Proceedings of the “Second International Conference on Oceanography of the Eastern Mediterranean and Black Sea: Similarities and Differences of Two Interconnected Basins”

METU Cultural and Convention Center
Ankara, TURKEY
14-18 October, 2002

Oceanography of the Eastern Mediterranean and Black Sea

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Similarities and Differences of Two Interconnected Basins

Eker-Develi, E., Kideys, A. E., Tugrul, S., Yılmaz, D., Ediger, D. 2003. Phytoplankton dynamics in the dynamics in the northeastern Mediterranean with respect to dust deposition. Proceedings of “Second International Conference on Oceanography of the eastern Mediterranean and Black Sea: Similarities and differences of two interconnected basins, 14-18 October 2002, Ankara, Turkey, Yilmaz, A. (Eds), pp. 687-694.

Phytoplankton dynamics in the northeastern Mediterranean with respect to relative dust deposition

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Abstract- In order to understand the effect of atmospheric dust deposition on phytoplankton abundance and biomass, surface waters of two stations (one shallow and one deep) in the northeastern Mediterranean were monitored along with usual physico-chemical parameters and satellite observation on atmospheric dust as well as precipitation data during December 2000 and April 2002. In terms of abundance, *Emiliania huxleyi* almost always dominated the phytoplankton at the deep station, while in the shallow station diatoms were the dominant group. However, in the study area, even during their high occurences in autumn, the maximum concentration of *E. huxleyi* did not exceed 50,000 cells l^{-1} which is much lower than those reported from the Black Sea and northeastern Atlantic during bloom periods which were shown to cause high reflectance from satellite observations. High reflectance events rarely coincided with high *E. huxleyi* (or diatom and dinoflagellate abundance). For the deep station, phytoplankton abundance and biomass increase was observed rarely (one case in March and possibly in December 2001-January 2002) following the wet deposition. Dry deposition seemed to increase nutrient levels (i.e. in March and August) but not necessarily phytoplankton quantities probably due to either other suboptimal (e.g. strong vertical mixing) conditions or phosphate limitation.

Key words: Phytoplankton, Northeastern Mediterranean, Nutrients, *Emiliania huxleyi*, Saharan dust

Introduction

Atmospheric deposition is an important source of nutrients (NOx, NH_4, PO4 and iron) for the oligotrophic seas and oceans. According to calculations, atmospheric inorganic phosphorus (IP) and inorganic nitrogen (IN) deposition (dry + wet), mainly during dust events and stratification, can support between ~15 to 70% (1-4 g C m^{-2} yr $^{-1}$) of the new production in the southeastern (SE) Mediterranean (Herut, 2002). Dry deposition is more important than wet deposition in the SE Mediterranean in terms of leachable (bioavailable) IN and IP due to the semiarid future of this region compared to the western part. Dry deposition of leachable inorganic nitrogen to the eastern Mediterranean is about twice higher than riverine, while dry deposition of inorganic phosphorus is somewhat lower than riverine input. In addition, Dulac *et al*. (1996) reported that atmospheric supply of dissolved Fe to the oceans is ~3 times higher than that delivered via rivers. Saydam (1996) suggested that the wet deposition of reduced iron from desert dusts to the surface waters of the Mediterranean, during the day, has the potential to induce phytoplankton blooms. He further claimed that the coccolithophorid *Emiliania huxleyi* blooms, which were triggered by reduced iron, cause high reflectance in the satellite images of NOAA-AVHRR due to their calcium carbonate scales.

Even though there are studies estimating the importance of nutrients coming with dust for the seas (Herut, 2002; Herut *et al*. 1999, Ozsoy and Saydam, 2001), except Walsh and Steidinger (2001)'s recent work, the effects of dust deposition on the abundance, biomass and composition of phytoplankton were not jointly studied (Dulac *et al*., 1996). Weekly or biweekly phytoplankton (as well as other oceanographic) samples collected during and after wet and dry deposition events (detected from satellites images of Seastar-SeaWIFS and NOAA-AVHRR) in a shallow and a deep station in the NE Mediterranean during December 2000 – April 2002 were analyzed to investigate this problem.

