SHORT-TERM SCALE OBSERVATIONS ON PHYTOPLANKTON IN THE EASTERN HARBOR OF ALEXANDRIA, EGYPT

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ABSTRACT

The species composition and abundance of phytoplankton beside surface salinity and nutrient salts (ammonia, nitrate, phosphate and silicate) were studied weekly from 24 December 2002 to 9 December 2003 at a fixed station in the Eastern Harbor of Alexandria. The results indicated that, surface salinity showed relatively wide variations, while nutrient salts displayed wide and rapid changes on the short term scale. Ammonia fluctuated within the range of 0.15 - 43.7 µM/L, nitrate: 0.42 – 72.8 µM/L, phosphate: 0.12 to 3.4 µM/L, and silicate: 0.8 – 12.1 µM/L. Parallel to the above mentioned conditions, the phytoplankton count varied between a minimum of 0.12×10^3 unit/L and a maximum of 1.21×10^6 unit/L, while chlorophyll a fluctuated from 0.3 to 17.58 µg/L. Both the count and biomass (Chlorophyll a) displayed several peaks over the year The phytoplankton community was represented by a total of 151 species, including 76 diatom species, 61 dinoflagellates, and a few representatives of different freshwater groups. Eighteen species appeared as dominant, but most of them dominated once a year and the rest dominated intermittently 2-3 times, except the dinoflagellate *Alexandrium minutum* which dominated five times over the year. As compared to the earlier records, the present study reported serious changes in both the water fertility and the dynamics of the phytoplankton community in the Eastern Harbor.

1. INTRODUCTION

The phytoplankton community usually displays rapid response to the environmental changes in both species composition and numerical density. These changes are more frequent in shallow areas, which lie under the stress of human activities, occurring within short-term scale that are not easy to be recognized throughout seasonal or monthly observations.

The Eastern Harbor of Alexandria is one of the embayments which have ecological, economic and touristy importance on the southeastern Mediterranean Coast. It is eutrophic semi-closed bay exposed to several kinds of human activities, including fishing, yacht sport, land-based effluents, boat building workshops, recreation. During the second half of the past century the ecosystem of the harbor passed through different phases of fundamental changes in environmental and biological characteristics. The first phase was before the construction of the High Dam in 1964 when the Nile flood had been causing marked dilution of the harbor's water in late summer. The second phase occurred after the cessation of the Nile flood, with increasing effect of the sewage pollution (96.5×10^3 m³/ day) reaching to the harbor directly through eleven submersible outfalls (Zaghloul and Halim, 1990) and indirectly (263×10^3 m³/ day) from Kayet Bey sewer (Aboul-Kassim, 1987). These conditions have made the water

of the harbor eutrophic and the plankton production almost continuous all the year round at a high level (Ismael, 1993).The third phase in the harbor started after 1993 when all sewers of the harbor were closed, except those at Kayet Bey and EL-Silsila, due to the diversion of sewage discharge into Lake Mariout.

The harbor's ecosystem has received the attention of many authors in different disciplines of marine sciences (c.f. Tawfik, 2001), but all the conducted studies based upon seasonal or monthly observations. The present study aims at following the changes of the phytoplankton composition and count in the Eastern Harbor at weekly interval relative to analogous changes in some environmental factors in order to identify the real variability of these parameters on the short-term scale.

2. MATERIALS AND METHODS

The samples were collected weekly at a fixed station in the Eastern Harbor (Fig. 1) throughout a complete year from 24 December 2002 to 9 December 2003. The sampled station lies near the hunting club, whereas it is affected by the club activities, including recreation, fishing sport, liquid and solid wastes. It is also near to the main opening connecting the harbor to the open sea. For phytoplankton study, 2 liters of surface water were collected, preserved in 4% neutralized formalin. The identification of phytoplankton species was done following Meunier (1913; 1919); Lebour (1925; 1930); Hustedt (1930); Cupp (1943); Hendey (1964); Taylor (1976); Dodge (1982); Tomas (1996). The phytoplankton count was estimated according to Utermöhl (1958) and chlorophyll *a* according to Parsons *et al.* (1984). The phytoplankton diversity index

was computed according to Shannon and Wiever (1963).

