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PHYTOPLANKTON VARIABILITY IN THE EASTERN HARBOUR OF ALEXANDRIA DURING 2000

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ABSTRACT

Assessment of short-term phytoplankton variability was conducted at a fixed station in the Eastern Harbour of Alexandria (Egypt) from January to November 2000. The persistent variations resulted from the variable interplay among the continuous variability of the physical and chemical habitat properties. The high fertility observed and the occurrence of several blooming pulses, caused by less than a dozen species, at intermittent periods in summer and fall could be attributed to anthropogenic eutrophication and geographical dispersion from neighboring areas into the harbour.

The occurrence of distinct increasing diatom population during mid- winter and the phyto-flagellate bloom in early spring contributed important features of the annual phytoplankton variability cycle.

The study documented the rapid change in the phytoplankton community structure and species composition. Another different causative species could replace a dense phytoplankton bloom immediately after its dissipation.

Short-term scale sampling (at least twice per week) proved to be advisable to describe the actual processes of habitat-phytoplankton variability in such a highly dynamic marine basin.

The applied statistical analyses suggested an important role for the water salinity to control phytoplankton variability. Yet, it is

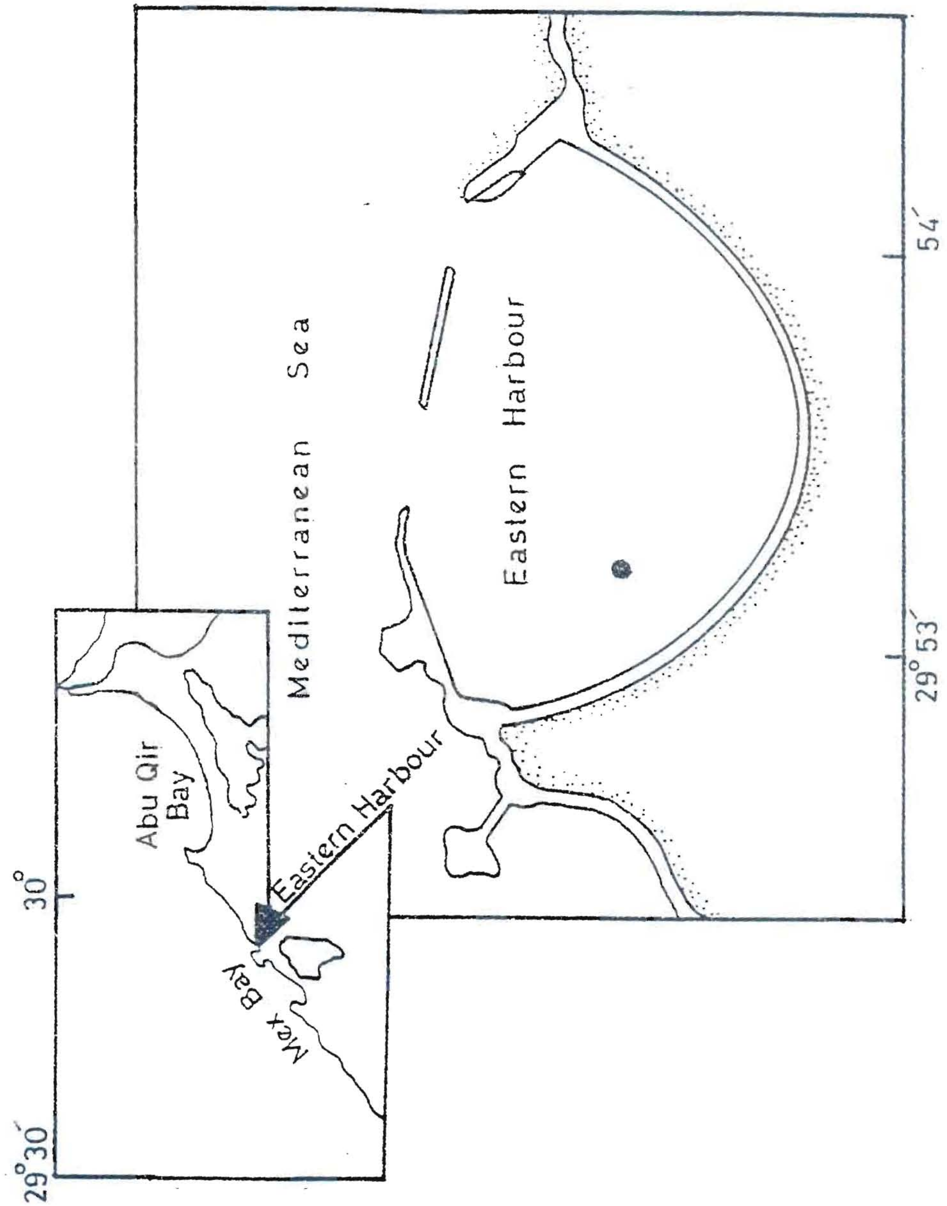

Fig.1 - The Eastern Harbour of Alexandria and location of the sampling station (●).

with the community structure. The statistical program system (NCSS, Hintze, 1993) was used.

RESULTS

Habitat variability

The surface and the over bottom temperature and salinity measurements and the surface concentrations of nutrients are shown in Figure 2.

