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Short-time scale phytoplankton variability and ambient conditions in a highly dynamic marine basin

Wagdy LABIB*

Abstract : The variability of the phytoplankton standing crop, succession and biomass was assessed at surface layer of a fixed sampling station in a highly dynamic marine basin, Mex Bay, West of Alexandria (Egypt). The survey at this station was operated for 50 days between 26 May and 4 September 1992. The bay receives a daily injection of a heavy load of nutrients input from land-based sources. Remarkable physical and chemical variability was observed with the massive development of algal episodes, raising chlorophyll *a* and oxygen content to abnormal values. The causative phytoplankton species of the different blooms achieved their maximum occurrence with different nutrient levels. A phytoplankton bloom is not necessary to accompany or follow a period of enhanced nutrient concentrations. The phytoplankton progressed differently and there was distinct succession in the dominance of the major species. The community structure can be shifted over a few days, another of different species can replace a dense bloom.

Key words : *short-term physical, chemical and phytoplankton variability*

1. Introduction

ROUND (1971) discussed the role of "shock" events associated with changes in daylength, temperature and overturn conditions, in determining species succession and growth. If the actual processes of phytoplankton changes to be understood, short time scale sampling proved to be advisable, instead of weekly or biweekly intervals (WINTER *et al.*, 1975). The timescale variation in phytoplankton abundance, composition and biomass can be circadian (SOURNIA, 1974), seasonal (HARRISON and PLATT, 1980) or vary from a few days to one year (HARRIS, 1980). HARRIS and PICCININ (1980) found that changes in species composition / abundance tend to average environmental variables over short scales. According to CÔTE and PLATT (1983), physical transient events can dramatically alter the species and structural composition of phytoplankton community, conditions for growth and rate of primary production. RICHMOND (1986) reported that phytoplankton require a time from a few hours to several days to adapt a new environmental condition. Studies dealing with the daily changes in plankton population are rather limited (*e.g.* KLEIN and SOURNIA, 1987, SOURNIA *et al.*, 1987 ; ABI-SAAB, 1992).

Mex Bay, west to Alexandria (longitute 29° 50′E and latitude 31° 10′N) has an average width of 3 km, total area of about 20 km^2 and average depth of 10 m (Fig. 1). The bay receives directly from Lake Maryout, through Umum Drain, a daily of $6–11.8 \times 10^6 m^3$ of agricultural wastewater (SAID *et al.*, 1991). It is also affected by additional volume of wastewater from industrial outfalls at its western part. The discharge water in to the bay is largely the cause of man-made eutrophication.

The previous investigations on the phytoplankton standing crop in Mex Bay stressed its monthly variations in relation to physicochemical parameters (DORGHAM *et al.*, 1987 ; EL-SHERIF, 1989 ; ABDALLA *et al.* 1992 ; SAMAAN *et al.*, 1992).

The present study represents the first attempt to document the importance of short-time scale sampling to fully describe the phytoplankton variability and ambient envi-

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* National Institute of Oceanography and Fisheries, Kayet Bey, Anfoshi, Alexandria, Egypt.

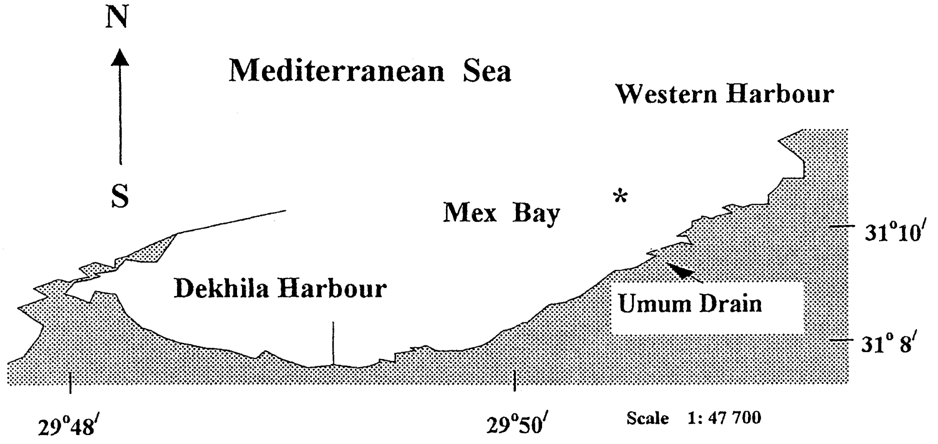

Fig. 1. Study area and sampling station (*).

rommental conditions in a highly dynamic marine basin.

