
17	SIPHONOLAIMIDAE		2					4	0.9
18	SPHAEROLAIMIDAE					3		3	0.9
19	THORACOSTOMOPSIDAE			2	2		1	1	0.9
20	CERAMONEMATIDAE	1			3		1		0.7
21	DIPLOPELTIDAE				2	1	1	1	0.7
22	DRACONEMATIDAE				4				0.6
23	MONHYSTERIDAE						1	3	0.6
24	ENCHELIDIIDAE	1		1	1				0.4
25	IRONIDAE				2				0.3
26	LEPTOSOMATIDAE						1	1	0.3
27	TARVAIIDAE				1	1			0.3
28	TRIPYLOIDIDAE	1	1						0.3
	TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Le tableau 4 indique la composition générique des nématodes identifiés dans des échantillons de 100 individus. Comme en Nouvelle-Calédonie, l'espèce *Laxus cosmopolitus,* redécrite récemment par Ott et al. (1995), domine dans l'ensemble des prélévements mais cette dominance est beaucoup plus marquée aux stations FI1 et FI3.

Le tableau 5 résume les caracréristiques de la diversité des nématodes à différents niveaux de regroupement taxonomique et morphofonctionnel. A noter la dominance des " epistrate feeders " (2A) qui suggèrent une prépondérance de l'utilisation de la production primaire benthique par rapport aux apports particulaires de la colonne d'eau, identique à celle observée en Nouvelle-Calédonie (Boucher, sous presse).

Tableau 4 : Liste des genres de nématodes et dominance générale moyenne (GMD). Les noms de genre acceptés dans la nomenclature zoologique sont en italiques.

Table 4 : Genera list of nematodes and mean general dominance (GMD). Genera names accepted in the zoological nomenclature are in italic.

GENRE	FI1	FI2	FI3	FI4	FI5	FI6	FI7	GM	GMD
Laxus	36	7	24	2	1	1	1	72	**10.29**
Marylynnia	5	9	3	17	6	2	7	49	**7.00**
Sabatieria		3		2	11	23	2	41	**5.86**
Paradesmodora	20	3	13	3	1			40	**5.71**
Nannolaimus	2	16	2	3	3	7	4	37	**5.29**
Ptycholaimellus		1		12	11		10	34	**4.86**
Cobbia	2	5	1	6	2	9	8	33	**4.71**
Prochromadorella	2	1	12	6	1		9	31	**4.43**
Molgolaimus				1	9	4	12	26	**3.71**
Laimella		7		5		10		22	**3.14**
Dorylaimopsis					11		8	19	**2.71**
Paranticoma		1	3	5	3	1	2	15	**2.14**
Metacyatholaimus		9		1	3	1		14	**2.00**
Terschellingia		5		1	2	3	2	13	**1.86**
Desmodora		1	3	3	2	2	1	12	**1.71**
Euchromadora		2	8		2			12	**1.71**
Elzalia					1		9	10	**1.43**
Leptonemella	2	2				6		10	**1.43**
Metalinhomoeus	4	4	1					9	**1.29**
Promonhystera	5		4					9	**1.29**
Chromaspirina	1	1	1	3	1	1		8	**1.14**
Daptonema	2	3			3			8	**1.14**
Halalaimus				1	2	4	1	8	**1.14**
Alaimella	1		4				2	7	**1.00**
Axonolaimus			5		2			7	**1.00**
Desmoscolex		1		1	2	3		7	**1.00**
Nudora	4		3					7	**1.00**
Aponchium			5				1	6	**0.86**
Astomonema		2					4	6	**0.86**
Leptolaimus		6						6	**0.86**
Diplopeltula				2	1	1	1	5	**0.71**
Oncholaimellus	1		1	2	1			5	**0.71**
Pseudolella					5			5	**0.71**
Sphaerolaimus					3		2	5	**0.71**
Theristus				1	2	2		5	**0.71**
Didelta		3			1			4	**0.57**
Draconematinae				4				4	**0.57**
Echinodesmodora		1		1		2		4	**0.57**
Epacanthion			2	2				4	**0.57**
Gomphionema				3		1		4	**0.57**
Monhystera						1	3	4	**0.57**
Parodontophora	1	1					2	4	**0.57**
Pomponema			3		1			4	**0.57**
Richtersia	3					1		4	**0.57**
Viscosia	2		1			1		4	**0.57**
Zalonema	1					3		4	**0.57**
Antomicron						3		3	**0.43**
Halichoanolaimus		1		2				3	**0.43**
Metadasynemella				3				3	**0.43**
Stylotheristus				1		1	1	3	**0.43**
Cheironchus				1	1			2	**0.29**
Choanolaimus		2						2	**0.29**

Tableau 4 (suite)

GENRE	FI1	FI2	FI3	FI4	FI5	FI6	FI7	GM	GMD
Desmodorella						1	1	2	0.29
Eleutherolaimus					2			2	0.29
Eurystomina	1		1					2	0.29
Ingenia	1	1						2	0.29
Pseudotarvaia				1	1			2	0.29
Scaptrella		1		1				2	0.29
Thalassironus				2				2	0.29
Xenonema						2		2	0.29
Cervonema							1	1	0.14
Cylicolaimus							1	1	0.14
Dasynemoides	1							1	0.14
Filoncholaimus				1				1	0.14
Mesacanthion							1	1	0.14
Metenoploides						1		1	0.14
Nannolaimoides	1							1	0.14
Neotonchus						1		1	0.14
Odontophora		1						1	0.14
Onyx	1							1	0.14
Paralongicyatholaimus							1	1	0.14
Penzancia	1							1	0.14
Polygastrophora				1				1	0.14
Pselionema						1		1	0.14
Pseudocella						1		1	0.14
Pseudometachromadora							1	1	0.14
Retrotheristus					1			1	0.14
ScaCobb							1	1	0.14
Sigmophoranema					1			1	0.14
Steineria					1			1	0.14
Subsphaerolaimus							1	1	0.14
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**700**	**100**

Le tableau 5 fournit une mesure des paramètres de la diversité des nématodes en fonction de différents critères de regroupement taxonomique (espèce, genre, famille), les valeurs des indices de diversité, la structure démogrphique et la composition trophique du peuplement. Le rapport 1B/2A est un indice nutritionnel qui augmente avec la quantité de matière particulaire sédimentée.

Tableau 5 : Diversité du peuplement de nématodes. N = nombre d'espèces, de genres et de familles ; SR= richesse en espèces ; FCW = indice alpha de Fisher et al. ; H'= indice de Shannon ; J'= équitabilité de Pielou ; V= déviation au modèle neutre de Caswell; 1A= mangeurs de dépôts sélectifs; 1B: mangeurs de dépôts non sélectifs; 2A= mangeurs d'épistrates; 2B= carnivores-omnivores. 1B/2A = ration des deux catégories précitées.
Table 5 : Diversity of nematode taxa assemblages at different level of agglomeration; SR= species richness; FCW= alpha index of Fisher et al.; H'= Shannon index; J'= evenness; V= Caswell statistics; 1A= selective deposit-feeders; 1B= non selective deposit feeders; 2A= epistrate feeders; 2B= carnivores-omnivores; 1B/2A = index of POM matter utilisation.

Code station	**29**	**28**	**26**	**9**	**4**	**13**	**30**	
Nouveau code	**FI1**	**FI2**	**FI3**	**FI4**	**FI5**	**FI6**	**FI7**	**Moyenne**
N espèces	25	32	22	35	35	36	32	31
N genres	24	29	21	33	34	31	32	28.9
N familles	14	14	14	19	16	17	18	16
SR	4.99	6.08	4.34	6.95	7.17	6.51	6.3	6.05
FCW	10.7	16.2	8.7	19.2	19.2	20.2	16.3	15.79
H'	3.39	4.46	3.75	4.65	4.8	4.54	4.39	4.28
J'	0.73	0.89	0.84	0.91	0.91	0.79	0.88	0.85
V	-3.18	2.47	0.09	4.83	-0.33	-8.4	-0.26	-0.68
Mâles	36	11	20	25	25	31	25	24.71
Femelles	50	38	47	32	46	48	33	42.00
Juvéniles	14	51	33	43	29	22	42	33.43
A/J	5.1	0.4	1.2	1.2	1.7	2.8	1.2	1.94
1A	7	33	9	22	23	33	29	22.29
1B	15	15	10	4	24	28	17	13.71
2A	72	47	76	62	47	37	49	48.71
2B	6	5	5	12	6	2	5	5.86
1B/2A	0.21	0.32	0.13	0.06	0.51	0.76	0.35	0.33

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Microphytobenthic biomass and production of the Great Astrolabe Reef lagoon sediments

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Abstract

Microphytobenthos biomass (chlorophyll) and production (oxygen budget) were studied in the Great Astrolabe Reef lagoon in April and May 1993. In this study, the term microphytobenthos includes cyanobacteria and all the unicellular algae living in or on sediments. Biomass estimated with chlorophyll was present until 8 cm depth in the sediments. In average, chlorophyll concentration at the SWI was 8.3±1.2 mg Chl m^{-2} (upper 0.5cm). Net production appeared negative or positive independently of the station depth. Average gross production was 0.3 g C m^{-2} day^{-1} and strongly correlated with the station depth. Biomass and production were in the range of French Polynesian lagoon data.

1. Introduction

The Great Astrolabe Reef (GAR) is located north-east of Kadavu and south of Viti Levu. It extends about 35 km north of the north-eastern coast of Kadavu (18°45'S, 178°30'E). Its general description appears in Morrison & Naqasima (1992). The total area of the lagoon is 210 km^2. Its average depth is 20m.

Many studies were carried out on macrophytobenthos (South, 1992; South & Kasahara, 1992; South & Yen, 1992, Pollard & Kogute, 1993, South, 1993). However, these studies dealed with taxinomy and none of them concerned microphytobenthos productivity.

In shallow coastal ecosystems, benthic primary production (macrophytobenthos + microphytobenthos) plays an important role in carbon budget. The term microphytobenthos includes here cyanobacteria and all the unicellular algae living in or on inert substratum in aquatic environments. As compared to planktonic algae, and to macroscopic « algae » in the common sense, this category has long bee neglected (Charpy-Roubaud & Sournia, 1990).

The bulk of production data on microphytobenthos has been obtained through photosynthetic measurements. Both the oxygen (*e.g.* Pomeroy, 1955; Pamatmat, 1968; Sournia, 1976a, b,c, Charpy-Roubaud, 1988) and the ^{14}C methods (*e.g.* Grontved, 1960; Steele & Baird, 1968; Marshall et al, 1973; Cadée & Hegeman, 1974, 1977; Colijn et al, 1983) have been and still are employed. Here, we used oxygen method to estimate the lagoon sediment primary production because it is more accurate for the lagoon sediments (Charpy-Roubaud, 1987).

2. Material and methods

The study was carried out with the research vessel ship of the University South Pacific N.O. APHAREUS. Thirteen stations (Figure 1) were investigated in the GAR lagoon for primary production measurements. All stations were prospected by SCUBA; their depth and their visual characteristics appear in Table 1. At some stations, the bottom structure don't allow to carry out any experiment to measure primary production and any corer because the experimental material used.

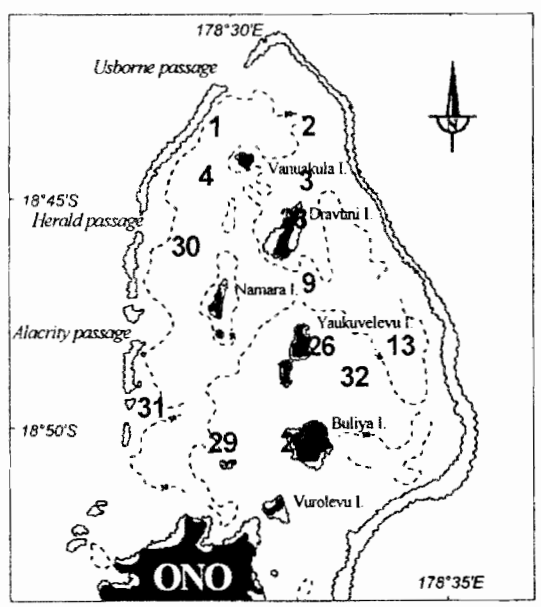

Figure 1: Station locations

Table 1: Characteristics of the prospected stations

Date	station	Z (m)	observations
20/04/93	1	19	fine sand with cyanobacteria
21/04/93	2	29	very fine sand
18/04/93	3	11	shells
17/04/93	4	39	coarse sand, shells, coral heads
24/04/93	9	35	coarse sand,, limestone corals
23/04/93	32	34	coarse sand, deep current
25/04/93	28	24	shells and Halimeda
17/04/93	30	35	very fine sand with bioturbation
26/04/93	26	9	
27/04/93	27	12	
19/04/93	13	36	coarse sand, shells, coral heads
28/04/93	29	8	algae

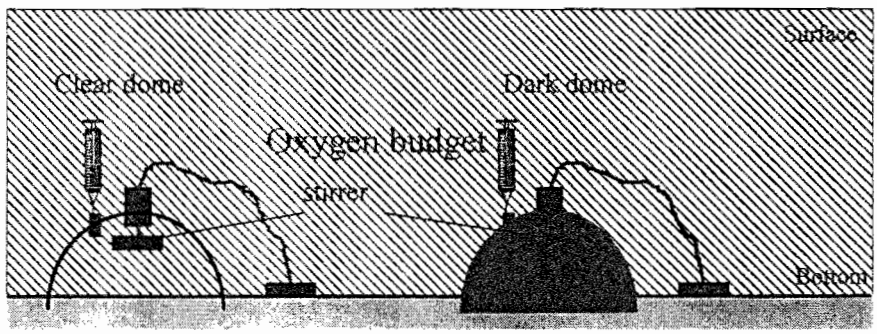

Figure 2: Benthic production measurement device

Microphytobenthos biomass was estimated by sediment chlorophyll (Chl) concentration measurements following the procedure described by Plante-Cuny (1984) and Charpy-Roubaud (1986). The hand-corer was 2.7 cm inner diameter, from which 0.5 cm-thick (for the first) and 1 cm-thick (for the following) slices were removed to 8 cm depth of sediment when it was possible. Pigments extraction followed in 90% aceton. Readings were made before and after acidification on a spectrophotometer. Results are expressed as mg Chl g^{-1} de sediment.

To measure phytobenthic production, sediments were incubated within clear and dark Plexiglas domes (Figure 2) during 4 to 6 hours. Stirring took place within the dome during the whole incubation to prevent the build-up of O_2 gradients. One hundred and twenty ml of sea-water was taken with serynge at the beginning and at the end of incubation. Oxygen was determined in the traditional manner using modified Winkler procedures on samples. Reproducibility of results had been tested in a previous work (Charpy-Roubaud 1986).

Gross oxygen production (GOP) = NOP - OR

NOP= Net oxygen production

OR= Oxygen respiration measured in dark domes

The gross O_2 production may be converted into gross carbon production (GCP) by the equation of McCloskey et al (1978) : GCP = (NOP×0.375×PQ) + (OR×0.375×RQ)

PQ and RQ = photosynthetic and respiratory coefficients.

3. Results and discussion

3.1 Biomass

In 4 stations (3, 32, 31, 29), it was impossible to core and the sediment were sampled at the surface. In other stations, Chl and Pha decreased with depth in the sediment (Figure 3). This pattern was more or less important according to the station . Pigment was present until 8 cm depth in the sediment except at stations 27 and 28.

Chl concentrations in the upper 0.5 cm varied between 0.4 and 5.7 mg g^{-1} and was in average 1.65±0.24 mg g^{-1} (n=39). This average corresponds to a microphytobenthic biomass of 8.3±1.2 mg Chl m^{-2} (upper 0.5cm). Between 0.5 and 5cm depth Chl concentration was in average 0.4 mg g^{-1} (n=159) (Table 2).

Average vertical profiles of Chl appears in Figure 4. The inter-station heterogenity was maximum in the upper sediments.

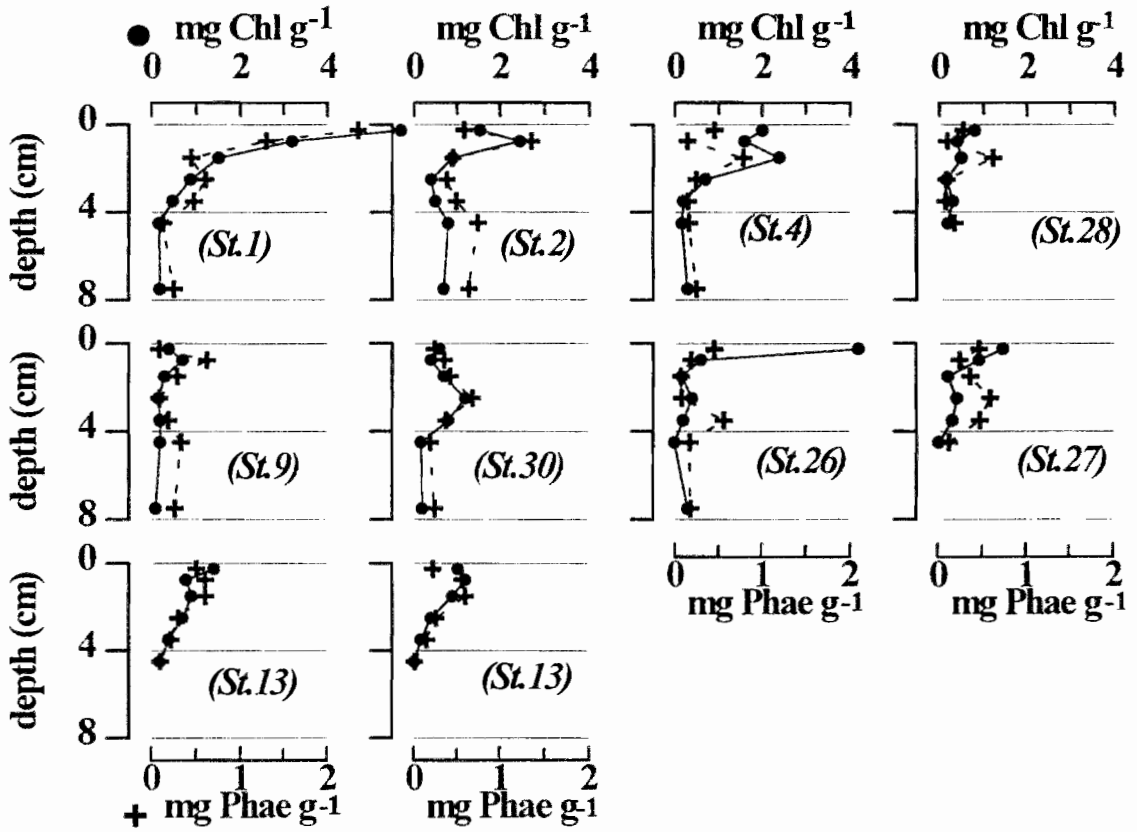

Figure 3: Chlorophyll (Chl) and Phaeophytin (Pha) profiles in the GAR lagoon sediments

Table 2: Chl concentration (mg g $^{-1}$) in GAR lagoon sediments

St	Depth							Average	SE
		0-0.5	0.5-1	1-2	2-3	3-4	4-5	0.5-5cm	0.5-5cm
13	36	1.40	0.78	0.90	0.70	0.40	0.20	0.60	0.29
13	36	1.03	1.20	0.90	0.40	0.17	0.02	0.54	0.50
1	19	5.70	3.20	1.50	0.87	0.48	0.18	1.25	1.20
2	29	1.54	2.45	0.90	0.40	0.50	0.80	1.01	0.83
4	40	2.01	1.60	2.40	0.70	0.20	0.17	1.01	0.97
30	40	0.60	0.40	0.70	1.20	0.80	0.17	0.65	0.39
9	35	0.40	0.70	0.30	0.17	0.20	0.20	0.31	0.22
28	22	0.80	0.40	0.50	0.17	0.30	0.20	0.31	0.14
26	9	4.20	0.60	0.17	0.40	0.20	0.00	0.27	0.23
27	12	1.45	0.90	0.20	0.40	0.30	0.00	0.36	0.34
31	34							0.70	
3	10.8							0.80	
32	25							0.9	
29	8							0.76	
	Average	1.65	1.22	0.85	0.54	0.36	0.19	0.40	
	n	39	31	31	31	31	31		
	SE	0.24	0.17	0.12	0.06	0.04	0.04		

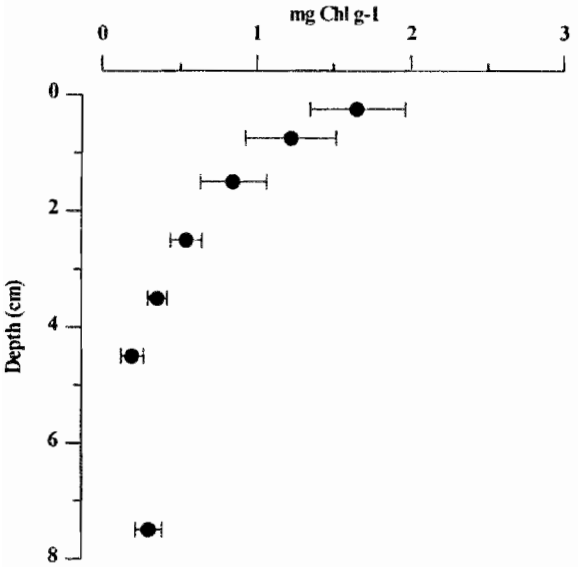

Figure 4: Average ± SE of Chl vs sediment depth

Chl concentration in the upper 0.5 cm was not correlated with station depth (Figure 5) and maximum of phytobenthos biomass (5.7 mg g^{-1}) was observed at 19m depth.

