Picophytoplankton dynamics in the equatorial Pacific (0°S 150°W)

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INTRODUCTION

As part of JGOFS program, the French cruise FLUPAC was undertaken in the west part of the equatorial Pacific in October 1994. During a 7-day time-series at 0°S 150°W, abundances of the major phytoplankton groups were observed using flow-cytometry. Diel variations in cell abundance were interpreted in terms of cell division and grazing. A simple model was developed to estimate division and grazing rates of the picophytoplanktonic groups. Forward scattered light (FS) variations were related to changes in cell volume. This led to an estimation of mean cell size and carbon content for all groups of picophytoplankton. Using these results, an estimate of primary production was made and compared to ^{14}C measurements.

MATERIAL AND METHODS

Water samples were collected by hydrocast performed 6 times a day. 12-L Niskin bottles were used to collect water for nutrients and pigment analysis at

12 depths between 0 and 150 m. Picoplankton cells were counted by flow-cytometry each day for the 3, 11, 19 and 23 h (local time) hydrocasts. Flow cytometric measurements were performed within two hours after sampling with a FACScan flow cytometer (Becton-Dickinson) as reported in Blanchot & Rodier (1996). Pigment analysis were performed immediately after sampling following Neveux & Lantoine (1993). Primary productivity (^{14}C) was determined using *in situ* incubations by classical method and Let Go (Dandonneau & Le Bouteiller, 1992). Incubations were started at dawn and were retrieved after 6 or 12h.

RESULTS AND DISCUSSION

Water column density was homogeneous from the surface to 60 m. In this layer, nitrate concentrations were on the order of 3 µM, while chlorophyll concentrations generally fell between 0.3-0.4 $\mu g.l^{-1}$. These relatively low nitrate concentrations were slightly lower than normal due to an inhibition of the equatorial upwelling by tropical wave activity (Stoens *et al.*, 1999). The size structure of chlorophyll *a* was nearly constant in the mixed layer. On average, plankton < 3 µm in size (observed with the flow-cytometer) accounted for 70% of the total phytoplankton. *Prochlorococcus* were about twenty times more abundant than *Synechococcus* and picoeukaryotes. Cells of the three groups were homogeneously distributed in the mixed layer with typical abundances of $1.4 \pm 0.3\ 10^5$ *Prochlorococcus*.ml^{-1}, $8.5 \pm 1.8\ 10^3$ *Synechococcus*.ml^{-1} and $6.0 \pm 0.8\ 10^3$ picoeukaryotes.ml^{-1}. These concentrations were similar to those measured in the equatorial upwelling region under El Niño conditions (e.g. Landry *et al.*, 1996).

The abundances of each cell phytoplankton group exhibited a marked diel cycle within the mixed layer. Maximum cell abundances of *Prochlorococcus*, picoeukaryotes and *Synechococcus* were generally recorded at 23, 3 and 19 h and minimum cell abundances at 11, 19 and 11 h, respectively (Fig. 1). For all three groups, the general tendencies in the FS (a proxy for the mean size of an algal group) variations are inversely related to the cell abundance (Fig. 1). Variations in both the cell abundances and the mean size of each algal group corresponded to that expected of a population with synchronized cell division (Blanchot *et al.*, 1997; Vaulot & Marie, 1999). Each day, the mean cell size increased during the daylight hours and decreased when the cells divided at night. The decreases in cell numbers outside the division period were assumed to be due to grazing mortality.

Assuming that only grazing and cell division were responsible for variations in abundance, a simple model was developed to estimate growth (µ) and grazing rates (g) (André *et al.*, 1999). In this model, the cell number, N(t), varies over a time step, dt, by dN (t) according to: $dN(t) = [\mu_d (t) + g(t)]\ N(t)\ dt$. The instantaneous division rate (μ_d) was assigned a gaussian shape and during a diel cycle grazing was assumed to proceed at a constant rate. Predicted cell numbers were fitted to the measured ones using a least square regression procedure. In the mixed layer, estimated division rates for *Prochlorococcus*, picoeukaryotes and *Synechococcus* averaged 0.53 (± 0.18), 0.42 (± 0.13) and

