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REPORT

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Picophytoplankton biomass, community structure and productivity in the Great Astrolabe Lagoon, Fiji

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Abstract Phytoplankton biomass, community structure and productivity of the Great Astrolabe lagoon and surrounding ocean were studied using measurements of chlorophyll concentration and carbon uptake. The contribution of picophytoplankton to biomass, productivity and community structure was estimated by size fractionation, ^{14}C-incubation and flow cytometry analysis. Picoplankton red fluorescence was demonstrated to be a proxy for chlorophyll < 3 µm. Consequently, the percentage contribution to chl $a < 3$ µm from each picoplankton group could be calculated using regression estimated values of ψ_i (fg chl a per unit of red fluorescence). In the lagoon, average chlorophyll concentration was 0.8 mg m^{-3} with 45% of phytoplankton <3 µm. Primary production reached 1.3 g C m^{-2} day^{-1} with 53% due to phytoplankton <3 µm. *Synechococcus* was the most abundant group at all stations, followed by *Prochlorococcus* and picoeukaryotes. At all stations, *Prochlorococcus* represented less than 4% of the chl a <3 µm, *Synechococcus* between 85 and 95%, and Picoeukaryotes between 5 and 10%. In the upper 40 m of surrounding oceanic waters, phytoplankton biomass was dominated by the >3 µm size fraction. In deeper water, the <1 µm size fraction dominated. *Prochlorococcus* was the most abundant picoplankton group and their contributions to the chlorophyll a <3 µm were close to that of the picoeukaryotes (50% each).

Key words Flow cytometry · Chlorophyll · Fiji · Primary production · Nutrient

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Introduction

It is now well recognized that in the intertropical area of the central and west Pacific ocean, picoplankton dominates phytoplankton biomass (Peña et al. 1990; Le Bouteiller and Blanchot 1991; Le Bouteiller et al. 1992). In the open ocean, *Prochlorococcus* account for the majority of the biomass and productivity. (Blanchot and Rodier 1996; Landry et al. 1996; Campbell et al. 1997). In coral reef environments, the dominance of *Synechococcus* was first recorded using epifluorescent microscopy (Blanchot et al. 1989), which was later confirmed by flow cytometry (Charpy and Blanchot 1996). A recent paper by Charpy and Blanchot (1998) show that in 11 French Polynesian atoll lagoons, *Synechococcus* formed the predominant group in terms of abundance, carbon biomass and primary production in most lagoons. However, average lagoonal picoplankton abundance varied by a factor of 200, depending on the geomorphology of the atolls.

Here, we present results from picoplankton biomass measurements (chlorophyll extraction and flow cytometry) and primary production experiments carried out in the lagoon and surrounding oceanic waters of the Great Astrolabe in April and May 1994. The experiments were undertaken with three aims: (1) to estimate the average productivity of the lagoon, (2) to estimate relative contributions of picoplankton groups to community productivity using size-fractionation methods and flow cytometry analysis, and (3) to identify the biological or geomorphological forces which drive the lagoonal system.

Materials and methods

Study site

The description of the Great Astrolabe reef and lagoon appears in Morrison and Naqasima (1992). The Great Astrolabe (18°45'S,

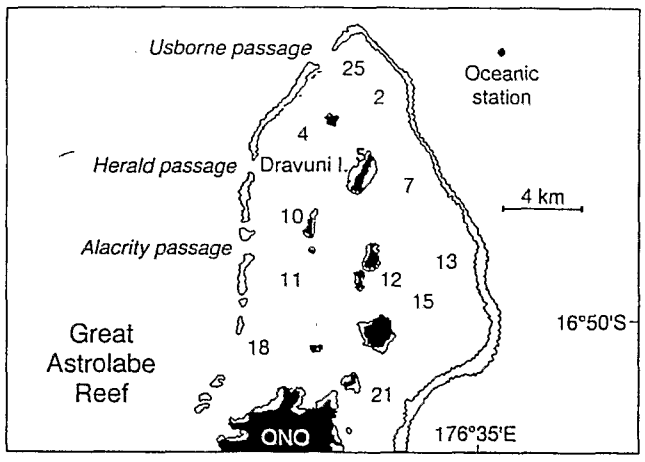

Fig. 1 Station locations in the Great Astrolabe Reef lagoon and surrounding ocean

178°30'E) is situated north-east of Kandavu and south of Viti Levu (Fig. 1). The climate is humid tropical with an average temperature of 25 °C and annual rainfall of 2.6 m. Prevailing winds are from the south-east. The GA lagoon, approximately 210 km^2, in contrast to the Tuamotu atoll lagoons of French Polynesia, encompasses 13 small volcanic islands, four of which are inhabited (1000 inhabitants in total). The maximum depth is about 40 m and the average is 20 m (Naqasima et al. 1992). The residence time for the GA lagoon was estimated at 15–25 days by MacLeod (1992). The GA lagoon water is relatively free from contamination except close to the inhabited islands (Morrison et al. 1992).