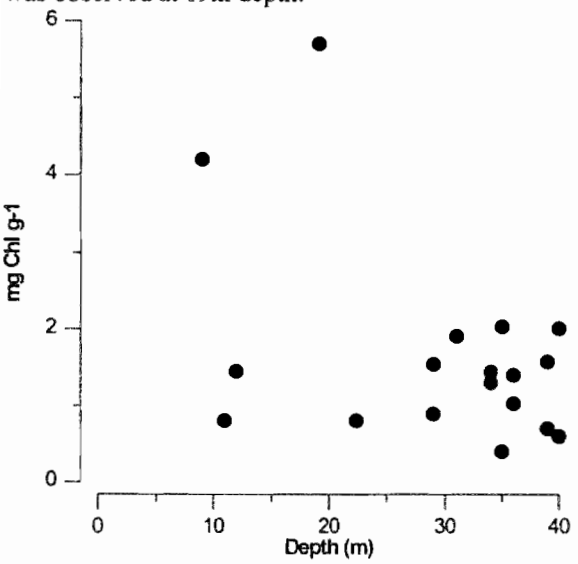

Figure 5: Chl ($_{0\text{-}0.5\ cm}$) vs depth of stations

Pha concentrations in the upper 0.5 cm varied between 0.1 et 2.4 mg g^{-1} and was in average 0.56±0.65 mg g^{-1} (Table 3). Below, in the 0.5-5cm sediment depth, Pha was 0.37 mg g^{-1}
Average vertical profiles of Pha appears in Figure 6

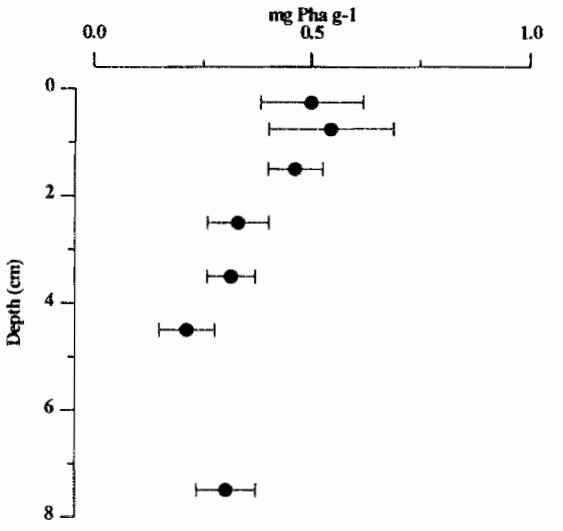

Figure 6: Average ± SE of Pha vs sediment depth

The percentage of active chlorophyll appears in Figure 8.

3.2 Production

Results are summarized in Table 4.

Gross oxygen production was correlated with the depth of the station (Figure 7). Using the equation of the linear regression line GOP *vs* Depth and a daylight period of 10h, we can estimate the average gross oxygen production at 20m, average depth of the lagoon (MacLeod 1992), to 0.7 g O_2 m^{-2} day^{-1}. This production is equivalent to 0.3 g C m^{-2} day^{-1}.

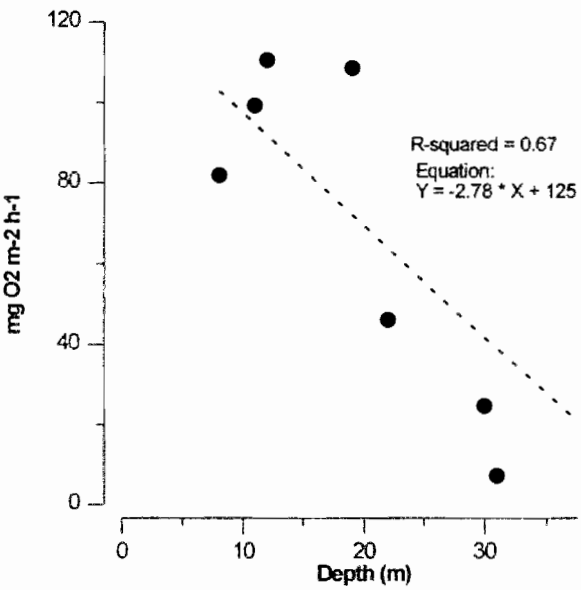

Figure 7: Gross oxygen production vs station depth

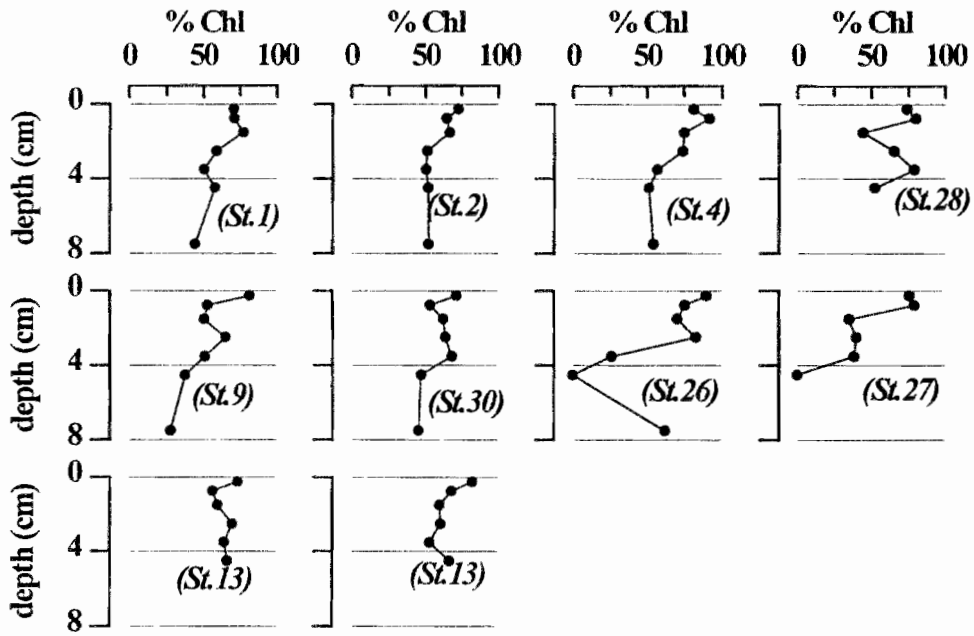

Figure 8: Percentage of active chlorophyll versus depth

Table 3: Pha concentration (mg g^{-1}) in GAR lagoon sediments

St	Depth							Average	SE
		0-0,5	0,5-1	1-2	2-3	3-4	4-5	0,5-5cm	0,5-5cm
13	36	0.50	0.60	0.60	0.30	0.22	0.10	0.36	0.09
13	36	0.22	0.56	0.60	0.26	0.15	0.01	0.32	0.10
1	19	2.35	1.30	0.44	0.60	0.47	0.13	0.59	0.16
2	29	0.58	1.35	0.45	0.38	0.19	0.74	0.62	0.17
4	40	0.45	0.14	0.78	0.24	0.15	0.16	0.29	0.10
30	40	0.24	0.35	0.42	0.68	0.37	0.19	0.40	0.07
9	35	0.09	0.62	0.29	0.09	0.19	0.33	0.30	0.08
28	22	0.28	0.10	0.62	0.09	0.08	0.18	0.21	0.09
26	9	0.45	0.19	0.07	0.08	0.56	0.17	0.21	0.08
27	12	0.46	0.24	0.36	0.59	0.47	0.12	0.36	0.07
Average		0.56	0.55	0.46	0.33	0.29	0.21	0.37	
SE		0.65	0.45	0.20	0.23	0.17	0.20		

Table 4: Net oxygen production (NOP), respiration (OR) and gross oxygen production (GOP) (mg O_2 m^{-2} h^{-1}) of sediment community of GAR lagoon

date	stat	Z	NOP	OR	GOP
18/04/93	3	11	21.45	-77.82	99.3
20/04/93	1	19	46.36	-62.30	108.7
21/04/93	2	30	-50.60	-75.36	24.8
22/04/93	30	40	-13.51	-23.06	9.6
23/04/93	31	39	38.54	-16.56	55.1
23/04/93	9	31	-12.05	-19.36	7.3
24/04/93	30	40	-58.28	-67.07	8.8
25/04/93	28	22	-38.86	-85.14	46.3
26/04/93	26	8	24.15	-57.80	82.0
27/04/93	27	12	-10.28	-120.89	110.6
		Average±SE	**-5.3±11.7**	**-60.5±10.5**	**55.2±13.4**

Table 5: Chlorophyll concentrations in French Polynesia lagoon surface sediments. z = thick of the sediment layer

Area	Depth (m)	z (cm)	mg Chl m^{-2}	References
Takapoto atoll	10-17	3	19-47	Sournia (1976a)
Moorea Island	1	3	295	Sournia (1977)
Moorea Island	0.5-2	2	7-32	Vaugelas (1980)
Tahiti (Vairao)	10-30	2	3.3-10.5	Vaugelas (1980)
Takapoto atoll	5-15	2	15-29	Vaugelas (1980)
	20-40		2.3-11.8	
Tikehau atoll	0.6-40	0.5	10±1.5	Charpy-Roubaud (1988)
Takapoto atoll	8-30	0.5	6±1	Charpy-Roubaud & Charpy (1994)
GAR lagoon	8-40	0.5	8.3±1.2	This study

Table 6: Primary production of marine soft bottoms in tropical area

Area	Method	Depth (m)	g C m^{-2} day^{-1}	References
Takapoto atoll	O_2	0.5-1	0.9	Sournia (1976a)
Moorea Island	O_2	0.2-0.8	1.13	Sournia (1976b)
Madagascar	^{14}C	5	0.35	Plante-Cuny (1973)
Florida	^{14}C	15-25	0.23	Bunt & Lee (1972)
Tikehau atoll	O_2	25	0.25	Charpy-Roubaud (1988)
Takapoto atoll	O_2	25	0.14	Charpy-Roubaud & Charpy (1994)
GAR lagoon	O_2	20	0.3	This study

3.3 Comparison with other coral reef areas

Microphytobenthos biomass was in the range of data reported for French Polynesia lagoons (Table 5). Average gross primary production was in the range of data published for some tropical areas (Table 6)

4. Conclusion

According to the station, net production appeared negative or positive. However, even at 40 m, sediments had a gross primary production. This production decreased with depth and the average microphytobenthos biomass (8.3±1.2 mg Chl m^{-2}) and gross production (0.3 g C m^{-2} day^{-1}) were close to the biomass and production observed in Tuamotu atoll lagoons.

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Some main processes of organic matter mineralization and nutrient fluxes at the sediment-water interface in the Great Astrolabe lagoon (Fiji)

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Abstract

The fluxes of dissolved inorganic N, P and Si from the sediments were calculated using pore water gradient concentration measured using the peeper technique at 2 stations in the Great Astrolabe Reef lagoon (Fiji)). The nutrient concentrations of pore water reached maximum values of 130 µM NH_4, 8 µM PO_4 and 90 µM SiO_2. Fluxes calculated from concentration gradients were from the sediment to the water column. NH_4, PO_4 and SiO_2 fluxes were respectively in the range 18-64, 0-2, 2-50 µmol m^{-2} d^{-1}.

1. Introduction

The Great Astrolabe Reef (Fiji) belongs to the remote places in the world which can be considered as free of anthropic impacts. Then, it can represent a « reference » level for environmental studies.
Since the small population uses natural resources for survival where fishing is the main local food supply, it is necessary to estimate the ability of the lagoon to recycle its natural potentiality which allows the people to live here, at the back of beyond.
One of the keys to solve this problem is the estimation of the primary production which is sustained by the nutrient pool of C, N, P and Si.
The inputs of Si and P can be accounted on the weathering of basaltic islands which emerge in many places inside of the lagoon : 13 islands which represent a total surface of 34 km^2 while the lagoon surface is 210 km^2 (16 %). The input of dry deposition is the other main source for this very large lagoon surrounded by oligotrophic waters of the Pacific Ocean.
From these rough observations it can be supposed that the main limiting factor for primary production is Nitrogen. This is probably the reason why the phytoplankton is submitted to the dominance of nitrogen-fixing species (cyanobacteria).
An important compartment involved into the recycling of the organic matter is the sediment and its associated pore water. The aim of this contribution is an attempt to quantify the fluxes of the nutrients which come from the sediment-water-interface (SWI). A further step will be the evaluation of the contribution of these fluxes compared to the other lagoonal sources and sinks.

2. Material and methods

The field work has been focused on stations 4 and 13 where the depth is 40 and 36 m respectively Figure 1.

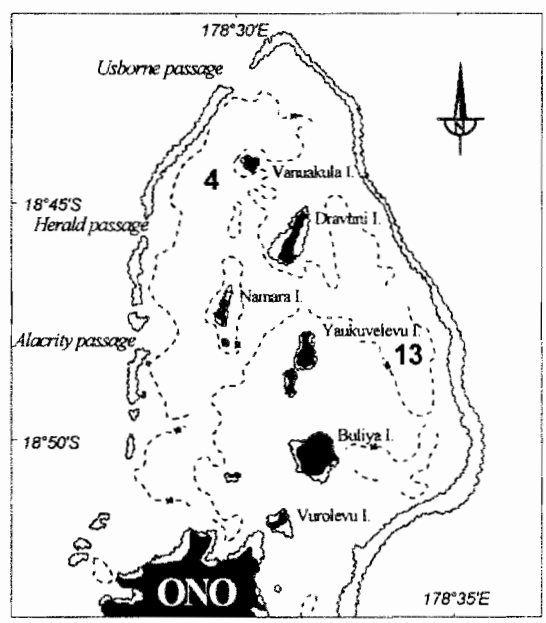

Figure 1: Station location

The pore water sampling has been done with « peepers » (Hesselin 1976) embedded into the sediment during 18 days to insure chemical equilibration.
Conventional analytical methods have been used on the field or in the laboratory to carry out the analysis of nutrients and major elements.
The pH was determined at room temperature (T = 22 °C) on submicro-samples (500 µl) using an Ingold micro-electrode and the Hansson's calibration method described by Almgren et al. (1975) with a precision of ± 0.01 pH unit. Gran's potentiometric titration was used for alkalinity measurements

(Stumm and Morgan 1981). The accuracy was ± 0.5 %. Standard colorimetric procedures were used for nutrient analysis (SiO_2, NH_4 and PO_4) and total dissolved sulfide, adapted for submicro samples (Merck Spectroquant methods; sample volume: 0.5 or 1 ml, precision ± 4 %).

3. Results

Concentrations profiles obtained at stations 4 and 13 are shown on Figures 2 to 9. For both stations large concentration gradients occur for all the analyzed species.

3.1 Concentration profiles

Data are available only for station 13 but the observed profiles are these usually observed in such marine environments (Charpy et al. 1996).
Both pH and alkalinity show a sharp variation at the SWI :
- pH decreases from 8.40 in the water column, just above the interface to 8.00 at 2.5 cm below it.
- Alkalinity, on the reverse, exhibits increasing values from 2.25 to 2.40 mM within the same depth interval.

These opposite variations show that active organic matter mineralization occurs in the sediment. Within the first centimeter below the interface we can reasonably suppose that oxidation of organic matter is carried out by using dissolved oxygen. Since this reaction increases the total DIC ($\sum CO_2 = [H_2CO_3] + [HCO_3^-] + [CO_3^{2-}]$) without any significant variation of the alkalinity, we can infer that the observed increase of alkalinity is due to the dissolution of the sediment i.e. $CaCO_3$ (probably under the aragonite form, which is the main component of coral sand). Therefore, within the 0 to 2 cm layer below the SWI the main OM mineralization processes can be represented by the two reactions :

$$(CH_2O)_x(NH_3)_y(H_3PO_4)_z + xO_2 \rightarrow x\,CO_2 + y\,NH_3 + z\,H_3PO_4 + x\,H_2O$$

$$CaCO_3 \rightarrow Ca^{2+} + CO_3^{2-}$$

From which we can deduce :

$$\frac{\Delta\Sigma CO_2}{\Delta O_2} = 1 \text{ and } \frac{\Delta Alk}{\Delta O_2} = \frac{y-z}{x}$$

$$\text{then: } \frac{\Delta\Sigma CO_2}{\Delta Alk} = \frac{x}{y-z}$$

As the stoichiometric coefficients are always as : y > z and x >> (y-z) we can infer that $\Delta\sum CO_2 > \Delta$Alk and the pH *must* decrease, as it can be observed. However, this pH variation must be buffered by the dissolution of calcium carbonate which leads to an increase of the alkalinity by the amount of :

$$\Delta Alk = 2\Delta[Ca^{2+}]$$

Within the 2cm upper layer the alkalinity increase is within the range 30 to 70 µM. then the variation of the dissolved calcium concentration is only within the range 15 to 35 µM and this small variation is not recorded on the calcium profile.
As pH and alkalinity keep changing below the oxygenated layer of the sediment, this show that the mineralization of the organic matter is still going on but the terminal electron acceptor cannot be the oxygen in account of the anoxic environment. Usually, in marine coastal environments, the sulfate ion SO_4^{2-} replaces oxygen and is reduced into S(-II) by the sulfate-reducing bacterial strains. This leads to a sharp increase in dissolved sulfide concentration into the pore water.
At both stations no dissolved $\sum H_2S$ (with $\sum H_2S = [H_2S] + [HS^-]$) occurs into the pore water. A possible explanation can be found in the fact that lots of detrial iron-rich particles are bring into the sediment by the basalt weathering which is a quite different situation as it is observed in other atolls where the iron is only a trace element.
If Fe(III) and SO_4^{2-} are both oxidants with respect to organic matter, then soluble Fe(II) and soluble sulfide S(-II) are released into the pore water medium. Subsequently, Fe(II) reacts very quickly on sulfide and leads to FeS precipitation. This reaction pathway is able to explain why neither Fe^{2+} nor $\sum H_2S$ can be detected into the pore water.

The sum of the three reactions can be written as follow :

$$\frac{9}{8}(CH_2O)_x(NH_3)_y(H_3PO_4)_z + \frac{x}{2}SO_4^{2-} + \frac{x}{2}Fe(OH)_3 + xH^+ \rightarrow \frac{9x}{8}CO_2 + \frac{9}{8}y\,NH_3 + \frac{9}{8}z\,H_3PO_4 + \frac{x}{2}FeS + \frac{19}{8}H_2O$$

and the ratio

$$\frac{\Delta Alk}{\Delta SO_4} = \frac{\frac{9}{8}(y-z)+x}{\frac{x}{2}} \quad (1)$$

$$\text{and : } \frac{\Delta\Sigma CO_2}{\Delta SO_4} = \frac{\frac{9x}{8}}{\frac{x}{2}} \approx 2.4 \quad (2)$$

since the ratio (1) is always close to 2 in account of the usual values accepted for x, y and z (with y-z << x) we can deduce that the ratio $\frac{\Delta\Sigma CO_2}{\Delta Alk}$ is always greater than 1. Hence the total DIC increases faster than the alkalinity and the pH keeps decreasing. This trend is well observed for the peeper C at station 13 (Figure 4). Unfortunately, NH_4 and SiO_2 have not been measured on peeper C. Only the PO_4 increase can yield about the mineralization processes.

Nutrients profiles observed at station 4 (40 m depth) show very sharp concentration gradients at the SWI in account of the same processes observed at station 13. A striking fact is an increase of the concentrations up to 7 to 10 cm below the SWI for NH_4 and SiO_2 while, for PO_4, the concentration increases between the SWI and 15 cm below it. The same pattern is observed for this nutrient at station 13 (Figure 7).

These observations suggest that a sediment layer located between 7 and 10 cm below the SWI acts as a nutrients source allowing diffusion to process either upward or downward this layer. Since the N:P molar ratio is close to 30 within this layer, the organic matter which undergoes the mineralization is probably not constituted of phytoplankton alone. This ratio represents more likely the degradation of dead meiofauna. The decrease observed downward is probably due to several synergetic processes such as bacterial uptake and chemisorption onto carbonate crystals surfaces.

