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NUTRIENT AVAILABILITY AND THE DYNAMICS OF THE PLANKTON PRODUCTION IN THE SOUTHERN BLACK SEA, THE SEA OF MARMARA AND THE NORTHEASTERN MEDITERRANEAN

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ABSTRACT

Recent changes have been documented in the riverine discharge in the northwestern shelf of the Black Sea in both diminished flow and in nutrient concentrations (decrease in Si and increase in NO_3) (Cociasu et al, 1997) and these changes have caused increases in both amplitude and frequency of phytoplankton blooms with major shifts in taxonomic groups (Bologa et al.,1995; Humborg et al., 1998). Between the 1960-1980 the proportion of non-diatoms has increased eight-fold and during 1980s average phytoplankton biomass in the NW shelf inceased eight-fold (Bologa et al., 1995). These changes are evident in the deep region of the sea as rates of primary production and chlorophyll-a concentrations have both doubled between the mid 1970s and early 1990s (Vedernikov and Demidov, 1993). According to Sorokin (1983) and Vedernikov & Demidov (1993), in 1970s and 1980s, primary production in the Black Sea displayed two phytoplankton maxima throughout the year; the major one occurred in early spring while a secondary peak appeared in autumn. Recently (1990s), additional summer blooms have frequently been observed in both the coastal and open waters (Hay & Honjo, 1989; Hay et al., 1990, 1991; Sur et al., 1996; Yilmaz et al., 1998). Water transparency has significantly changed in the Black Sea in the recent years (Vladimirov et al., 1997). 60 years, Secchi disk depth had decreased from 20-21m to 15-16m (between 1920-1980). The values in excess of 15 m were no longer observed after 1990 and the mean values were only 6-10 m in the 1990-1993 period and then it started to increase again after 1993. The main reason for the drastic decrease in the water transparency was the enhanced bloom of Peridinium and Coccolitophores during 1986-1992 period. The interannual variations observed in the chlorophyll-a concentrations after 1990s were more significant and pronounced than the ones observed in 1970s and 1980s. It was observed that the general trend was the increasing of different index of pelagic productivity during the last 40-50 years (1950s, 1960-1990s) (Vedernikov and Demidov, 1993; 1998; Yilmaz et al., 1998).

Coastal waters of the Black Sea are principally fed by the riverine input whereas the cyclonically dominated open ecosystem is mainly controlled by the influx of nutrients from the oxygenated lower layers by vertical diffusion and wind induced mixing processes that is much effective in winter. However, the input from the anoxic layer is limited due to the presence of a permanent halocline in the Black Sea. Halocline coincides with the suboxic zone where intense denitrification and redox-dependent processes also limit nitrogen and phosphorus input to the productive layer. In comparison, the role of atmospheric sources of nutrients appears to be marginal (Kubilay et al., 1995). The surface mixed layer in the Rim Current is enriched with nitrate but drastically poor in phosphate. There are thus very high N/P ratios in the upper nutricline and these P-limited waters are mixed vertically with the surface waters in winter and early spring, bloom in such areas is limited by phosphorus. Nitrate-limited production occurs in the central gyres due the low N/P ratios of the chemocline established just below the euphotic zone. The relatively high molar N/P ratios (~ 20) of POM indicate that the anomalously low ratio of nitrate/phosphate in the oxic/anoxic interface of the entire deep basin is due to nitrate removal via denitrification, greatly exceeding P-export from the suboxic waters. Bioassay experiments supported the phenomenon that the central Black is nitrogen limited while the coastal areas are phosphorus limited.

The depth-integrated production rates determined in the last three years ranged from 50 to 700 $mgC/m^2/d$ in the Black Sea and the maximum rate is still lower than the values already known for the NW shelf and off the Romanian coast for the 1970-1980 period (Bologa et al., 1995) and similar to those of the central Black Sea given for the late 1980 and early 1990s (Vedernikov and Demidov 1993). Photosynthetic carbon production rates are relatively higher at the near surface layer down to the 10 % light depth but the phytoplankton populations locating at more lower light levels (at 1%) in the central open regions and below the 0.1% light depth in the Rim Current regions are evident. The vertical distribution of *in situ* fluorescence and chlorophyll-a show a general trend of having subsurface maximum at 1% light level and a secondary peak at <0.1% light depth in the Rim Current region. These populations are capable of doing photosynthesis when they are exposed to sufficient light. In general the biomass indices (e.g. chl-a, *in situ* fluorescence and phytoplankton abundance etc.) show homogeneous vertical distribution in the water column in winter and early spring months. Chlorophyll-a concentrations were measured in the range of 1-2 μg/L in the central regions and 4-6 μg/L in the coastal region for the bloom periods in the years of 1990s.