The surface salinity and nutrient salts (NO_3, NH_4, PO_4 and SiO_4) were determined according to Strickland and Parsons (1972). The correlation of phytoplankton abundance with the nutrients and salinity was measured.

3. RESULTS

Although the surface salinity in the Eastern Harbor demonstrated relatively wide variations (34.9-41.3‰), it was higher than 38‰ during most of the study period. The low values (36.5–37.8‰) appeared for some weeks of January and February, while the minimum salinity (34.9‰) occurred during three weeks only in July and August (Fig. 2).

The nutrient salts demonstrated markedly wide weekly variability (Figs. 3 and 4). Ammonia (NH_4) attained an annual average of 5.33 µM/L, varying from a minimum of 0.15 µM/L to a maximum of 43.7 µM/L. Most weeks of the period from May to August were characterized by markedly high concentrations, while weeks of March sustained the lowest values (Fig. 3). In addition, two exceptionally high concentrations of ammonia were recorded on 24 December (19.35 µM/L) and 29 April (43.7 µM/L).

Nitrate showed a different weekly distributional pattern, whereas it fluctuated between 0.42 µM/L and 2.02 µM/L during the period from the beginning of July to the 7th of October, but it displayed drastic changes during the rest of the year. During the period 13 May-10 June, the concentration of nitrate ranged from 19.6 to 27.72 µM/L, while abnormally high values appeared on 24 December (72.8 µM/L), 31 December (36.1 µM/L), 7 January (52.1 µM/L), and 11 February (86.2 µM/L) (Fig. 3).
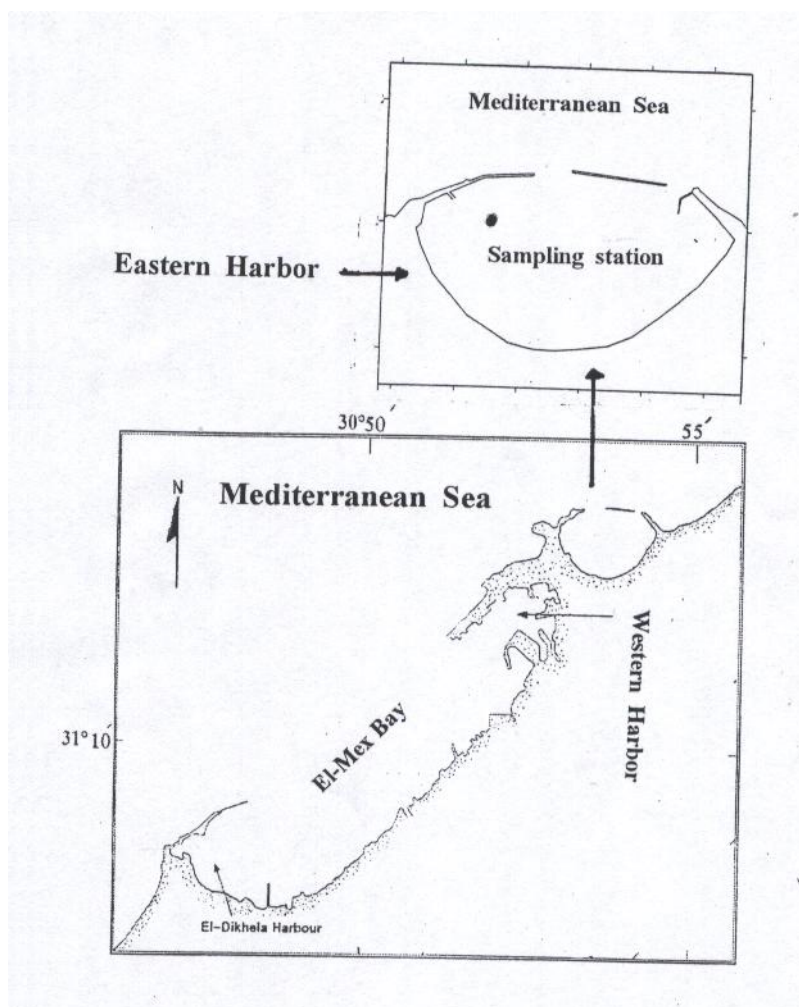
Fig. (1): The map of the Eastern Harbor of Alexandria showing the sampling station.
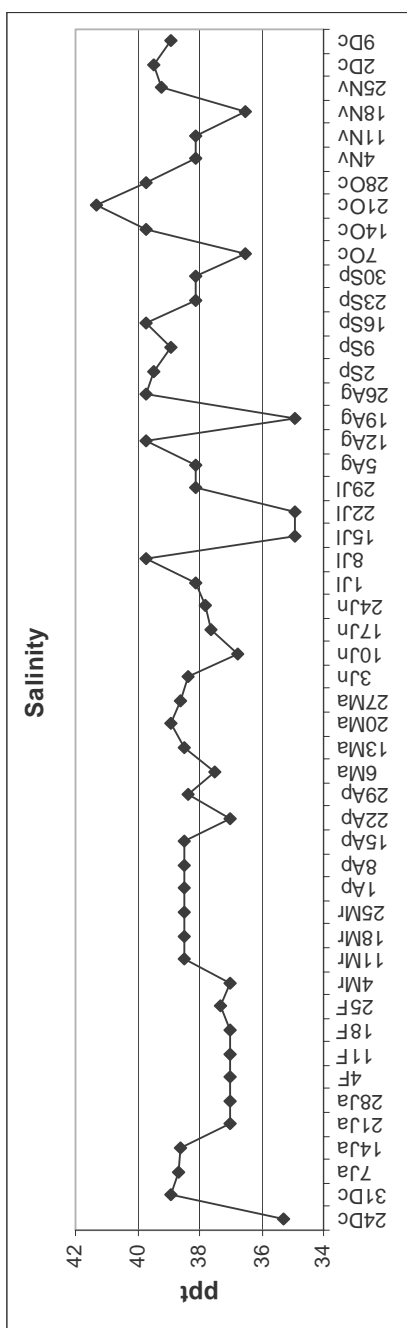
Fig. (2): Weekly variations of surface salinity in the Eastern Harbor (24 December 2002-December 2003).
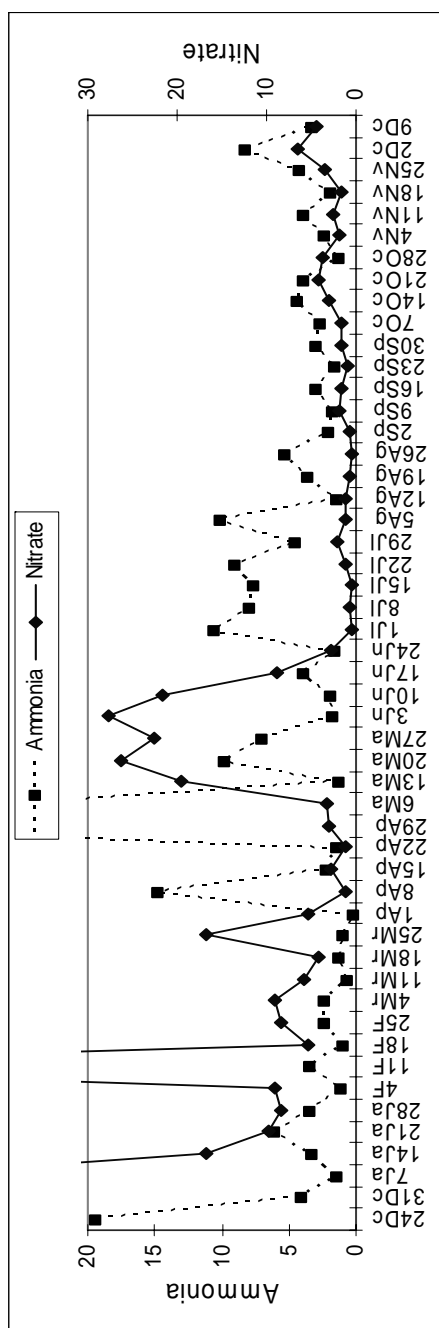