2. Masterials and methods

The sampling station with 5 m depth (Fig. 1) was operated for 50 days between 26 May and 4 September 1992.

The measurements included the determination of the surface water temperature, salinity (refrectometer, S / Mill), oxygen (Winkler method), chlorophyll *a* and nutrient contents, nitrate, nitrite, phosphate and silicate (STRICKLAND and PARSONS, 1972). Water stability calculated on the basis of temperature and salinity data (WILLIAMS, 1962).

The phytoplankton samples were first examined for identification under a research microscope, then preserved by the addition of neutral formalin (4%), and a few drops of Lugol's acid solution and counted (UTERMÖHL, 1958).

The correlation matrix and the multiple-regression stepwise statistical model was computed to understand the relation between the numerical standing crop, chlorophyll *a* (dependent variables) and the measured physicochemical parameters (independent variables).

3. Results

3-1 Physical conditions

Physical parameters during the period from 26 May to 4 September 1992 are shown in Fig. 2. The most important factors driving the processes that determine the modification of surface temperature and salinity variations seem to be the wide fluctuations of surface heat fluxes (with respect to the limited height of the water column) and the volume of the discharge water (with respect to the whole volume of the basin).

Surface temperature range normally from 21 ℃ with the start to 30 ℃ in late August. Two periods of remarkable temperature increase were recorded during the first week of June and in early July. Generally, temperature shows a tendency to an increase as days went by. Temperature is positively, insignificantly correlated to the numerical standing crop and chlorophyll *a* content (r=0.157 and 0.296, respectively). The corresponding multiple-regression equation is :

$$\text{Chlorophyll } a\ (\mu \mathrm{gl}^{-1}) = 1.029 + 0.436 \times \text{temperature } (R^2 = 0.09).$$

Salinity exhibited wide range of fluctuations. Generally, salinity values are lower than that assumed for the inner boundary of the Mediterranean neritic waters of Alexandria (EL-MAGHRABY and HALIM, 1965 ; SAID *et al.*, 1991). Exceptionally, salinity can be high as 39‰, but values between 209‰ and 339‰ are common. Such high values suggest the lateral advection of the marine water from the open basin. Salinity is insignificantly correlated to the phytoplankton counts and chlorophyll *a* negatively with the latter parameter (r=0.09 and