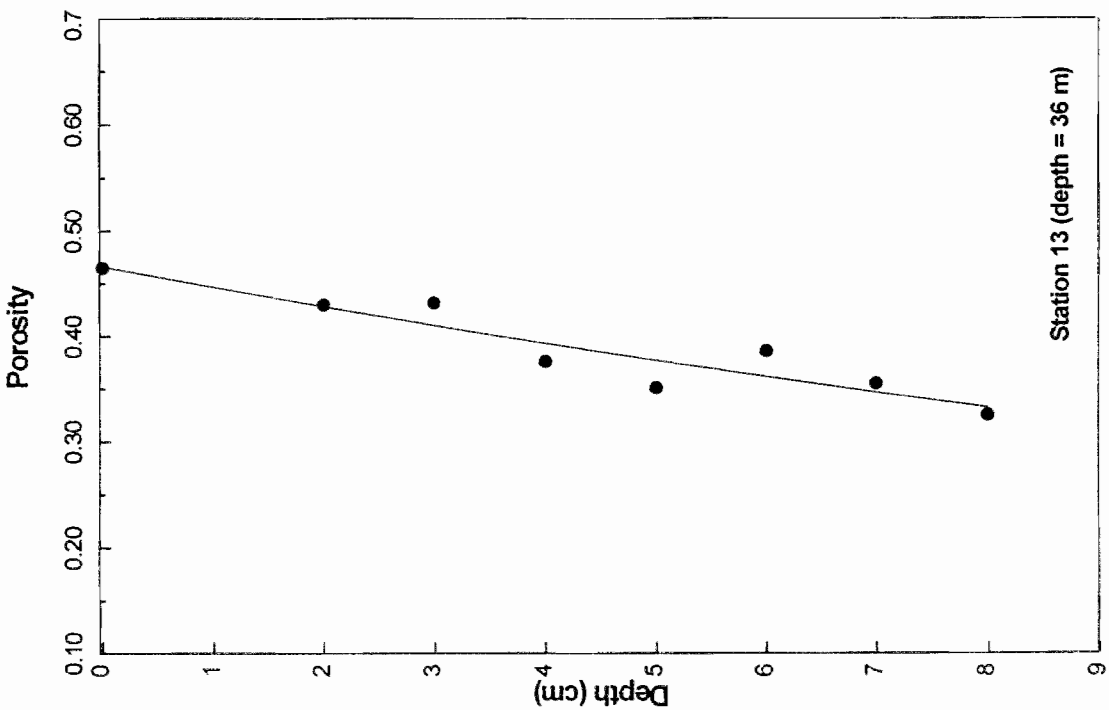

Figure 2: Porosity profile at station 13

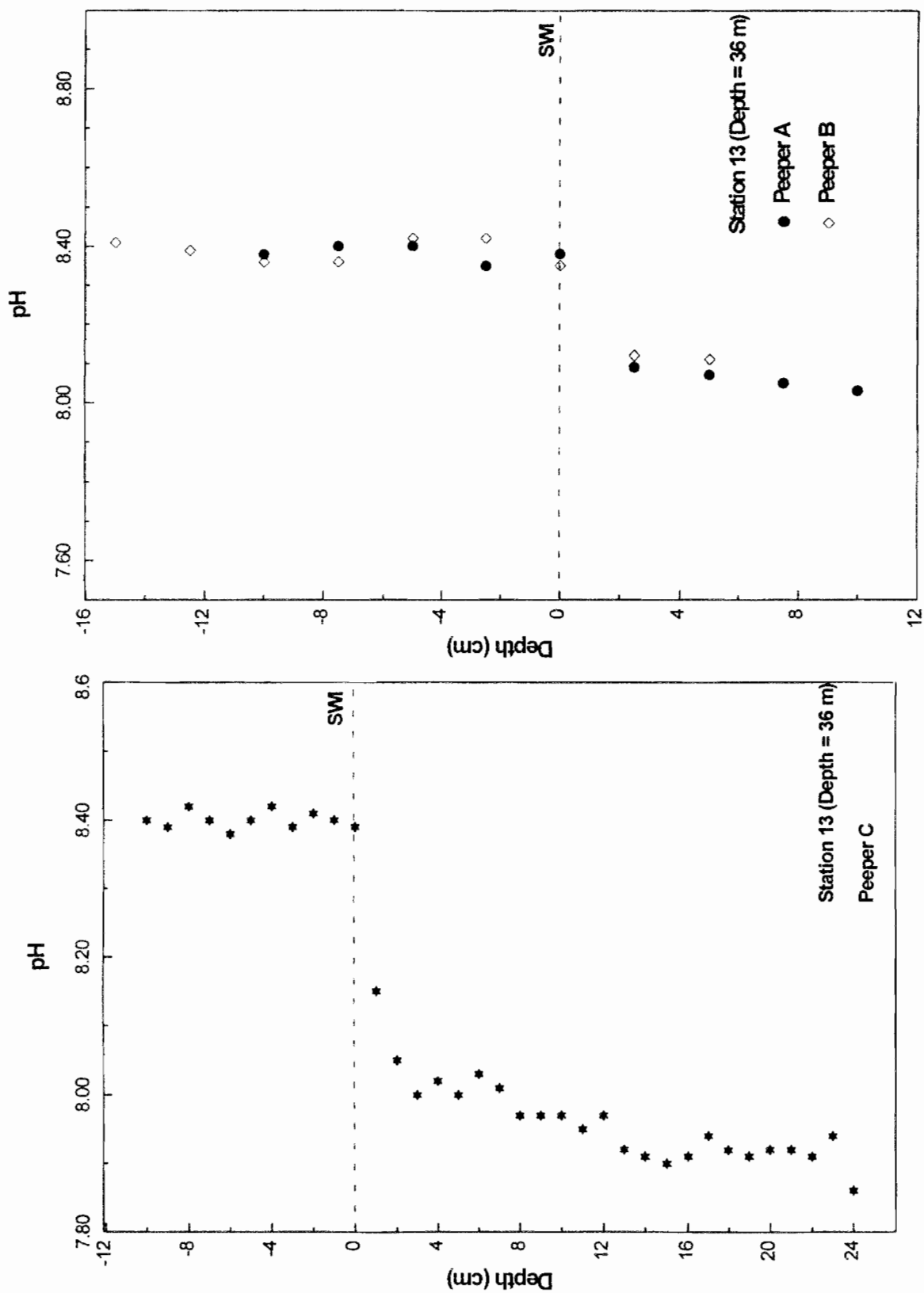

Figure 3: pH profiles at station 13

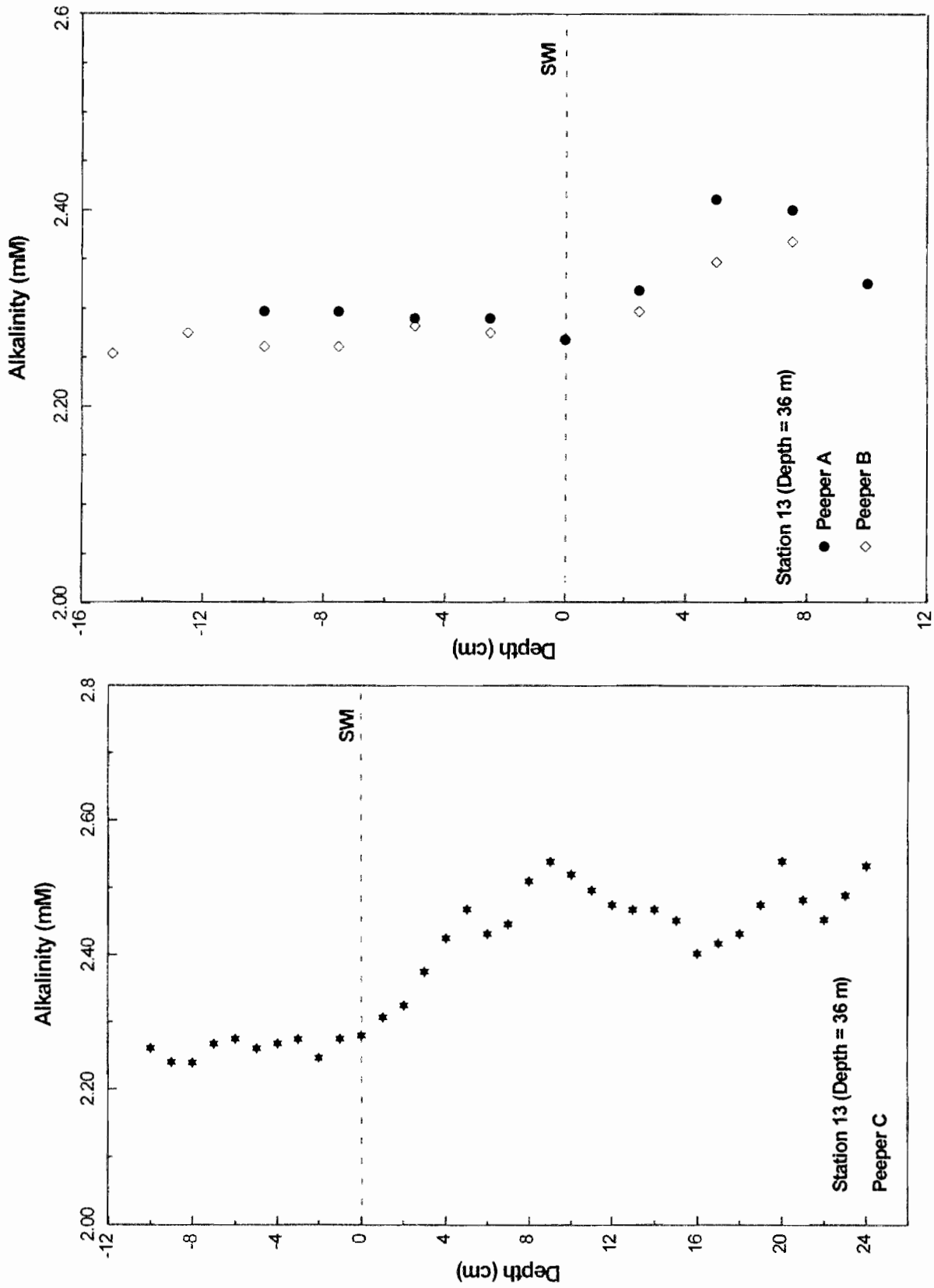

Figure 4: Alkalinity profiles at station 13

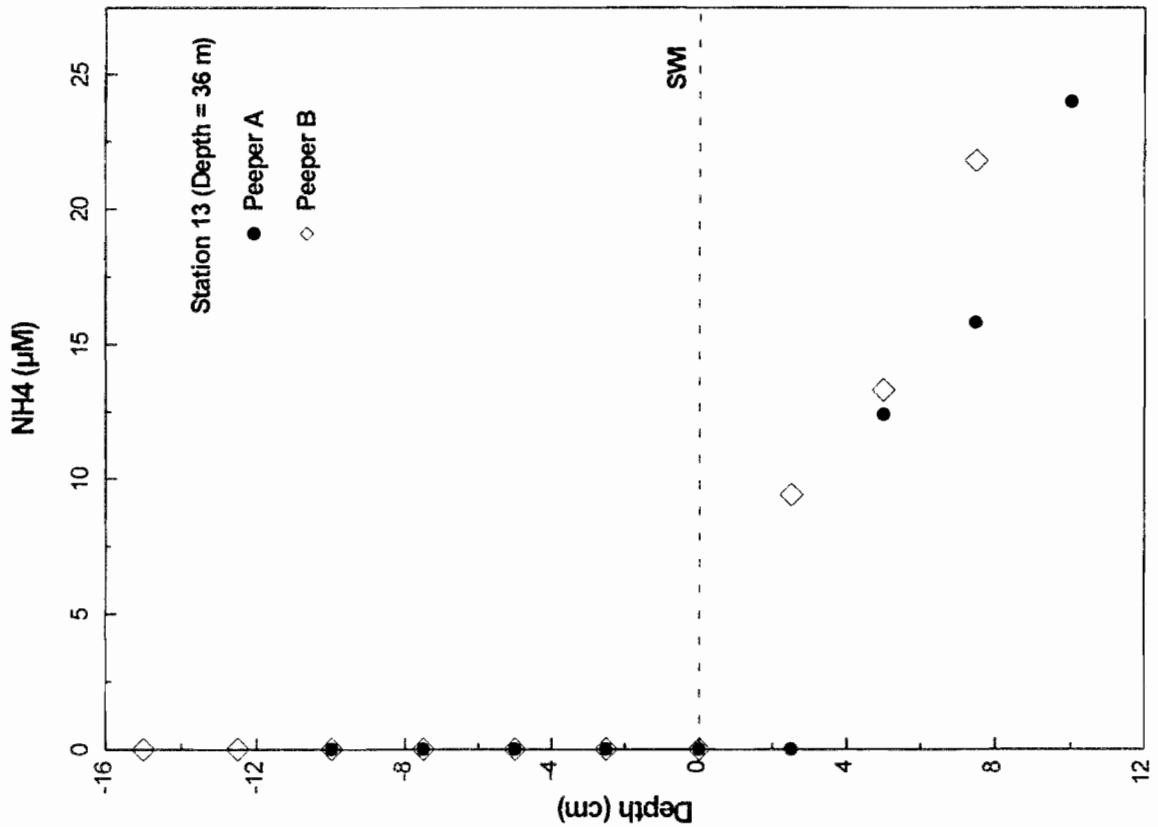

Figure 5: NH_4 profiles at station 13

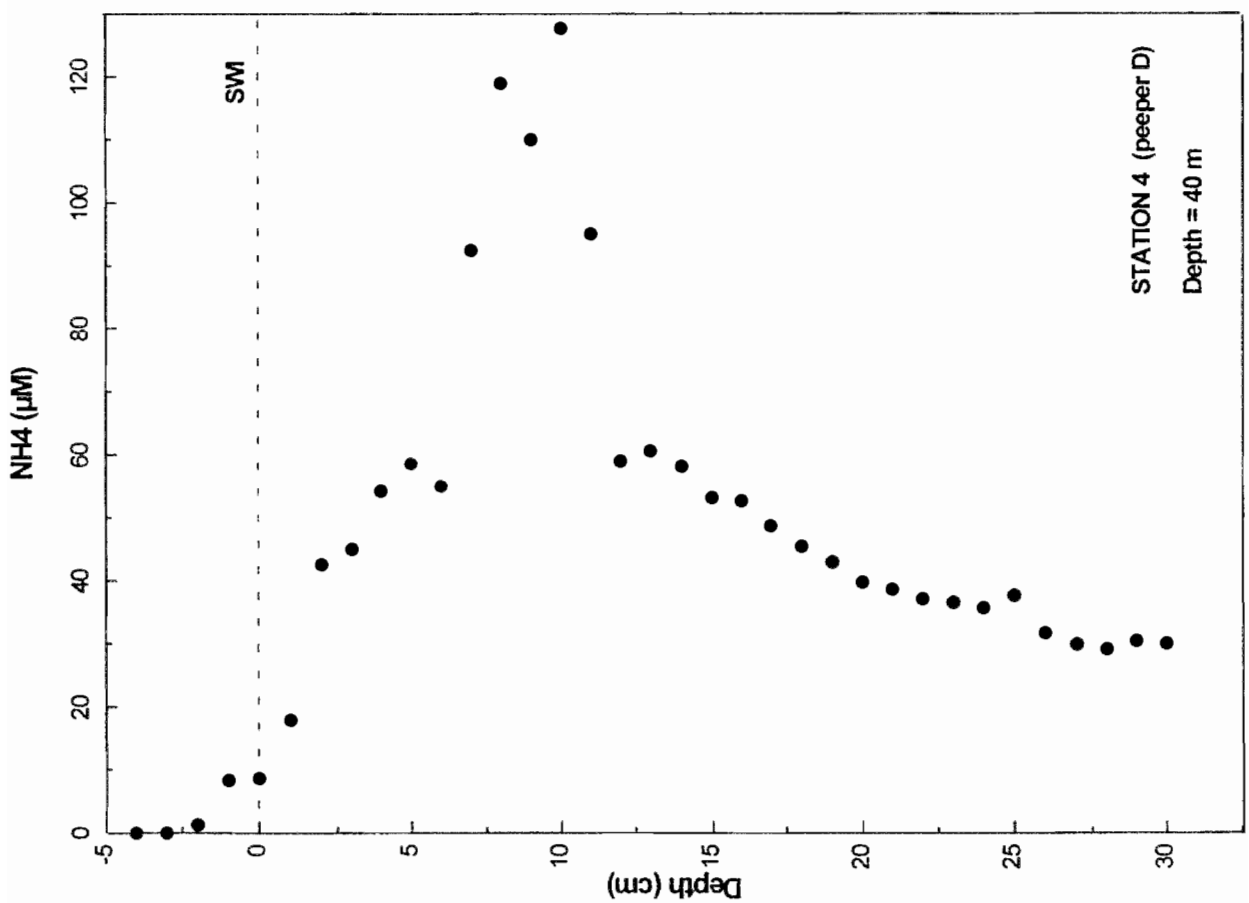

Figure 6: NH_4 profiles at station 4

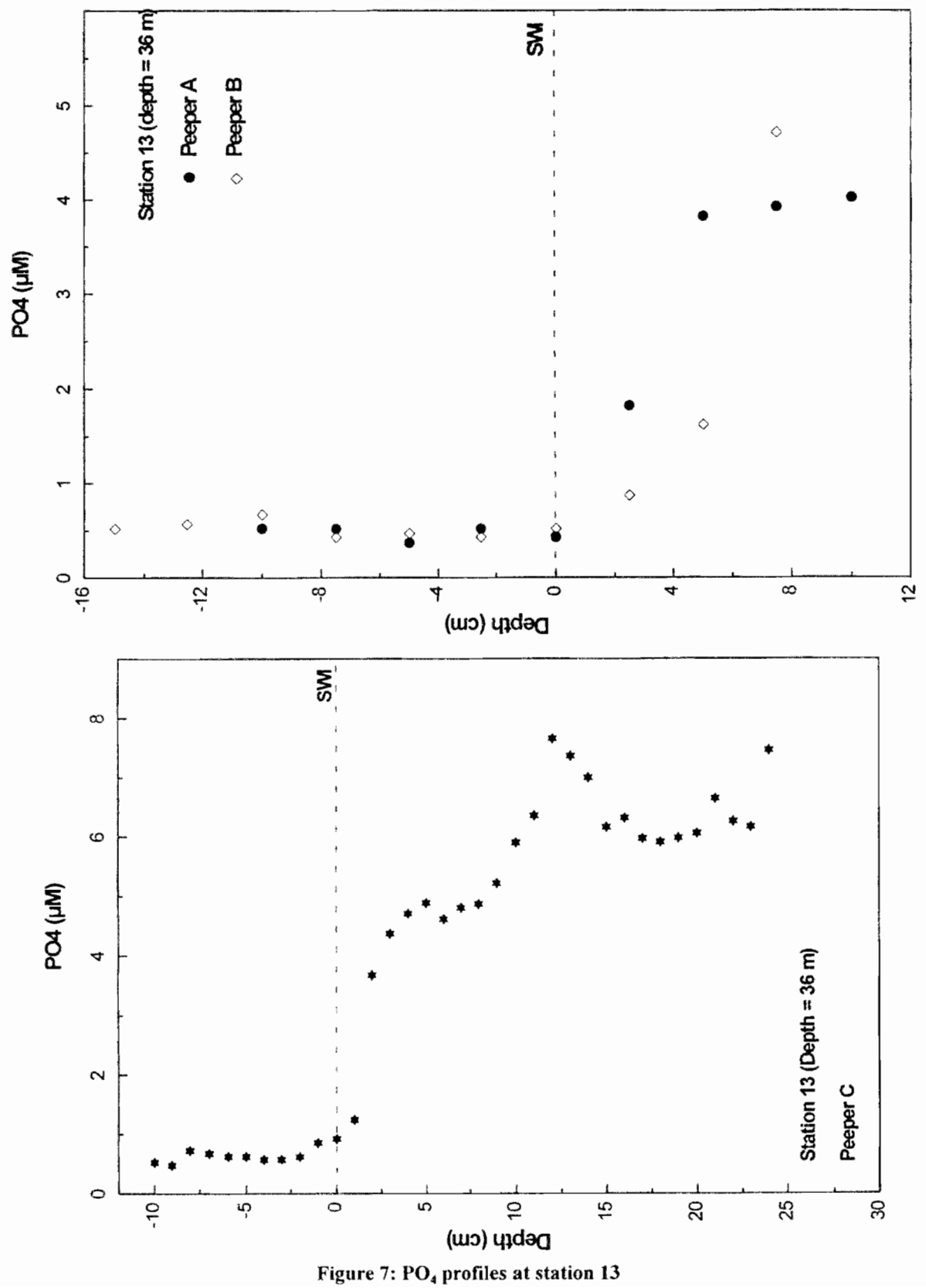

Figure 7: PO_4 profiles at station 13

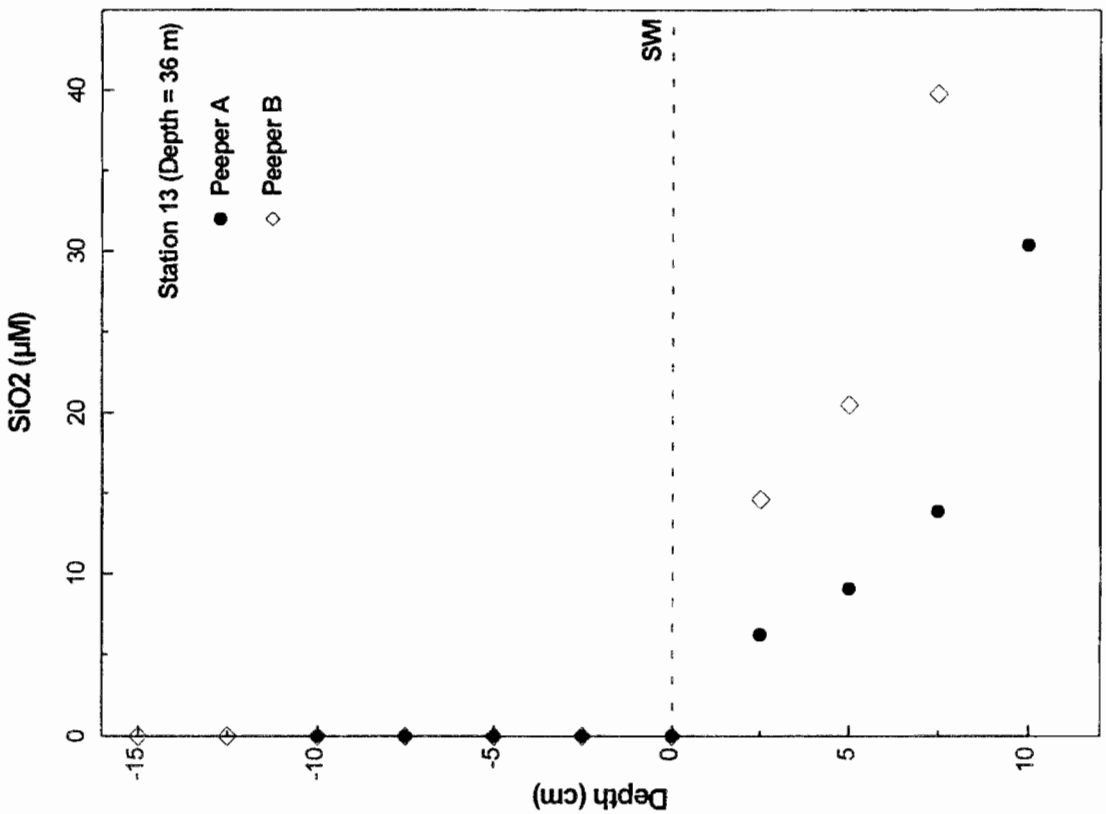

Figure 8: SiO_2 profiles at station 13

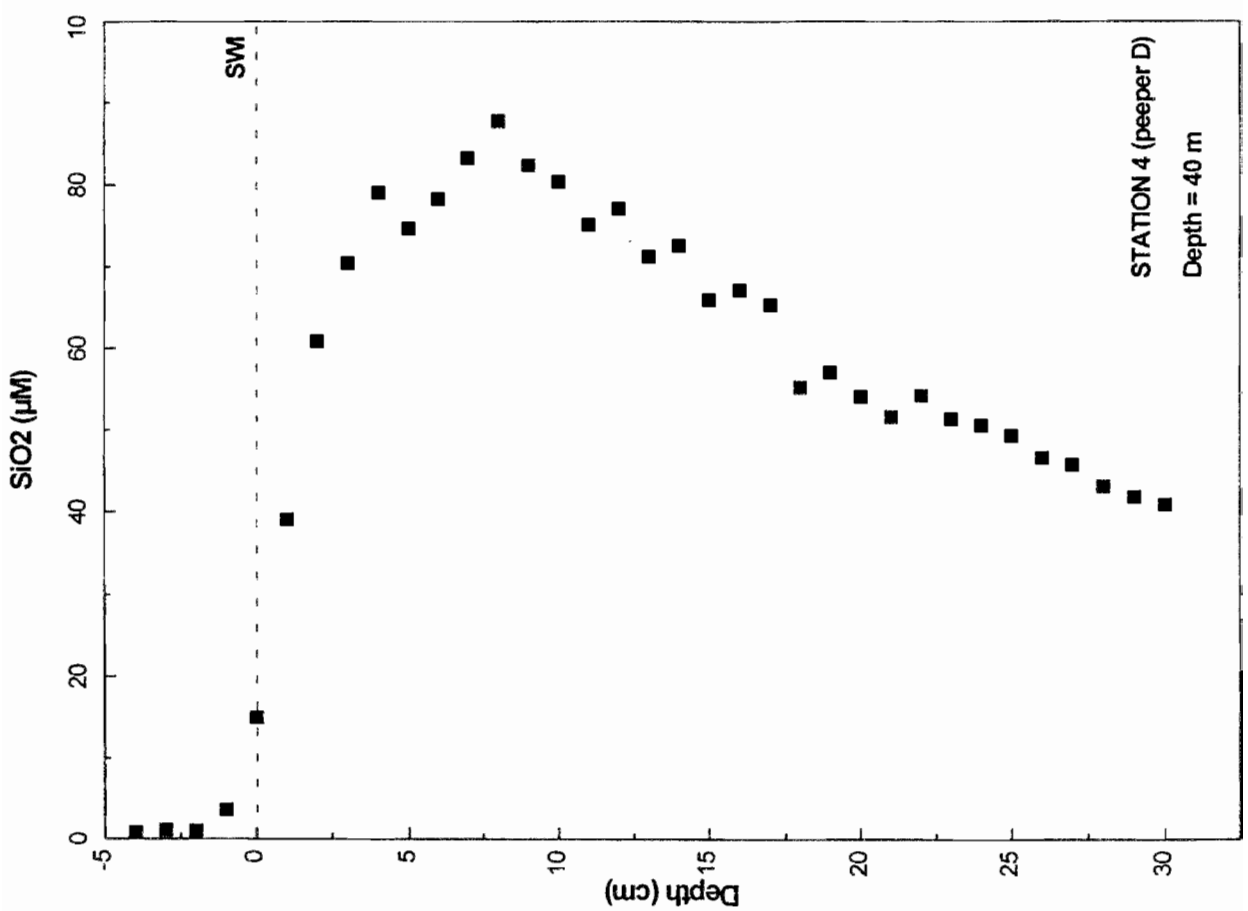

Figure 9: SiO_2 profiles at station 4

3.2 Nutrients fluxes at the sediment-water interface

Fluxes of nutrients have been calculated after the estimation of the concentration gradient at the SWI for NH_4, PO_4 and dissolved SiO_2.
The concentration gradient is related to the diffusionnal flux through the first Fick's law :

$F = - \Phi \cdot Ds \cdot gradC$ where :
Φ is the sediment porosity at the SWI : $\Phi = 0.46$
Ds is the *in situ* diffusion coefficient is calculated from the molecular diffusion coefficient corrected from the tortuosity coefficient and from the sea water viscosity :

$Ds = \frac{\Phi}{k} \cdot D°$ where k is the ratio of the viscosity of sea water to fresh water (k = 1.08) and D° the molecular diffusion coefficient.