The eastern Mediterranean is one of the well known region of low productivity in the world due to limited nutrient supply to its surface layer from external and internal sources (Bethoux, 1981, Dugdale and Wilkerson 1988). The seasonality and the magnitude of primary productivity are principally determined by the extent and duration of winter mixing which provides nutrient input from intermediate layers to the euphotic zone (Krom et al., 1992; Yilmaz and Tugrul, 1998; Ediger and Yilmaz 1996). Chlorophyll-a concentrations measured in the last 3-4 years ranged from 0.01-0.5 μg/L in summer to 0.1-1 μg/L during the late winter-early spring bloom period. A well-developed deep chlorophyll maximum (DCM) near the base of the euphotic

zone is a characteristic feature of the Northeastern Mediterranean throughout almost the whole year while this peak was broadened and observed at shallower depths during bloom periods (Krom et al., 1992; Berman et al., 1984; Azov et al., 1986; Yilmaz et al., 1994; Ediger and Yilmaz, 1996). Nevertheless this prominent feature may disappear under severe winter conditions, as experienced in the late winter of 1992 (Ediger and Yilmaz, 1996).

The deep water of the Northeastern Mediterranean is relatively rich in dissolved inorganic nutrients (NO_3=4-6 μM and PO_4=0.15-0.22 μM) but with a relatively high N:P ratio (=26-28) compared to the deep oceanic values (=14-17) (Takahashi et al., 1985). Therefore, nutrient inputs from the deep layer to the surface waters by advective and convective mixing in winter occur with the indicated high ratios (Yilmaz and Tugrul, 1998). This process most probably leads to phosphorus-limited algal growth in the euphotic zone of the eastern Mediterranean (Krom et al., 1991; Zohary and Robarts, 1996). The bioassay experiments proceeded in the last two years supported this phenomenon and when the excess amount nutrients were provided to the phytoplankton populations, phosphorus seems to stimulate the growth. Moreover, the limited nutrient supply from the deep waters with relatively high N/P molar ratios of dissolved nutrients is expected to affect the chemical composition of biogenic particles synthesized in the euphotic zone and it has been shown that N/P molar ratio in POM is generally higher than the Redfield ratio. The primary production rates were determined in the range of <100-400 $mgC/m^2/d$ in the Northeastern Mediterranean for the 1995-1998 period and the relatively higher production rates were recorded for the near surface waters. On the other hand the phtoplankton populations locating the at the DCM depths are highly capable of doing photosynthesis when they have been exposed to sufficient light and they produce almost equal amount of organic carbon with the phytoplankton which habitat the near surface layer.

The Sea of Marmara is a land-locked basin with shallow and narrow straits connecting the Black and Mediterranean seas. Primary production is always limited to the upper less saline Black Sea origin waters (the top 20m) and the subhalocline waters of Mediterranean origin are relatively rich in nutriens (NO_3+NO_2=8-10 μM and PO_4=0.8-1.2 μM) but depleted in dissolved oxygen (30-50 μM) throughout the Marmara basin. The lower boundary of the surface layer coincides with bottom of the euphotic zone as well as the nutricline in the Sea of Marmara. The primary production which was estimated as in the range of 200-400 $mgC/m^2/d$ for the 1995-1998 period and the POM export to the lower layers remain nitrogen limited and this suggestion (Polat et al., 1998) was confirmed by bioassay experiments which were proceeded in 1997-1998 period. There are two main sources of nutrients in the Sea of Marmara: one is the direct input from the Black Sea (both in inorganic and organic forms) and the other is the input from the nutricline through diffusion and vertical mixing and advection processes. The Sea of Marmara represents a transition state between the Black and Mediterranean seas if one considers euphotic zone processes and ecosystems dynamics of the phytoplankton populations.