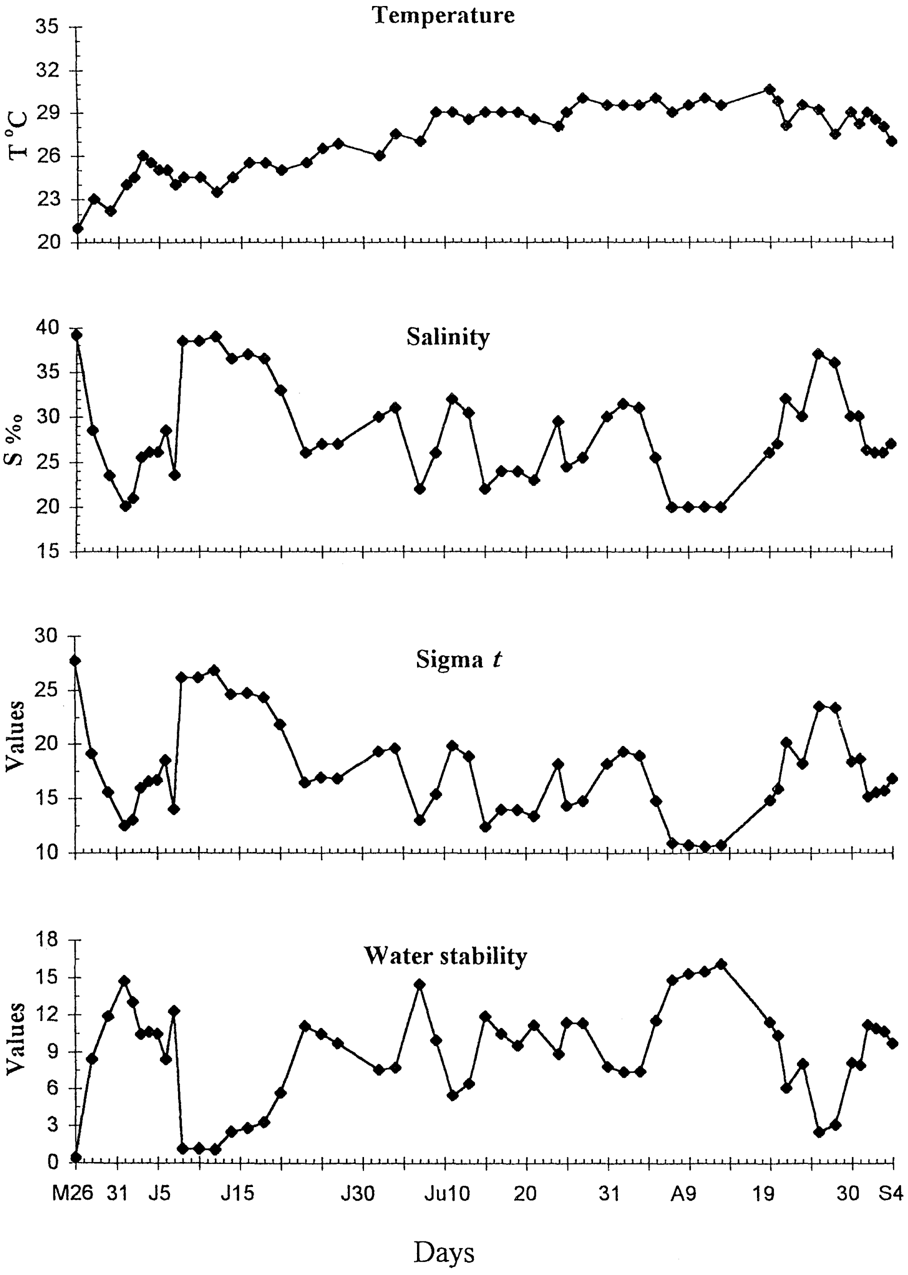

Fig. 2. Physical parameters during the period from 26 May to 4 September, 1992.,

0.10, respectively). The regression equation is :

Chlorophyll a ($\mu g\ l^{-1}$)$=15.527-0.111$ $\times$salinity ($R^2=0.01$).

Water density (Sigma t) fluctuations are almost a mirror image of salinity fluctuations rather than temperature ($r=0.54$ and 0.375, respectively).

Except for higher salinity at times, the water was well stable with maximum (14.84–16.11‰

during 8–14 August), associated with lower salinity over the whole period (20). High values of Sigma-*t* imply small values of water stability and *vice versa*. The permanent stability caused the insignificant correlation with the standing crop and chlorophyll *a* ($r=0.05$ and 0.03, respectively). The corresponding multiple-regression equation is :

$$\text{Chlorophyll } a\ (\mu \text{g l}^{-1})=7.453+0.586 \times \text{stability } (R^2=0.01).$$

However, chlorophyll *a* variations seem depending upon the temperature and stability combination :

$$\text{Chlorophyll } a\ (\mu \text{g l}^{-1})=0.656+0.307 \times \text{temperature}+0.438\times \text{stability } (R^2=0.14).$$

3-2 Nutrient conditions

Nutrient concentrations in Mex Bay are mainly governed by their input from land-based sources and the exhaustion by phytoplankton blooms at times (Fig. 3).

Nitrate varied dramatically throughout the whole period. Lower concentrations (1.26–2.8 μmol l^{-1}) were measured during 9–19 June, following a red tide bloom period (*Scrippsiella trochoidea*, the causative organism), and accompanying a minor bloom (predominance of microflagellate species). On the other hand, 3 major nitrate peaks were detected on 26 June (12.78 μmol l^{-1}), 12 August (14.79 μmol l^{-1}), associated with distinct drop in the standing crop (around 0.013×10^6 cell l^{-1}), as well as on 28 August (15.78 μmol l^{-1}), with a moderate phytoplankton increase (0.77×10^6 cell l^{-1}, *Skeletonema costatun*, *Gymnodinium catenatum* and *Nitzschia closterium* dominated).

Nitrite concentrations ranged between 0.35 and 3.9 μmol l^{-1}.

