THE SOUTH PACIFIC OCEAN TIME SERIES (SPOT) STATION: A FIRST FOCUS ON DIAZOTROPHS COMMUNITY

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INTRODUCTION

Nowadays it is difficult to predict the impact of global changes, such as the expansion of higly stratified oceanic gyre, on the functioning of our ecosystems without knowing plankton biodiversity, the metabolic rates of these species and their trophic relationships.

To predict planktonic changes we need to know from the different Plankton Functional Types (PFTs) that have been identified (Le Quéré et al. 2005, Falkowski et al. 2008) « **how many of who**? **Is doing what**? » and these PFT need to be investigated over **large distance and long periode of time,** with the help of oceanographic cruises and long term observatory programs.

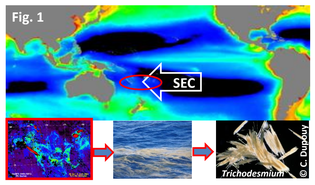
► **However, long lasting ocean time series are rare and are mainly based in the Northern hemisphere, when the South West Pacific is the least known area in terms of plankton diversity.**

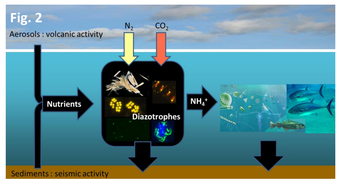
New Caledonia oceanic region is located between tropical (warm and fresher) and sub-tropical (colder and saltier) water masses on the way of the deep (1000 m) South Equatorial Current (SEC, Ganachaud et al. 2013). The SEC is originated from the South Pacific Gyre in the French Polynesia region and it is part of El Niño-Southern Oscillation (ENSO). Changes on SEC properties will impact strongly the South-West Pacific climate and ecosystems up to Australia, going through the Coral Sea and the different ecosystems found on its way (Fiji, Tonga, Vanuatu and New Caledonia, Fig. 1 and 2).

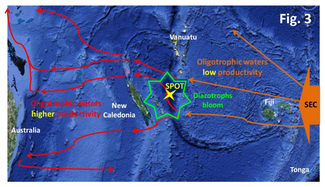
Since several decades, researchers (Dandonneau 1986, Dupouy et al. 2011 and references therein) have observed, spectacular **seasonal blooms** of the PFT N_2-fixers *Trichodesmium* **with interanual fluctuations which are not explained yet**.

N_2-fixers have an ecological advantage compared to other phytoplankton PFTs they have a high degree of autonomy towards C and N requirements. They can as well stimulate the productivity of other bacteria, phytoplankton and zooplankton PFTs, through the (i) release of NH_4^+ during N_2-fixation, (ii) their population growth and decay.

In addition of *Trichodesmium* many nano- and picoplanktonic N_2-fixers cyanobacteria have been detected in the South-West Pacific (Biegala and Raimbault 2008, Bonnet et al. 2009, Moisander et al. 2010, Fig. 3) which can contribute significantly to N_2-fixation and **the rise of plankton productivity of the different ecosystems on the way of the SEC current.**







AIMS

The **SPOT** station (**168°E-20°S, -4500 m**) is a recent deep-sea and multidisciplinary marine research observation station which objective is the establishment of the **first long time series of basic parameters in the South West Pacific**.

The main studies concerns the biodiversity, the productivity of key **P**lankton **F**unctional **T**ypes, the biogeochemistry of carbon and nitrogen cycles, and their impact on the reef and coastal ecosystems productivity.

SPOT station is based on the same philosophy of long-lasting observation as HOT (Hawaii Ocean Time-series) and the data will be used to describe and understand the **seasonal and long-term variations of the South-West Pacific ecosystem** related to **ENSO (El Niño Southern Oscillation).**

