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.

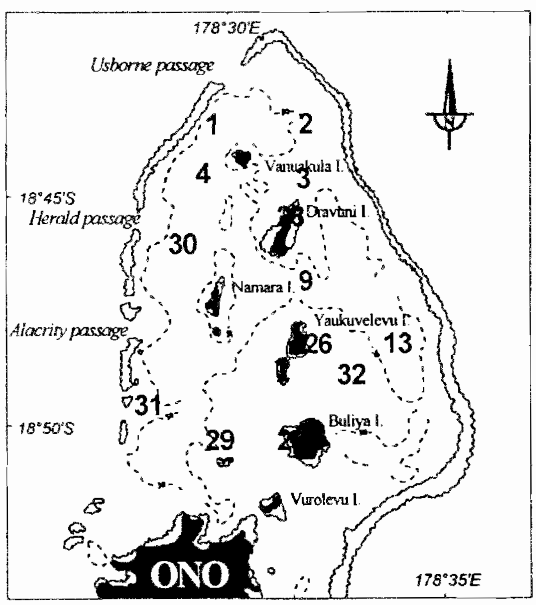

Figure 1: Station locations

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

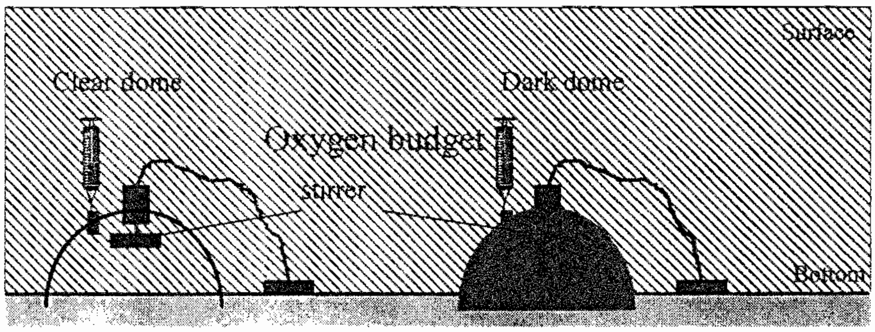

Figure 2: Benthic production measurement device

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.