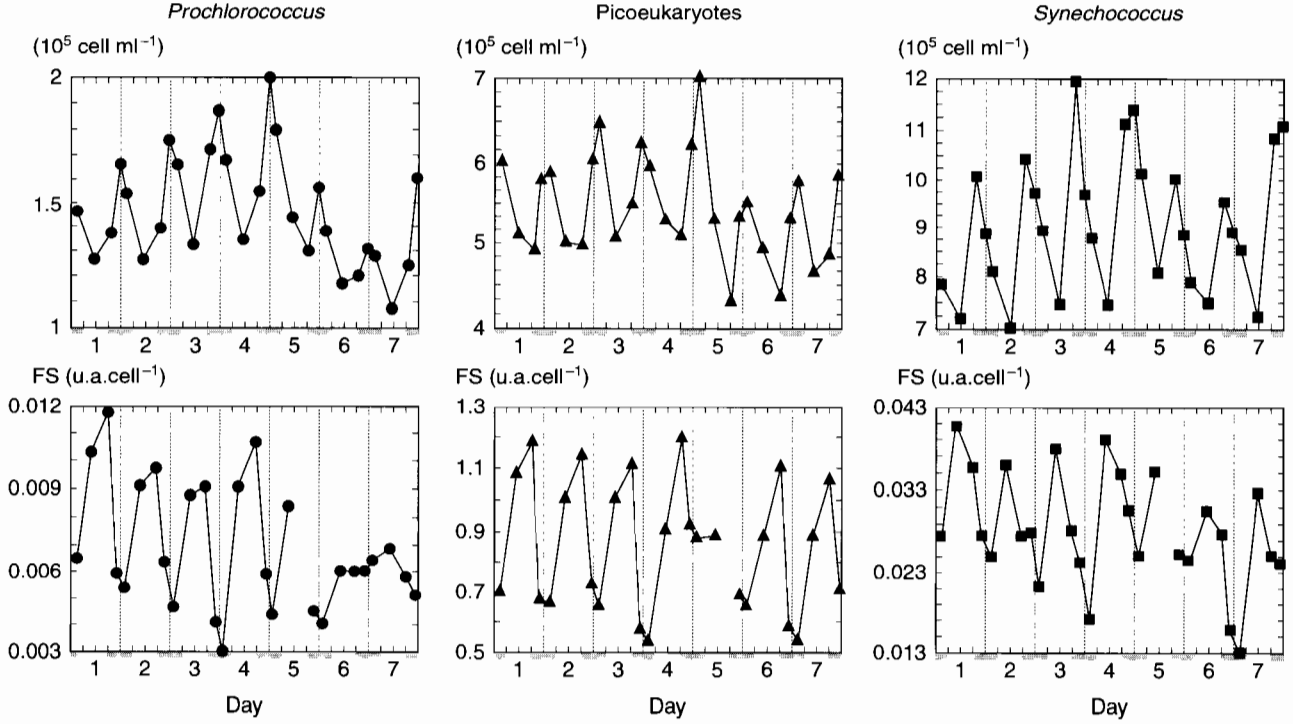

Figure 1. Fluctuations in cell abundances and FS within the mixed layer (mean 0-40 m) at the time-series station. The shaded areas mark the night periods (from 18:00 to 06:00 LT).

0.57 (± 0.18) d^{-1}, respectively. The mean estimated grazing rates were 0.58 (± 0.16) d^{-1}, 0.46 (± 0.17) d^{-1} and 0.63 (± 0.16) d^{-1}, respectively. These rates confirmed the close balance between growth and grazing for each group over diel time intervals in the equatorial Pacific (Fig. 2). The estimated rates significantly varied from day to day during the time-series (Fig. 2).

As FS is proportional to (cell volume)$^{\alpha}$, we can write ln (FS_{max}/FS_{min}) = $\alpha\mu$). This leads to the calculation of α as 1.68. This estimated value of α is consistent with that in Chisholm (1992), Binder *et al.* (1996) and Blanchot *et al.* (1997). Assuming that the populations and the standard beads obey the same law, the mean size of *Prochlorococcus*, picoeukaryotes and *Synecho-*