Distinct seasonal temperature variations could be observed. Surface water temperature oscillated between 12.3 °C (in January) and 28.5 °C (in late August). It increased by 3 °C in late February-early March. Two thermal regimes can be observed. The first extends from January to early April with a homothermal condition and/or inverse thermal stratification. The second lasted from mid-April to early November when the surface water was normally warmer than the above bottom. The highest difference between the surface and over-bottom temperature reached 2 °C in late July.

The correlation matrix of physico-chemical measurements and the standing crop is given in Table 1, while salinity against the standing crop is shown in Figure 3. Temperature is insignificantly correlated with the standing crop ($r = 0.157$, $p \leq 0.05$, $n = 97$), probably due to the wide temperature range and the occurrence of different blooming pulses during the different seasons. It is difficult to define a certain limited temperature range when the phytoplankton bloomed within. Temperature also is insignificantly correlated with the variability of the phytoplankton groups, relatively higher with euglenophytes, and it was negatively correlated with microflagellates. Yet, temperature could be an important factor affecting blooms at time.

Table (1): The correlation matrix

	Temp.	Salin.	$NO3^{1-}$	$SiO4^{4+}$	$PO4^{3-}$	Diat-oms	Dino.	Micro.	Eugl.	St. crop
Temp.	1.0									
Salin.	$\underline{-0.4}$	1.0								
$NO3^{1-}$	$\underline{-0.5}$	0.1	1.0							
$SiO4^{4+}$	$\underline{-0.3}$	0.1	$\underline{0.6}$	1.0						
$PO4^{3-}$	-0.2	0.0	$\underline{0.4}$	$\underline{0.6}$	1.0					
Diatoms	0.1	$\underline{-0.5}$	0.0	$\underline{-0.2}$	-0.1	1.0				
Dino.	0.1	0.0	-0.2	0.2	$\underline{0.3}$	0.0	1.0			
Micro.	-0.1	0.0	-0.1	-0.1	-0.2	-0.1	0.0	1.0		
Eugl.	0.2	-0.2	0.0	0.0	0.2	0.2	0.2	0.0	1.0	
St. c.	0.2	$\underline{-0.3}$	-0.1	0.0	0.1	$\underline{0.7}$	$\underline{0.7}$	0.1	$\underline{0.3}$	1.0

Values under line = significant at $p \leq 0.05$ level

The seasonal variability of the surface salinity was fairly large. Salinity can be as high as 39 ppt, but values between 35 and 37 ppt were common.