Material and Methods

Samples were taken by using a 5 l Niskin bottle from 0.5 and 15 m in the shallow station (36.33Nº, 34.15Eº) and 0.5, 25, 50, 75 and 100 m in the deep station (36.30Nº, 34.24Eº) between December 2000 and April 2002 (Fig. 1). The satellite images on chlorophyll (as well as nutrient levels, unpublished data and Fig. 6) suggest that, at least for most of the year, and the deep station which is 8 miles offshore do not seem under the direct influence of coastal rivers (e.g. Lamas, Goksu and Seyhan). This is important as coastal processes may shadow any effect from the atmosphere.

Phytoplankton samples were taken into one-litre dark bottles and preserved by buffered formaldehyde to obtain a final concentration of 2.5%. Samples were concentrated by sedimentation method (Eker *et al.*, 1999). The micro and nano-phytoplankton were counted using a Sedgewick-Rafter cell and Palmer Maloney Counting Chamber under a phase contrast binocular microscope. The volume of each cell was calculated by measuring its appropriate morphometric characteristics (i.e. diameter, length and width) (Hillebrand *et al*., 1999). Volume values were converted to biomass assuming 1 μm^3 equals to 1 pg.

The temperature, salinity and density of the water column were measured with a SeaBird CTD probe. For analysis of conventional chemical (PO_4-P, NO_3-N and Si) parameters, seawater samples were taken from different depths of the two stations. Nutrient samples were taken into acid-cleaned polyethylene bottles and kept frozen for a few weeks until analysis by a Technicon Model three-channel Auto-analyzer (Strickland and Parsons, 1972). Satellite images of NOAA-AVHRR were downloaded from the internet sites of http://isis.dlr.de/services/ISIS/ISIS-query.html (German Remote Sensing Data Center, DFD, ISIS-Intelligent Satellite Data Information System) and http://noaa.bilten.metu.edu.tr (TÜBİTAK-METU-Bilten) while, Seastar-SeaWIFS images were taken from http://seawifs.gsfc.nasa.gov/cgibrs/seawifs_browse.pl (Fig. 2). Precipitation values were obtained from Erdemli Meteorological Station, which is ~10 km far from the shallow sampling station.