Phosphate concentrations, except for its maximum on 1 September (7 μmol l^{-1}, with the bloom of *G. catenatum*), were always low, exhibiting a narrow range of variations.

Silicate concentrations show a wide range (7.31–64.93 μmol l^{-1}), never fell down limiting the phytoplankton growth. The diatom peaks in July and August occurred with enhanced silicate concentrations.

The high daily injection of the nutrients to the bay leads to continuous replenishment of nutrient elements. Subsequently, insignificant correlation was found between their concentrations and the numerical standing crop and chlorophyll *a* content.

3-3 Phytoplankton variability

The phytoplankton standing crop, chlorophyll *a* and oxygen contents admitted remarkable variation (Fig. 4). The physical and chemical forcing in the bay was favorable to create rich spectra for algal blooms. These blooms resulted in abnormal biomass increase and high surface dissolved oxygen.

The standing crop attained an average of 3.55×10^6 cell l^{-1}, reflecting a clear sign of heavy eutrophication, with a pronounced down shift in the phytoplankton structure. The phytoplankton community was relatively poor (48 species). Diatoms (31 species) contributed an average of 1.67×10^6 cell l^{-1}, 47% to the total, followed by dinoflagelaltes (17 species, 26.2%). The fresh-water forms are numerous, including 9 chlorophycean species (15%, *Ankistrodesmus falcatus*, *Crucigenia quadrata*, *Scenedesmus dimorphus* and *S. quadricauda* were the major species), 6 euglenophycean (8%, mainly, *Euglena acus*, *E. caudata* and *E. granulata*), and 6 cyanophycean (3.8%, *Lyngbya*, *Merismopedia*, *Oscillatoria* and *Spirulina* spp).

The phytoplankton progressed differently during the investigated period. There was distinct succession in the dominance of the major species (Fig. 5 and Table 1).

The dinoflagelate, *Scrippsiella trochoidea*, formed a red tide bloom period between 1–5 June. The centric diatom, *Thalassiosira subtilis*, culminated its peak on 11 June. The dinoflagelate, *Gymnodinium catenatum*, became leading on 8 July. This was followed immediately by the predominance of the pennate diatom, *Nitzchia closterium*. The dominance of diatoms (*Rhizosolenia delicatula*, *Nitzschia closterium* and *Skeletonema costatun*) extended during July – early August. The euglenoid, *Euglena granulata*, shared the dominance to a lesser degree. Again, the dinoflagellates regained their important contribution in late August (*Prorocentrum triestinium*), and in early September (*Gymnodinium catenatum*).