Despite the large fluctuations occurred, prominently some features are detected; surface salinity >38.5 ppt from January to early spring, it was the period of homohaline condition and/or slightly higher values over the bottom. This was followed by a sharp decrease from mid-April till early November, while salinity over the bottom was always higher, with 35.8 - 39 ppt. The salinity profile indicated a weak halo-stratification to be existed by late March, and it was distinctly developed during the rest of the period (the highest difference of 2.2 ppt measured during the third week of June between the less saline surface water and that over the bottom).

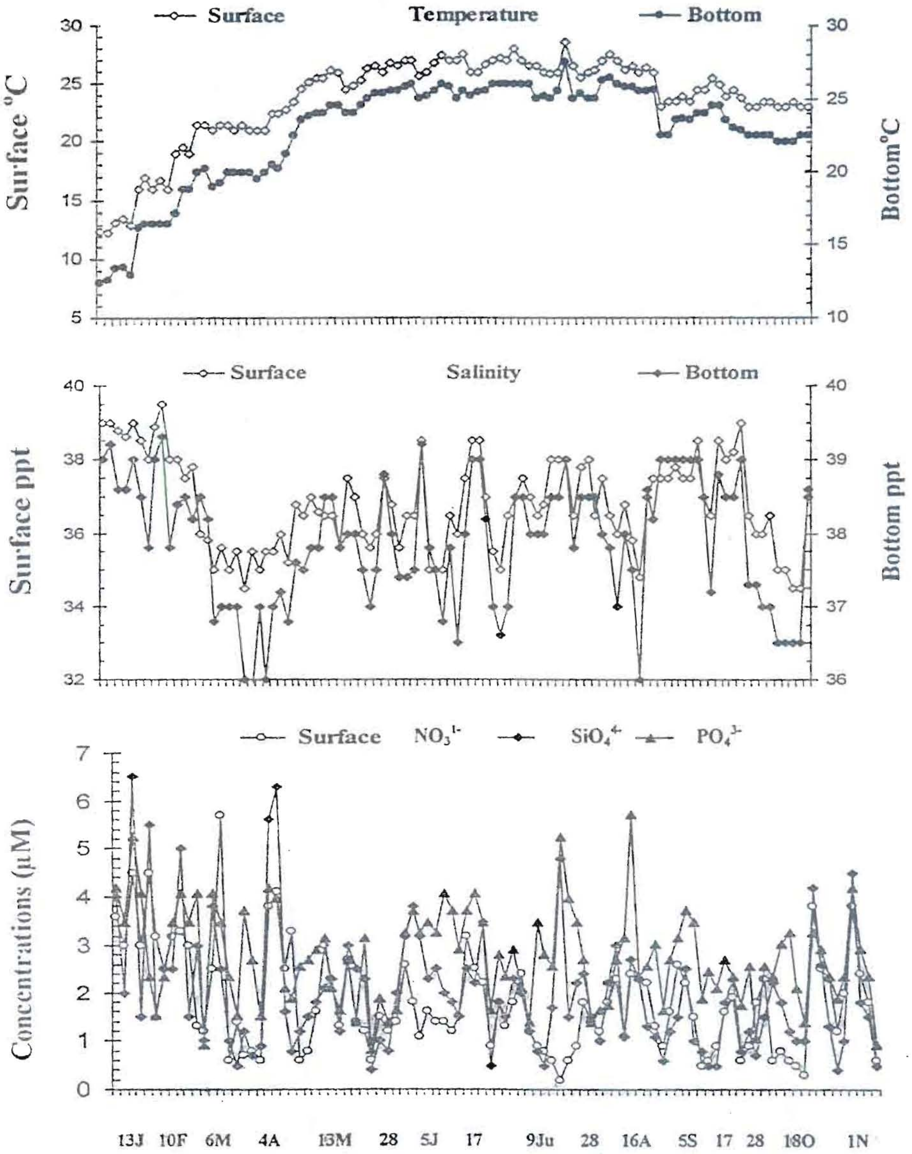

Figure 2. Variability of temperature, salinity and nutrient concentrations in the Eastern Harbour from January to November 2000.