Water sampling

The ASTRO expedition studied the Great Astrolabe lagoon and the surrounding ocean between April 17 and May 1, 1994. Ten stations were sampled in the lagoon and one outside the reef (Fig.1). The numbering of the stations is the same as Torréton (1999) used. Water samples were collected with acid-cleaned Niskin bottles at 5 m depth intervals between 0 m and 40 m (the deepest station). Outside the reef, water samples were collected at 20 m intervals to 120 m and then at 150 m and 200 m. Dissolved nutrient (NH_4, NO_2, NO_3, SiO_2, PO_4) concentrations were determined on board shortly after sampling using the standard techniques described by Strickland and Parsons (1972). In this work, for convenience, we use $N_n = NO_3 + NO_2 + NH_4$. Surface irradiance was recorded during incubations with-a LI-COR solarimeter.

Production and biomass measurement

Primary production measurements (clean technique, Fitzwater et al. 1982), chlorophyll determination and size fractionation (Nuclepore filters) were conducted according to Charpy (1996). Two to five subsamples of unscreened sea-water (Furnas 1987) were incubated *in situ* with 2 µCi of ^{14}C-bicarbonate in polycarbonate bottles. Incubation bottles were filtered successively through 3 µm, 1 µm Nuclepore filters and then 25 mm Whatman GF/F glass fiber filters. One bottle was filtered directly through GF/F filters for an estimate of total production. To remove inorganic carbon 250 µl of 0.5N HCl were added to the filter in the scintillation vial. After 12 h, 100 µl of Protosol was added to the filter. Radioactivity on the filters was measured with a liquid scintillation counter and corrected for quench using an internal standard and the channels ratio method. Carbon uptake was calculated using $\Sigma CO_2 = 90\ mg\ l^{-1}$. Areal production was calculated by trapezoidal integration and daily production was estimated by dividing the production measured during the incubation period by the fraction of total daily irradiance during that period.

Chlorophyll *a* (chl *a*) concentrations were determined by fluorometry (Yentsch and Menzel 1963). Vacuum during fractionation never exceeded 0.004 atm. Fluorescence was measured before and after acidification with 50 µl of 1 M HCl. The fluorometer was calibrated using the SIGMA chl *a* standard. For chlorophyll *a* determinations a 250 ml water sample was size fractioned using the same methods as for the productivity samples.

Enumeration of populations was performed according to Blanchot and Rodier (1996). Samples were counted with a Becton-Dickinson FACScan flow cytometer. The excitation source was a blue laser beam (15 mW, 488 nm). The red fluorescence (RF) of the chlorophyll was analyzed with wave lengths > 650 nm. In order to calibrate the optical measurements and to check the flow rate, known quantities of fluorescent beads (Polyscience, 2 µm) were added to each sample. List mode files were transferred to a microcomputer and analyzed on CYTOPC software (Vaulot 1989). At all lagoonal stations, the *Prochlorococcus* populations were sufficiently bright to be completely resolved by the FACScan system. During the oceanic profile, we could not use the flow cytometer immediately and samples were stored in the dark at 5 °C for 5 h before analysis.

In order to assess the short-term variability of picoplankton, picoplankton biomass was studied at station 5, at 10 m depth at hourly intervals over a 24-h cycle. Problems with the flow cytometer due to a tropical depression on the last day constrained us to use epifluorescent microscopy to count cells for the cycle experiment. Therefore, only *Synechococcus* and picoeukaryotes were enumerated. Samples for cells counts were processed following Blanchot et al. (1992). Briefly, cells were harvested by filtration onto black 0.2 µm Nuclepore filter (references 110656). The coefficient of variation for 200–800 cells counted on 20–80 fields was 12% on average.

Estimating biomass from flow cytometry

To estimate the contribution of picoplankton groups to chlorophyll, we used Li's method (1995) as we did for Tuamotu atoll lagoons (Charpy and Blanchot 1998): assuming that fluorescence is a proxy for chl *a*, we estimated the picophytoplankton biomass as chl *a* from *in vivo* red fluorescence (Yentsch and Champbell 1991; Li et al. 1993; Shimada et al. 1993):

$$\text{chl } a < 3\ \mu m = \sum_{i=1}^{i=3} n_i \times f_i \times \psi_i \qquad \text{(Eq. 1)}$$

where i refers to the three recognizable groups (i.e *Prochlorococcus*, *Synechococcus* and picoeukaryotes; n = cell concentration; f = mean cell fluorescence; ψ = fg chl $a < 3$ µm per relative unit of red fluorscence. Assuming that the < 1 µm fraction consists primarily of prokaryotic cells (Charpy and Blanchot 1996), we can also estimate the chlorophyll < 1 µm using Eq. 2:

$$\text{chl } a < 1\ \mu m = \sum_{i=1}^{i=2} n_i \times f_i \times \psi'_i \qquad \text{(Eq. 2)}$$

where ψ' = fg chl $a < 1$ µm per relative unit of red fluorescence.