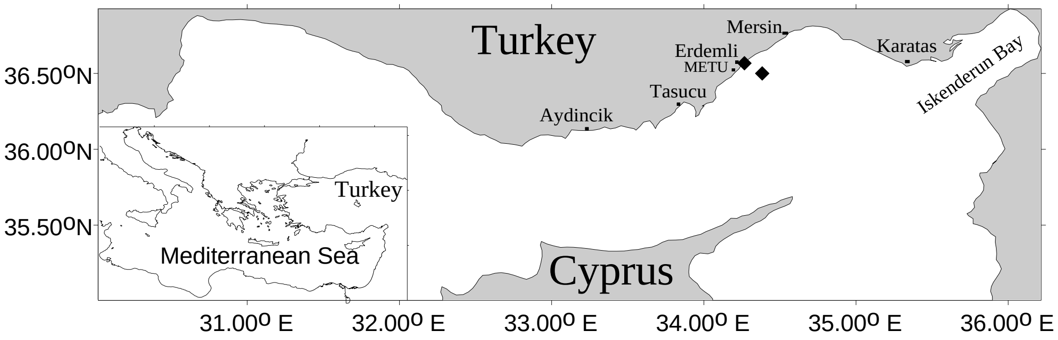


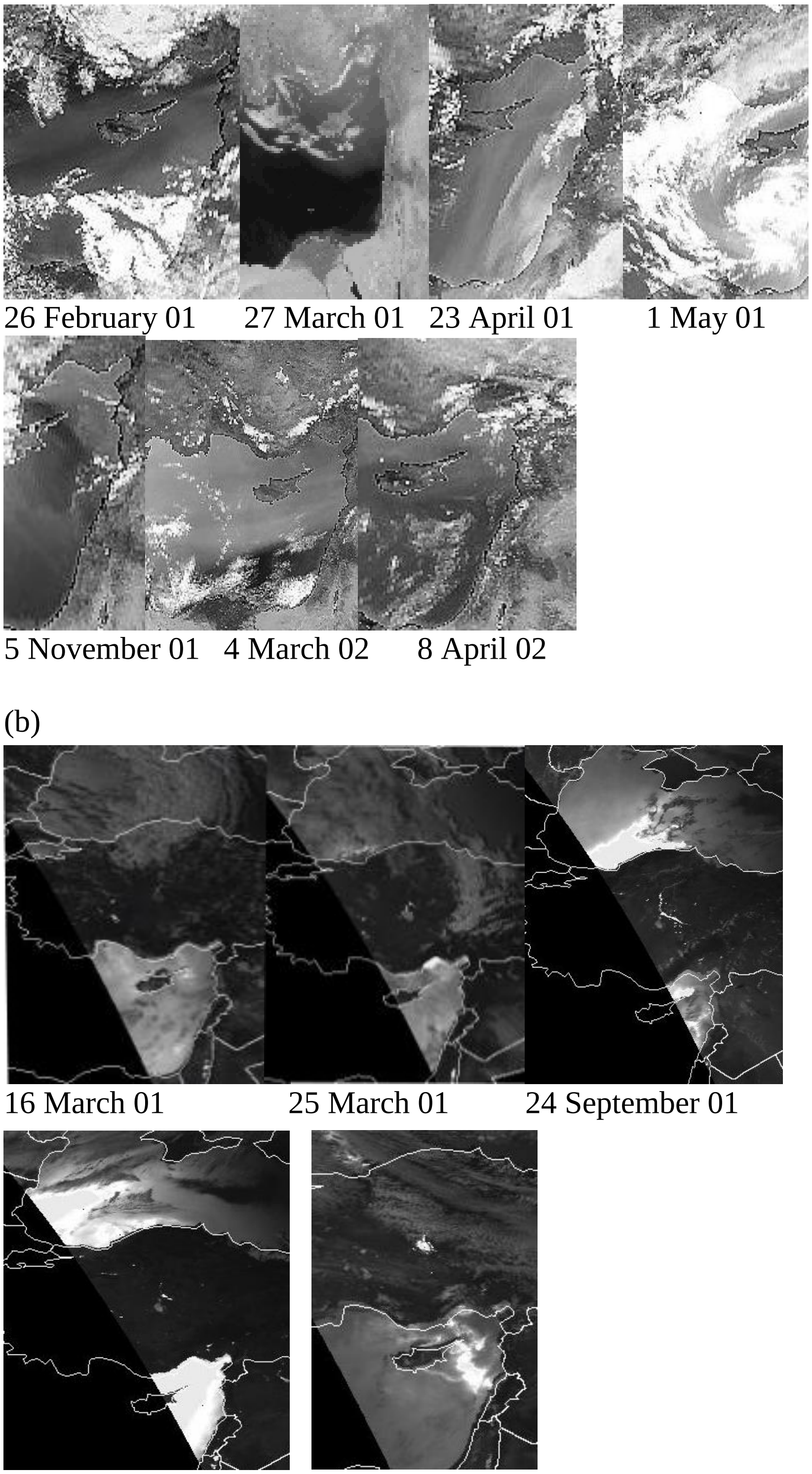
Figure 1. Sampling stations between December 2000 and April 2002.

Results

According to SeaWIFS images, dust was transported towards the study area episodically during the sampling period with a higher intensity in spring (Fig. 3a). Conclusive relationship could not be observed when abundance and biomass of phytoplankton groups were compared with the wet (excluding one case in March) and dry dust deposition (excluding one case in August) events observed from the satellite images.High reflectance events were mainly observed in spring and late summer-autumn period (Fig. 2). The coccolithophorid *Emiliania huxleyi* did not reach to bloom concentrations (which is assumed to be ~1000,000 cells l^{-1}) during the sampling period but maximum concentrations of this phytoplankton species was reached in late autumn (Fig 3b). In parallel, the number of coccoliths was also very low (details not given here). High reflectance events rarely coincided with high *E. huxleyi* (or diatom and dinoflagellate abundance) (Fig. 3b). In winter there was not any high reflectance event observed from the NOAA-AVHRR images as shown in Figure 2.