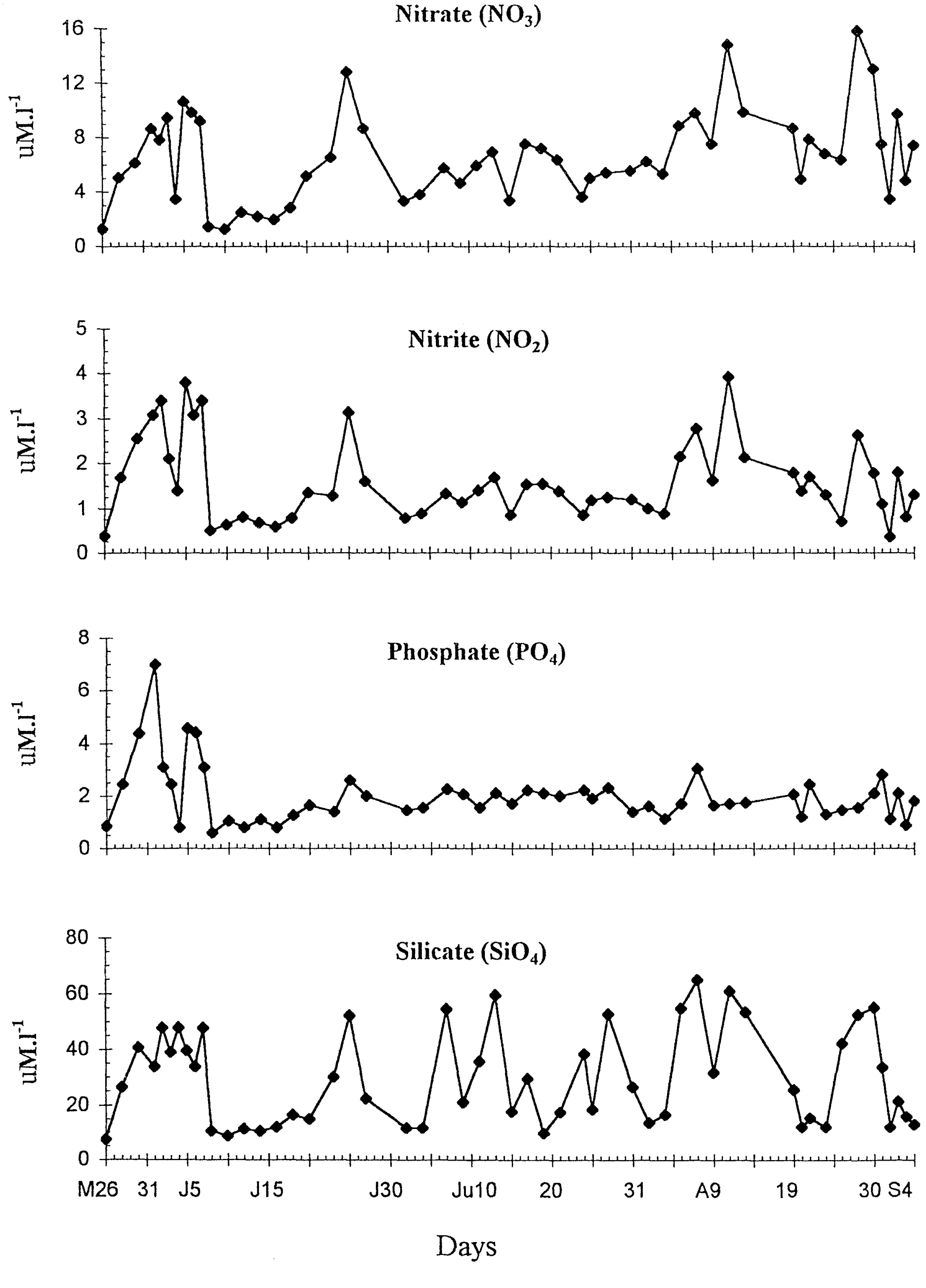

Fig. 3. Chemical parameters during the period from 26 May to 4 September, 1992.

The multiple-regression equations of the major species are given as :

S. trochoidea (cell l^{-1}) $= 89.8 - 11.54 \times \text{Temp} - 4.22 \times \text{S} + 3.42 \times \text{Sig.t} - 1.18 \times \text{Sta} + 54.83 \times NO_3 - 99.87 \times NO_2 + 96.11 \times PO_4 + 3.48 \times SiO_4$ $(R^2 = 0.062)$

T. subtilis (Cell l^{-1}) $= 42.45 - 14.9 \times \text{Temp} + 36.81 \times \text{S} - 41.92 \times \text{Sig.t} - 0.05 \times \text{Sta}$.