Results

Lagoon

Environmental setting

The two way ANOVA table (Table 1) decomposes the variability of lagoonal nutrient concentrations into

Table 1 Two way ANOVA for nutrient and chlorophyll concentrations, primary production (PP), and picoplankton abundance by station and depth. SS, sum of square; F, F-ratio; N_n, $NO_3 + NO_2 + NH_4$

	SS_{depth}	df_{depth}	F_{depth}	P_{depth}	$SS_{station}$	$df_{station}$	$F_{station}$	$p_{station}$	$SS_{residual}$	$df_{residual}$
PO_4	0.02	5	1.17	0.3465	0.37	8	13.67	0.0000	0.1	29
$NO_3 + NO_2$	0.16	5	0.84	0.5348	3.18	8	10.34	0.0000	1.1	28
NH_4	0.10	5	0.62	0.6850	2.60	8	10.30	0.0000	1.0	29
N_n	0.47	5	1.24	0.3155	4.81	8	7.96	0.0000	2.1	28
SiO_2	0.03	5	1.00	0.4362	1.39	8	31.75	0.0000	0.2	28
Chlorophyll	0.68	5	3.54	0.0123	1.11	8	3.59	0.0049	1.2	30
PP	37	5	4.75	0.0027	120	8	9.65	0.0000	45	29
Prochorococcus	1.1×10^9	5	3.88	0.0085	50×10^9	8	111.37	0.0000	1.6×10^9	28
Synechococcus	2.6×10^9	5	0.81	0.5543	104×10^9	8	20.70	0.0000	17.8×10^9	28
Picoeukaryotes	1.2×10^6	5	1.03	0.4185	60×10^6	8	32.64	0.0000	6.5×10^6	28

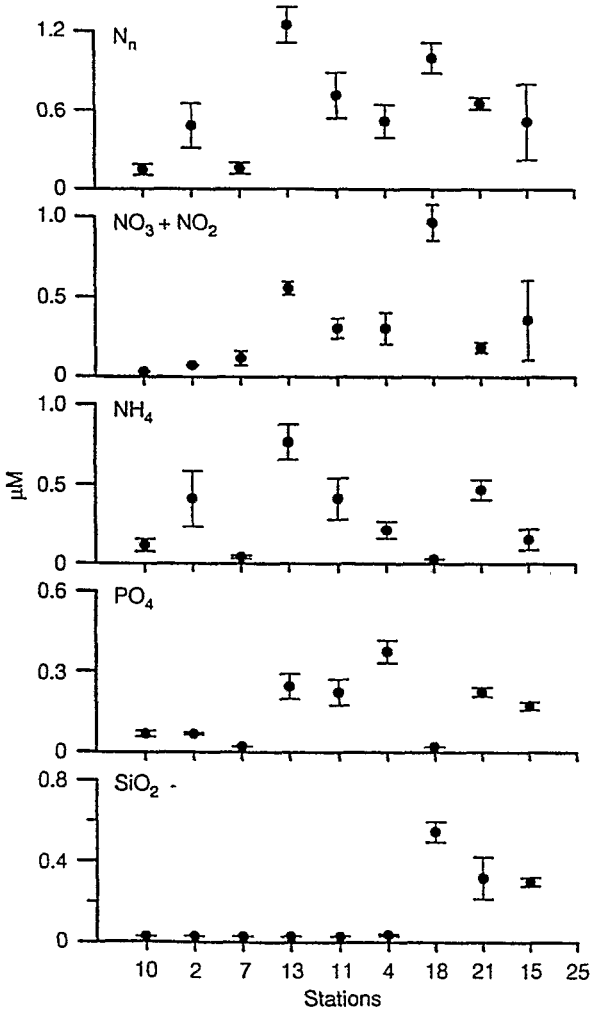

Fig. 2 Average ± SE of nutrient concentrations in 10 stations of Great Astrolabe lagoon. N_n, dissolved mineral concentration

contributions due to the depth and the sampling station. Since all the *P*-values of station effect are less than 0.01, the factor station has a statistically significant effect at the 99% confidence level. This is not the case for depth. Two groups of stations emerge according to the PO_4 concentrations: $PO_4 > 0.15$ µM (stations 13, 11, 4, 21 and 15) and $PO_4 < 0.15$ µM (stations 10, 2, 7 and 18). Three groups can be distinguished by their dissolved mineral concentration (N_n): $N_n < 0.3$ µM (stations 4, 7 and 10), 0.3 µM $< N_n < 0.7$ µM (stations 15 and 21), $N_n > 0.7$ µM (stations 11, 13 and 18). The high value of N_n observed at station 18 was due to high concentration of NO_3 (1.0 µM ± 0.1). Silicate concentrations were very low (< 0.1 µM) at all stations except for three stations located at the south of the lagoon (stations 18, 21 and 15) (Fig. 2).