$gradC = \lim \left| \frac{\partial C}{\partial z} \right|_{z \to 0}$ where z is the space coordinate positively oriented downward. Thus a negative flux means that the species diffuses upward, from the sediment to the water column.

The results are summarized in the Table 1.

Table 1: Nutrient fluxes at the WSI

STATION	PEEPER	FLUX (µmol m^{-2} d^{-1})		
		NH_4	PO_4	SiO_2
4	D	-64.2	-1.9	-50.3
13	A	-18	-0.51	-2.4
«	B	-21	-0.13	-1.6
«	C	-	-0.98	-

As generally observed the calculated fluxes vary greatly from one station to another. This can be accounted on particular sedimentation conditions which include bottom currents, local inputs from the shore and so on.. Since the water column is highly depleted in metabolizable nitrogen (NO_3^-, NH_4^+) the SWI appears to be able to satisfy a part of the requirements in this element for the benthic communities. High flux of silica together with nitrogen at station 4 can provide a correct nutritional environment to sustain the production of benthic diatoms, while directly metabolizable N under the NH_4^+ form can be used to develop cyanobacteria mats.
Some meteorological conditions (high wind speed or storm) can disturb the superficial sediment, enhance the dispersion flux at the SWI and bring into the water column an unusual amount of nutrients
If such fluxes can be developed in many parts of the lagoon they could be partly at the origin of random algal bloom which have been reported in the past and for which no clear explanation was found (D.R. Green).

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Report of picophytoplankton study during the astro cruise In the Great Astrolabe Reef (18°45'S-178°30'E) Fiji.

by Jean Blanchot

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Abstract

Prochlorococcus were studied with a flow cytometer, in the lagoon of the Great Astrolabe Reef (Fiji) the distribution of pico- phytoplankton within the water column was mostly homogeneous. The *Prochlorococcus* (Proc.) and *Synechococcus* (Syn.) were the most abundant groups and the picoeukaryotes (Peuk.) were an order of magnitude less abundant. The *Synechococcus* dominated the integrated : cell number, *in vivo* fluorescence and carbon biomass. In the surrounding ocean, the phytoplankton distribution was heterogeneous. Proc. and Peuk. had a subsurface maximum near the nitracline; Syn. was only abundant in surface layers and decreased drastically downward. No group clearly dominated. *Prochlorococcus* dominated in integrated cell numbers, whereas *Synechococcus* in integrated fluorescence, and picoeukaryotes in integrated carbon biomass. By comparing the present results with the results reported from offshore oligotrophic oceans and from a closed atoll, we conclude that active exchanges occur between the lagoon and the surrounding ocean.

1. Introduction

The plankton includes all heterotrophic bacteria, plants and animals that are passively drifting along with water movements. In the subtropical and oligotrophic Pacific ocean, the main components of plankton in numerical abundance and carbon biomass are the heterotrophic-bacteria and the picophytoplankton (<2µm), (Campbell and Vaulot, 1993; Campbell *et al.*, 1994). In order to estimate the fertility and the biomass of the Great Astrolabe Reef Lagoon water column. We decided to study the following main components. The heterotrophic bacteria are reviewed in chapter X and the results of the picophytoplankton are reported in this paper. The organisms of picophytoplankton are composed of: 1) the prokaryotes or phytobacteria and 2) the eukaryotes. The phytobacteria are dominated by two genera *Prochlorococcus* (≈ 0.6µm)and *Synechococcus* (≤1µm). The prokaryotes are mainly micro-flagellates. We studied the picoplankton by using an on board flow cytometer (FCM) which allowed us to count the dimly fluorescent *Prochlororoccus*, which are too dim to be observed with an epifluorescent microscope.

2. Material and methods

Observations were made during the ASTRO cruise, aboard R/V "L'ALIS", 16 April - 1 May 1994, in the lagoon of the Great Astrolabe Reef (18°45'S-178°30'E) FIJI and in the surrounding ocean (Fig. 1). The cruise was organised by the ORSTOM-groups from Papeete (French Polynesia), and from Noumea (New Caledonia), in collaboration with the USP Suva. This work was supported in part by the French Embassy in Suva.

2.1 Sampling

Water samples from discrete depths were collected with 1.7 l Niskin bottles (General Oceanic) attached to a wire. In the lagoon the selected stations were the same as the benthic stations, selected in respect of the depth and of the substratum.

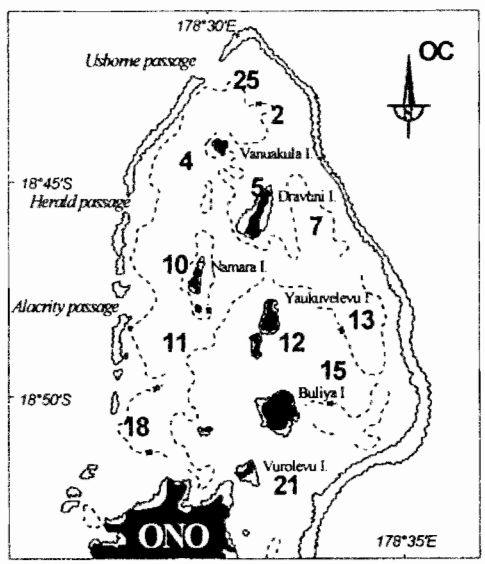

Figure 1: Station locations in GAR lagoon (OC = oceanic station

The standard depths are shown in the depth profiles at the selected stations: 10 in the lagoon

and one in the surrounding ocean near D'Urville Channel. In the lagoon samples were collected from the surface to the bottom (20m to 40m) and in the ocean from the surface to 200m.

2.2 Flow-cytometry

Samples for flow cytometer analysis were run at sea as reported by (Blanchot and Rodier, *in press*). Briefly, 0.1 ml was analysed. FCM data acquisition was performed *in vivo* without delay after sampling. A FACScan flow cytometer (Becton-Dickinson), equipped with argon laser (power = 15mW, at 488 nm) was installed in a dimly lit and temperature controlled laboratory. Sea-water filtered through GF/F filters was used as sheath fluid. For each cell, five signals were recorded on 4-decade logarithmic scales: two light scatters: and three fluorescence. The scatters are respectively: the size side scatter (SSC, link to cell absorbency), and the forward light scatter (FLS, link to cell size). The photomultipliers were set up to quantify : the red fluorescence (RF) from Chl (wavelength > 650 nm), the orange fluorescence (OF) from phycoerythrin PE (564-606 nm), and the green fluorescence (GF) from phycourobilin PUB (515-545 nm), following (Wood *et al.*, 1985; Olson *et al.*, 1988). Cellular fluorescence was always expressed relatively to the fluorescence of the beads (in arbitrary units, AU), by dividing the mean cell fluorescence by the mean bead fluorescence.

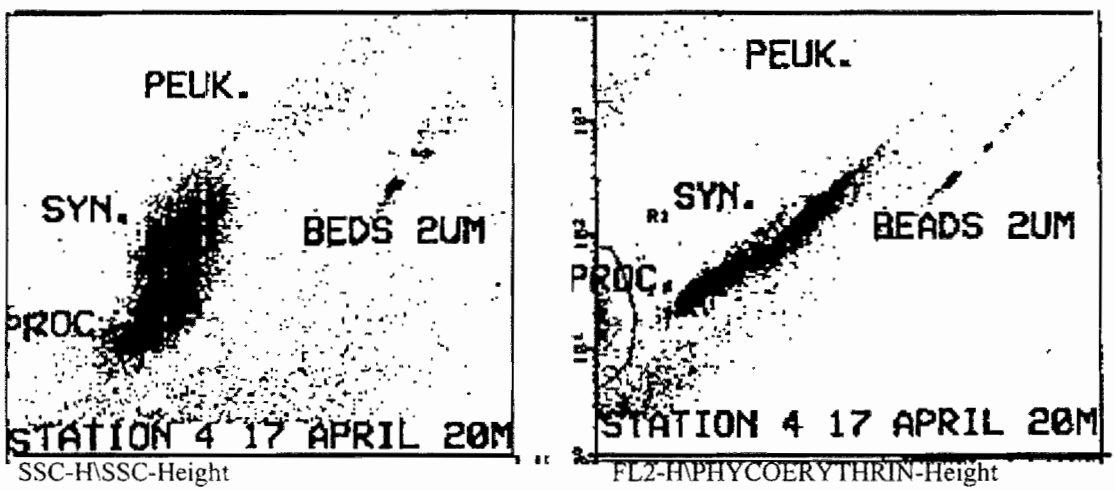

Figure 2: FACScan cytograms of Greeat Astrolabe Reef lagoon water. . St-4 fluorescence orange FL2(phycoerythrin), FL3= red fluorescence (Chlorophyll a and b); SSC = side size scatter; Proc. = Prochlorococcus; Syn. = Synechococcus; Peuk. = picoeucaryotes, Beads 2µm;

Cell groups (*Prochlorococcus*, *Synechococcus* and picoeukaryotes) were determined, using their optical properties; Figure 2. Prochlorophytes, referred to as *Prochlorococcus marinus*, were easily discriminated from the picoeukaryotes by their much smaller red fluorescence and scatter. *Synechococcus* spp., have intermediate RF and SSC signals between those of *Prochlorococcus* and picoeukaryotes and were distinguished clearly by their OF. Picoeukaryotes always have the largest RF and SSC. In order to estimate numerical abundance, we used the histograms provided by the FACScan analysis system (number versus red fluorescence intensity; Lysis II software). At all stations, the *Prochlorococcus* populations were sufficiently bright to be completely resolved by the FACScan system.

2.3 Enumeration of cells by epifluorescent microscopy

FCM, trouble the last day constrained us to use epifluorescent microscopy to count cells for the cycle experiment. Only Syn. and Peuk. were enumerated. A time series of cast was performed at Station 5, 10m in order to study short-term variability of cell abundance. One depth was sampled at 1h interval during 21 h time series. Sample for cells counts were performed following (Blanchot et al., 1992). Briefly, cells were harvested by filtration on to black Nuclepore filter 0.2 µm (Ref. 110656). The coefficient of variation varied from for 200-800 cells counted on 20-80 fields was 12% .

2.4 Carbon biomass estimates-

The conversion factors used for carbon estimates were computed by Blanchot and Rodier *(in press)*. We used respectively: 61 fgC/ *Prochlorococcus*, 104 fgC/ *Synechococcus* and 3110 fgC/ picoeukaryotes.

2.5 Nutrients and chlorophyll determination

NO_3 + NO_2 analyses were performed with a delay of few hours on the field station of Dravuni. as described by (X?) chapter. In this paper, for convenience, NO_3 + NO_2+ NH_4 will be referred to as Nitrogen nutrients (N_n).
Samples for chlorophyll *a* (Chl *a*) were harvested by filtration onto Whatman GF/F filters. Chl *a* was determined fluorometrically on a methanol (95%) extract using a Turner model 112 fluorometer calibrated with commercial pure Chl *a* (Sigma). Details of the fluorometric method and size fractionation's are given in Charpy.(1996).

3. Results and discussion

3.1 Environmental setting

Our study occurred during a June 1994. In the lagoon, the sum of nitrogen nutrients (N_n=NO_3+NO_2+NH_4) was always (≥ 0.1µm), but the nitrate concentration varied from poor stations (10, 2) to rich stations (7, 18), Figure 3.
At the external station, N_n was always (≥ 0.1µm). But the surface layers were nitrate depleted and the nirtracline occurred between 50 and 60m, Figure 4.

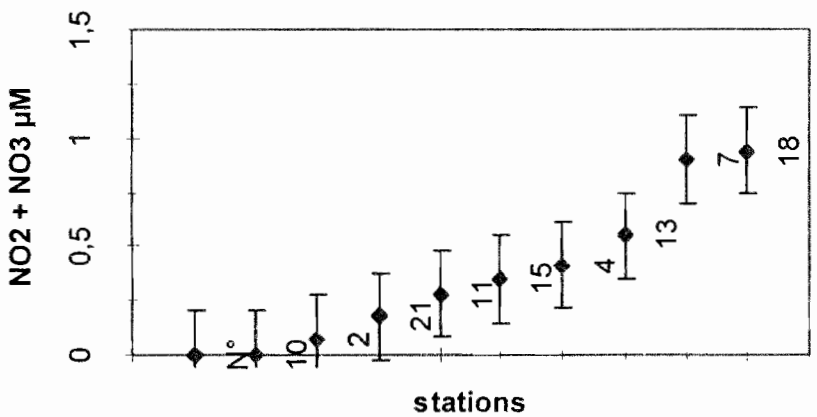

Figure 3: : Mean concentration off Nitrogen nutrients in the lagoon

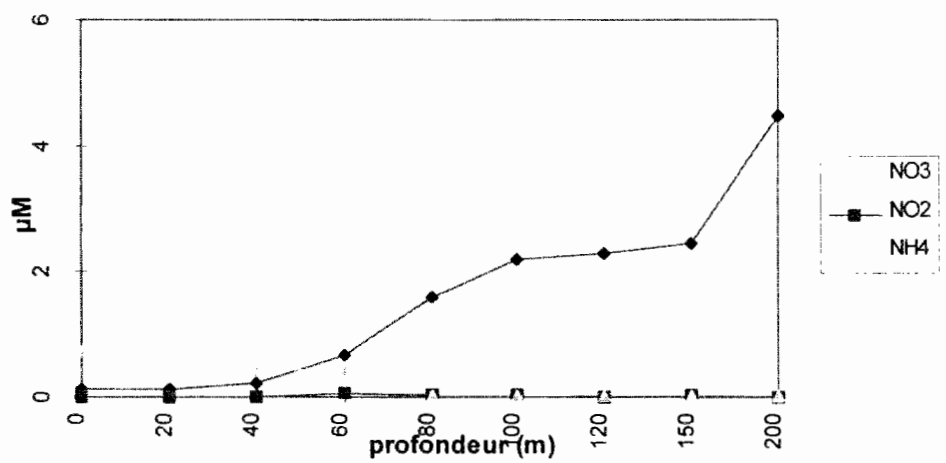

Figure 4: Vertical profiles of Nitrate at the St-Ext

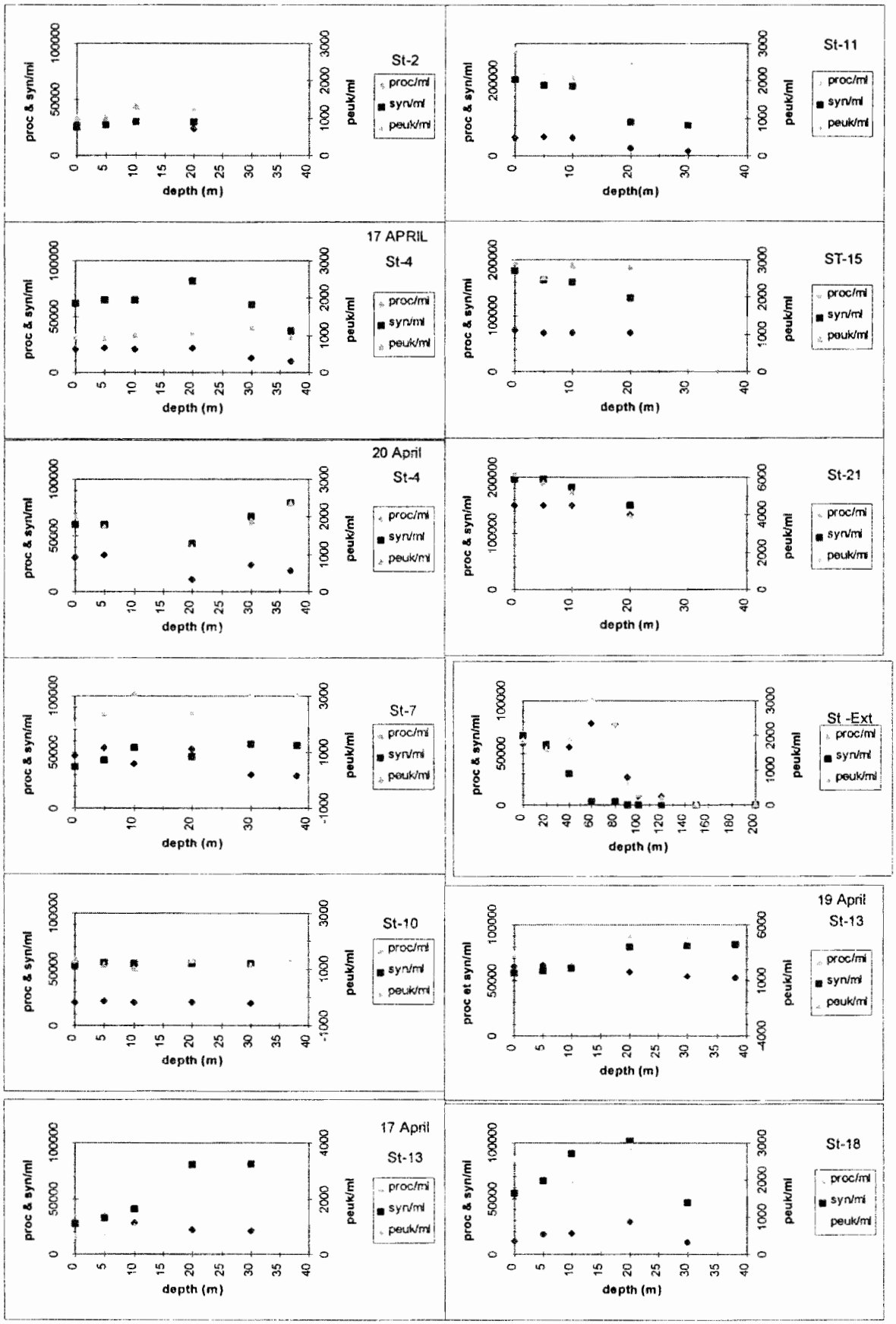

Figure 5: Depth profiles of Proc. (♦), Syn. (■) and Peuk. (∇) abundance at the lagoonal stations , and at the St-Ext.

3.2 Cell abundance distribution

In the lagoon, the phytoplankton distribution was roughly homogeneous in the water column. The depth profile of cells are shown Figure 5. In the lagoon the Syn. are the most abundant group whatever the station. The Proc. were less abundant but had the same order of magnitude as the Syn. The Picoeukaryotes were an order of magnitude less abundant. The mean abundance of cells (station 21 excluded), from the surface to 30m are respectively ($4.1 \pm 3.2\ 10^4$, $8.5 \pm 5.5\ 10^4$, $2.2 \pm 1.3\ 10^3$ cells ml^{-1}, n=11). The great sd are essentially due to the large abundance of cells at St21. At this station the maximum abundances occurred and were respectively $1.51x10^5$, $2.0x10^5$, $6.2\ x10^3$ cells ml^{-1}.
The stations belong to three sub-categories the relative poor and rich lagoonal stations and the intermediate stations. The lagoonal stations are characterized by homogeneous depth-profiles. The intermediate stations are characterized by heterogeneous depth-profiles. The relatively poor lagoonal stations. had in average a cell number Proc. and Syn. ($<10^5$ ml^{-1}), the mean Peuk. cell number is ($<310^3$ ml^{-1}), St (2, 4, 7, 10). The relative lagoonal rich stations had in average a cell number of Proc. or of Syn. ($>10^5 ml^{-1}$) and), the mean Peuk. cell number is ($>310^3 ml^{-1}$), St (11, 15,21). The intermediate stations, had a two layers., with cell number in surface layers less abundant than in subsurface layers St (13, 18). The maximum abundances occurred at station 21 and were respectively for Proc. Syn. and Peuk. $1.51x10^5$, $2.0x10^5$, $6.2\ x10^3$ cells ml^{-1}. Therefore the lagoonal community is dominated by Syn. But the lagoonal abundances of cells reported here shown a north/south or a relative poor/rich gradient. In the south, near Ono Island the abundances could thrive to an order of magnitude more that the mean cell number of all the other stations.
In the surrounding ocean, the phytoplankton distribution was heterogeneous. The depth-profiles of cells are shown Figure 5. The *Prochlorococcus* are the most abundant group, the *Synechococcus* are less abundant but had the same order of magnitude and the Picoeukaryotes were an order of magnitude less abundant. The Proc. and the Peuk. had a subsurface maximum near the nitracline. The Syn. were abundant in surface layers and decreased drastically downward. Maximum abundances (cells ml^{-1}) were 7.710^4 Proc., $6.7x10^4$ Syn. and $3.1x10^3$ Peuk. The typical Proc. dominance in numerical abundance was observed in Pacific subtropical ocean regions (Campbell and Vaulot, 1993; Campbell et al., 1994; Blanchot and Rodier, *in press*) This dominance is particularly important in nitrate-depleted layers and in the convergence areas (Blanchot and Rodier, *in press*). In the upper layers of offshore tropical Pacific Ocean waters, *Synechococcus* constitute only a small percentage of integrated values (Blanchot and Rodier, *in press*). As reported in the environmental setting the surrounding ocean is not N_n depleted, therefore the three components are well represented in the well illuminated layers.