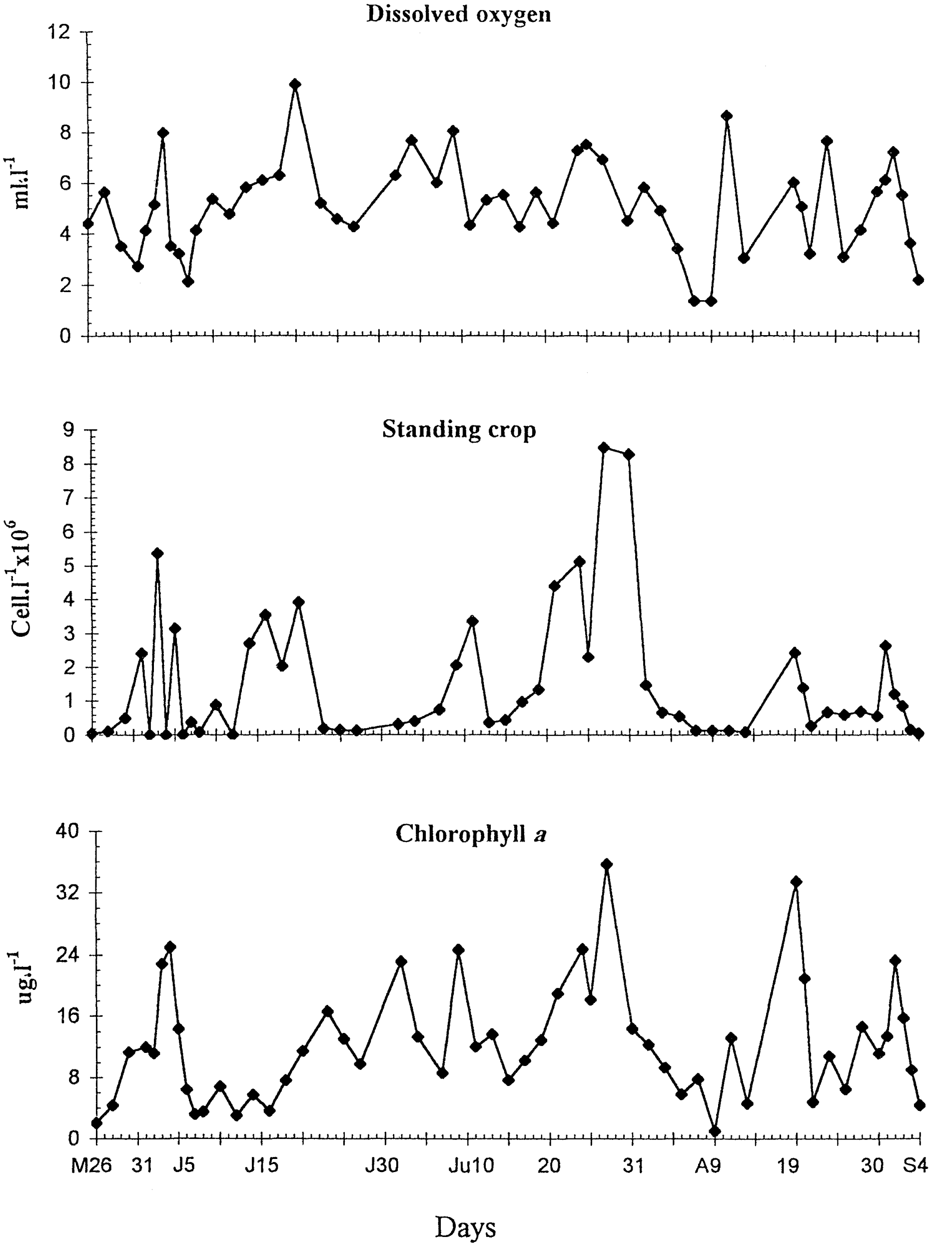

Fig. 4. Dissolved oxygen, standing crop and chlorophyll *a* during the period from 26 May to 4 September, 1992.

$+18.19 \times No_3 - 56.65 \times NO_2 + 42.12 \times PO_4$
$+0.23 \times SiO_4$ ($R^2 = 0.113$)
S. costatum (cell l^{-1}) $= 148.64 - 16.31 \times$ Temp
$+28.11 \times$ S $- 31.35 \times$ Sig.t $+ 17.33 \times$ Sta.
$-1.37 \times NO_3 + 81.42 \times NO_2 - 42.56 \times PO_4$
$-2.11 \times SiO_4$ ($R^2 = 0.14$)
R. delicatula (cell l^{-1}) $= 3852.93 + 10.43 \times$ Temp
$-228.65 \times$ S $+ 192.68 \times$ Sig.t $- 83.6 \times$ Sta.
$+17.55 \times NO_3 - 87.69 \times NO_2 - 103.03 \times PO_4$
$+0.62 \times SiO_4$ ($R^2 = 0.529$)

