Vertical distribution of marine cyanobacteria *Synechococcus* spp. in the Black, Marmara, Aegean and Mediterranean seas

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Abstract-Vertical distribution of unicellular cyanobacteria *Synechococcus* spp. within the euphotic zone are studied in highly contrasting seas by epifluorescence microscopy. Cell counts from all seas clearly showed that majority of the population are suspended in the upper mixed layer. Changes in biomass within the mixed layer is small compared to changes below pycnocline down to the bottom of the euphotic zone especially in the Black Sea and the Sea of Marmara. Visual inspection of the individual cells under epifluorescent microscope revealed that cells at subsurface chlorophyll-*a* maximum layer (SCML - based on in-situ fluorometer readings) reflect brighter and longer fluorescence than the ones at surface and at lower depths at all seas. Based on the flow cytometer mean forward light scatter data for size distribution it could be concluded that cells at surface mixed layer (0-10 meters) were larger in size than the cells at lower depths (20-60 meters) in the Black Sea. Time versus cell count plots have shown that cells of cyanobacterium *Synechococcus* spp. are under grazing pressure starting from midnight till noon and begin slowly to rebuild its population in the afternoon via dividing throughout the evening. Significant correlations ($r>P_{.01}$.) have been observed between cell counts and physical and chemical parameters with depth.

Keywords- Black Sea, Sea of Marmara, Aegean Sea, Mediterranean, *Synechococcus* spp, grazing, flow-cytometer, epifluorescence microscope.

Introducton

Picoplanktonic chroococcoid cyanobacteria *Synechococcus* spp. are known to be major contributors of the total photosynthetic biomass in the oceans, especially in the more oligotrophic regions such as the Mediterranean Sea (for references see Uysal, 2000, 2001). This group also possess high specific growth rates. In oligotrophic oceans this group contribute up to an estimated 25% of photosynthetic carbon fixation (Waterbury *et al.*, 1986) and accounted for 64% of the total photosynthesis in the North Pacific Ocean (Iturriaga and Mitchell, 1986).

Materials and Methods

Water samples were collected through a rosette sampler attached with a CTD probe during the cruises. Water samples were drawn from the closing bottles into 100 ml dark coloured polyethylene bottles and preserved with 4% buffered formalin. 10 ml aliquots from each sample were filtered onto 25 mm diameter, black, polycarbonate, nuclepore membrane filters with a 0.2 μm pore-diameter. Cells on filters were counted using a Nikon epifluorescent microscope (for details see Uysal, 2000, 2001).

Results

Changes in *Synechococcus* spp. abundance with depth in relation to ambient temperature, salinity profiles are shown in Fig. 1. *Synechococcus* spp contents of contrasting water masses in the Mediterranean clearly showed that majority of the population are suspended in the surface mixed layer. Below this layer an abrupt decline in abundances with depth are observed in all regions.

The vertical profiles of the cell distribution for the rim current, western and eastern gyres and for the Batumi anticyclone (Fig. 2) in relation to temperature, salinity, dissolved oxygen, fluorescence and light transmission have shown that cells are much more abundant at the surface mixed layer above the thermocline in the Black Sea. At the coastal station 1, included in the rim current, majority of the cells were suspended in the surface mixed layer reaching a maximum of $9.76x10^4$ cells/ml at the surface level. This then gradually decreased to $7.95x10^4$ cells/ml at 10 m and below at 20 m to a level of $3.63x10^4$ cells/ml. Cell numbers dropped to $1.42x10^4$ cells/ml just below the thermocline at 30 m depth and below at 40 m there were only $5.26x10^3$ cells/ml left. There were no significant changes in abundance at lower depths.