Phytoplankton biomass and production

Lagoonal phytoplankton biomass estimated by chlorophyll concentration ranged from 0.4 to 1.2 mg m^{-3} and was on average 0.83 ± 0.04 mg m^{-3}. Picoplankton (< 3 µm) represented 45 ± 2% of the total phytoplankton. Primary production ranged from 1.6 to 12 mg C m^{-3} h^{-1} and the average contribution of picoplankton was 53 ± 2% (Fig. 3). The factors station and depth had a significant effect on phytoplankton biomass and primary production (Table 1). Stations 21 and 15, located at the southeast, presented highest integrated (upper 20 m) phytoplankton biomass but not the highest integrated production. However, the daily light energy during the incubations was low (21 Ei m^{-2}). At these stations, 45% of the chlorophyll and 41% of the primary production were due to cells with a size < 1 µm (Fig. 5). At other stations, the > 3 µm fraction dominated both biomass and production and represented more than 45% of phytoplankton biomass and production. The integrated production (upper 20 m) was maximum (1.3 g C m^{-2} d^{-1}) at station 2 located at the north of the lagoon (Fig. 5) when the daily light energy was 31 Ei m^{-2}, and minimum (0.6 g C m^{-2} d^{-1}) at station 11, west of the lagoon, when the daily light energy was 21 Ei m^{-2}. Production

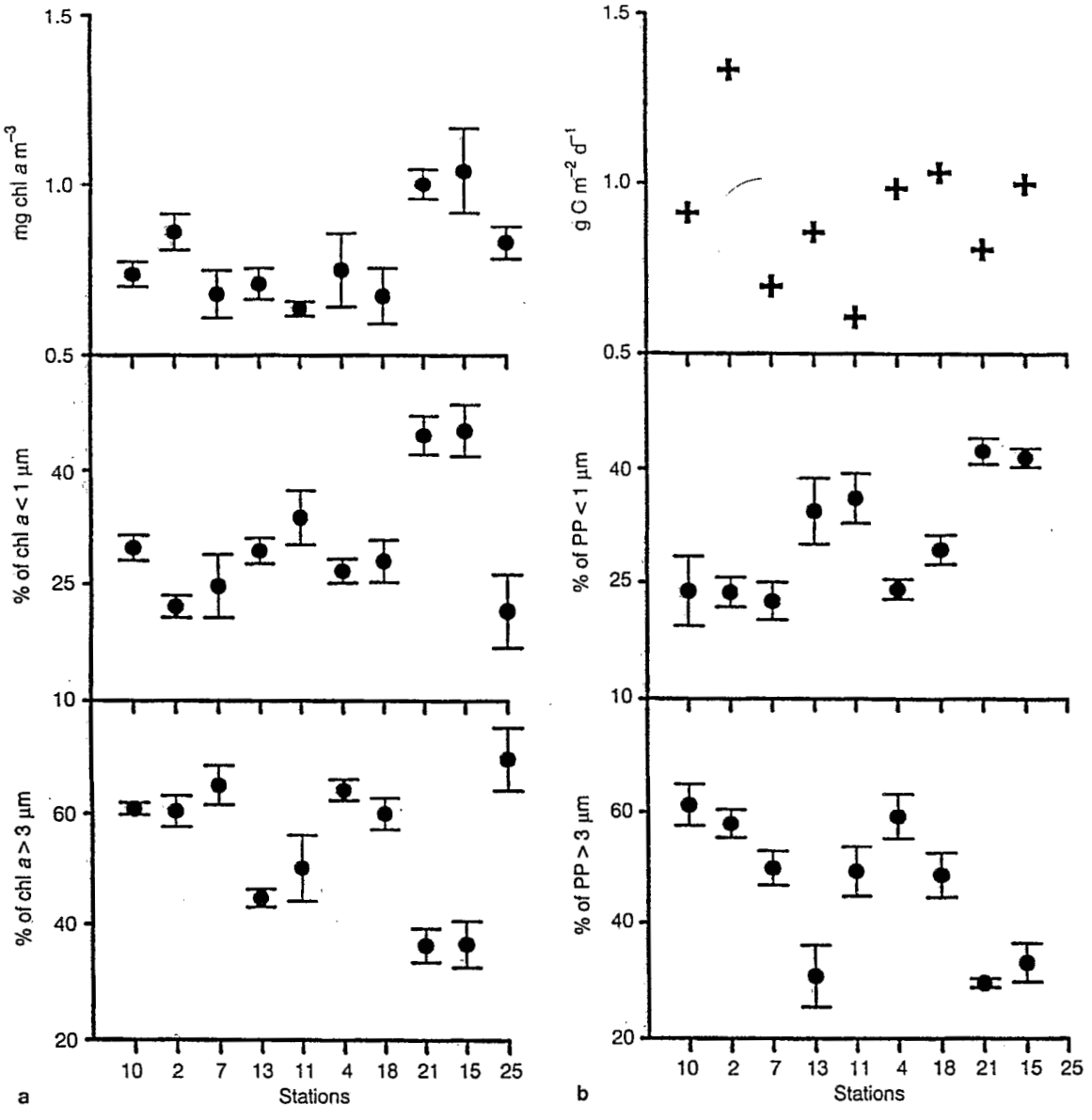

Fig. 3a averages ± SE of chl *a* and percentages < 1 µm and > 3 µm; **b** integrated primary production in the upper 20 m and percentages < 1 µm and > 3 µm in the Great Astolabe lagoon

per unit of biomass (P^B) was high with an average for the lagoon of 8.4 ± 0.5 mg C mg^{-1} chl *a* h^{-1}, and decreased with depth (Fig. 4).