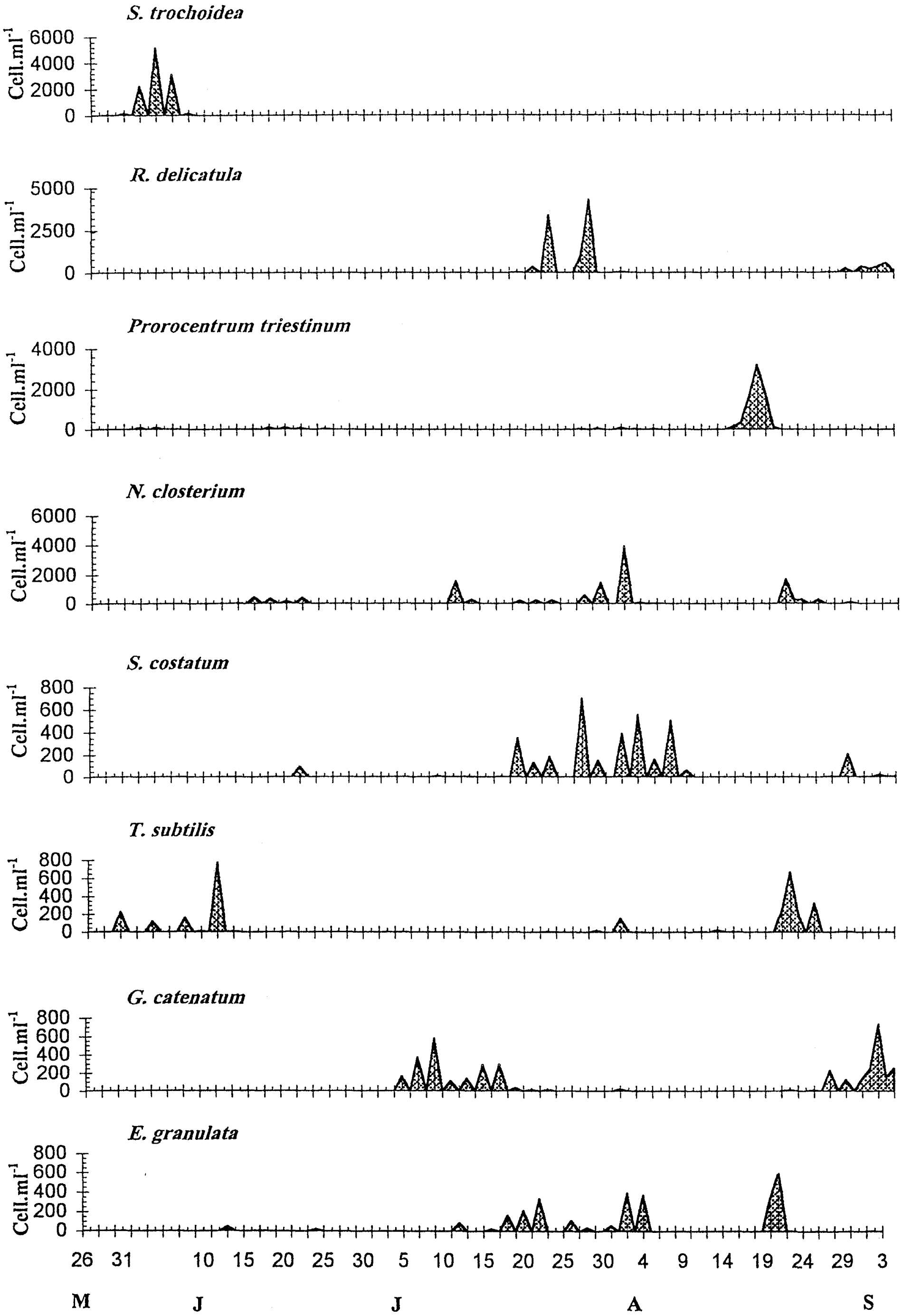

Fig. 5. Dominant phytoplankton species during the period from 26 May to 3 September, 1992.

Table 1. Maximum density of the major species, chlorophyll *a* content, dissolved oxygen and ambient environmental conditions during the investigated period.

Peak day	species	Density (cell $l^{-1} \times 10^6$)	Chl. *a* ($\mu g\ l^{-1}$)	D.O. ($mg\ l^{-1}$)	Temp. (℃)	Sal. (‰)	Sig.t	Stab.	NO_3 ($\mu mol\ l^{-1}$)	NO_2 ($\mu mol\ l^{-1}$)	PO_4 ($\mu mol\ l^{-1}$)	SiO_4 ($\mu mol\ l^{-1}$)
3 June	*S. trochoidea*	5.1	22.83	5.14	26	25.5	15.94	10.38	9.45	2.1	2.45	22.83
11 June	*T. subtilis*	0.76	6.74	5.34	24.6	38	26.14	1.12	1.26	0.63	1.05	8.67
26 July	*S. costatum*	0.70	18.1	7.5	29	24.5	14.32	11.36	4.96	1.18	1.9	18.4
28 July	*R. delicatula*	4.3	35.7	6.9	30	25.5	14.78	11.33	5.38	1.25	2.3	52.7
31 July	*N. closterium*	3.9	14.4	4.5	29.5	30	18.15	7.82	5.52	1.2	1.4	26.6
20 Aug.	*P. triestinum*	3.2	33.4	6	30.6	26	14.83	11.39	8.64	1.78	2.1	25.35
21 Aug.	*E. granulata*	0.61	20.89	5.1	29.8	27	15.84	10.31	4.9	1.38	1.2	11.89
1 Sept.	*G. catenatum*	0.73	23.2	7.2	29	26	15.14	11.21	3.43	0.35	1.1	11.95