Information gathered from the flow cytometer mean forward light scatter data revealed that *Synechococcus* spp. cell size differ with depth. Results have indicated an apparent decrease in cell sizes with depth. Cells at the surface mixed layer (0-10 m) were larger than the cells at lower depths (20-60 m). As shown in Fig. 12, majority of the cells at surface mixed layer fall into 0.7-0.8 μm size group where the dominant cell size at lower depths between 20-60 m was about 0.5 μm. Significant correlations ($r>P_{.01}$.) have been observed between cell counts and physical and chemical parameters (Table 1). Highly significant negative correlations were found between cell counts and salinity, depth and nutrient salts (phosphate, nitrate, silicate). This could be summarized as the decrease in cell counts and increase in others with depth.

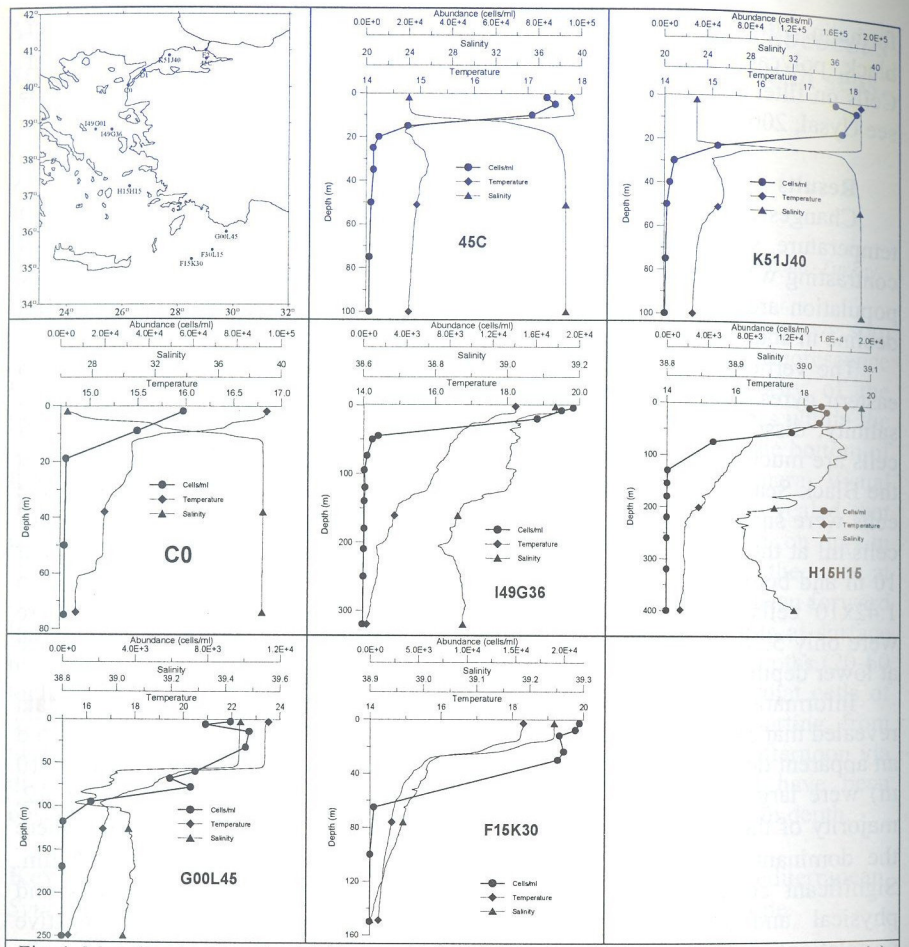

Fig. 1. Map showing cyanobacteria sampling stations (a) and abundance of *Synechococcus* spp (●) as a function of depth relative to those of temperature and salinity in October, 2000.