In the lagoon, *Synechococcus* were the most abundant group whatever the station. *Prochlorococcus* were less abundant but had the same order of magnitude as the *Synechococcus*. Picoeukaryotes were an order of magnitude less abundant. The factor station had a significant effect on the abundances of the three picoplankton groups while depth had a significant effect only an *Prochlorococcus* abundance (Table 1). The maximum of picoplankton abundance was observed at station 21 which had 140 ± 4 × 10^3 *Prochlorococcus* ml^{-1}, 180 ± 14 × 10^3 *Synechococcus* ml^{-1} and 5.3 ± 0.3 × 10^3 picoeukaryotes ml^{-1} (Fig. 5). Station 15 had the highest chlorophyll concentration and picoplankton abundance.

Contribution of the different groups to total chlorophyll a

There was a significant correlation between the sum of the total red fluorescence and the chlorophyll <3 µm ($r^2 = 0.64$, $P = 0.0000$, $df = 40$). Therefore, the chlorophyll content per unit of red fluorescence, ψ_i (fg chl *a* <3 µm per unit of RF), can be estimated for the lagoon by regression using measured values of chl *a* <3 µm, n_i and f_i and using Eq. 1. The fit of data to

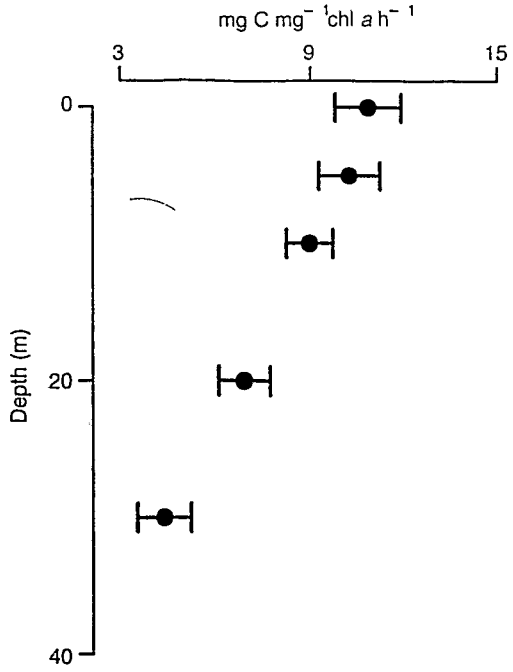

Fig. 4 Vertical profile of assimilation number in the Great Astrolabe lagoon

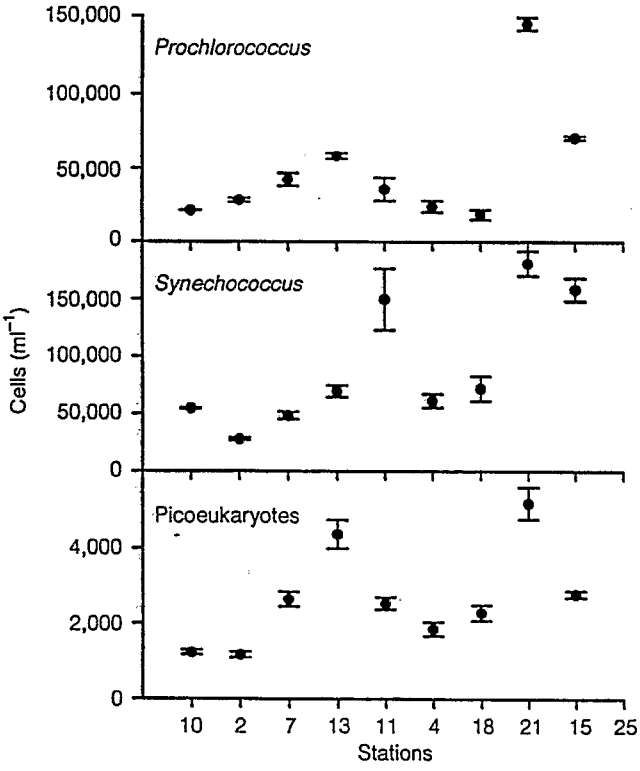

Fig. 5 Average ± SE of cell abundances of the three recognised groups in the Great Astrolabe lagoon

the regression was good ($r^2 = 0.9$, $P < 0.0000$, $df = 40$) and the values of ψ_i were 2.76, 4.87 and 1.94 fg chl a <3 µm RF^{-1} for the *Prochlorococcus*, *Synechococcus*