Nutrient concentrations (mainly IN and IP) were almost twice higher at the shallow station than at the deep station between December 2000 and November 2001 (Fig. 4). Related with this, both total phytoplankton abundance and biomass values were higher in the shallow station than at the deep station (Fig. 5). The difference between the deep and shallow station in terms of total abundance and biomass was much lower in late autumn - winter months (from October to March). During the rainy period (e.g. December 2001 – April 2002), nitrate and silicate concentrations increased more than 10 fold at the shallow station, which could be mainly contributed by the coastal leaching (Fig. 4b). In contrast, nutrient concentrations at the deep station did not appear to increase above the summer values (i.e. the dry period) during the rainy period (Fig. 4a). However it should be noted that, more notably for the deep station, the highest phytoplankton quantities were observed in winter and spring months.

According to Spearman Rank Correlation analysis, the precipitation was positively correlated with diatom abundance at the deep station only ($p<0.05$). Among nutrients only silicate concentration was positively correlated with diatom and total biomass at the deep station. No correlation was found between other nutrients (nitrate+nitrite and phosphate) and phytoplankton quantity at both the deep and shallow station.



26 February 01 27 March 01 23 April 01 1 May 01

5 November 01 4 March 02 8 April 02

(b)

16 March 01 25 March 01 24 September 01

2 October 01 9 April 02

Figure 2. Most intense dust transport (a) and high reflectance (b) events during the study period