3.3 In vivo cellular fluorescence

3.3.1 Increase of in vivo fluorescence per cell

The increases of fluorescence with depth are presented Figure 6. In the lagoon the increase of fluorescence values normalised to surface values for the three groups, was roughly the same and remain weak (<2) at 30m. In the surrounding ocean, the increases with depth vary with groups the deep Proc; were 11 times more fluorescent as the surface one, the deep Syn; were 4 times more and the deep Peuk. 6 times more. These increases occurred under the mixed layers in the nitrate rich layers. In the mixed layers from the surface to 60m, the increase is weak (<2). The increase of fluorescence with depth of *Prochlorococcus* (normalised to surface fluorescence) was more important than the increase of fluorescence of the other groups. For the increase of fluorescence to be at a maximum, then the barrier layer need to be well developed. In the homogeneous well mixed layers from the surface to the bottom in the lagoon and in the upper layers (from the surface to 60m) ,the increase of fluorescence (normalised to surface values) remain weak (<2). In the external stations outside the barrier reef, the increase of fluorescence below the nitracline is high. This is particularly true for the Proc. and is likely due to 2 main reasons. The first one is the ability of *Prochlorococcus* to photoaclimate to low light intensities as reported by Olson *et al.* (1990c), with high increase of divinyl chlorophyll *a* and *b* per cell (Goericke and Repeta 1993, Moore et al., 1995, Partensky et al.; in press). The second one, occurred only at the oceanic stations below 60m, the presence of different genetic strains in the field, with dimly fluorescent strains in upper well lit layers and brightly fluorescent strains in the poorly illuminated layers as suggested by Figure 6 (St-Ext., 60m AST078) and proved by DNA analysis near Hawaii (Campbell and Vaulot 1993).

3.3.2 Group fluorescence

In the lagoon the Fluorescence of Syn. and Proc. were large, the two groups reaching a maximum at 30m. In the surrounding ocean, the 3 groups were highly fluorescent. The Syn. were the larger group from the surface to 40 m then decreased drastically downward. Proc. and Peuk. were present throughout the whole water column. their maximum extended from to 80-90m (Fig. 7).

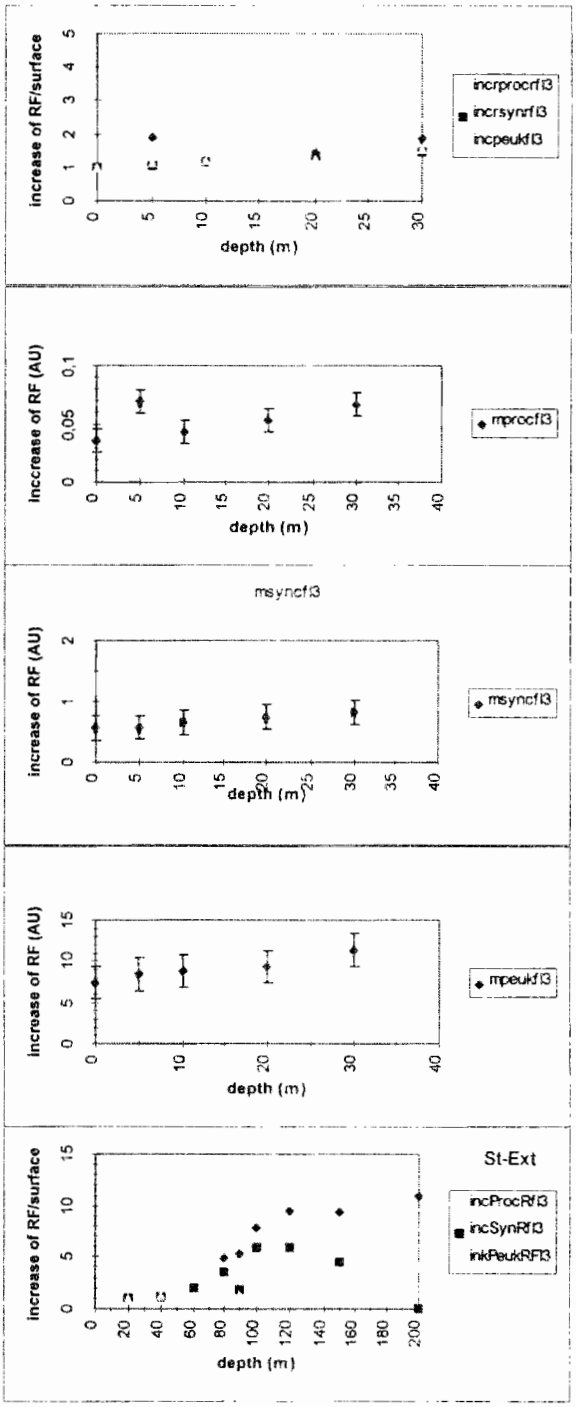

Figure 6: Increase in mean cellular red-fluorescence for *Prochlorococcus* (♦), *Synechococcus* (■), and Picoeukaryotes (V) as a function of % surface irradiance. Fluorescence values are normalized to surface values as defined by 100% irradiance. arbitrary units (AU).

3.4 Carbon biomass of phytoplankton estimated by conversion factor

At the typical station (St-4, 17 April), the Syn. are the dominant group throughout the whole water column. The respective percentage of integrated biomass for the Proc., Syn., and the Peuk. are respectively 10%, 61%, 29%.

At the oceanic station, the dominant group are the Peuk. The maximum carbon biomass occurred at the nitracline (60m), where the Peuk. reached their maximum. The Syn. disappeared below 60m. The respective contributions of the Proc., Syn., and the Peuk. 29%, 22% and 43% (Fig. 8).

3.5 Integrated values of cellular abundance, cellular in vivo fluorescence and Carbon biomass

To summarise our results we present Table-1, the integrated values percentages of cell abundance, *in vivo* fluorescence and carbon biomass. In the lagoon, the Syn. dominated all the integrated values: cell number, *in vivo* fluorescence and carbon biomass. In the surrounding Ocean no group clearly dominated the integrated values. The Proc. dominated in integrated cell numbers. The Syn. dominated in integrated fluorescence. The Peuk. dominated in integrated carbon biomass.

In the closed atoll of Takapoto Syn. was only slightly higher than Peuk.(Table 2) but in the two lagoons the dominance of Syn. is clearly a characteristic of inner waters. The percentage of Proc. at Takapoto lagoon was the half of the one from Fiji, and is a likely a consequence of the low exchange between the surrounding ocean and the lagoon. It could be also due to an apparent incompatibility to have great abundance of Proc. and Syn. in the same water for unknown reason (Blanchot and Rodier, *in press*; Partensky *et al.*, *in press*). So, to our knowledge the station 21 is atypical with 1.5 10^5 Proc. ml^{-1} and 2.010^5 Syn. ml^{-1}

In the surrounding ocean the dominance of Proc. was much higher around Takapoto than around Great Astrolabe Reef. This is the consequence of the non depleted waters in Fiji and also the exchange of water between lagoon and ocean.

3.6 Short term variability of cell abundance

The polynomial curved (x^3) fitted at the best the variations of abundance are presented Figure 10. There was a significant correlation between the tendency curves and the data ($p<0.001$, for Syn.) and ($P<0.01$, for Peuk.). The minimum of cell abundance occurred at noon for the Syn. and ad midnight for the Peuk. Inversely the maximum abundance of Syn. occurred ad midnight ant the maximum of Peuk. at noon. This preliminary results suggest that the cell cycle of Syn. and Peuk. are inverse (Fig. 9). The division of Syn. occurred after the sunset and are completed at midnight. Inversely the division of Peuk. occurred after the sunrise and is completed at noon. The division of Syn. agree

with the observed division of Proc. at 0°-150°W (Vaulot et al., 1995). To my knowledge little is know o the division of Peuk. in the tropical areas.

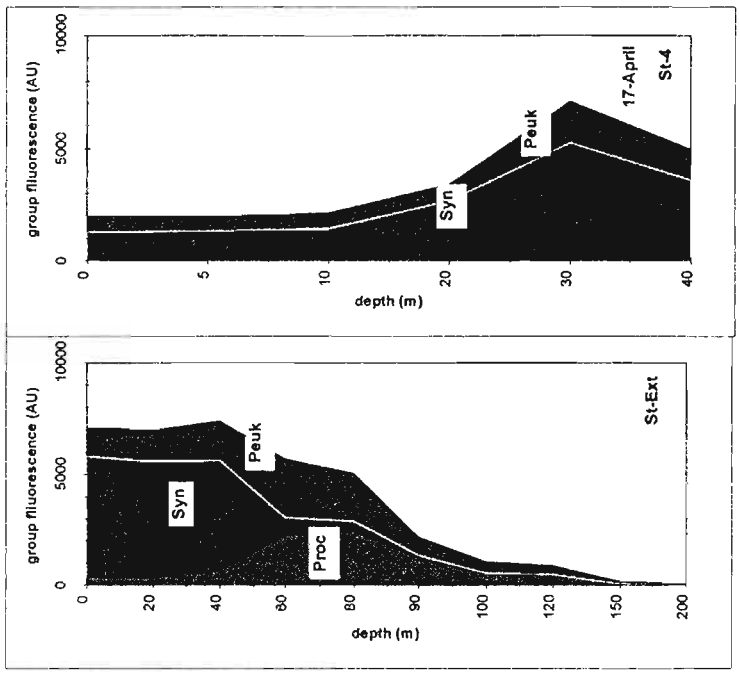

Figure 7: Total red-fluorescence in arbitrary units (AU) for *Prochlorococcus* (Pro.), *Synechococcus* (Syn.) and picoeukaryotes (Picoeuk.), overlaid by Chl *a* concentration. The red fluorescences of each population are calculated from mean cellular fluorescences weighted by cell concentrations. Same stations as for Fig.3.

Table 1 INTEGRATED VALUES in the lagoon (10 stations) and at the external stations

from surface to bottom	LAGOON		
integrated percentages	Prochlorococcus	Synechococcus	Picoeukaryotes
cell abundance	32 ± 11%,	66 ±11 %	1 ± 2%
fluorescence in vivo	3 ± 2%	69 ± 6%	28 ± 6%.
Integrated Carbon biomass	13±4%	46±11%	41±9%
from surface to 200m		OCEAN	
cell abundance	69%	29%	2 %
fluorescence in vivo	22%	46%	32%.
Integrated Carbon biomass	27%	19%	54%

Table 2 INTEGRATED VALUES in the lagoon of TAKAPOTO (145°20' W, 14°30'S), 9 stations) and at the external stations

from surface to bottom	LAGOON		
integrated percentages	Prochlorococcus	Synechococcus	Picoeukaryotes
cell abundance	17 ±8%	81±2	2±0%
fluorescence in vivo	2±1%	57±19%	41±19%.
Integrated Carbon biomass	7 ± 1%	55±3%	38±3%
from surface to 200m		OCEAN	
cell abundance	98%	1%	1 %
fluorescence in vivo	42%	5%	53%.
Integrated Carbon biomass	60%	1%	39%

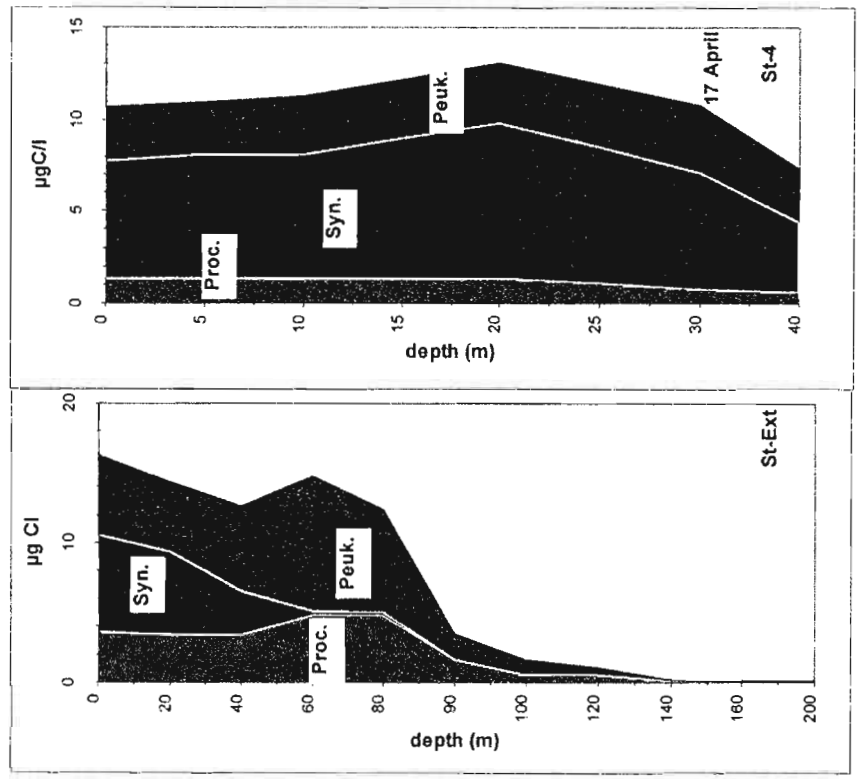

Figure 8: Carbon biomass (µgC l^{-1}) for Proc., Syn. and Peuk., The carbon biomasses are calculated from cell concentrations and conversion factors (see text).

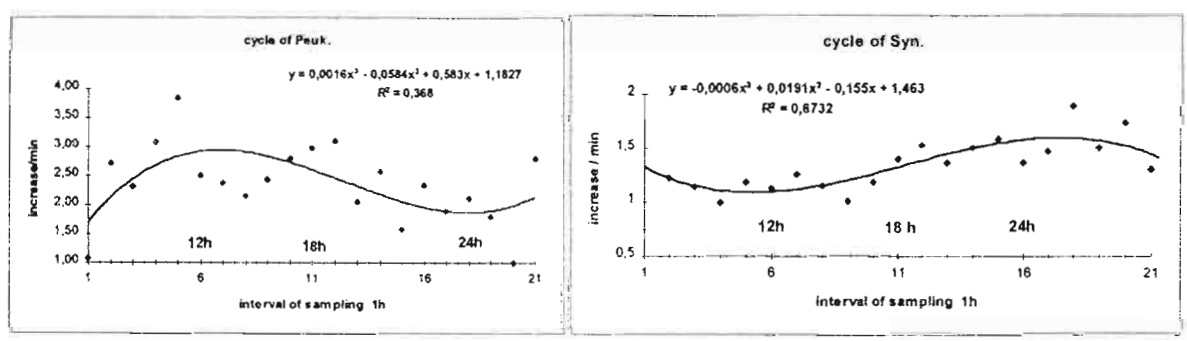

Figure 9: Short term variability of Syn. and Peuk. abundance St-5, 10m 27 April.

4. Conclusion

The community structures of the lagoon and of the surrounding ocean are different. In lagoonal environments the community is largely dominated by the *Synechococcus* (66% of cell abundance and 46% of Carbon biomass) and in the surrounding ocean there is no clear dominance of a group over the other.

In offshore ocean, in a very oligotrophic zone, the Proc. dominance is huge (96% of cell abundance and 78% of Carbon biomass ; 14°S-165°E). (Blanchot et Rodier in press). Contrary to the closed atoll of Takapoto (14°30S-145°20'W), the dominance of Syn. is large (78% of cell abundance and 53% of Carbon biomass); (Charpy and Blanchot, 1996). As our results are intermediate between those reported from offshore oligotrophic ocean, and as the lagoon of the Great Astrolabe Reef is open by several deep passages (Figure 1), we conclude that active exchanges occur between the lagoon and the surrounding ocean.

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Biomass, production and heterotrophic activity of bacterioplankton in the Great Astrolabe Reef Lagoon (Fiji)

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Abstract

Biomass, production and heterotrophic activity of bacterioplankton were determined over a 2 weeks cruise in the Great Astrolabe Reef lagoon (Fiji). Biomass (determined by epifluorescent microscopy), production (assessed by ^{3}H-thymidine incorporation into DNA) and growth rates are distributed homogeneously over the water column (20 to 40m deep). Bacterial variables do not differ significantly from site to site inside the lagoon. Bacterioplankton biomass and production vary little over a diurnal period with coefficients of variation of 9 and 22%, respectively. On average, over the whole study bacterial abundance is 0.77 10^9 cell l^{-1} (15.5 µgC l^{-1}) and bacterial production averages 4.3 µgC $l^{-1}d^{-1}$. Attached bacteria were distinguished in selected samples and on average 10.4% of the bacteria are attached to particles while they contribute for 14.1% to total production. Growth rates for bacterioplankton differs significantly for the free (0.19 d^{-1}) and attached (0.30 d^{-1}) communities. Fixation seems to provide an advantage for bacterial growth into this lagoon. Carbon growth yield (CGY) was determined experimentally into two dilution cultures by comparing the net increase of bacterial biomass and the net decrease of dissolved organic carbon (DOC). Both determinations led to a very low growth yield (average 5.8%). By applying the average CGY value to bacterial production rates into the lagoon, heterotrophic activity was estimated to average 74 µgC $l^{-1}d^{-1}$. The turn-over rate of DOC (average 1572 µgC l^{-1}) is therefore estimated to average 0.048 d^{-1} during that period. Both bacterioplankton abundance and production values appear to be greater than in oceanic water surrounding the Great Astrolabe Reef lagoon.

1. Introduction, objectives

Planktonic bacteria play an important role in most of the ecosystems studied. The development of epifluorescent microscopy and tracer approaches have led to better understand their contribution to cycle of energy and matter in various pelagic ecosystems. However, little is known about their importance in coral reef lagoons because most of the results in coral reefs environments have focused on water overlying coral reefs (Sorokin, 1974, Pascal & Vacelet, 1981, Moriarty *et al.* 1985, Linley & Koop, 1986, Hoppe *et al.* 1988, Ducklow, 1990, Moriarty *et al.* 1990) with only few exceptions in atoll lagoons (Sorokin, 1974, Yoshinaga *et al.* 1991, Torréton & Dufour, 1996), and Island lagoons (Sorokin, 1974, Landry *et al.* 1984, Yoshinaga *et al.* 1991). Coral reefs areas are characterized by high and efficient recycling processes and low inputs of new nutrients (Crossland & Barnes, 1983). Atoll and island lagoons may represent large bodies of water where heterotrophic bacterioplankton could contribute for an important part of total carbon, nitrogen and phosphorus. Thus the description and comprehension of bacterioplankton dynamics is essential in the studies of carbon and nutrient cycling in coral reefs environments.

This study intends to describe bacterioplankton biomass, productivity and heterotrophic activity in the water column of the coral lagoon of the Great Astrolabe Reef (Fiji). Bacteriobenthos biomass and productivity has been described previously in *Syringodium isoetifolium* seagrass beds in an area of this lagoon (Pollard & Kogure 1993). But very little is known in the water column of this lagoon. Vertical and horizontal distribution and short term variations of bacterioplankton parameters were investigated during a 2 week campaign in April 1994.

Two distinct microbial communities can be identified. One is attached to the substrate, forming epifloral community and the other occurs as free bacteria suspended in the water column. Free and attached bacterial communities do not present the same fate. Free bacteria are mostly exported *via* grazing by phagotrophic nanoplankton and attached bacteria may be exported by sedimentation or by grazing by larger organisms including mesozooplankton. They do not either present the same metabolic properties (Hoppe et al. 1988). Moriarty (1979) reports that up to 50% of the bacteria are attached in some coral reef environments. An objective of that study was therefore to estimate the contribution of attached bacteria to biomass and activity of the whole community and to investigate if fixation was an advantage in the Great Astrolabe Reef lagoon.

The importance of standing stocks and fluxes across bacterioplankton will be further

compared to other components of the planktonic trophic network obtained during the same survey (Charpy 1996 and Blanchot 1996, this volume).

2. Materials and Methods

2.1 Study sites and sampling

The Great Astrolabe Lagoon lies in the South of Viti Levu the main island of Fiji. The general characteristics of this lagoon were summarized by Naqasima et al. (1992).

This work was performed during a campaign on the ORSTOM R/V Alis from 18 to 29 May 1994. Bacterioplankton parameters were determined every day through the lagoon water column. A total of 10 sampling stations (20 to 40 m deep, see Fig. 1 and Tab. 1) were investigated over the whole water column.

Bacterioplankton parameters were also recorded along a diurnal cycle on station 5 (at 10m depth) in order to appreciate the representativeness of a single measurement at this scale and to detect any trend in the diurnal evolution of bacterial biomass and activity. An oceanic station (OC), Northeast of the lagoon (Fig. 1) was also visited during the cruise.

Water samples were collected using acid-washed Niskin bottles and treated on board immediately after sampling. All sample handling was performed using either disposable sterile hardware or acid-washed Polycarbonate bottles.

2.2 Abundance, biovolume

Water samples received 0.2 µm filtered and buffered formalin (2% final concentration) and were stored at 2°C in the dark until filtration within 6h after sampling. Bacteria were then collected onto 0.2 µm Nuclepore membranes after staining with DAPI (Porter & Feig, 1980). Membranes were mounted on microscopic slides and stored at -20°C until counting within one month. Bacterial cells were counted under epifluorescence (magnification 1000). At least 400 cells on at least 20 fields were counted. Replicate filters of the same sample differ on average by 11.7% of the mean.

