MESOSCALE DYNAMICS OF PICOPHYTOPLANKTON IN THE MEDITERRANEAN SEA, WITH A FOCUS ON PHOTOACCLIMATION RESPONSES

C. Brunet [1] *, R. Casotti1 and V. Vantrepotte [2]

[1] Stazione Zoologica di Napoli, Villa Comunale, 80121 Napoli, Italy - * brunet@szn.it
[2] Université du Littoral, LISE, UPRES-A ELICO 8013, 62930 Wimereux, France

Abstract
Phytoplankton dynamics were investigated at the Italian side of the Strait of Sicily in July 1997 using HPLC pigment analysis of fractionated samples (< 3 µm and > 3 µm) and flow cytometry. Phytoplankton were dominated by the picoplankton fraction (more than 80% of total chlorophyll), which was numerically dominated by cyanobacteria of the genus *Prochlorococcus*, with average concentrations of 6.2 x 10^4 cell ml^{-1}. Picophytoplankton composition varied with water mass characteristics and along the water column, with the highest pigment diversity observed in the DCM. Photoacclimation responses were investigated using both, on board incubations and high-rate sampling at one site, and showed a strong response of the picoeukaryotic component to the diel light cycle.

Keywords: phytoplankton pigments, diel variability, flow cytometry, photoacclimation

The Strait of Sicily is a highly dynamical area, where different water masses mix, originating from the Atlantic Ocean and the western basin, the Levantine basin, and the Adriatic Sea (1). As a consequence, the area is hydrologically dynamic and several mesoscale physical structures are frequently present, such as filaments or meanders. It is therefore a site very suited to study the physical-biological coupling at mesoscales. In July 1997 a cruise took place in the framework of the SYMPLEX project (Synoptic Mesoscale Plankton Experiment), aimed at investigating phytoplankton dynamics as related to mesoscale physical structures. Several transects were sampled across a coastal filament, originating from horizontal advection of deep waters upwelling along the southern coast of Sicily. Apart from discrete samples taken at 45 stations (8 depths), also a fixed station was sampled every 3 h for a total of 50 h at 6 depths. At the same time as the fixed station, on-board incubations on filter-fractionated samples were done, to compare physiological responses to the diel light cycle and variations induced by changes in the light field, as for example induced by upwelling or mixing.

Mesoscale sampling

The filament separated a western area, dominated by the modified Atlantic Water (MAW), detected from its lower salinity in the first 50 m, from the so-called Ionian Water (IW), present in the eastern area, which was saltier. A strong horizontal temperature gradient (front) delimited the filament of cold water upwelling along the southern coast of Sicily, which was also very evident from satellite imagery (AVHRR). Phytoplankton biomass was low in the whole area (chl *a* average of 0.09 µg l^{-1} ± 0.08 µg l^{-1}), characterized by a recurrent Deep Chlorophyll Maximum (DCM), situated between 60 and 100 m depth) with picophytoplankton dominating (up to 94% of total chl *a*). The highest phytoplankton diversity was observed in the picoeukaryotic component (< 3 µm in size) of the DCM, with dinophytes, pelagophytes, prymnesiophytes and chlorophytes contributing to a significant fraction of the total chl *a* biomass of this fraction. Prokaryotic phytoplankton (*Synechococcus* and *Prochlorococcus*) dominated mainly in the MAW (more than 60%), while in the deeper DCM picoeukaryotes dominated (69%). In the IS, the relative percentage of phytoplankton < 3 µm was slightly lower than in the MAW, but picoeukaryotes dominated as well. Inside the filament, high concentrations of *Prochlorococcus*, with a higher cell red fluorescence with respect to the surrounding stations, clearly marked the deep origin of this cold water.

Diel sampling and on-board incubations

In order to estimate velocities of the vertical transport of phytoplankton during the upwelling, cellular red fluorescence estimated through flow cytometry on the picophytoplankton fraction was analyzed, and compared with both the data from the diel cycle sampling and the on board-incubations. The water column at the fixed station, located east of the filament, was strongly thermally stratified for the whole sampling period. Picophytoplankton dominated the DCM (70% of total chl *a*), located between 70 and 90 m depth (1.55 to 0.45% of incident light), and *Prochlorococcus* and picoeukaryotes dominated the picophytoplankton. Larger size phytoplankton dominated, instead, the surface layer of the water column. Photoprotective pigment markers, such as the ratios zeaxanthin/(violaxanthin + antheraxanthin + zeaxanthin) and Diatoxanthin/ (Diatoxanthin + Diadinoxanthin) showed high values in surface waters in the picophytoplankton fraction (both ratios) or in the larger phytoplankton (the second ratio), indicating the need of photoprotection in surface waters due to the excess light intensities present at the time of sampling. This process showed a significant diel variation in both size classes in the first 20 m, but indicated a faster reaction in the picophytoplankton fraction, suggesting a higher physiological plasticity of these small-sized algae, at least with respect to light utilization. Surprisingly, diel variations were observed even in the DCM, even though very little light irradiances were measured, suggesting that a response to the diel light cycle was present even at very low light intensities.

The on-board incubations consisted of incubating natural phytoplankton assemblages at higher (shift-up) or lower (shift-down) light intensities than present at their sampling depth, in order to estimate kinetic coefficients of the photoacclimation reaction. The shift-up experiments showed a very fast synthesis of Diatoxanthin with respect to total chl *a* in the picophytoplankton, suggesting faster photoacclimating responses of these algae as compared to larger phytoplankton (0.29 versus 0.10 h^{-1}). For the shift down experiment (from 1% to 0.1% incident light), no change in pigments was observed, but a significant increase in divinyl-chl *a*, a marker of *Prochlorococcus*, indicating a very strong photoacclimation response of this species, which successfully occupies the very deep layers of the water column. From flow cytometric detection of cellular red fluorescence of chlorophyll, it has been observed that the kinetics of low-light acclimation of *Prochlororcoccus* was much faster than that of *Synechococcus*, while the opposite was true for the kinetic of high-light acclimation. This confirms the hypothesis that *Synechococcus* is more adapted to high-light, nutrient poor surface waters, while *Prochlorococcus* is better suited to low-light, high nutrients waters reflecting their relative vertical distribution. The analysis of the picophytoplankton community proved to be a powerful tool to describe water mass changes and to estimate variations of physiological processes over time, which, in turn, may help to estimate vertical velocities of mixing in the surface layer of the water column (2).

References

1 - Bohm E., Nardelli B. B., Brunet C., Casotti. R., Conversano F., Corato F., D'Acunzo E. , D'Ortenzio F., Iudicone D., Lazzara L., Mangoni O., Marcelli M., Marullo S., Massi L., Mori G., Nardello I., Nuccio C., Ribera d'Alcala M., Saggiomo V., Santoleri R., Scardi M., Sparnocchia S., Tozzi S., Zoffoli S., 1998. SYMPLEX Experiment: first results on oceanic mesoscale dynamics and related primary production from AVHRR and SeaWifs satellite data and field experiments. SPIE, 3496 : 137-148.

2 - Brunet C., Casotti R., Aronne B. and Vantrepotte V., 2003. Measured photophysiological parameters used as tools to estimate vertical water movements in the coastal Mediterranean. *J. Plankton Research*, 25, in press.