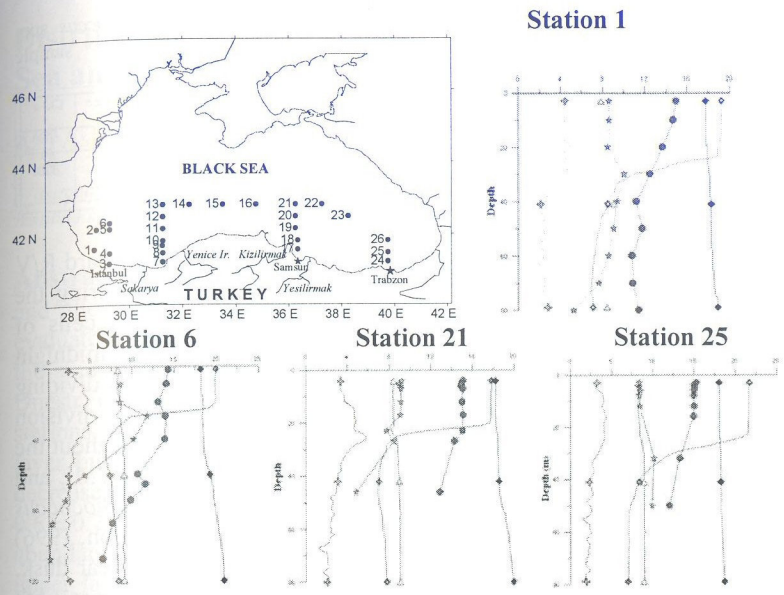

Fig. 2. Cyanobacteria sampling stations in the Black Sea (a) and abundance (3 x log of cells/ml) of *Synechococcus* spp (●) as a function of depth relative to those of temperature (◆), salinity (♦), dissoved oxygen (★), fluorescence (✚), and light transmission (▲) at station 1 (rim current) at station 6 (western gyre) at station 21 (eastern gyre), and at station 25 (Batumi anticyclone) in Sept.-Oct. 1996.

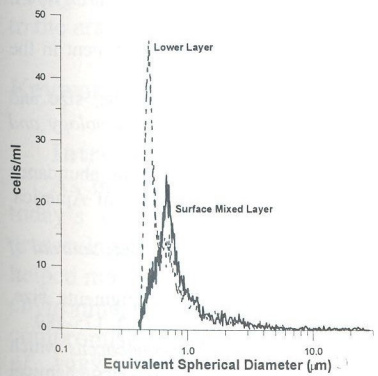

Fig. 3. *Synechococcus* spp. cell size distribution at surface mixed and lower layers in the Black Sea.

The pozitive correlation between the cell counts and the temperature, dissolved oxygen, in-situ fluorescence and chlorophyll-*a* denotes decrease in all with depth in harmony.Briefly, we can conclude that, besides grazing pressure and the timing schedule of sampling during the day, the abundance distribution of cyanobacterium *Synechococcus* spp. in the water column is much dependent on the ambient physico-chemical factors.

Table 1. Relationships between (a) physical, (b) chemical parameters and *Synechococcus* spp. abundance based on Spearman's rank correlation coefficient (*correlation coefficient, ** sample number, *** significance level).

	Temp.	Salinity	Dis. Oxygen	Depth	Time	Phosphorus	Nitrogen	Silicium	Fluorescence	Chl-*a*
Abundance	.6695 117 .0000	-.6298 117 .0000	.3307 117 .0004	-.7164 117 .0000	.0548 117 .5552	-.2980 * 117 ** .0013 ***	-.6761 117 .0000	-.5947 117 .0000	.7132 117 .0000	.6880 46 .0000

From our field and onboard microcosm experiments conducted on board R/V Bilim in the Black Sea (Uysal *et al.*, 1998) and field data collected during the Arabian Sea expedition (Sherry and Uysal, 1995) we found out that cells of *Synechococcus* spp. in general are under grazing pressure starting from midnight till noon and begins slowly to rebuild its population in the afternoon via dividing throughout the evening (Uysal, 2000, 2001). In other words, cell division dominates during the latter half of the day even if grazing continues throughout the day. This feature is apparent at the surface layer and is also true for the SCML and the chlorophyll minimum layer. Similar diel variations in *Synechococcus* abundances were also observed in the equatorial Pacific (DuRand and Olson, 1996) and Sargasso Sea (Olson et al., 1990) where the maximum was found near dusk. Similar to this study, the amplitude of the dial variation tended to decrease with depth in the equatorial Pacific (DuRand and Olson, 1996).

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