Fig. (3): Weekly variations (in µM/L) of ammonia and nitrate in the Eastern Harbor (24 December 2002 - December 2003).
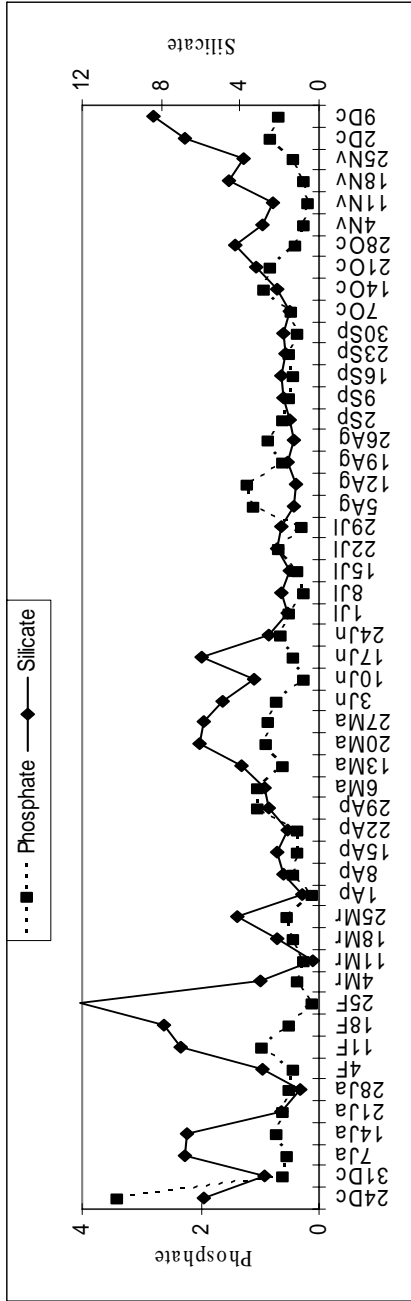
Fig. (4): **Weekly variations (in µM/L) of phosphate and silicate in the Eastern Harbor (24 December 2002 - December 2003).**