N. closterium (cell l^{-1}) $= 133.46 + 47.82 \times \mathrm{Temp}$
$- 107.32 \times S + 108.79 \times \mathrm{Sig.t} - 27.76 \times \mathrm{Sta.}$
$+ 10.42 \times NO_3 + 89.15 \times NO_2 - 97.06 \times PO_4$
$+ 5.89 \times SiO_4$ ($R_2 = 0.104$)

P. triestinium (cell l^{-1}) $= 695 + 2547 \times \mathrm{Temp}$
$- 4009.7 \times S + 3872 \times \mathrm{Sig.t} - 1274.5 \times \mathrm{Sta.}$
$- 4016.7 \times NO_3 + 10644.2 \times No_2 + 862.9 \times PO_4$
$+ 286.7 \times SiO_4$ ($R^2 = 0.145$)

E. granulata (cell. l^{-1}) $= 15.78 + 7.04 \times \mathrm{Temp}$
$- 20.52 \times S + 22 \times \mathrm{Sig.t} - 6.59 \times \mathrm{Sta.}$
$+ 15.78 \times NO_3 + 21.44 \times NO_2 - 36.6 \times PO_4$
$+ 1.3 \times SiO_4$ ($R^2 = 0.218$)

G. catenatum (cell l^{-1}) $= 17.95 + 14.89 \times \mathrm{Temp}$
$- 45.6 \times S + 56.81 \times \mathrm{Sig.t} - 4.23 \times \mathrm{Sta.}$
$- 4.21 \times NO_3 - 16.1 \times NO_2 + 0.445 \times PO_4$
$+ 0.65 \times SiO_4$ ($R^2 = 0.06$)

Generally, chlorophyll *a* runs in parallel with the numerical standing crop ($R^2 = 0.29$). Several peaks were recorded (maximum of 38.9 $\mu g\ l^{-1}$ on 22 July). Deviations are mainly due to species composition.

4. Discussion

The present data shows Mex Bay, subjected to daily input of a huge volume of discharge water, to be characterized by distinct physical, chemical and biological structural properties. The bay is highly eutrophicated with repeated algal outbreaks, causing water discoloration at times. These algal episodes raised chlorophyll *a* content and oxygen to abnormal values.

The daily injection of the nutrients and the permanent stability of the water seem to favor the phytoplankton blooms. However, the data shows that a bloom is not necessary to accompany of follow a period of enhanced nutrient concentrations and even intermediate values are sufficient to trigger a phytoplankton peak.

The phytoplankton species seem to have different nutrientional requirements and it was well documented that the pennate diatoms (*Rhizosolenia delicatula* and *Nitzschia closterium*, the causative species in July and August) require low nutrients to dominate the community (TURPPIN and HARRISON, 1979 ; ISHIZAKA *et al.*, 1983). The species, *Nitzschia frigida* dominated under similar conditions in the Eastern Harbour of Alexandria (LABIB, 1994 a). However, the present dinoflagellates achieved their maximum occurrence under plenty of nutrients. These species were previously recorded red tide forms in the neritic waters of Alexandria (LABIB, 1994, a, b, 1996, 1998 : LABIB and HALIM, 1995).

The success of the pennate *Rhizosolenia delicatula* to grow well under the dinoflagelate bloom of *G. catenatum* agree with other observation in Alexandria waters (LABIB, 1994 a, b).

The community structure can be shifted over a few days. A dense bloom can be replaced by another of different species.

It is concluded that short-time scale sampling in a system of wide fluctuations is advisable to describe its physical, chemical and biological aspects.

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