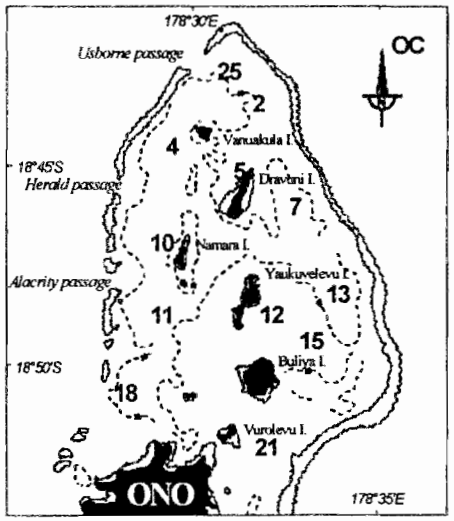

Figure 1: Map of the Great Astrolabe Reef lagoon. Sampling locations are figured by station numbers. OC designs the oceanic station.

Table 1: Characteristics of the sampling sites

station	latitude (S)	longitude (E)	depth (m)	sampling date
2	18°43'29"	178°31'45"	28	04-18-94
4	18°44'34"	178°29'28"	39	04-20-94
5	18°45'11"	178°31'15"	17	04-27-94
7	18°46'05"	178°32'44"	43	04-19-94
10	18°46'59"	178°29'11"	37	04-18-94
11	18°48'49"	178°29'11"	39	04-20-94
13	18°48'17"	178°33'50"	38	04-19-94
15	18°49'28"	178°33'08"	29	04-22-94
18	18°50'46"	178°26'38"	34	04-21-94
21	18°52'08"	178°21'58"	30	04-22-94
25	18°42'40"	178°30'58"	31	04-29-94
OC	18°41'12"	178°35'12"	3000	04-26-94

Station 5 was studied only for the diurnal pattern of bacterioplankton variables and dilution cultures (no vertical profile). OC : oceanic station

Mean cell volume was estimated by delimiting bacterial contours on photographic slides projected on a sheet at a final magnification of 10000. Length and width of individual cells were determined with a digitizing tablet. Bacterial volume was computed by assimilating bacteria to a cylinder with an hemisphere at both sides. At least 2 photographic slides were used per sample for a total of at least 150 cells. Mean cell volume estimation differs on average by less than 20% on the 2 slides of the same sample (Torréton & Dufour, 1996).

2.3 Bacterial production using TdR incorporation

2.3.1 Routine measurements

Bacterial production of biomass was determined by following the rate of [*methyl*-^{3}H]thymidine incorporation into DNA (TdR, Fuhrman & Azam, 1982).

TdR incorporation was performed routinely on freshly collected samples (within 1 hour) using 10 nM [methyl-^{3}H]thymidine (Amersham, 1.74 TBq/mmol). After 30 min incubation at 28°C (±1°C in situ temperature), duplicate 10 ml samples were chilled in a 2°C water bath. Samples were filtered onto 0.2 µm Nuclepore membranes and rinsed with 5 ml of 0.2 µm filtered lagoon water. Vacuum was disconnected and filters received 15 ml ice-cold 5% TCA. After 15 min vacuum was reapplied and the membranes were rinsed 3 times with 5 ml of ice-cold 5% TCA. Membranes were stored at -20°C in scintillation vials before radioactivity determination (within 2 weeks). DNA was hydrolyzed by adding 0.5 ml of 0.5N HCl into the vials. The vials were then heated at 100°C during 30 min in a water bath. Radioactivity was determined after allowing samples to stay with scintillation cocktail overnight. Quench correction was made with external standards. Incorporation was calculated after subtraction of a zero time blank.

The proportion of TdR incorporation in the > 3 µm size class was determined at every station on 10m deep samples using the procedure described above and by replacing 0.2 µm membranes by 3 µm ones.

2.3.2 Saturation kinetics

Saturation kinetics were assayed regularly in order to check if 10 nM was sufficient to saturate incorporation process and limit isotope dilution. Every assay was performed on 15 replicate subsamples (5 ml each). Each concentration of the label (2, 5, 10, 20 and 30 nM) was applied to duplicate samples and a zero time blank.

2.3.3 Isotope dilution

Isotope dilution assays (Pollard & Moriarty 1984) were performed at different stations in order to determine the contribution of labeled TdR to total incorporation. Every assay was performed on 8 replicate subsamples (5 ml each). All the subsamples received 10 nM of labeled thymidine and increasing amounts of unlabeled thymidine (0, 20, 40 and 60 nM). A zero time blank was performed for every concentration and was subtracted from the signal. Maximum incorporation rate were computed from the regression of [total TdR added] versus 1/observed incorporation rate: [L+A] = Vmax.L/Vobs - P, where L and A are the concentrations of labeled and unlabeled TdR, P is the "pool" of thymidine inducing intra and extra cellular isotope dilution, and Vobs and Vmax are observed and maximum TdR incorporation rates respectively. Of course this procedure gives a correct estimate of isotope dilution only if incorporation into the target molecule is the rate limiting step.

2.3.4 Extraction of DNA

A total of 15 additional TdR incorporation assays were done in triplicates as described in section 2.3.1. After incubation, precipitation and filtration steps, membranes were stored at -20°C until analysis at the laboratory. Labeled DNA was extracted enzymatically from these membranes following a modification of Wicks & Robart's (1987) procedure as described in Torréton & Bouvy (1991). Recovery of the label into the DNA fraction was then compared with the label recovered on the same samples using the standard TCA precipitation procedure.

2.3.5 Calibration of TdR incorporation against cell production

The conversion factor of TdR incorporation into cell production was estimated in dilution cultures of lagoon water. These cultures are described in § 2.6.

2.4 DOC determinations

Samples were filtered through burnt (440°C, 4h) Whatman GF/F glass fiber filters to remove particulate carbon greater than 0.7 µm. The filtrate was then dispatched into replicate Teflon capped glass tubes previously acid washed and burnt (550°C, 4h). Ten ml samples receive $HgCl_2$ (10 ppm final concentration) to prevent bacterial growth during the storage of the samples. The tubes were then stored in the dark at 4°C until analysis. After elimination of CO_2 by adding 0.1ml HCl 1N and bubbling 10 min with CO_2 free air, DOC was analyzed using HTCO technique (Sugimura & Suzuki, 1988) on a Total Organic Carbon analyzer (Shimadzu TOC 5000). Blank value average 200 µgC l^{-1} and was not subtracted from the signal.

2.5 Bacterioplankton growth yield and heterotrophic activity

Bacterioplankton carbon growth yield was estimated in the lagoon water cultures used to calibrate [*methyl*-^{3}H]thymidine incorporation into cell production (see 2.6.). DOC consumption was estimated and related to bacterial biomass production into the cultures. Growth yield of bacterioplankton was defined as the slope of the regression line of bacterial biomass versus DOC decrease. Production divided by carbon growth yield

was used to assess DOC consumption by heterotrophic bacteria into this lagoon.

2.6 Lagoon water cultures

Two dilution cultures were realized by inoculating 10 and 30% of 1µm filtrate of lagoon water (station 12, 04-23-95) into 0.2 µm filtered lagoon water in order to remove potential limitation of bacterial growth by available nutrients and grazing by eukaryotes greater than 1 µm. The absence of flagellates in the cultures was verified during microscopic enumeration of bacteria. Bacteria were allowed to grow in the dark at 30°C under gentle agitation. Periodically (1.5 to 2 hours) water samples were removed and bacterial abundance, biovolume, DOC and ^{3}H-TdR incorporation were recorded as described above excepted that TdR was added at 20nM in order to prevent isotope dilution and/or unsaturation of incorporation into fast growing populations in these cultures. Comparison of rates with 20nM and 40 nM were made occasionally and showed no significant differences showing that maximum incorporation was achieved at 20nM. Recovery of the label into the DNA and TCA fractions was estimated systematically in the dilution cultures.

3. Results and discussion

3.1 Methodological background

3.1.1 Saturation kinetics

Saturation kinetics showed that 10 nM was sufficient to saturate the incorporation process (Fig. 2).

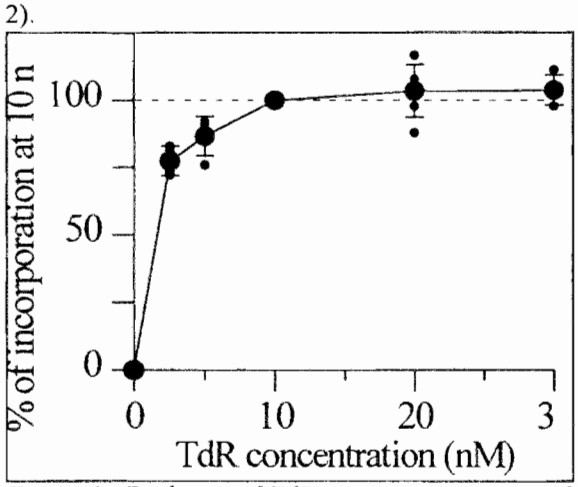

Figure 2: Evolution of TdR incorporation rate with increasing concentrations of labeled TdR. Five experiments were performed. Rates are normalized by giving 100% to the 10 nM value

3.1.2 Isotope dilution

On average the "dilution pool" was not significantly different from zero, representing 0.7 nM (SE = 1.0 nM, n = 6) using the isotope dilution plots method (Tab. 2, Fig. 3). Thus labeled TdR constitutes nearly 100% of TdR incorporated according to this procedure and it was not necessary to correct TdR incorporation for isotope dilution.

Table 2: Dilution pool of TdR determined using the isotope dilution procedure

Station	Depth (m)	Vobs (pMh^{-1})	Vmax	Vobs/Vmax (%)	Dilution Pool (pM)
5	10	18.08	25.97	69.60	1.59
5	10	24.26	28.38	85.47	0.77
25	0	10.19	14.12	72.15	3.89
25	5	7.91	9.91	79.84	0.26
25	10	11.20	13.47	83.15	1.17
25	20	11.27	11.20	100.65	-3.30
		Average		81.81	0.73
		SE		4.53	0.96

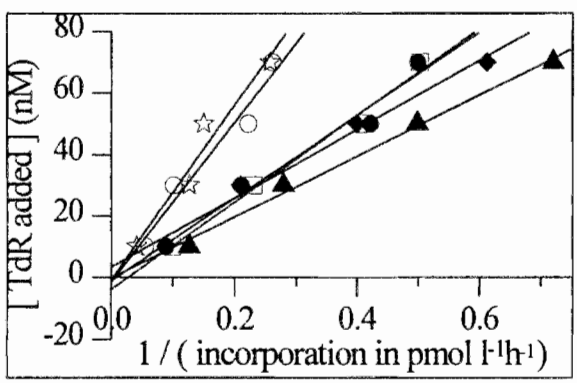

Figure 3 : Isotope dilution plots of TdR incorporation. Y-intercept represents the opposite of the dilution pool. Six experiments were performed on stations 2 (□), 5 (○), 7 (☆), 10 (●), 11 (▲), and 13 (◆).

3.1.3 Incorporation into DNA versus cold TCA precipitate

In the water column samples, label recovered into DNA averages 75.0 % with minor fluctuations (SE=1.3 %, n=15, see Tab. 3). This shows that TdR is not extensively catabolized but incorporated preferentially in the DNA like in other atoll lagoons (Torréton & Dufour, 1996). Thus, on the remaining *in situ* samples, incorporation into DNA was calculated by multiplying incorporation into cold TCA precipitable material by 0.75.

During bacterial growth into the dilution cultures, recovery of the label into the DNA and TCA fractions was stable (mean 90.5 %, SE=3.1 %, n=8, see Tab. 3) and significantly higher than in situ ($P<0.001$, Student's t-test). This has already been observed in other coral reef lagoons (Torréton & Dufour, 1996). This difference, although limited in importance during that study, is of particular interest

as TdR incorporation is basically an estimation of DNA synthesis. DNA is not the only macromolecule labeled by ^{3}H-TdR, but usually for commodity only incorporation into cold TCA precipitate (including DNA, RNA and proteins) is determined. TCA derived production estimate ($Prod_{TCA}$) is therefore estimated by:

$Prod_{TCA}$ = Incorporation into TCA x TCF_{TCA} (1)

Where TCF_{TCA} is the Thymidine Conversion Factor based on incorporation into TCA precipitate. However, the real bacterial production value ($Prod_{DNA}$) should be given by incorporation into DNA: $Prod_{DNA}$ = Inc. into DNA x TCF_{DNA} (2).

Where TCF_{DNA} is the Thymidine Conversion Factor based on incorporation into DNA. But DNA constitutes on average 75.0% and 90.5% of labeled TCA precipitated macromolecules on *in situ* sample and in lagoon water cultures, respectively. This can be resumed by :

Inc. into TCA = Inc. into DNA / 0.75 (3)

and CF_{TCA} = 0.905 CF_{DNA} (4)

Therefore using (3) and (4), (1) comes :

$Prod_{TCA}$ = Inc. into DNA / 0.75 x 0.905 CF_{DNA} (1')

And using (2), (1') comes :

$Prod_{TCA}$ = $Prod_{DNA}$ x 0.905/0.75

Cell production calibrated against TdR incorporation into cold TCA precipitate would therefore lead to a 1.21 fold overestimation of the real bacterioplankton production. This artifact is not very important in that ecosystem as the percent of labeled incorporated into DNA is rather high for *in situ* samples. But in waters showing a stronger catabolism pathway for ^{3}H-TdR, this difference of incorporation pattern between *in situ* and cultured bacteria may lead to a much greater overestimation (Torréton & Bouvy, 1989).

3.1.4 Calibration of TdR incorporation against cell production

After a lag phase of less than 10 hours, bacterial cells and TdR incorporation grew exponentially (Fig. 4). Four different methods usually yielding slightly different results were proposed to relate cell multiplication and TdR incorporation (Ducklow *et al.* 1992). However, if care is taken to account for the proportion of inactive cells, all the four methods lead to the same conversion factor (Torréton & Dufour, 1996).

Table3 : Proportion of TdR incorporated into DNA using DNase extraction method.

Water column samples

Station	Depth (m)	TCA pmol l^{-1} h^{-1}	DNA pmol l^{-1} h^{-1}	% in DNA
2	0	18.97	15.54	81.9
4	30	17.85	12.70	71.1
5	10	12.84	9.81	76.4
5	10	14.09	11.38	80.8
7	0	13.11	9.72	74.1
10	0	4.75	3.57	75.2
11	0	12.77	9.40	73.6
13	30	8.73	5.89	67.5
15	0	9.31	6.47	69.5
18	29	10.84	8.06	74.4
21	0	9.58	8.05	84.0
21	5	11.59	8.33	71.9
21	10	11.29	8.86	78.4
21	20	12.47	8.43	67.6
25	20	11.27	8.84	78.4
		Average		75.0
		SD		5.0
		SE		1.3

Dilution cultures

Culture	Day-time	TCA pmol l^{-1} h^{-1}	DNA pmol l^{-1} h^{-1}	% in DNA
A	12	6.23	6.60	105.9
A	14	19.50	15.58	79.9
A	16	39.01	37.14	95.2
A	18	37.84	30.24	79.9
B	8	7.84	7.45	94.9
B	10	34.61	31.55	91.2
B	12	113.47	95.63	84.3
B	14	122.13	112.96	92.5
		Average		90.5
		SD		8.8
		SE		3.1

TCA : ^{3}H-TdR recovered into the TCA precipitable fraction, DNA : ^{3}H-TdR recovered into the DNA fraction. % in DNA : DNA x 100 / TCA. Each value is the average of duplicate determinations. Culture A: 10% inoculum, culture B: 30% inoculum (4-24-94).

Cells multiplication and TdR incorporation were then related using the cumulative method proposed by Bjornsen & Kuparinen (1991). This method claims the advantage to be « model free », *i.e.* to not require assumptions about the proportion of active cells.

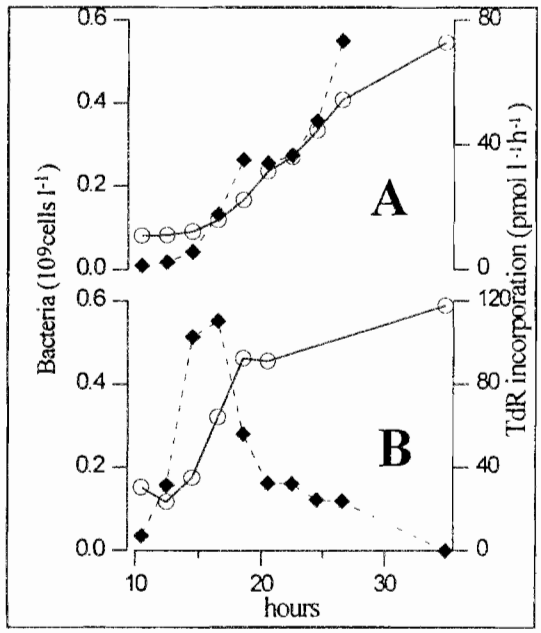

Figure 4: Evolution of bacterial abundance (○) and TdR incorporation into DNA (◆) along the seawater cultures. A: 10% inoculum, B: 30% inoculum.

Least squares linear regressions were used to compute the thymidine conversion factor (TCF) assuming the relation : Cells = TCF (ΣTdR)+ ß where: Cells is the net increase of bacterial cells cumulated over the successive time intervals, ΣTdR is the integral of TdR incorporation cumulated over the successive time intervals and ß is the intercept of the regression of cells versus ΣTdR.

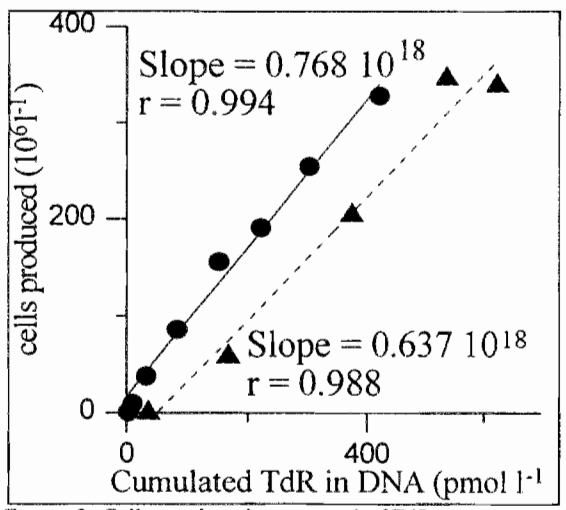

Figure 5: Cells produced vs integral of TdR incorporation cumulated over successive time intervals. The slope of the regression lines represent the conversion factor (CF) for TdR incorporation into cell production. ●: 10% inoculum, ▲: 30% inoculum

The two independent determinations lead to similar results (see Fig. 5). The average conversion factor, 0.7 10^{18} cells per mol of TdR incorporated into DNA is close to the average CF determined in Tikehau lagoon (1.0 10^{18}, Torréton & Dufour, 1996). Incorporation of TdR into DNA (in mol $l^{-1}h^{-1}$) was thus multiplied by 0.7 10^{18} to obtain bacterial production in cell $l^{-1}h^{-1}$. These production values were multiplied by 20 fgC $cell^{-1}$ (Lee & Fuhrman, 1987) in order to obtain production values in gC $l^{-1}h^{-1}$.

3.1.5 Bacterial growth yield into the seawater cultures

Although limited by the precision inherent to the method, DOC decreased significantly within the cultures ($P < 0.05$, see Fig. 6) while bacterial carbon increased. Cells multiplication and DOC consumption were related using a cumulative method as described above for TdR incorporation. Least squares linear regressions were used to compute the carbon growth yield (CGY).

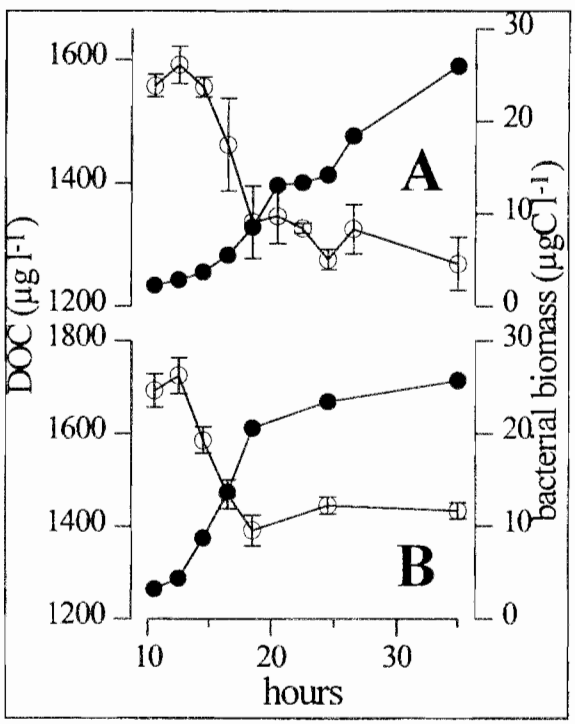

Figure 6: Evolution of bacterial carbon (●) and DOC (○) within the seawater cultures. A: 10% inoculum, B: 30% inoculum

The relation : δBC = CGY (δ DOC)+ ß was assumed, where, δBC is the net increase of bacterial carbon cumulated over the successive time intervals, δ DOC is the net decrease of DOC and ß is the intercept of the regression. The two independent determinations lead to very convergent results (see Fig. 7) with an average CGY of 5.8 %.

This very low growth yield has been observed in Tikehau and Takapoto lagoons (Torréton & Dufour, unpublished data) and a comparable CGY was determined during the North Atlantic bloom with the same method for seawater culture realization and for DOC determination (Kirchman *et al.* 91). This CGY is thus very unlikely

to be a methodological artifact but rather an index of severe bottom-up limitation of bacterioplankton.

Production values in gC l^{-1} h^{-1} were thus divided by 0.058 in order to obtain heterotrophic activity of the bacterioplankton community.