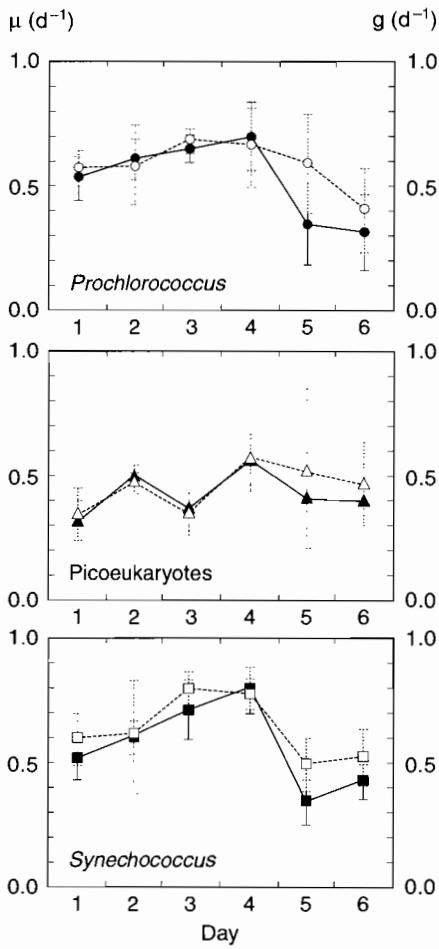

Figure 2. Mean estimates (0-40 m) of growth rate (μ, d^{-1}, filled symbols) and grazing mortality (g, d^{-1}, open symbols) at the time-series station.

coccus were estimated from FS signal to be 0.7, 2 and 1.0 µm, respectively. These values are in the range of published values (Chisholm *et al.*, 1988; Campbell *et al.*, 1994; Morel *et al.*, 1993). Using the conversion factors of Verity *et al.* (1992), the cell carbon contents (Cc) were predicted to be 84, 1490 and 246 fgC cell^{-1}, respectively. Over a depth range of 0-100 m, integrated picophytoplanktonic carbon biomass (1.8 gC m^{-2}) was mainly due to *Prochlorococcus* (52%) and picoeukaryotes (40%) while *Synechococcus* (mainly restricted in the mixed layer) contributed for only 8%. The biomass estimate for *Prochlorococcus* was confirmed by the ratio of divinyl-chlorophyll *a* (e.g. Goericke & Welschmeyer, 1993) to total picophytoplankton chlorophyll (~ 58%). Based on our estimates of growth rate and carbon cell contents, net and gross particulate primary production were computed for each algal group and for the whole picophytoplankton. The 0-100 m integrated picophytoplanktonic production was mainly due to *Prochlorococcus* (57%) and picoeukaryotes (33%), while *Synechococcus* only contributed a small fraction (10%). The picophytoplanktonic production measured with ^{14}C technique was intermediate between the predicted net and gross productions (Table I).

Table I. Predicted daytime net community production, daily gross production for the three algal groups and for the whole picophytoplankton; measured picophytoplankton ^{14}C assimilation. Values are average integrals (0-100 m) for the time-series station, in gC m^{-2} d^{-1}.

0-100 integrated productions (gC.m^{-2} d^{-1})								
Prochlorococcus		***Picoeukaryotes***		***Synechococcus***		***Picophytoplankton***		***Picoplankton***
net	**gross**	**net**	**gross**	**net**	**gross**	**net**	**gross**	**^{14}C**
0.43	0.78	0.25	0.44	0.08	0.13	0.76	1.34	1.1

CONCLUSION

Diel variations in abundance of oceanic picoplankters showed the usefulness of flow-cytometry measurements for the study of plankton community dynamics in oceanic regimes, such as the equatorial Pacific, where synchronized cell division is the rule.

ACKNOWLEDGMENTS

IRD, IFREMER and INSU grants supported this work. It is a France-JGOFS participation. We thank the crew of the R.V. *L'Atalante* for their help on board and the chief Scientist Dr. R. Le Borgne. We thank particularly Dr. Y. Dandonneau and Dr. A. Le Bouteiller for providing us the ^{14}C data.

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ISSN 0304-5722

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Bulletin de l'Institut océanographique, Monaco
Numéro spécial 19

Ce volume est publié par François DOUMENGE,
Directeur du Musée océanographique,

Avec le concours d'Anne TOULEMONT,
Maître de Conférences à l'Institut océanographique.

Réalisation : TyPAO Sarl (Paris 11e)

ISBN 2-7260-0210-2 (numéro spécial 19)