PHYSICS

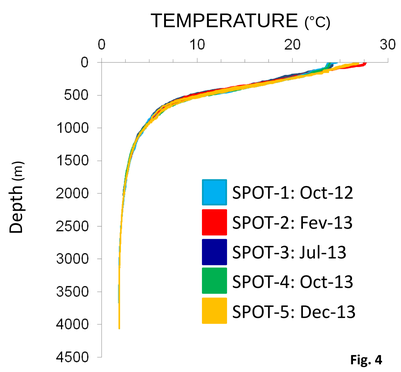


Fig. 4

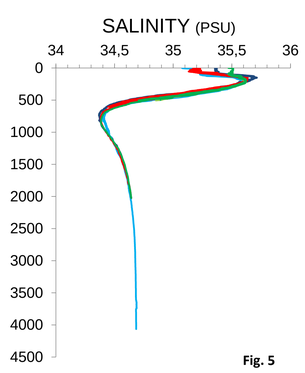


Fig. 5

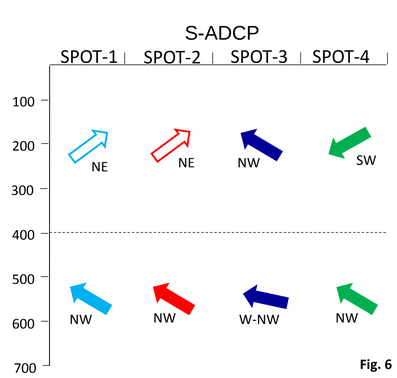


Fig. 6

CHEMISTRY

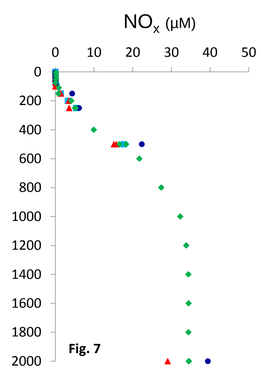


Fig. 7

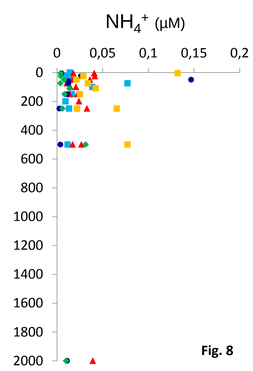


Fig. 8

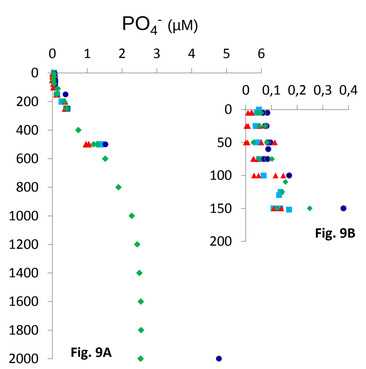


Fig. 9A

Fig. 9B

PHYTOPLANKTON

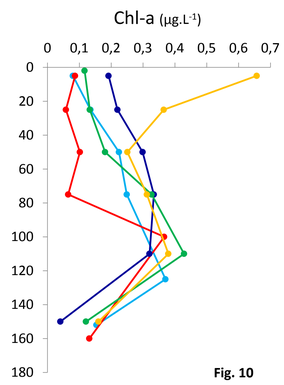


Fig. 10

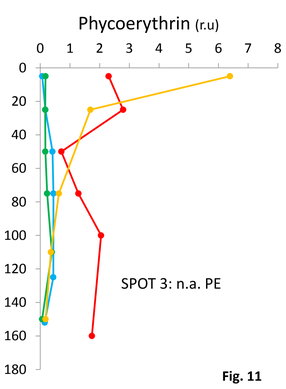


Fig. 11

RESULTS & DISCUSSIONS

PHYSIQUE: Water masses at SPOT comes essentialy from the SEC current orientated west (Fig. 6). Changes of orientation on surface water during SPOT-1 and 2 (Fig. 4 and 5) were from eddys formation on SEC current (AVISO Sea Level Anomalies, data not shown).

CHEMISTRY: Nutrients such as NO_x NH_4^+ and PO_4^- were typical of oligotrophic waters in the first 100 m and increaseed below the deep chlorophyl-a maximum (DCM = 100-130 m) to reach their maximum concentration at 1000 m and remained constant down to 2000 m (Fig.7, 8, 9A). Among all the cruises the « winter » one (SPOT-3) had slightly higher concentrations of ammonium and phosphate in surface waters (Fig. 8, 9B). In winter, NOx and phosphate below the DCM 150 m were also the highest.

PHYTOPLANKTON: During all the SPOT cruises a maximum of Chl-a concentration and Phycoerythrin was reached between 80-130m (DCM), apart from SPOT-5 where the maximum was measured in surface waters (Fig. 10). The extent of Chl-a concentration in surface between New-Caledonia and Vanuatu waters was shown by satellite images (Fig. 12A-E) and counts of diazotrophic cyanobacteria community was done by microscopy down to 4000 or 2000 m (Fig. 13, 14).