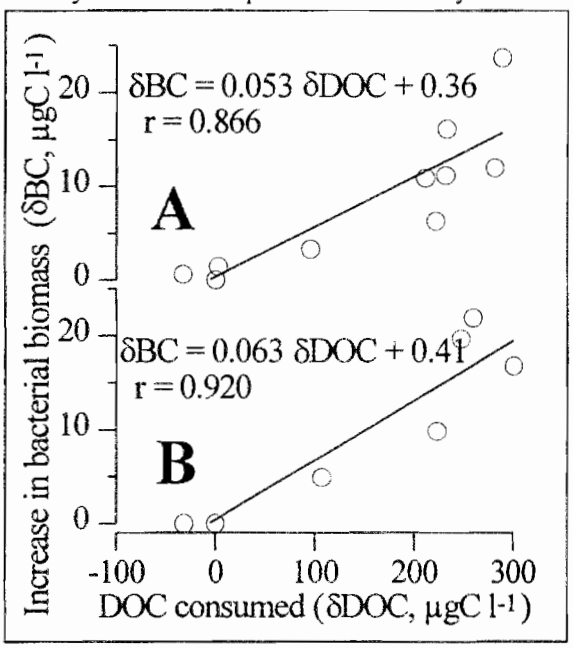

Figure 7: Plot of bacterial carbon produced versus DOC consumed over successive time intervals in the two cultures. The slope of the regression lines represent the carbon growth yield (CGY). A: 10% inoculum, B: 30% inoculum

3.2 Bacterioplankton biomass, production and growth rate in the Great Astrolabe Reef lagoon

3.2.1 Spatial variations

3.2.1.1 Vertical variations

Ten profiles of bacterioplankton parameters were realized from sub-surface to the bottom of the water column (25 to 45m). Bacterial parameters show little variations along the water column with coefficient of variation (CV%) representing 11, 18 and 17% for bacterial abundance, production and growth rate respectively (Tab. 4, see Fig. 8).

Water column may thus be considered roughly homogenous for bacterioplankton parameters observed during this cruise.

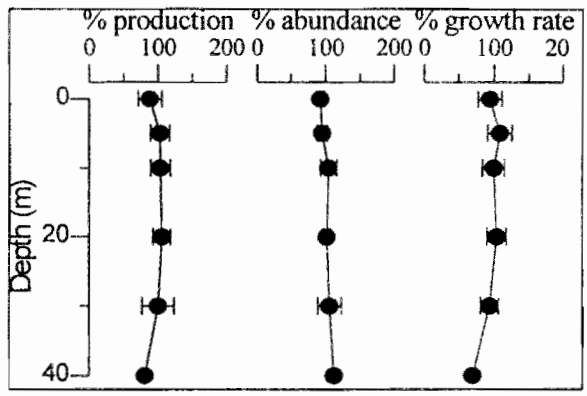

Figure 8: Average profiles of bacterial abundance, production and growth rate normalized to the average value per profile. Horizontal bars represent standard deviation.

3.2.1.2 Horizontal variations

Average values for vertical profiles do not differ very much from site to site into the lagoon. Coefficient of variation for averages of the 10 profiles are 10, 19 and 21 % for bacterial abundance, production and growth rate respectively (Tab. 5).

Variations are more important on integrated values as CV raise to 26 and 27 % for bacterial abundance and production respectively (Tab. 6). These weak differences, integrating both inter-station and day-to-day variations are thus mainly due to depth differences between the stations.

Table 4: Bacterial abundance. TdR incorporation and specific TdR incorporation per cell along vertical profiles.

Bacterial abundance (10^9 cells l^{-1})

Depth	2	4	7	10	11	13	15	18	21	25	ALL PROFILES		
0	0.73	0.68	0.62	0.77	0.72	0.64	0.70	0.62	0.70	0.58			
5	0.67	0.68	0.61	0.80	0.78	0.76	0.74	0.63	0.71	0.58			
10	0.84	0.70	0.59	0.95	0.85	0.74	0.66	0.84	0.85	0.64			
20	0.65	0.87	0.73	0.92	0.71	0.74	0.70	0.73	0.73	0.65			
30		1.03	0.84	0.98	0.58	0.74		0.64					
40			0.79								AVG	SD	CV%
AVG	0.72	0.79	0.70	0.89	0.73	0.72	0.70	0.69	0.75	0.61	0.73	0.07	9.7
SD	0.09	0.16	0.11	0.09	0.10	0.05	0.03	0.09	0.07	0.04			
CV%	12	20	15	10	13	7	4	13	9	6	11		

TdR into DNA (pmol l^{-1} h^{-1}) (a)

Depth	2	4	7	10	11	13	15	18	21	25	ALL PROFILES		
0	14.23	9.90	9.83	3.56	9.58	6.85	6.98	6.03	7.18	7.64			
5	12.64	10.37	11.07	7.93	11.25	7.83	7.10	10.98	8.69	5.93			
10	14.08	7.06	11.83	9.38	11.82	8.62	6.93	7.73	8.47	8.40			
20	11.52	8.91	10.18	9.23	9.59	9.93	9.42	7.82	9.35	8.45			
30		13.39	10.77	9.38	6.09	6.55		8.13					
40			8.42								AVG	SD	CV%
AVG	13.12	9.92	10.35	7.90	9.67	7.96	7.61	8.13	8.42	7.61	9.07	1.74	19.2
SD	1.28	2.31	1.17	2.50	2.24	1.38	1.21	1.79	0.91	1.18			
CV%	10	23	11	32	23	17	16	22	11	15	18		

TdR specific incorporation (10^{-21} mol $cell^{-1}$ h^{-1})

Depth	2	4	7	10	11	13	15	18	21	25	ALL PROFILES		
0	19.4	14.6	15.9	4.6	13.2	10.8	9.9	9.7	10.3	13.1			
5	18.8	15.3	18.1	9.9	14.5	10.3	9.6	17.4	12.2	10.2			
10	16.7	10.1	20.2	9.8	14.05	11.6	10.4	9.2	10.0	13.1			
20	17.7	10.2	13.9	10.0	13.5	13.5	13.4	10.7	12.8	13.1			
30		13.0	12.8	9.6	10.4	8.8		12.7					
40			10.7								AVG	SD	CV%
AVG	18.2	12.6	15.3	8.8	13.1	11.0	10.8	11.9	11.3	12.4	12.5	2.6	21
SD	1.2	2.4	3.5	2.3	1.6	1.7	1.7	3.3	1.4	1.4			
CV%	7	19	23	27	12	16	16	28	12	12	6		

(a): Incorporation into cold TCA precipitate was multiplied by 0.75 (average labeled DNA/labeled TCA ratio) to obtain incorporation into DNA.

Table 5: Average bacterioplankton biomass, productions and growth rates along the 10 vertical profiles.

Station	Bacterial biomass 10^9 cell l^{-1}	Bacterial biomass µgC l^{-1}	TdR incorporation pmol $l^{-1}h^{-1}$	Bacterial production 10^6 cell $l^{-1}h^{-1}$	Bacterial production µgC $l^{-1}d^{-1}$	Spec. Incorporation 10^{-21} mol cell $l^{-1}h^{-1}$	Growth rate d^{-1}
2	0.724	14.5	13.1	221	4.43	18.2	0.31
4	0.793	15.9	9.9	167	3.35	12.6	0.21
7	0.697	13.9	10.4	175	3.49	15.3	0.26
10	0.886	17.7	7.9	133	2.67	8.8	0.15
11	0.729	14.6	9.7	163	3.26	13.1	0.22
13	0.724	14.5	8.0	134	2.69	11.0	0.19
15	0.702	14.0	7.6	128	2.57	10.8	0.18
18	0.694	13.9	8.1	137	2.74	11.9	0.20
21	0.746	14.9	8.4	142	2.84	11.3	0.19
25	0.612	12.2	7.6	128	2.57	12.4	0.21
mean	0.731	14.6	9.1	153	3.06	12.5	0.21
SE	0.024	0.5	0.6	10	0.20	0.8	0.01
CV%	10	10	19	19	19	21	21

Table 6: Integrated bacterioplankton biomass and productions along the 10 vertical profiles.

Station	Bacterial biomass 10^{12} cell m^{-2}	Bacterial biomass mgC m^{-2}	TdR incorporation 10^{-9} $m^{-2}h^{-1}$	Bacterial production 10^{12} cell $m^{-2}d^{-1}$	Bacterial production mgC $m^{-2}d^{-1}$
2	18.0	360	320	5.39	108
4	29.4	588	352	5.95	119
7	32.6	652	462	7.80	156
10	32.1	642	305	5.15	103
11	25.0	500	326	5.49	110
13	25.8	516	286	4.82	96
15	17.5	350	199	3.36	67
18	24.8	496	287	4.85	97
21	18.9	378	218	3.69	74
25	15.6	312	196	3.31	66
mean	24.0	479	295	4.98	100
SE	2.1	41	27	0.45	9
CV%	26	26	27	27	27

3.2.2

3.2.2 Temporal variations

A diurnal cycle of abundance and activity was performed on 27 May at station 5 in order to estimate the representativity of single measurements to describe parameters at the scale of the day. Results (Tab. 7, Fig. 8) show that the variations are moderated at this time scale as CV% average 9 and 22 for bacterial abundance and production respectively (Tab. 7) with no significant trend along the day time (Fig. 8).

Table 7: Evolution of bacterial parameters along a diurnal cycle at 10m depth on station 5 (27-04-94 to 28-04-94).

Day time	BACT 10^9 cell l^{-1}	TdR pmol $l^{-1}h^{-1}$	Spec. Inc. 10^{-21}mol $cell^{-1}h^{-1}$
6.8	0.96	22.11	22.98
9.0	1.06	11.53	10.84
12.0	0.95	13.47	14.23
15.0	1.03	14.09	13.73
18.0	0.86	21.29	24.71
21.0	0.95	17.96	18.89
24.0	0.98	20.82	21.24
3.0	1.01	15.50	15.28
6.0	1.18	16.50	13.96
Mean	0.999	17.03	17.32
SE	0.030	1.25	1.60
CV%	9	22	28

Bacterioplankton variables determined using discrete sampling into the lagoon may thus be considered representative of the daily average value within around 20%. From day to day, during a two weeks period, fluctuation of bacterial parameters should not exceed the spatial fluctuations between stations as one or two stations were investigated every day.

3.2.3 Average values

Once, short term fluctuations has been established and eventual spatial fluctuations documented, it is possible to examine and compare average values with other ecosystems. Average parameters recorded in the lagoon and at the oceanic station are summarized in Table 8.

3.2.3.1 Bacterial biomass

With 0.77 10^9 cells l^{-1} (Tab. 8), average bacterial abundance is very similar to the values reported by Yoshinaga *et al.* (1991) in Majero Atoll and is about 1.5 - 2 times less the average values in Tikehau and Takapoto lagoons, Tuamotu, French Polynesia (Torréton & Dufour, 1996, Dufour & Torréton, 1993). Average cell volumes are small and stable in the lagoon, ranging from 0.042 to 0.065 $\mu m^3 cell^{-1}$ (average = 0.055, Tab. 8) and fall in the range (< 0.070 μm^3) where Lee & Fuhrman (1987), after direct estimations of carbon content per cell, proposed 20 fgC $cell^{-1}$ whatever the size. Based on this value, average bacterial biomass into the lagoon is 15.5 µgC l^{-1}.

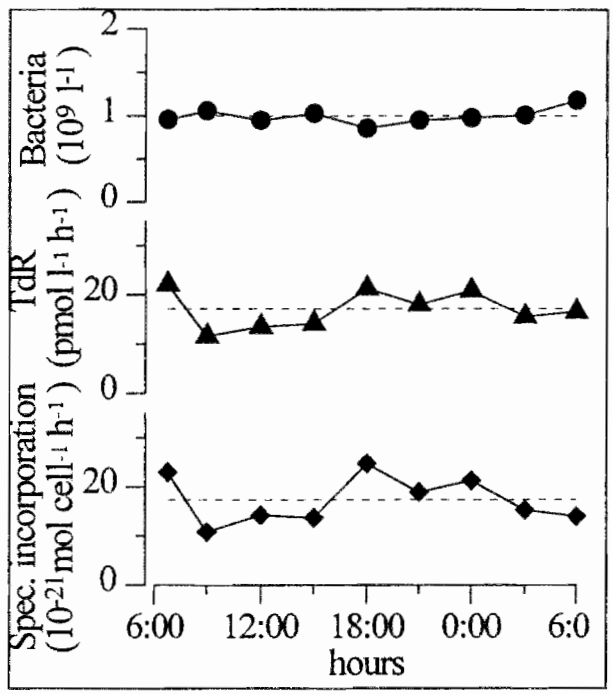

Figure 9: Diurnal evolution of bacterioplankton parameters at station 5 at 10m depth.

Table 8: Average bacterioplankton variables recorded during this study.

	biomass 10^9 cell l^{-1}	biovolume μm^3 $cell^{-1}$	TdR pmol $l^{-1}h^{-1}$	TdR/ Cell 10^{-21}mol $cell^{-1}h^{-1}$	biomass attached % of total	TdR attached % of total
Mean	0.77	0.055	12.8	16.8	10.4	14.1
SD	0.14	0.015	3.6	4.3	0.9	0.9
N	56	12	56	56	12	12

Data include 10 vertical profiles (46 data, see Tab. 4) and a diurnal cycle on station 5 (9 data, see Tab. 7). Biovolume, attached bacteria and TdR incorporation by attached bacteria were determined only on 12 samples (see Tab. 9).

3.2.3.2 Bacterial production

With 12.8 pmol $l^{-1}h^{-1}$ on average, bacterial incorporation of TdR is 13 times more important in the lagoon than the average at the oceanic station. Using the TCF determined above (0.7 10^{18} cells per mol of TdR incorporated into DNA) and 20 fgC/cell this leads to 0.18 µgC $l^{-1}h^{-1}$ or 4.3 µgC $l^{-1}d^{-1}$. This value is about 1.5 fold less the average value determined by Pollard & Kogure (1993) in the same lagoon in 1989 (6.6 µgC $l^{-1}d^{-1}$, SE=1.2, n=6, using a theoretical conversion factor of 0.5 10^{18} cells per mol of TdR incorporated into DNA and 30 fgC/cell). However, their values were determined only in the 5

m water column overlying a seagrass bed 100 m from the shore of Dravuni island. Considering these differences, bacterioplankton activity may be considered in good agreement between the two studies.

3.2.3.3 Bacterial growth rates

With 16.8 10^{-21} mol $cell^{-1}h^{-1}$ on average, bacterial specific incorporation rate per cell represent and average growth rate of 0.212 d^{-1}, therefore an average generation time of 1/0.212 = 4.7 days. This is quite long, considering the average temperature of about 28°C during the study and is an index of bottom-up limitation of bacteria.

3.2.3.4 Free and attached bacteria

The distinction between free and attached bacterioplankton has ecological consequences as free and attached bacterial production are not exported in the same way and do not present the same metabolic properties (Hoppe *et al.* 1988). Losses of attached bacteria may occur by sedimentation - very unlikely in free-living bacteria - or *via* grazing by higher trophic levels (mesozooplankton). Microscopy shows that a non negligible proportion of total abundance, 10.4% of the total on average (Tab. 9), is constituted by bacteria attached to particles. An even greater proportion of the total activity seems to be attributed to attached bacteria. TdR incorporation retained by 3 µm membranes represents, indeed, 14.1% of the total on average (Tab. 9).

Therefore, when the abundance and activity of the free community are calculated (by subtracting attached from the total), it can be seen that the average growth rate (0.19 d^{-1}) is significantly lower ($P<0.001$) than growth rate of the attached bacteria (0.30 d^{-1}). This shows that attachment seems to present an advantage for bacterioplankton community of the Great Astrolabe Reef lagoon. Particles are well known to present a favorable environment for microbial growth as bacterial exoenzymes activities release simple organic molecules directly taken up by attached bacteria (Hoppe *et al.* 1988). In oligotrophic systems where bacteria are likely bottom-up controlled (Dufour & Torréton, 1996), the attachment to particles seems to lead to a greater growth rate for the microbial community.

Table 9: Specific TdR incorporation rate per cell (10^{-21} mol $cell^{-1}h^{-1}$) for free and attached bacteria

Station	Date	------ total ------			---- attached ----			----- free -----			attached	attached
		cells 10^9 l^{-1}	Prod. 10^6 $l^{-1}h^{-1}$	µ d^{-1}	cells 10^9 l^{-1}	Prod. 10^6 $l^{-1}h^{-1}$	µ d^{-1}	cells 10^9 l^{-1}	Prod. 10^6 $l^{-1}h^{-1}$	µ d^{-1}	cells % total	Prod % total
2	04-18-94	0.841	9.90	0.28	0.050	1.18	0.56	0.791	8.71	0.26	6.0	12.0
4	04-20-94	0.699	4.97	0.17	0.048	0.62	0.31	0.650	4.34	0.16	6.9	12.5
5	04-27-94	1.063	6.08	0.14	0.163	0.74	0.11	0.900	5.34	0.14	15.3	12.2
5	04-28-94	1.182	8.70	0.18	0.189	1.41	0.18	0.992	7.29	0.18	16.0	16.2
7	04-19-94	0.587	8.31	0.34	0.055	1.45	0.63	0.532	6.87	0.31	9.4	17.4
10	04-18-94	0.955	6.59	0.17	0.088	0.59	0.16	0.866	6.00	0.17	9.3	9.0
11	04-20-94	0.847	8.31	0.24	0.076	0.85	0.27	0.772	7.46	0.23	8.9	10.2
12	04-23-94	0.550	4.96	0.22	0.045	0.79	0.42	0.505	4.17	0.20	8.2	16.0
13	04-19-94	0.742	6.06	0.20	0.075	0.98	0.31	0.667	5.08	0.18	10.1	16.2
15	04-22-94	0.663	4.87	0.18	0.087	0.92	0.25	0.576	3.95	0.16	13.1	18.9
18	04-21-94	0.837	5.43	0.16	0.097	0.71	0.18	0.740	4.72	0.15	11.6	13.1
21	04-22-94	0.845	5.96	0.17	0.081	0.90	0.27	0.765	5.06	0.16	9.5	15.1
	mean	0.818	6.68	0.20	0.088	0.93	0.30	0.730	5.75	0.19	10.4	14.1
	SE	0.054	0.49	0.02	0.013	0.08	0.05	0.043	0.44	0.01	0.9	0.9

3.3 DOC concentrations, heterotrophic activity and DOC turn-over

DOC concentrations determined in various areas of the lagoon show very little fluctuations with the sampling site. The coefficient of variation for determinations at 10m depth is only 6% around the mean value (1560 µgC l^{-1}, n=10). No significant vertical variation can be inferred from the vertical profile determined on station 25. Therefore, the average value for all the data (1582 µgC l^{-1}, Tab. 10). seems to be representative of the average conditions into the lagoon during the period of that study.

DOC turn-over due to bacterioplankton consumption may be estimated from bacterial production (BP) and bacterioplankton carbon growth yield (CGY) determined in the two dilution cultures. Bacterial carbon consumption (BCC) would thus equal BP/CGY.

With an average BP of 4.32 µgC $l^{-1}d^{-1}$ (see § *3.2.3.2.*) and a CGY of 5.8% (see § *3.2.5.*), BCC = 4.32 / 0.058 = 74 µgC $l^{-1}d^{-1}$. DOC turn-over rate would thus equal 1572 / 74 = 0.048 d^{-1} and DOC turn-over time: 1 / 0.048 = 21 days.

Table 10: DOC concentrations in the Great Astrolabe Reef lagoon

station	date	depth (m)	DOC (µgC l^{-1})
2	04-18-94	10	1442
4	04-20-94	10	1498
5	04-23-94	10	1531
7	04-19-94	10	1698
11	04-20-94	10	1461
12	04-22-94	10	1655
18	04-21-94	10	1532
21	04-22-94	10	1509
22	04-22-94	0	1644
22	04-22-94	10	1631
25	04-27-94	0	1554
25	04-29-94	5	1650
25	04-29-94	10	1645
25	04-29-94	20	1563
	average		1572
	SE		22
	CV%		5

3.4 Comparison with open ocean

Determining bacterioplankton characteristics in the oceanic water column was not the main objective of that study. However, considering the weak variations observed into the lagoon one can guess that the unique profile performed at the oceanic station should be somehow representative of average oceanic conditions during the period of that study. Bacterioplankton characteristics show a classical vertical pattern with a maximum abundance in surface water and a maximum activity in deeper layers (Fig. 10), in relation with phytoplankton maximum production (Charpy, 1996, this volume). As a consequence this vertical pattern is even more pronounced for specific incorporation rate per cell (an index of bacterioplankton growth rate). Dissolved organic carbon decreases approximately regularly from surface to 100 m depth. No measurement of bacterioplankton variables were made below this level.

Abundance values inside the lagoon studied are on average only 1.5 times higher than in surrounding oceanic surface waters (average from 5 to 40 m, Tab. 11), but production values are around 13 fold greater in lagoon than at the oceanic station sampled. Therefore, specific incorporation rate per cell, an index of bacterial growth rate, is 8 times greater in lagoon water than at the oceanic station at the same levels (Tab. 11). This specific incorporation rate per cell leads to an average growth rate of 0.285 d^{-1} when multiplied by the TCF determined above. This is equivalent to an average generation time of 1/0.285 = 3.5 days.

On the other side, DOC values do not appear significantly different in the ocean (0 to 40 m) and in the lagoon. However, the limited biodegradability of DOC into lagoon waters (reflected by the amount unaffected after bacterial growth in the seawater cultures) shows that a smaller fraction of the labile DOC pool, while undetected using the HTCO technique, could explain the large differences between oceanic water and lagoon bacterioplankton growth rates.

The main differences are (1) that bacterioplankton variables present a strong vertical pattern in the ocean while vertical homogeneity seems to be the rule into the lagoon and (2) that bacteria seems thus only slightly more abundant in lagoon waters but have a far greater activity than in the surrounding ocean. This later point has already been observed in surface oceanic waters surrounding Tikehau lagoon (Torréton & Dufour, 1996).

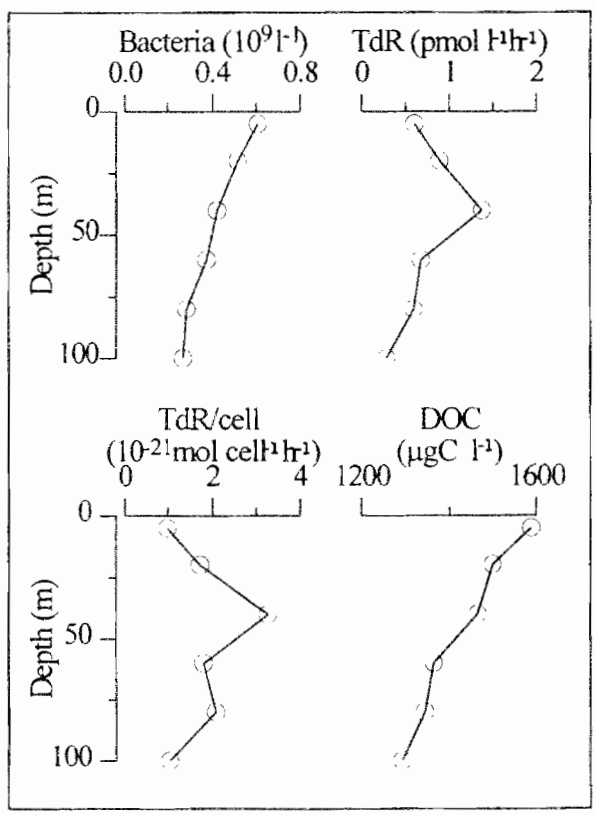

Figure 10: Abundance, TdR incorporation, specific incorporation rate per cell and DOC in the water column of the oceanic station.