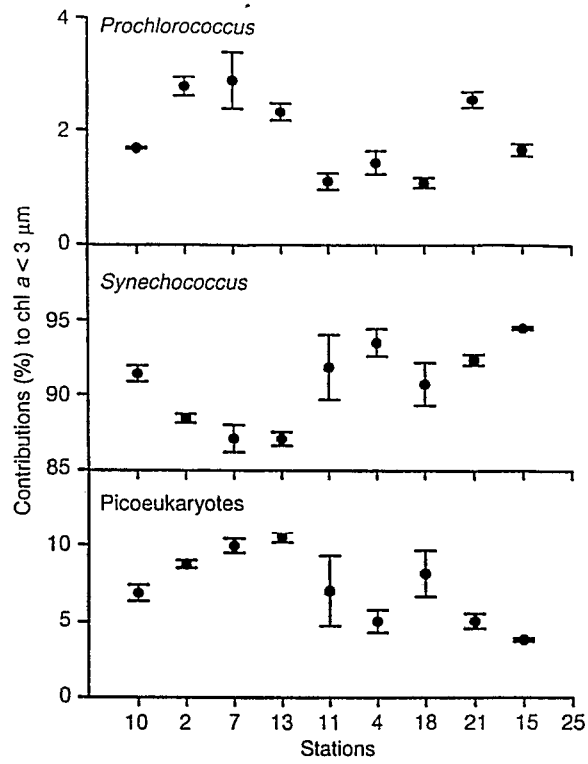

Fig. 6 Average ± SE contributions to the chl a < 3 µm and to the total chl a of the three recognised groups in the Great Astrolabe lagoon

and picoeukaryotes, respectively. The agreement between measured chl a and fitted values $\sum_{i=1}^{i=3} n_i + f_i \times \psi_i +$ chl $a > 3$ µm was very good ($r^2 = 0.7$, $P = 0.0000$, $df = 40$). Using regression estimated values of ψ_i, the percentage contributions to chl a <3 µm of each picoplankton group were calculated. On average, *Prochlorococcus*, *Synechococcus* and picoeukaryotes contributions to picoplankton chl a were 2.0 ± 0.1%, 90.5 ± 0.5% and 7.5 ± 0.5%, respectively. The major contributions of *Prochlorococcus* were windward of the lagoon where water exchange with the ocean is maximum. Using the percentage of chl a <3 µm, we can calculate the contributions of the three groups to the total chl a. These contributions were 0.9 ± 0.1%, 42.0 ± 1.9% and 3.3 ± 0.2%, respectively (Fig. 6).

Short term variability of cell abundance

To assess short-time variability, a diurnal cycle of abundance of *Synechococcus* and picoeukaryotes was measured on 27 May at station 5 using epifluorescent microscopy. The observed variations were moderate at this time scale, with coefficients of variation of 28.5% and 16.9% a for *Synechococcus* and picoeukaryotes, respectively (Fig. 7).

Ocean

In the upper 60 m of surrounding oceanic waters, N_n, PO_4 and Si concentrations were 1 µM, 0.2 µM and 0.5 µM, respectively. Below 60 m, nutrient concentrations increased reaching 4.5 µM N_n, 0.3 µM PO_4 and 1.4 µM Si at 200 m (Fig. 8). In the upper 60 m, chl *a* concentration was relatively high (>0.2 mg m^{-3}) and the chlorophyll maximum was at 30 m depth 0.44 mg m^{-3}) and represented 53% of the average lagoonal chl *a*. This layer was dominated by the >3 µm size fraction (Fig. 8). *Prochlorococcus* were the most abundant picoplankton group. The *Synechococcus* were less abundant but had the same order of magnitude, and the picoeukaryotes were an order of magnitude less abundant (Fig. 8). The *Prochlorococcus* and the picoeukaryotes presented the same trend with a subsurface maximum near the nitracline. The *Synechococcus* were abundant only in surface layers and decreased drastically with depth. Maximum abundances (cells ml^{-1}) were 7.7×10^4 *Prochlorococcus*, 6.7×10^4 *Synechococcus* and 3.1×10^3 picoeukaryotes.

Samples from the oceanic station could not be processed immediately due to the bad weather, and the fit of data was insufficient to estimate ψ_i (fg unit of red fluorescence). The picoeukaryotes were poorly preserved and as a result their red fluorescence was likely to have been affected by the delay before analysis. However, we were able to calculate ψ_i' because the fit of chl *a* <1 µm versus prokaryotic red fluorescence was good ($r^2 = 0.96$, $P = 0.0000$, $df = 9$) and the values of ψ_i' were 2.68 and 2.34 fg chl *a* <1 µm RF^{-1} for the *Prochlorococcus* and *Synechococcus* respectively. The agreement between measured and calculated values of chl *a* <1 µm was very good ($r^2 = 0.98$, $P = 0.0000$, $df = 8$). Therefore, the contribution of prokaryotic groups to chl *a* <3 µm was estimated by multiplying their contribution to the chl *a* <1 µm (calculated from Eq. 2) by the proportion of chl *a* <1 µm in the <3 µm fraction. The contribution of picoeukaryotes to chl *a* <3 µm was estimated as the percentage of chl *a* in 1–3 µm fraction (Fig. 8).