The seasonal changes in surface phytoplankton biomass is explained by the variations in *Trichodesmium* sp. concentrations as revealed by Phycoerythrin measurements (Fig. 11) and microscopic counts (Fig. 14). Although the summer phytoplankton bloom was formely attributed to *Trichodesmium*, the winter one was attributed to other eukaryotic species, october months being known as an « interseason » in terms of surface Chl-a biomass (Dupouy et al. 2011). In this study we confirmed that *Trichodesmium sp.* was also present during the winter 2013 bloom (Fig. 13C). This result is surprising and more data should be acquired on the eukaryotic phytoplanktonic community to fully caracterise this bloom. It is important to stress that this winter Chl-a bloom occured in surface every year within the last 11 years of observations, when the summer bloom was only detected six times over the same period (Dupouy et al. 2011). An important richness in *Trichodesmium* sp. was found all the year long even in low concentrations (Fig. 13E) and these filamentous cyanobactria were observed in deep waters, up to 2000 m, during interseason cruises (Fig. 13B, 13D), which suggest cell sedimentation .

Overall the diazotrophic cyanobacterial community was largely dominated in abundance by small unicellular cells recovered within three size fractions (Fig. 14), although the picoplanktonic fraction was by far the most abundant and reached during interseason more than 300 cell.ml^{-1} in surface waters (Fig. 14D). Similarly as *Trichodesmium* a large range of cell size/shape was recovered within the UCYN community (Fig. 14E). For the first time the vertical distribution of this UCYN community was investigated well below the euphotic zone down to 2000 and 4000 m and **surprisingly some of the highest concentrations of picoplanktonic-unicellular cyanobacteria was detected below 500 m.** Although the presise identity of these tiny cells is not yet known they could be attibuted to UCYN-A, which are deprived of photosystem II (Zehr et al. 2008) and may be heterotrophic cyanobacteria, however a significant population of pigmented picocyanobacteria was detected by flow cytometry at these deep depths (data not shown), whose identity remained to be confirmed.

As UCYN community concentrations were obtained by fluorescent ribosomal stains (FISH technique, Biegala and Raimbault, 2008), all cells were active at time of sampling. This might not be the case for deep *Trichodesmium* concentration which physiological state remained to be caracterised as their concentrations were obtained by DNA stain (DAPI).

METABOLIC RATES: Primary production and nitrogen fixation (Montoya et al. 1996 modified according to Grosskopf et al. 2012) in surface waters increased significantly from winter (SPOT-3) to summer (SPOT-5) according to phycoerythrin riched phytoplankton biomass and diazotrophic cyanobacterial counts (Fig. 11, 14C-D, 15, 16).

However what was unexpected was the **simultaneous carbon and nitrogen fixation at 2000 m**, which may be related to the picoplanktonic UCYN simultaneously discovered (Fig. 14A-D, 15, 16). It is important to specify that great care was taken to maintain incubation bottles for C and N fixations in complete darkness and measurements were done in triplicates and show similar trends (data not shown).

METABOLIC RATES

Fig. 15

Fig. 16

ZOOPLANKTON

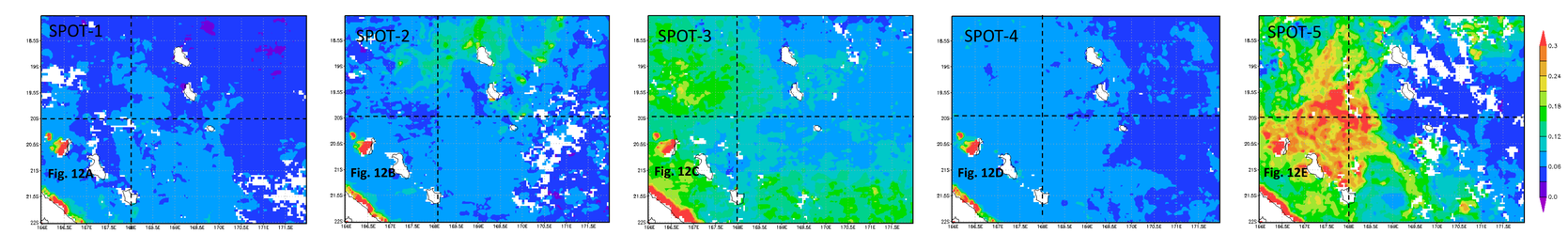
Fig. 17

Fig. 18

ZOOPLANKTON: Interseason at SPOT shows a zooplankton biomass 1.6 times higher than in summer (insert in Fig. 17) and both seasons were characterised by a peak in zooplankton biomass within the 250 µm mesh size. An additional peak was reached in summer within the largest size fraction.