Table 11: Average and standard error of bacterial variables recorded into the lagoon and at the oceanic station.

	Abundance 10^9 cell l^{-1}	TdR pmol $l^{-1}h^{-1}$	TdR/Cell 10^{-21}mol cell$^{-1}h^{-1}$	DOC µgC l^{-1}
	lagoon			
average	0.77	12.8	16.8	1572
SE	0.02	0.5	0.6	22
CV%	19	28	26	5
n	56	56	56	14
	ocean		**0 to 100 m**	
average	0.41	0.7	1.8	1426
SE	0.05	0.2	0.3	45
CV%	32	50	46	8
n	6	6	6	6
	ocean		**0 to 40 m**	
average	0.51	1.0	2.0	1518
SE	0.05	0.2	0.7	37
CV%	18	41	58	4
n	3	3	3	3

4. Conclusion

The use of ^{3}H-thymidine incorporation (10 nM final concentration) to estimate bacterioplankton production seems to be appropriate in the Great Astrolabe Reef lagoon as in other atoll lagoons (Torréton & Dufour, 1996). Most of the label is incorporated into DNA and isotope dilution is insignificant. Thymidine conversion factors determined in two dilution cultures average 0.7 10^{18} cell mol^{-1}, which is in the range of literature values.

Bacterioplankton biomass, production and growth rates are distributed homogeneously over the water column of the Great Astrolabe Reef lagoon. The comparison between average value over the ten profiles shows that bacterial variables do not differ significantly from site to site inside the lagoon.

At station 5, bacterioplankton biomass and production varied moderately over a diurnal period with coefficients of variation of 9 and 22%, respectively. And from day-to-day, variations of bacterioplankton biomass, production and growth rates should not exceed the moderate inter-stations variations (Tab. 5).

Fluctuations of bacterioplanktonic processes seem therefore very moderate both spatially and temporally over the 15 day period of the study.

Although less extensively studied, the proportion of attached bacterial abundance and activity shows also slight fluctuations from site to site, and thus, from day-to-day (Tab. 9). Dissolved organic carbon determined at least once every day also shows very moderate fluctuations around the mean value (Tab. 10).

On average, over the whole study bacterial abundance is 0.77 10^9 cell l^{-1} (15.5 µgC l^{-1}) with 10.4% attached to particles. Bacterial production averages 4.3 µgC l^{-1} d^{-1} with 14.1% due to attached bacteria. Over the 12 samples where they were distinguished, growth rates for bacterioplankton differs significantly for the free (0.19 d^{-1}) and attached (0.30 d^{-1}) communities. Therefore, in this low nutrient environment, attachment seems to provide an advantage for bacterial growth into this lagoon. The low average growth rate for the whole bacterioplanktonic community (0.21 d^{-1}, n=56) with an average temperature of *c.a.* 28°C suggests that bacterioplankton is resource limited into this lagoon.

Determined experimentally into two dilution cultures, the carbon growth yield (CGY) is very low (average 5.8%). This suggests that bacteria are limited by resource in the Great Astrolabe Reef lagoon. By applying the average CGY value to bacterial production rates into the lagoon, heterotrophic activity was estimated to average 74 µgC $l^{-1}d^{-1}$. Therefore, with a DOC concentration averaging 1572 µgC l^{-1} during that study, the turn-over rate of DOC is estimated to average 0.048 d^{-1} during that period. This low turn-over rate compared to the bacterial turn-over rate (0.21 d^{-1}) is another argument for a bottom-up limitation of bacterioplankton processes into this lagoon.

Bacterioplankton abundance, production and growth rate appear to be significantly greater than in oceanic water surrounding the Great Astrolabe Reef lagoon and confirm the more mesotrophic character of lagoon waters than their surrounding oceanic environment.

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Organic carbon, nitrogen and phosphorus in the Great Astrolabe Reef lagoon sediments. Preliminary results.

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Abstract

Carbon, Nitrogen and phosphorus were studied in the Great Astrolabe Reef sediment. Organic carbon, nitrogen and phosphorus percentages were respectively, in average for the whole lagoon top layer sediment, 0.19, 0.024 and 0.006. Organic carbon was lower than this measured in the French Polynesian atolls, organic phosphorus was higher.

1. Introduction

Measurements of organic material content of sediments are very important. Indeed, 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 was the amount of organic matter incorporated into those sediments from the water above. In this paper, we present results of carbon and phosphorus content in the sediments located at the sea-water interface (SWI) of the GAR lagoon.

2. Material and methods

Eleven stations (Figure 1) were investigated in the GAR lagoon for sediment C and N analysis. These stations were the same as for the microphytobenthic primary production study. Their depth and their visual characteristics appear in Table 1.

. All stations were prospected by scuba diving. Sampling was done with hand corer 2.7 cm inner diameter, from which 0.5 cm-thick (for the first) and 1 cm thick (for the following ones)slices were removed immediately on board. (following the method described by Charpy-Roubaud (1987).The P analysis were made in Papeete (French Polynesia) ORSTOM Center and the C analysis in Perpignan's University (France).

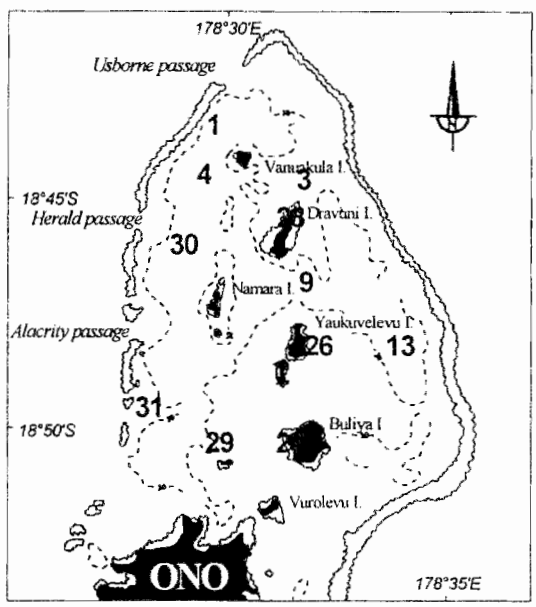

Figure 1: Station locations

Table 1: Characteristics of the prospected stations

Date	station	Z (m)	observations
20/04/93	1	19	fine sand with cyanobacteria
18/04/93	3	11	shells
17/04/93	4	39	coarse sand, shells, coral heads
24/04/93	9	35	coarse sand,, limestone corals
25/04/93	28	24	shells and Halimeda
17/04/93	30	35	very fine sand with bioturbation
26/04/93	26	9	
27/04/93	27	12	
19/04/93	13	36	coarse sand, shells, coral heads
28/04/93	29	8	algae

Total and organic carbon contents/ dry weight sediment were obtained by combustion in a LECO analyzer (after acidification of the samples with 2N HCl for organic carbon. The method consists in measuring the carbon oxidized to CO_2 and CO during dry combustion of the sediment sample in an induction furnace. Calcium carbonate content was calculated from mineral carbon using the molecular ratio 100/12 (ie. $CaCO_3$/C)

3. Results and discussion

3.1 Phosphorus

Percentages of organic phosphorus (OP) appear in Table 2. For the upper sediment, they varied between 2 10^{-3} and 9.8 10^{-3} % and were in average 5.5 10^{-3} %. The highest percentages of OP at the sediment water interface (SWI) were observed at station 30 where bioturbation was very important.

In average for the whole lagoon (Table 2 and Figure 2) % OP decreased with depth of the sediment.

For the whole depth of sediment sampled, we can observe 3 parts : the sediment at the SWI (0-0.5 cm), this one just below (0.5-2 cm) and the deepest (below 2 cm) (Figure 3).

Table 2: Percentage of organic phosphorus at different stations and sediment depth (cm) of GAR lagoon

Stat	depth	hsed							
		0-0.5	0.5-1	1-2	2-3	3-4	4-5	7-8	0.5-8
13	36	4.4 10^{-3}	4.3 10^{-3}	4.5 10^{-3}	2.1 10^{-3}	1.8 10^{-3}	3.3 10^{-3}	5.0 10^{-3}	**3.5 10^{-3}**
3	11	6.5 10^{-3}							
1	19	5.4 10^{-3}	3.7 10^{-3}	4.0 10^{-3}	0.0 10^{-3}	3.4 10^{-3}	5.1 10^{-3}	1.8 10^{-3}	**3.0 10^{-3}**
4	40	6.5 10^{-3}	6.0 10^{-3}	9.6 10^{-3}	6.1 10^{-3}	5.6 10^{-3}			
31	39	2.2 10^{-3}	6.0E-04	3.4 10^{-3}	3.9 10^{-3}	3.8 10^{-3}	7.0 10^{-3}	4.0 10^{-3}	**3.8 10^{-3}**
30	40	9.8 10^{-3}	6.8 10^{-3}	5.7 10^{-3}	6.4 10^{-3}	6.5 10^{-3}	4.0 10^{-3}	5.9 10^{-3}	**5.9 10^{-3}**
9	35	6.6 10^{-3}	6.0 10^{-3}	5.1 10^{-3}	4.0 10^{-3}	3.2 10^{-3}	2.4 10^{-3}	3.0 10^{-3}	**4.0 10^{-3}**
28	22	2.8 10^{-3}	1.4 10^{-3}	1.2 10^{-3}	0.0 10^{-3}	1.2 10^{-3}	0.9 10^{-3}	4.1 10^{-3}	**1.5 10^{-3}**
26	9	4.1 10^{-3}	3.9 10^{-3}	1.5 10^{-3}	1.5 10^{-3}	2.2 10^{-3}	1.5 10^{-3}	1.0 10^{-3}	**1.9 10^{-3}**
27	12	4.4 10^{-3}	4.3 10^{-3}	3.3 10^{-3}	2.2 10^{-3}	2.5 10^{-3}	1.3 10^{-3}		**2.7 10^{-3}**
29	8	7.8 10^{-3}	6.2 10^{-3}	3.1 10^{-3}	1.2 10^{-3}	1.8 10^{-3}	0.7 10^{-3}		**2.6 10^{-3}**
Av.		**5.5 10^{-3}**	**4.3 10^{-3}**	**4.1 10^{-3}**	**2.710^{-3}**	**3.210^{-3}**	**2.910^{-3}**	**3.510^{-3}**	

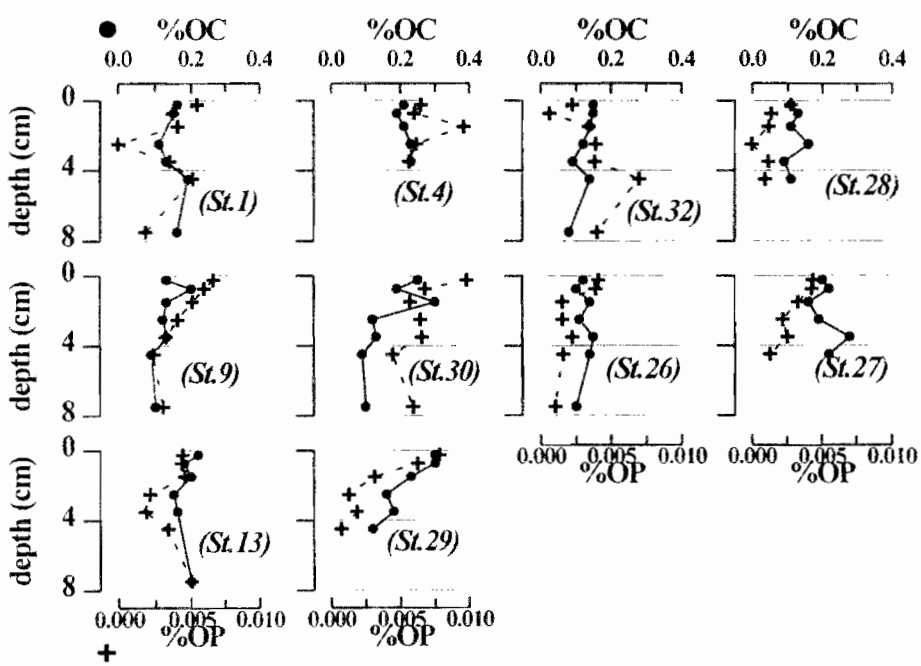

Figure 2: Profiles of organic carbon (OC) and phosphorus (OP) in the sediments of the GAR lagoon

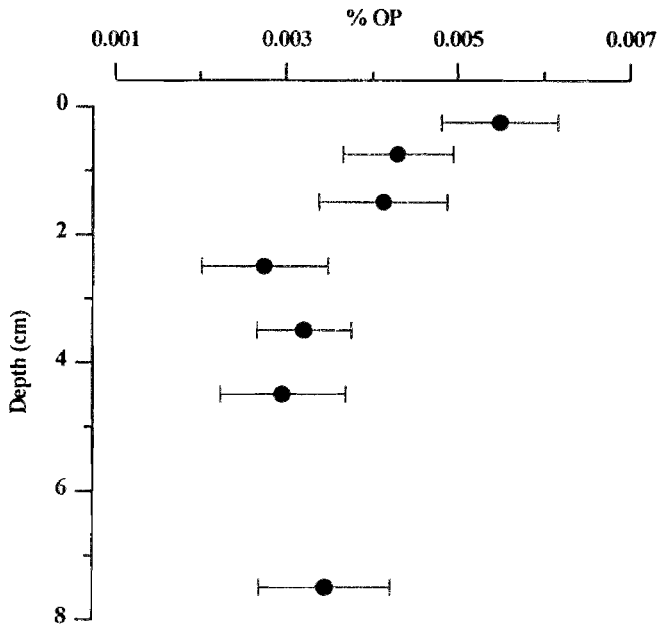

Figure 3: Average ± SE of percentage of organic phosphorus in GAR lagoon sediments

3.2 Carbon

The results of total Carbon, mineral Carbon and carbonates percents of the surface layer appear in Table 4.

The mineral carbon percents vary between 11.26 and 11.58 except at station 27 where it was only 10.65%. At this station, the carbonates were low (only 88.7%) if we compare with the ones of other stations (93.8 to 96.8 %). Organic carbon is more interesting for the aim of our study. The results for all studied sediment depth appear in Table 4.

Table 3: Percentages of organic carbon, organic nitrogen (OC, ON), mineral carbon (MC) in the 0-0.5 cm sediment depth layer

Stat	depth	% C	% OC	% ON	C/N	% MC	% $CaCO_3$
1	19	11.6	0.16	0.043	3.7	11.44	95.3
3	11	11.78	0.24			11.54	96.2
4	39	11.64	0.21	0.008	26.7	11.43	95.2
9	35	11.7	0.13	0.012	10.5	11.57	96.4
13	36	11.72	0.22			11.5	95.8
26	9	11.64	0.12	0.023	5.3	11.52	96
27	12	10.85	0.2	0.024	8.5	10.65	88.7
28	24	11.69	0.11	0.026	4.3	11.58	96.5
29	8	11.56	0.3	0.027	10.9	11.26	96.8
30	35	11.51	0.25	0.025	9.3	11.26	93.8
31	39	11.72	0.15			11.57	96.4
average		**11.6**	**0.19**	**0.024**	**9.9**	**11.4**	**94.9**

Table 4: Percentage of organic carbon at different stations and sediment depth (cm) of GAR lagoon

St.	depth	hsed							
		0-0.5	0.5-1	1-2	2-3	3-4	4-5	7-8	0.5-8
13	36	0.22	0.18	0.20	0.15	0.16		0.20	**0.18**
3	11	0.24							
1	19	0.16	0.15		0.11	0.13	0.19	0.16	**0.15**
4	40	0.21	0.19	0.21	0.23	0.23			**0.15**
31	39	0.15	0.15	0.14	0.12	0.90	0.14	0.80	**0.12**
30	40	0.25	0.19	0.30	0.12	0.13	0.90	0.10	**0.16**
9	35	0.13	0.20	0.13	0.12	0.13	0.90	0.10	**0.13**
28	22	0.11	0.13	0.11	0.16	0.90	0.11		**0.12**
26	9	0.12	0.10	0.14	0.11	0.15	0.14	0.10	**0.12**
27	12	0.20	0.22	0.16	0.19	0.28	0.22		**0.21**
29	8	0.30	0.30	0.23	0.16	0.18	0.12		**0.20**
Av		**0.19**	**0.18**	**0.18**	**0.15**	**0.16**	**0.14**	**0.12**	**0.15**

In the upper 05 cm, % of OC varied between 011 and 03 The maximum was at station 29 where numerous macro-algae were observed The 28, 26, 31, 1 and 9 group represent stations where the % OC was < 017 % In average for the whole lagoon, the values decreased with the sediment depth (Table 4) even if this trend was not true at each station We observe 3 groups : the 0-2 cm, 2-5 cm and 7-8 cm ones (Figure 4)

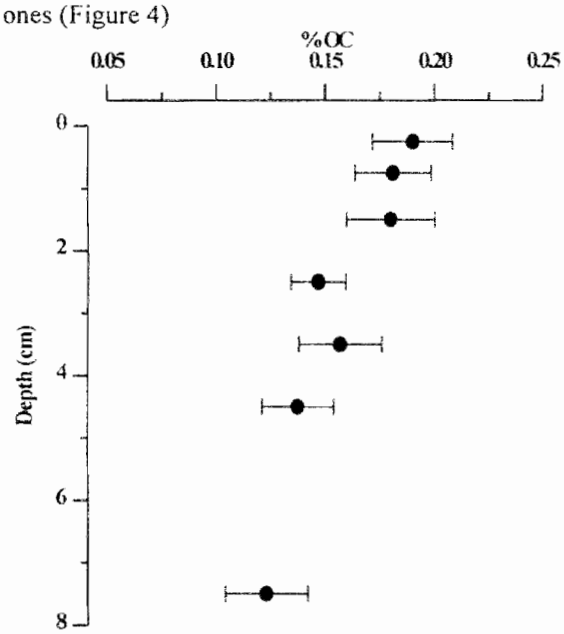

Figure 4: Average ± SE of percentage of organic carbon (OC) in GAR lagoon sediments

3.3 C/P

C/P ratio appear in Table 5: Organic

The C/P ratio on the upper 05 cm varied between 196 and 679 and was in average 378 The C/P ratio remained constant at stations 1,9,30 and 4, and increased at stations 28, 26 , 27 et 29 A very high value was observed just below the SWI at station 32 (Figure 5)

4. Comparison with other lagoons

Percentage P and C forms were studied in other lagoons (Table 5)

GAR sediments presented higher OP and lower OC contents than Tikehau and Takapoto atoll The OC was similar to the OC content of two island lagoon : Moorea (French Polynesia) and Noumea (New Caledonia)

The OC:OP ratio was 4 to five times lower in GAR sediments than in Tikehau and Takapoto sediments

Table 5: Organic carbon / organic phosphorus ratio at different stations and sediment depth (cm) in GAR lagoon

St	depth	hsed							
		0-05	05-1	1-2	2-3	3-4	4-5	7-8	05-8
13	36	**506**	420	444	705	873		400	**568**
3	11	**37**							
1	19	**295**	409			377	374	869	**507**
4	40	**325**	318	219	375	409			**330**
31	39	**679**	2500	412	308	237	20	200	**643**
30	40	**255**	281	529	186	20	203	170	**262**
9	35	**196**	336	256	299	409	383	333	**336**
28	22	**399**	949	917		776	1158		**950**
26	9	**293**	257	94	738	679	915	1000	**755**
27	12	**46**	514	489	872	1116	1692		**937**
29	8	**384**	482	737	129	978	1714		**1040**
Av		**378**	**549**	**549**	**597**	**605**	**830**	**495**	**633**

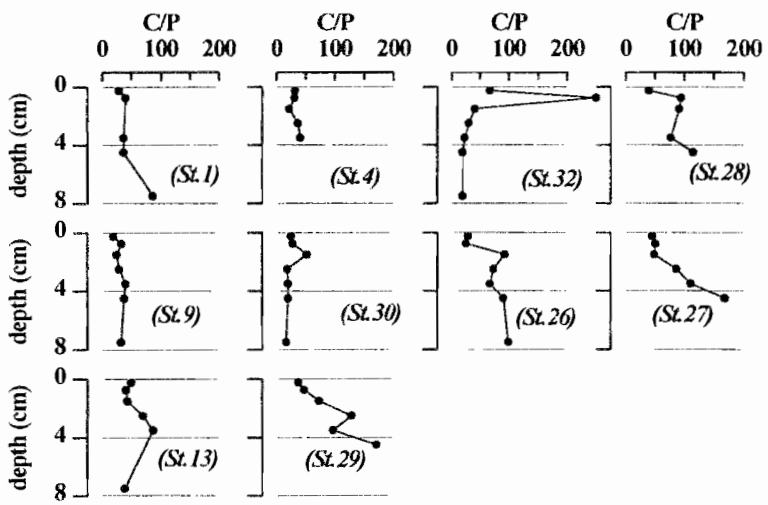

Figure 5: Profiles of C/P ratio in the sediments of the GAR lagoon

Table 5: % of total phosphorus (TP), mineral phosphorus (MP), organic phosphorus (OP), total carbon (TC), organic carbon (OC) in the upper layer of sediments of some coral reef lagoons

Site	% TP	% MP	% OP	% TC	% $CaCO_3$	% OC	OC/OP	References
Tikehau (atoll)	026	021	005	112	895	046	92	Charpy-Roubaud et al (unp. results)
Takapoto (atoll)	030	023	007	-	-	033	47	Charpy-Roubaud et al (unpub)
Moorea (island)				115	96	022		Delesalle et al, 1986; Schrimm, 1995
Noumea (island)				112	85	02		Buscail (pers. comm.)
GAR	037	028	009	116	949	019	2	This study

5. Bibliography

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