Synechococcus dominated picoplankton biomass in the upper 40 m. Below 40 m, *Prochlorococcus* and picoeukaryotes contributions to chl *a* <3 µm were close to 50% (Fig. 8).

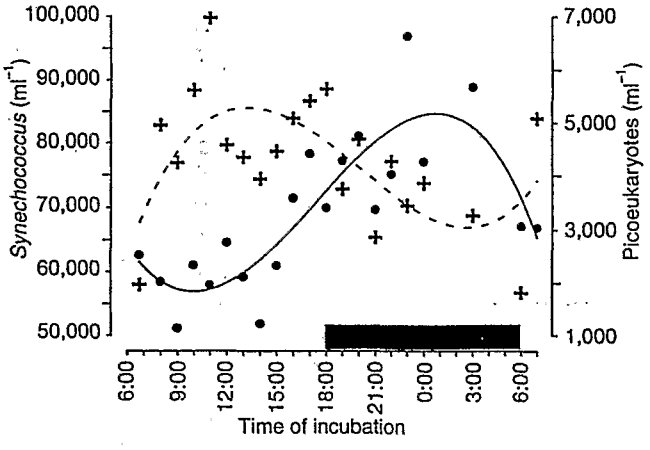

Fig. 7 Short-term variability of *Synechococcus* (●) and picoeukaryotes (+) abundance at station 5 at 10 m depth on April 27. Horizontal bar indicates hours of darkness

Discussion

Two stations in the lagoon (21 and 15) had significantly higher nutrient concentration and phytoplankton biomass than elsewhere. These stations are close to the biggest island of the lagoon (Ono), where salinity is low due to an input of freshwater (Morrison et al. 1992). The presence of this island is therefore probably

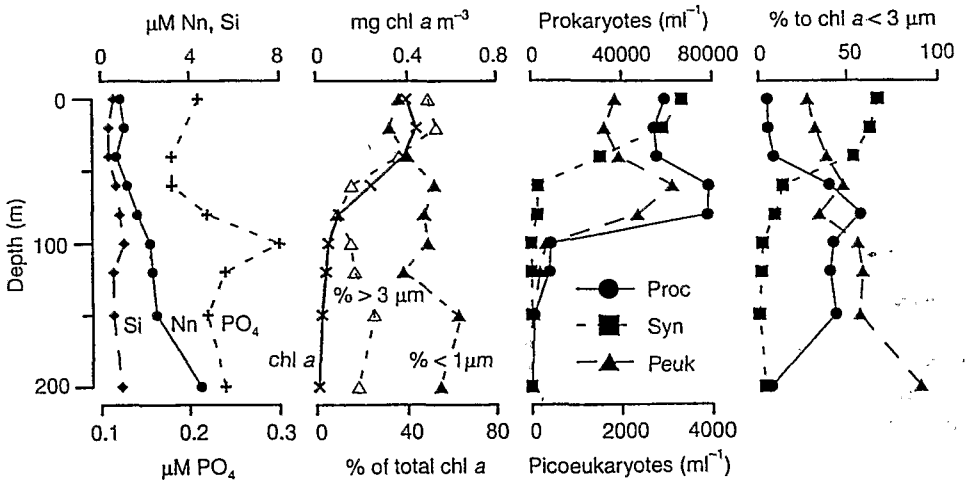

Fig. 8 Profiles of nutrient and chlorophyll concentrations, cell abundances and contributions to the chl *a* < 3 µm of the two prokaryotic groups (Proc, *Prochlorococcus*; Syn, *Synechococcus*) and picoeukaryotes (Peuk) in the Great Astrolabe surrounding oceanic waters

responsible for nutrient enrichment and consequently for the increase in phytoplankton biomass. Furthermore, during the time of our expedition, the weather was windy (> 20 m s^{-1}). This could explain the homogeneity of the water column for nutrient and phytoplankton variables. A similar vertical homogeneity was also observed in the same samples by Torréton (1999) for bacterial variables.

The average phytoplankton biomass was relatively high (0.83 ± 0.04 mg chl a m^{-3}) compared to other pacific coral reef lagoons: Tuamotu atoll lagoons (0.1–0.4 mg chl a m^{-3}, Charpy et al. 1997). Uvea lagoon in the Loyalty Islands (0.2 mg chl a m^{-3}, Le Borgne et al. 1997), the Great Barrier Reef (Furnas et al. 1990; Ayukai 1992). The high contribution of phytoplankton > 3 µm (55 ± 2%) contrasts markedly with the size structure of phytoplankton in Tuamotu atoll lagoons, where this fraction represented less than 30% (Charpy et al. 1997).