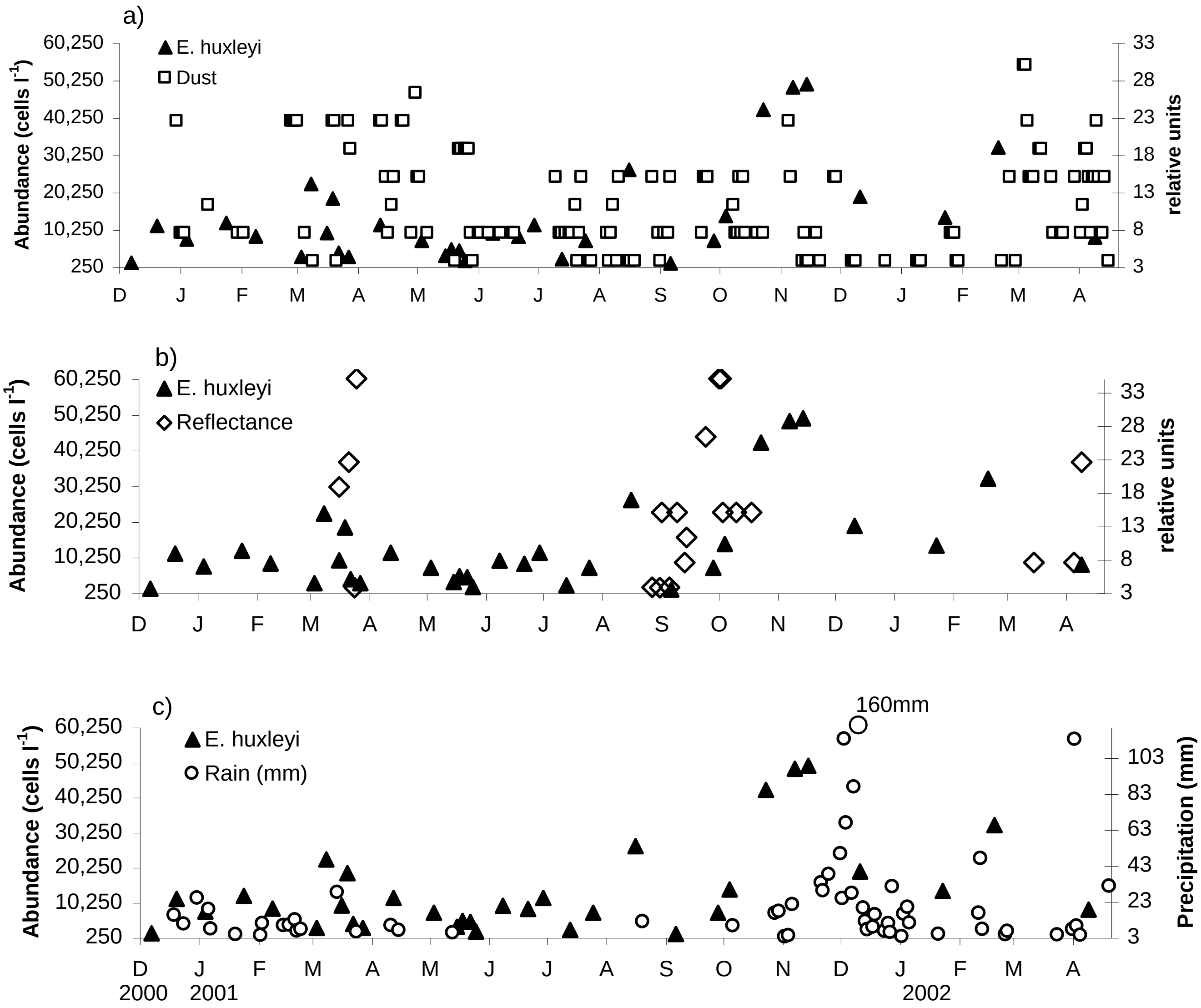


Figure 3. Comparison of *E. huxleyi* abundance with a) relative dust load and b) relative high reflectance observed from the satellites and c) precipitation events.

Diatoms had the highest biomass during the study period (Fig. 5a, c). Their contribution to the total abundance was also high at the shallow station while at the deep station the coccolithophorid *E. huxleyi* was generally more abundant than diatoms (Fig 5b, d). Both abundance and biomass of dinoflagellates were generally lower compared to diatoms during the year (Fig. 5).

Discussion

There are several investigations reporting the importance of nutrients coming with atmospheric deposition for the oligotrophic seas (Herut *et al.* 1999; Herut and Krom, 2002; Saydam and Senyuva, 2002; Guerzoni *et al.*, 1999) but these studies do not directly compare dust deposition events with biological data (i.e. mainly primary producers). Only Walsh and

Steidinger (2001), after analysing phytoplankton samples, reported that majority of Florida red tides was initiated when 71% of annual Saharan dust loading arrived during June-August when 47% of the annual rainfall also occured.