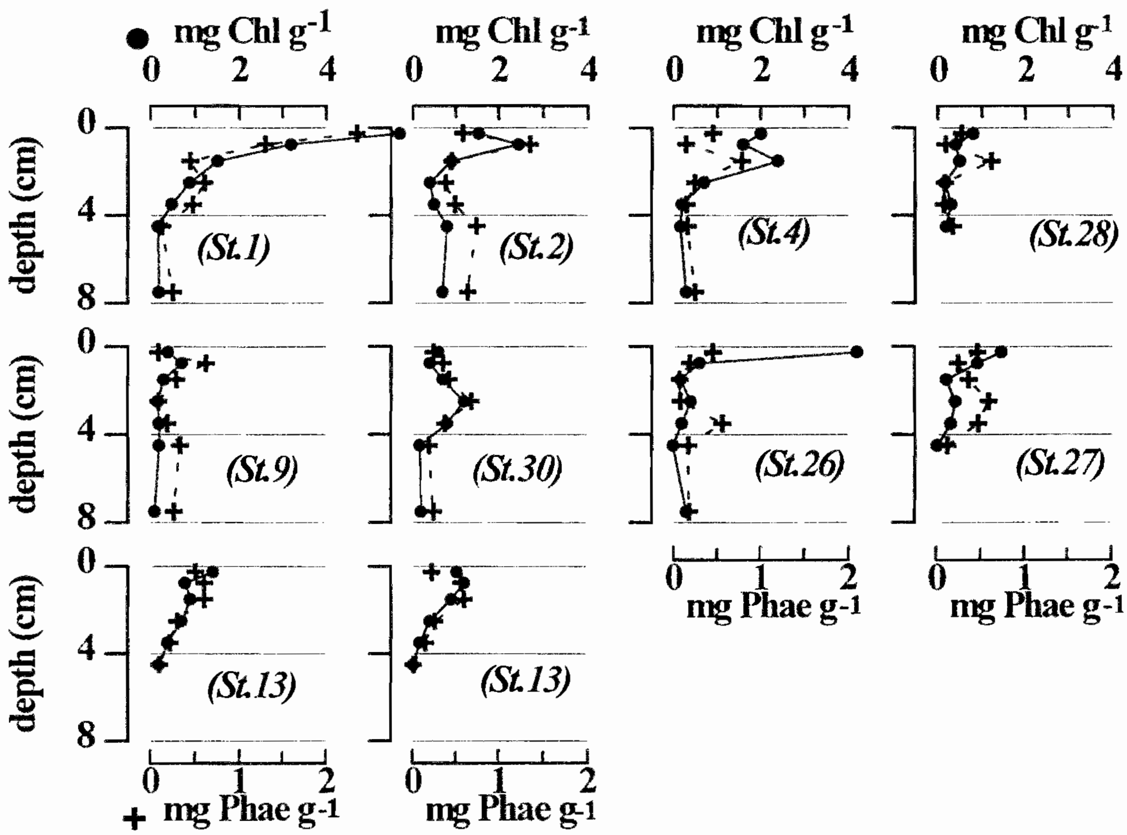

Figure 3: Chlorophyll (Chl) and Phaeophytin (Pha) profiles in the GAR lagoon sediments

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		

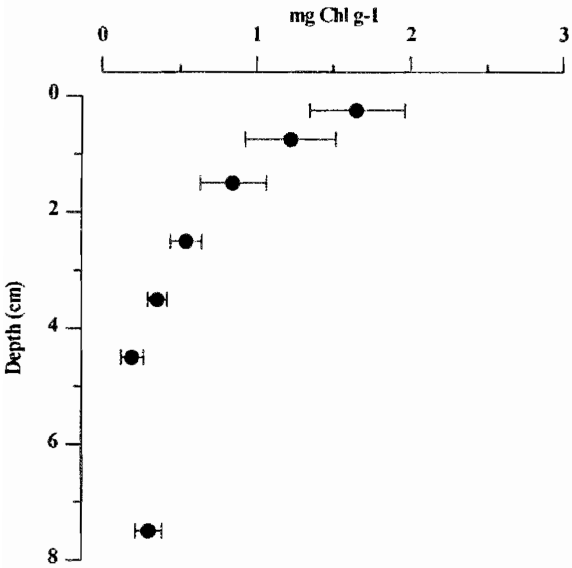

Figure 4: Average ± SE of Chl vs sediment depth

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.