Salinity seems to represent the most important factor controlling the standing crop variability, with a significant inverse correlation ($r = -0.35$, $p \leq 0.05$, $n = 97$), as well as with diatoms, which contributed most of the standing crop ($r = -0.48$, $p \leq 0.05$, $n = 97$).

Despite the large seasonal nutrient variability, some features are distinguished; building-up of high concentrations in winter (10 February - 25 March), which seem enhancing the standing crop and/or associated with limited phytoplankton growth at times; the high concentrations generally extended till the second week of May; and it was generally followed by a pronounced decrease in summer and fall accompanying intensive phytoplankton occurrence; the fast recovery of the nutrients affected by the input of discharge water; and a bloom triggering is not necessary to accompany or follow a period of enhanced nutrient concentrations and even intermediate values are sufficient to achieve its peak (late October - early November). Surface nitrate (NO_3^{1-}) fluctuated between 0.2 - 4.5 µM, silicate (SiO_2^{4+}) 0.4 – 6.5 µM, and phosphate (PO_4^{3-}) 0.8 – 4.9 µM. Generally, silicate concentrations were relatively lower than nitrate and phosphate due to its sever exhaustion by the occurrence of several successive blooming pulses, mostly of diatoms. Meanwhile, the very low nitrate and silicate concentrations coinciding with the phytoplankton blooms in summer and fall may explain these elements are controlling growth factors at times. Relatively high phosphate concentrations were associated with the intensive occurrence of phyto-flagellates in April, July and August.

The statistical matrix indicates insignificant correlation of nitrate, silicate and phosphate with the standing crop (Table 1). Yet, diatoms seem to be affected by silicate, and dinoflagellates by phosphate ($r = -0.205$ and 0.279, respectively, $p \leq 0.05$, $n = 97$).

Phytoplankton variability

The standing crop gained an average of 4.5×10^{6} cell. l^{-1}. Diatoms represented the major fraction (84.1 % of the total standing crop), dominating most of the time, and it was followed in abundance by dinoflagellates (12.86 %) and microflagellates (1.3 %), while euglenophytes and silicoflagellates contributed together 1.74 %.