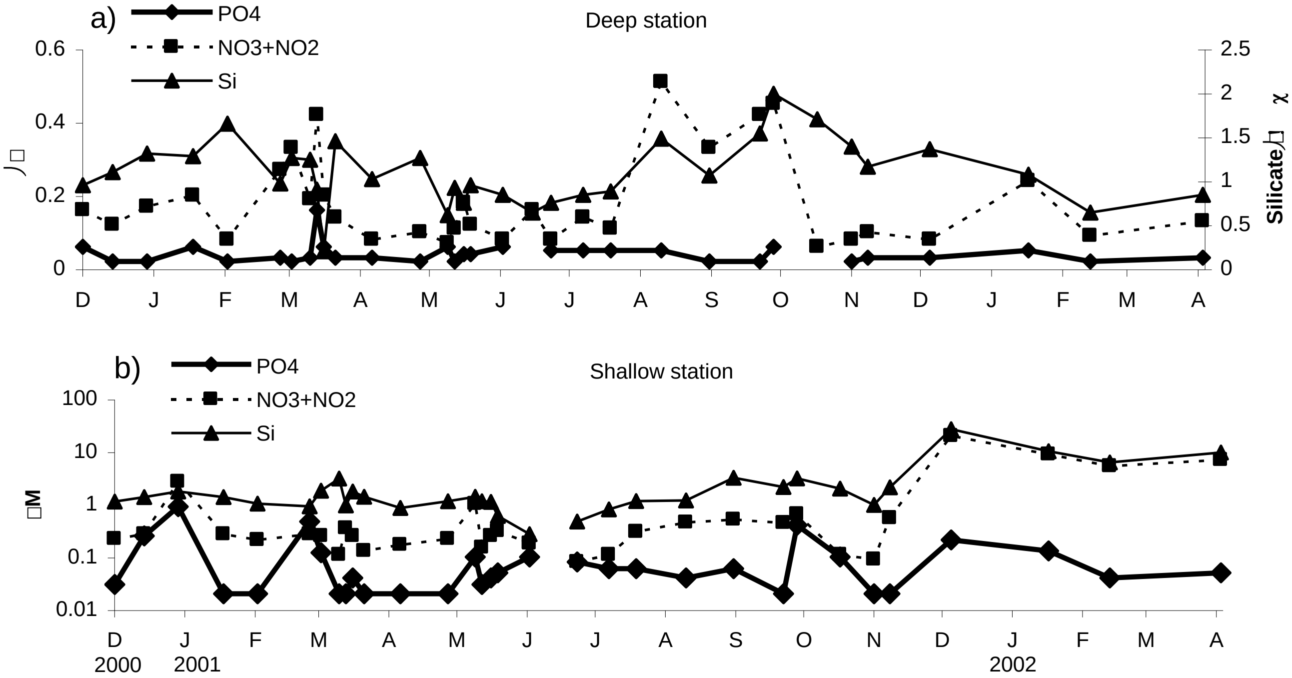


Figure 4. Surface nutrient concentrations a) at the deep, b) at the shallow station between December 2000 and April 2002.

In this study, relationships between the quantity (or composition) of different phytoplankton groups and atmospheric deposition (either wet or dry, as observed from satellites) were not conclusive. However, the rain itself could be a reason for the rise of nutrient levels and consequently phytoplankton abundance and biomass, regardless of Saharan dust accumulation at the atmosphere prior to precipitation. Maximum total phytoplankton abundance and biomasses were observed following the high precipitation events on 13th March 2001 and in December 2001-January 2002 (Figs. 3c, 5). However, according to statistical analysis no correlation was found between precipitation and nutrients (nitrate, phosphate and silicate) probably due to the consumption of nutrients by phytoplankton.

Positive correlation between silicate concentration and diatom biomass at the deep station may indicate that silicate input to the surface waters from either deep waters or atmosphere caused higher total diatom biomass. Increased nutrient and phytoplankton concentrations at the deep station observed in August could be either due to dry dust deposition or lateral transport from coastal areas. There was a strong stratification in this period and surface nutrient concentrations were higher than at the deeper depths (the figure is not shown here).

At the shallow station, local river input was more important than precipitation or mixing. Because of this, abundance and biomass of phytoplankton was high in late spring – summer months when river contribution was at highest levels (causing minimum salinity) at the shallow station in contrast to the deep station. Fast changes due to the terrestrial input and consumption by phytoplankton can be the reason for the absence of correlation between phytoplankton groups and nutrients at the shallow station.