The average primary production in the upper 30 m (1.2 g C m^{-2} day^{-1}) was 1.5 times the values commonly recorded for atoll lagoons (Charpy 1996; Charpy and Blanchot 1998) and for Uvea lagoon (Le Borgne et al. 1997) and 100 times higher than the value published by Sorokin (1979) for an other Fijian island: Ngellelevu atoll. Production per unit of biomass (P^B) was high but consistent with estimates obtained in the Tuamotu atolls and Uvea lagoon. Such high P^B is equivalent to a very short turn-over time. In Tikehau and Takapoto lagoons (Tuamotu archipelago), average chl a doubling rates of the < 1 µm size-range were estimated to be 1.1 and 1.3 d^{-1}, respectively (Charpy 1996). The relatively high phytoplankton biomass and productivity and the high proportion of chl $a > 3$ µm is probably the direct consequence of the elevated N_n level. Indeed, it is now well established that N_n concentrations promote an increase in size of phytoplankton (Le Bouteiller et al. 1992; Blain et al. 1997).

The lagoonal picoplankton community structure was overwhelmingly dominated by *Synechococcus*. *Prochlorococcus* and picoeukaryotes constituted less than 15% of the chl $a < 3$ µm. The contribution of *Synechococcus* sp to total chl a (42.0%) was in the upper range (1.4%–73.4%) observed by Charpy and Blanchot (1998) in Tuamotu atoll lagoons. However, the contributions of *Prochlorococcus* (0.9%) and picoeukaryotes (3.3%) to total chl a were very low compare to Tuamotu lagoons (1.2%–72.7% and 16.6%–79.2%, respectively). Such large differences in phytoplankton community structure are probably due to differences in nutrient availability. Indeed, the nutrients levels observed in the Great Astrolabe lagoon were largely higher than those observed in Tuamotu lagoons by Dufour and Berland (1999). Biotic factors like grazing can also affect phytoplankton community structure (Charpy and Blanchot 1998). Indeed, in coral reef waters, Pile (1997) observed that sponges significantly decreased concentrations of *Prochlorococcus* and *Synechococcus* while increasing autotrophic picoeukaryotes. Ayukai (1995) observed decrease in concentrations of phytoplankton and microbial communities from the reef face towards the leeward reef flat, in two area of the Great Barrier Reef. Different species of ciliates have been also reported to be particularly efficient in feeding on *Synechococcus* in pelagic environments (Kudoh et al. 1990) and in short-term experiments (Jacquet et al. 1999). In Tikehau atoll lagoon, phagotrophic nanoflagellates were the major grazers of *Synechococcus* (Gonzalez et al. 1998).

We tested for changes through time (over 24 h) in the distributions of *Synechococcus* and picoeukaryotes using Statgraphics time-series analysis. Two of the three tests (run above and below median and Box-Pierce) show that we can reject the hypothesis that the abundance of *Synechococcus* over time is random. However, we cannot reject the hypothesis for picoeukaryotes. *Synechococcus* abundance was minimum at noon and maximum at midnight. Division of *Synechococcus* occurred after sunset and was completed around midnight, similar to *Prochlorococcus* (Vaulot et al. 1995; Blanchot et al. 1997; Liu et al. 1997) and to *Synechococcus* in coastal waters of northwestern Mediterranean Sea (Jacquet et al. 1999).

Dissolved inorganic nitrogen and phosphorus concentrations were particularly high in the upper 40 m and not typical of oceanic waters in this area. Indeed, at a station located in the Fijian basin (15°S, 173°E), Lemasson et al. (1990) observed undetectable dissolved inorganic nitrogen and phosphorus concentrations in the upper 110 m. The high level of chl $a > 3$ µm observed close to the Great Astrolabe reef and the position of the chlorophyll maximum is also unusual for this oceanic area. Indeed, Dandonneau and Lemasson (1987) and Lemasson et al. (1990) observed a chl a concentration < 0.1 mg m^{-3} with 80% < 3 µm in the upper 40 m in the Fijian basin. Therefore, it appears that the 0–40 m layer was strongly influenced by the Great Astrolabe lagoon, as evidenced by the high contribution of *Synechococcus* to the chl $a < 3$ µm in this layer. Unfortunately, we did not identify the taxonomic groups of nano phytoplankton (2–20 µm). Below this 0–40 m layer, *Synechococcus* abundance decreased drastically and the relative contributions of *Prochlorococcus* and picoeukaryotes and phytoplankton biomass were similar (50%).

In conclusion, The Great Astrolabe lagoon phytoplankton biomass was particularly high, four times that of Tuamotu atoll lagoons, Picoplankton contribution (45%) was significantly lower than in Tuamotu lagoons (> 70%). Significant differences in phytoplankton biomass were observed among stations and are most likely due to terrestrial input of nutrients. *Synechococcus* largely dominated the phytoplankton biomass (91%) and contributed to 42% of total phytoplankton biomass. The contributions of *Prochlorococcus* and picoeukaryotes to phytoplankton biomass were

particularly low (1 and 3%, respectively). Short-term variability is probably due to the picoplankton rate of division. The upper layer of oceanic waters close to the Great Astrolabe is strongly influenced by lagoonal waters, as evidenced in picoplankton community structure.

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