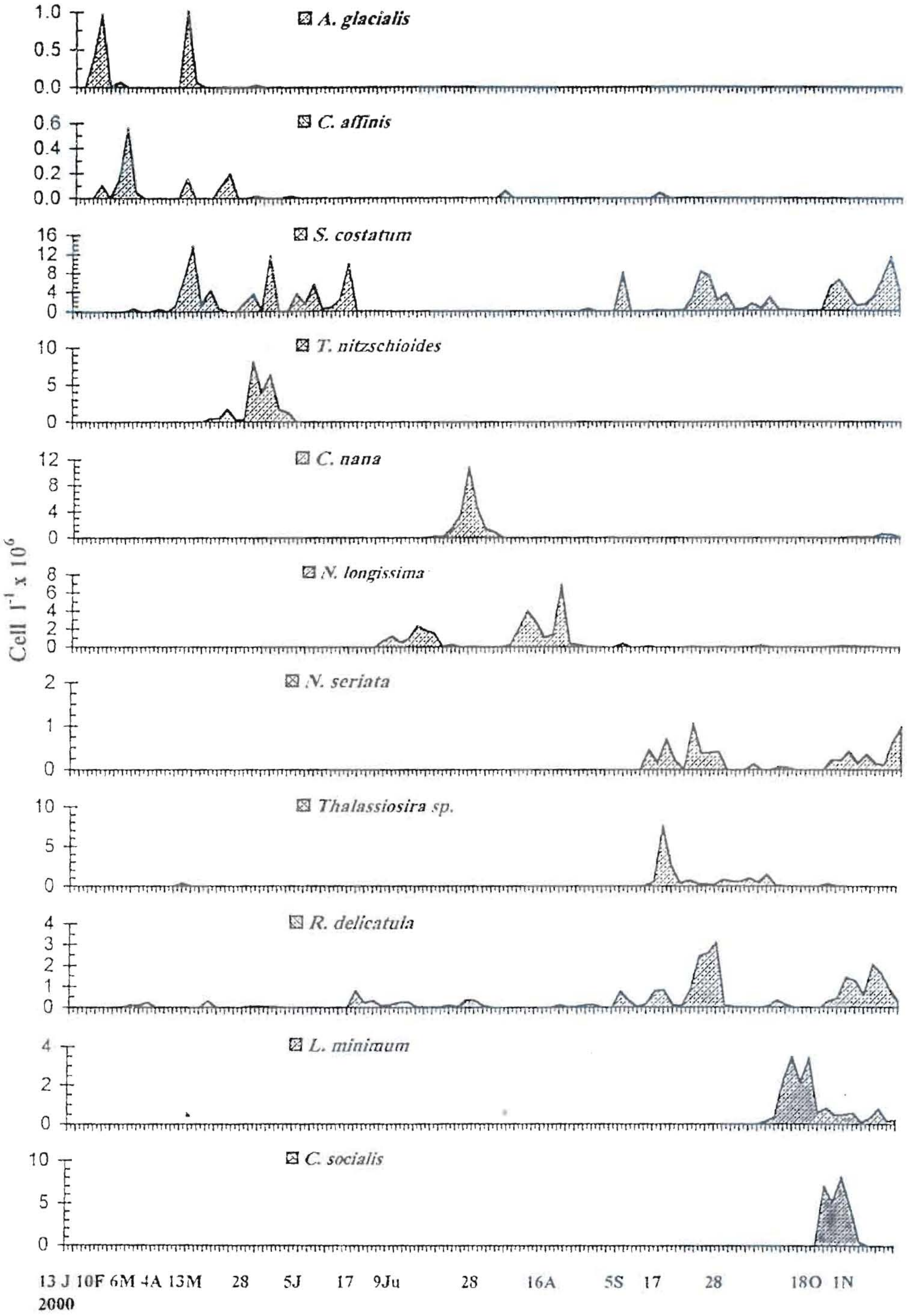

Fig. (5): Dominant diatom species in the Eastern Harbour from January to November 2000.

During May a steady increase in temperature was observed by days. Salinity was severely reduced and values between 34.5 and 35 ppt were frequently measured. The water column was divided into two-layer system with difference of 2 °C and 1.5 ppt on 31 May. The standing crop was rich (average 5.84×10^6 cell. l^{-1}), and several blooming pulses were recorded, indicating rapid change in the species composition. Diatoms contributed about 77 %, and it was followed by dinoflagellates (15.86 %). The phytoplankton succession showed *S. costatum* to be overwhelmingly dominant with its two major peaks on 14 and 31 May (13.8×10^6 and 11.7×10^6 cell. l^{-1}, respectively). The first bloom consumed most of nitrate, while the second one occurred at relatively high concentration (Fig.2). *Thalassionema nitzschioides* represented the main constituent of the community on 29 May (8×10^6 cell. l^{-1}, 57.7%), sharing in active role the dominance on 31 May (6.28×10^6 cell. l^{-1}, 36 %). Other important species in May were *Chattonella antiqua*, *Gymnodinium mikimotoi*, *P. minimum* and several *Chaetoceros* and microflagellate species.

The surface temperature in June showed a tendency to increase by days. Salinity was almost unchanged compared with May, and the water column was also stratified. The standing crop exhibited a wide range of variation (0.6×10^6 – 10.15×10^6 cell. l^{-1}, average 2.96×10^6 cell. l^{-1}). Diatoms formed the major fraction (87 - 99.72 %). The very fast changeable succession declared the predominance of *T. nitzschioides* in the first two days of June (1.6×10^6 and 1.2×10^6 cell. l^{-1}, respectively) and *S. costatum* to achieve its massive occurrence on 5, 7, and 17 June (3.69×10^6, 5.56×10^6, and 10.15×10^6 cell. l^{-1}, respectively). The last bloom reduced nutrient concentrations to its year minimum (Fig. 2). *Gymnodinium mikimotoi* dominated with the end of the month.