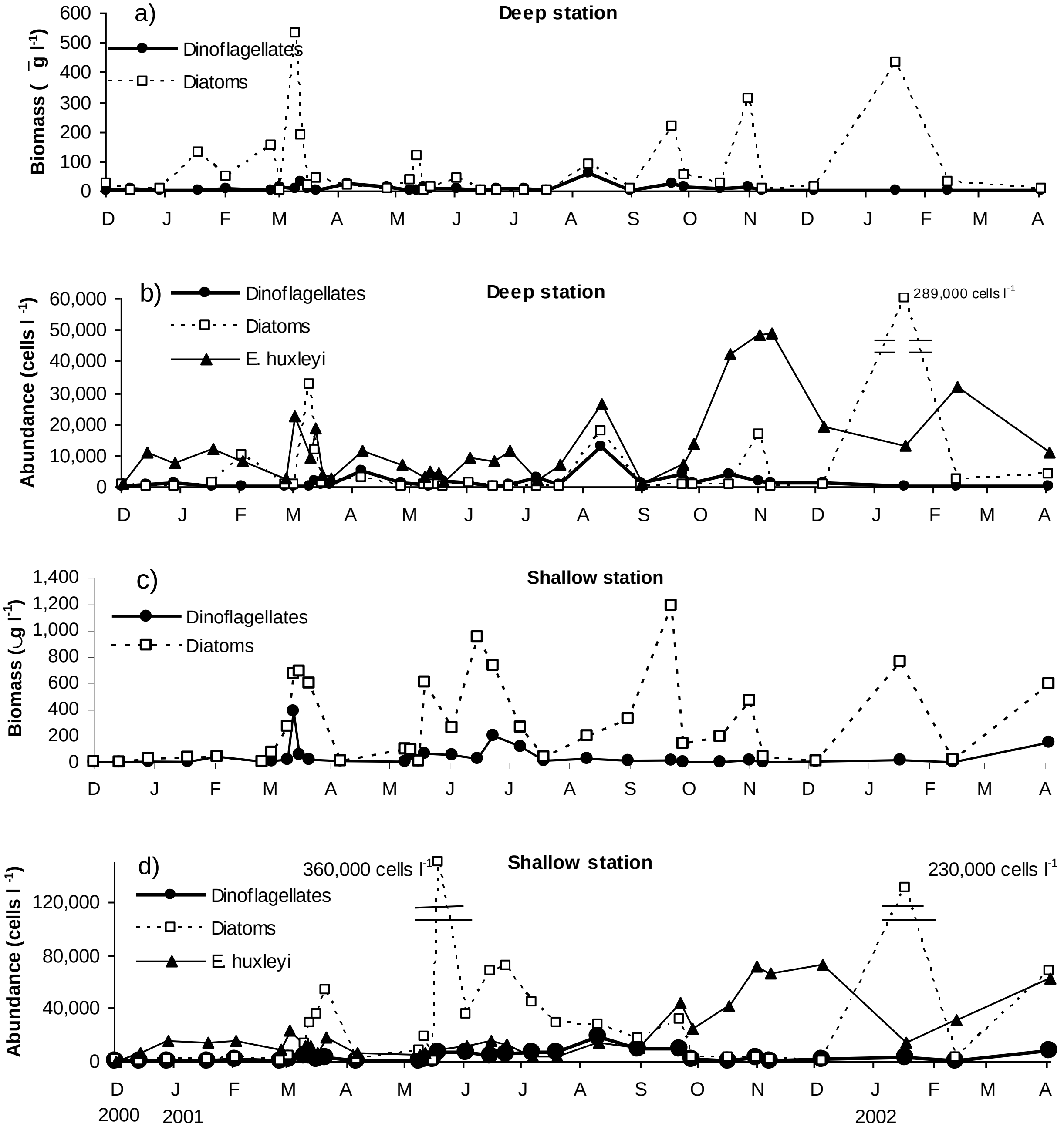


Figure 5. a) biomass and b) abundance of different phytoplankton groups at the deep station c) biomass and d) abundance of different phytoplankton groups at the shallow station between December 2000 and April 2002. (Diatoms formed >85% of total biomass while *E. huxleyi* and diatoms constituted >85% of total abundance both at the deep and shallow station)

Total phytoplankton abundance and biomass were higher at the shallow station related with the high nutrient concentrations (Fig. 4), most probably caused by fresh water discharges polluted by anthropogenic inputs of various origins. In winter, phytoplankton abundance and biomass values at the deep and shallow stations were relatively close to each other as compared to late spring-summer months. Low phytoplankton abundance and biomass at the deep station in summer months could be due to the nutrient limitation because of the stratification, most probably due to selective depletion of dissolved phosphate and iron ions in the seasonally stratified waters of the euphotic zone.

Diatom abundance was higher compared to dinoflagellates in the study area similar to previous investigations in the eastern Mediterranean Sea (Polat *et al.* 2000; Eker and Kideys, 2000; Lakkis, 1981).

Our data show that high reflectance events observed from the satellite images could not be suggested to be solely due to *E. huxleyi* in the study area. Moreover, the atmospheric deposition (not necessarily the wet one) input seemed to be important for all phytoplankton groups only during strong stratification period in our study, when phosphate-depleted river discharges to near-shore waters decrease to their lowest flow levels in summer-autumn months.

Acknowledgement *This study was supported by TUBITAK Project no: YDBAG 100Y-017. We are thankful to the crew of the R/V Erdemli.*

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