Among the zooplankton community, copepod was the dominant group (data not shown). Calanoids represented 40% of the zooplankton abundance during the interseason, while in summer they reduced by half to the benefit of harpacticoid copepods and appendicularian, which both doubled their population (Fig. 18). Calanoid copepods are herbivorous and fed mainly on non-diazotrophic nanoeukaryotic phytoplankton from the DCM, when appendicularian feed on picoplanktonic cells and detritus and the planktonic harpacticoids are so far the only known predator of *Trichodesmium* sp. Although more data should be acquired on each SPOT cuises, **our results suggest that surface *Trichodesmium* bloom can sustain a non negligeable secondary production by enhancing the shift in species composition and inducing the developement of larger organisms**.

MODIS-Satellite Chl-a concentration, 4 km (µg.m^{-3})



Trichodesmium sp. concentrations (trichome.L^{-1})

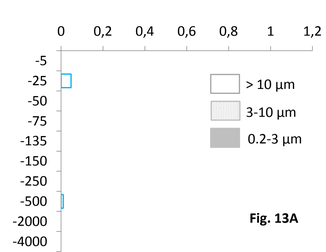


Fig. 13A

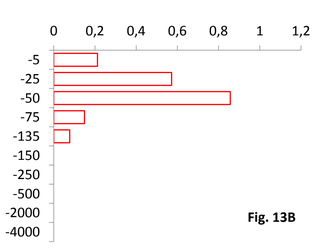


Fig. 13B

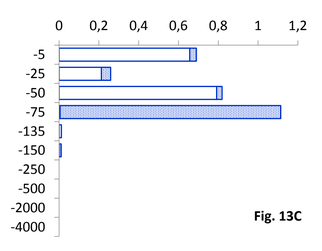


Fig. 13C

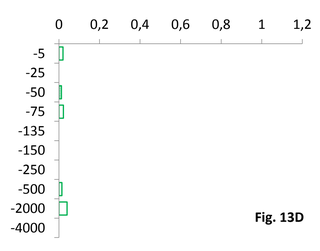
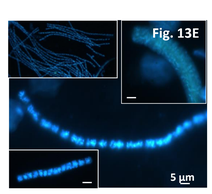


Fig. 13D



Note that the counts are not available for SPOT-5 yet.

UCYN *concentrations* (cell.mL^{-1})

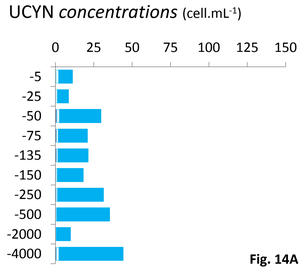


Fig. 14A

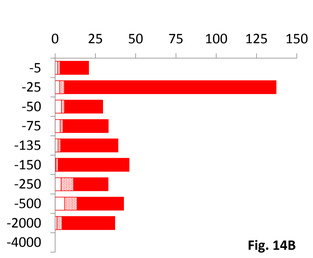


Fig. 14B

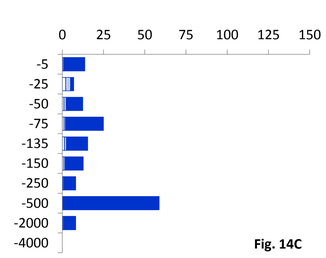


Fig. 14C

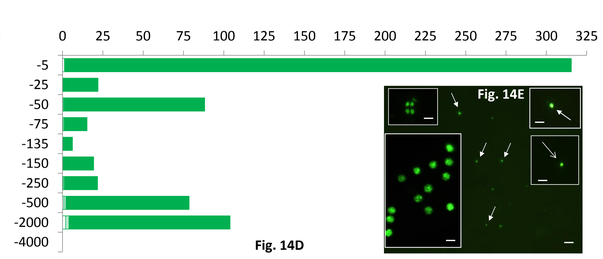


Fig. 14D

CONCLUSIONS

The compilation of the results of this first year multidisciplinary study at SPOT station confirmed our hypothesis that while being on the way of the oligotrophic SEC current a significant and higly diverse community of **diazotrophic cyanobacteria developed all the year long with seasonal shift among species and groups**. In addition we show that this community is **active in terms of C and N fixations** and seems to sustain in summer time higher trophic level production.

We also made significant **discovery of very deep population of picoplanktonic diazotrophic cyanobactria** which activity in both N and C fixations are suggested and remain to be confirmed.

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