Summer (July-September)

Surface temperature oscillated irregularly between 23 and 28.5 °C, and salinity between 34.8 - 38.5 ppt. Several blooming pulses were recorded at intermittent days, with nutrient levels ranged between 1.2 - 2.2 µM for nitrate, 1.8 -3.8 µM silicate, while phosphate was relatively high (3 - 3.5 µM). The standing crop in July was relatively lower compared with June (average 2.56×10^6 cell. l^{-1}), diatoms contributed 77.44 - 97.34 %. The species composition progressed as follows: *Nitzschia longissima* was leading between 6 - 18 July (density exceeding 1.2×10^6 cell. l^{-1}), The partial dissipation of *N. longissima* bloom was followed immediately by another dense one on 26 July, *Cyclotella* *nana*, became the sole causative species, culminating at 10.8x10^6 cell. l^{-1}. Other minor species in July were *S. costatum*, *R. delicatula* and *P. minimum*.

During August, surface temperature reached its maximum on 27 (28.5 °C), salinity was relatively high, but values between 35-35.5 ppt were occasionally measured. The water column was distinctly stratified. The standing crop attained an average of 5.05x10^6 cell. l^{-1}, mainly resulted from the dense red tide bloom of *Prorocentrum triestinum* (38.76x10^6 cell. l^{-1} on 16 August), which partially collapsed on the next day (6.38x10^6 cell. l^{-1}). Otherwise, the density ranged between 0.13x10^6- 4.16x10^6 cell. l^{-1}. The phytoplankton succession indicated *N. longissima* to dominate from 9-17 August, attaining its peak of 6.9x10^6 cell. l^{-1} on the last day. Other numerically important species were *Euglena* spp., *Alexandrium minutum and R. delicatula.*

The physico-chemical parameters measured in September were almost unchanged compared with August, with a sharp decrease in surface temperature in the last two days by 3 °C. The standing crop averaged about 6x10^6 cell. l^{-1}, diatoms formed 78.48 %, followed by dinoflagellates (19.8 %). *S. costatum* dominated on 5 September (8.2x10^6 cell. l^{-1}) and it was shared by *P. minimum* (1.5x10^6 cell. l^{-1}), and *R. delicatula* (0.82x10^6 cell. l^{-1}). Another bloom appeared on 17 September (9.34x10^6 cell. l^{-1}), it was mainly attributed to the overgrowing of a small size *Thalassiosira* sp. (7.58x10^6 cell. l^{-1}, 81 %), followed by *R. delicatula* (0.88 x10^6 cell. l^{-1}), *Nitzcshia seriata* (0.71x10^6 cell. l^{-1}) and *S. costatum* (0.41x10^6 cell. l^{-1}). A distinct change occurred on 24-25 September, *S. costatum* regained the dominance (8.4x10^6 and 7.5x10^6 cell. l^{-1}) accompanied with *R. delicatula* (2.4x10^6 - 2.6x10^6 cell. l^{-1}). This bloom severely affected the concentrations of nitrate and silicate. Other major species were *C. antiqua* and *G. mikimotoi*, while the minor ones included *N. seriata*, *P. triestinum* and *Thalassiosira* sp.

Autumn (October-November)

The surface temperature ranged between 23 - 25.5 °C and salinity between 34.5 and 39 ppt. During October, water column was still stratified within 0.4-1.5 °C and 0.3-1.5 ppt. the standing crop attained an average of 5.18x10^6cell. l^{-1}. Diatoms formed 90.5 %, while dinoflagellates ranked the second level (5.86 %). The species succession showed *S. costatum* to dominate on October 7th with 3x10^6 cell. l^{-1}. The community changed quickly and *Leptocylindrus minimum* became leading between 9-16 October (2.2x10^6 - 3.48x10^6 cell. l^{-1}). The

$$-1654471.7*\text{Salinity}-1362398.91*NO_3^{-} + 235740*SiO_2^{4-} + 1167906*PO_4^{3-}$$
$$R^2 = 0.1739 \text{ (multiple } r = 0.417\text{)}, p \leq 0.05 \text{ level}, n = 97.$$

These measured parameters in combination explain 41.7 % of the phytoplankton variability.Other unmeasured physical, chemical and biological parameters must also be considered.