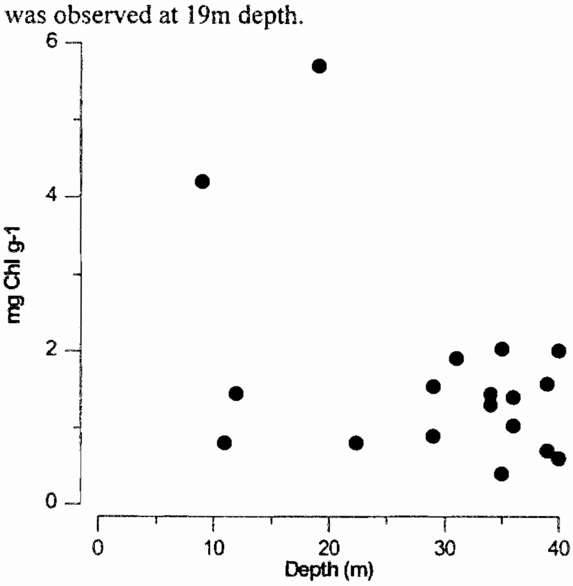

Figure 5: Chl ($_{0\text{-}0.5\ cm}$) vs depth of stations

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

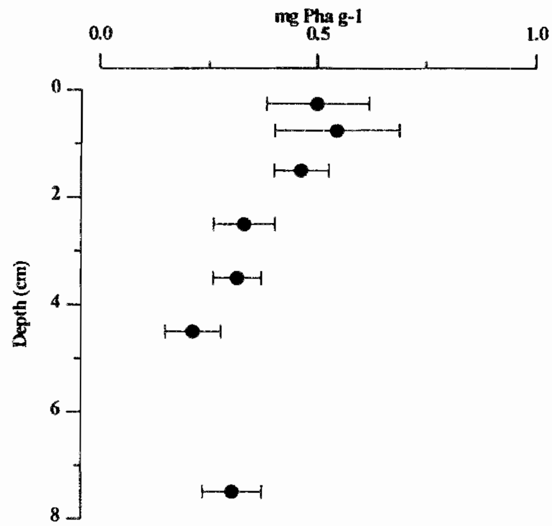

Figure 6: Average ± SE of Pha vs sediment depth

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}.

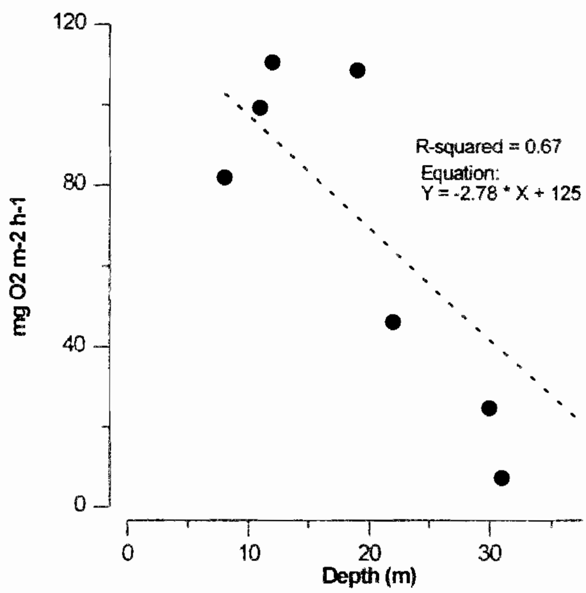

Figure 7: Gross oxygen production vs station depth

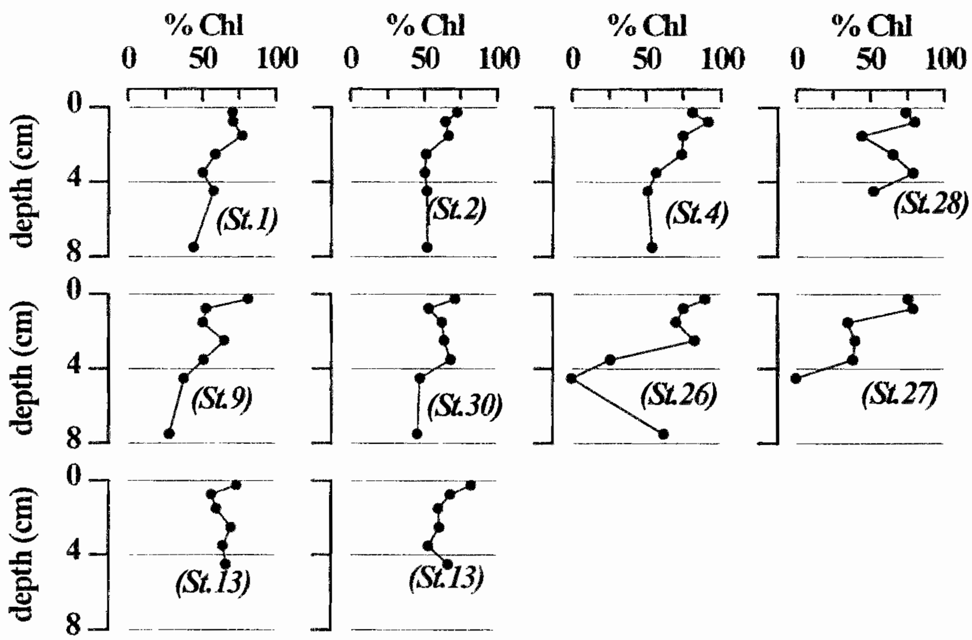

Figure 8: Percentage of active chlorophyll versus depth

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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