Salinity was fundamental. The multiple regression equation was:

The standing crop (cell. $l^{-1}x10^6$) = 63422210.79 - 1602225.2*Salinity, $R^2 = 0.122$, $p \leq 0.05$ level, $n = 97$, controlling alone about 35 % of the phytoplankton variability.

According to Smayda (1980), salinity has bearing on the temporal development and spatial distribution of the phytoplankton standing crop, blooming and species succession. The surface salinity sustained an average of 36.8 ppt (range 34.5-39.5 ppt), corresponding well with the previous average in the harbour, estimated as 35.8-37.4 ppt (El- Nady, 1981; Shriadah, 1982; Aboul-Kassim, 1987; Zaghloul, 1988, and Labib, 2000 b).

In case considering salinity, nitrate and phosphate variability, the model showed:

The standing crop (cell $l^{-1}x10^6$) = 59938661 - 1539823*Salinity -1058697* NO_3^- + 13111152*PO_4^{3-}, $R^2 = 0.17$, $p \leq 0.05$ level, $n = 97$, explaining together 41.3 % of the phytoplankton variability, and signaling the very limited contribution of temperature and silicate. However, the seasonal variations in temperature probably could affect the phytoplankton growth at times: the noticeable rise in surface temperature by 3 °C, observed between the last week of February - early March, seems enhancing the phytoplankton population. A similar case was also detected between the second and the third weeks of April, with the triggering of the phyto-flagellate blooms in early spring.

Meanwhile, the increased surface heating and the pronounced salinity differences between the surface and over the bottom created the suitable condition for the phyto-flagellates to bloom. Their occurrence appears to be μM), their bloom was proceeded by enhanced phosphate concentration on 18 April (4 μM). The specific relation between relatively high phosphate concentrations and the massive existence of dinoflagellate species was previously documented in the harbour (Zaghloul and Halim, 1992 and Labib, 2000a), as well as for the *Protoperidinium pouchetii* bloom in the Adriatic Sea (Riegman *et al.*, 1992). According to Pybus (1980) dinoflagellates during their bloom peaks can produce extracellular organic phosphorus, which may be converted into inorganic phosphate as these blooms declined.

Although some significant and insignificant relation was found between the physico-chemical parameters measured and the phytoplankton variability, the quantification of cause and effect as well as prediction is still problematic. The matter is more complicated since the phytoplankton variations are affected by the interaction of several factors simultaneously.

The high fertility observed and the increasing frequency of the phytoplankton blooms which are caused by less than a dozen species, particularly in summer and fall, could be explained as a direct impact of the anthropogenic eutrophication (Fonda Umani *et al.*, 1995). Meanwhile, the remarkable variations in salinity and ambient nutrient concentrations and the subsequent rapid change in the phytoplankton community structure could probably indicate geographical dispersion from neighboring areas by transport processes, with different properties into the harbour. Alvarez Cobelas *et al.* (1994), and Dokulil and Padisak (1994) reported shifts in species composition related to eutrophication.

The occurrence of distinct increasing phytoplankton population during mid-winter represented an important feature of the annual variability of the phytoplankton cycle in the harbour. The dominance attributed to the opportunistic, fast-growing diatoms, *S. costatum*, *C. affinis* and *A. glacialis*. These species seem to respond quickly to new nutrients induced, which has been also proved by enrichment experiments (Malej *et al.*, 1998).

The spring phyto-flagellate bloom represented also an important feature of the phytoplankton cycle. New production usually takes place immediately after the onset of water stratification (sensu Dugdal and Goering, 1967), and an abrupt phytoplankton increase in spring was reported by Falkowski and Raven (1997), in temperate waters. According to Sournia *et al.* (1987) and Cloern and

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