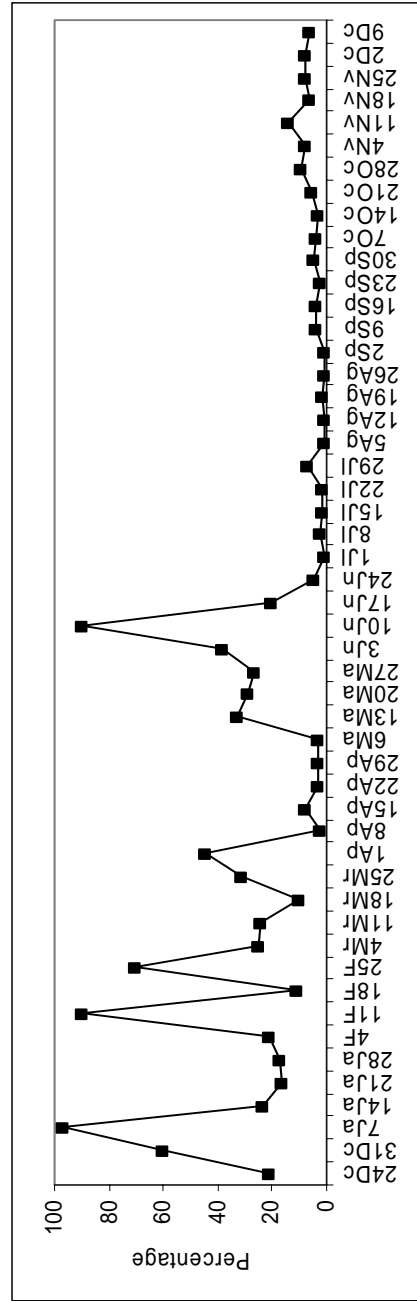Fig. (5): **Weekly variations of N/P ratio in the Eastern Harbor (24 December 2002 – December 2003).**
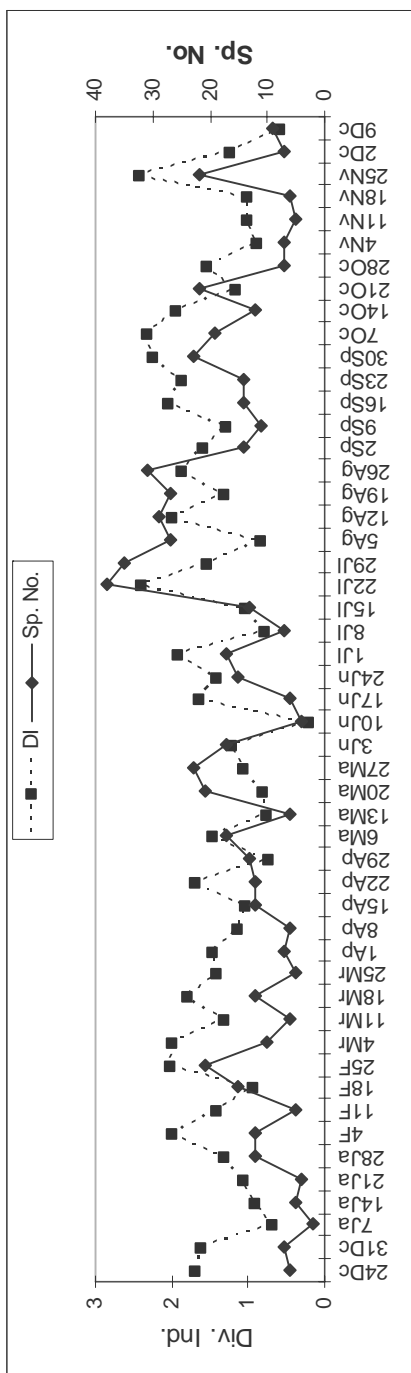
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Fig. (6): Weekly variations of species number and diversity index of phytoplankton in the Eastern Harbor (24 December 2002 - December 2003).
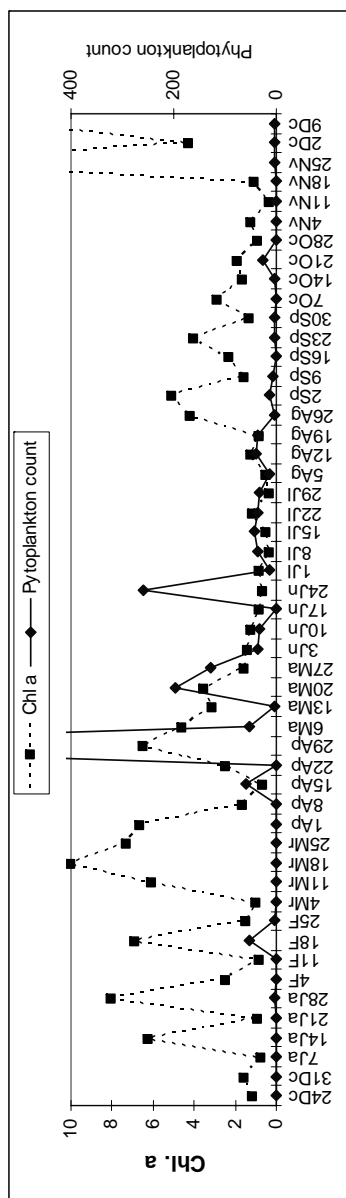
Fig. (7): Weekly variations of phytoplankton count (thousand unit/L) and chlorophyll *a* (µg/L) in the Eastern Harbor (24 December 2002 - December 2003).

Phosphate illustrated clear weekly variations with low values (less than 1 µM/L) over the year except a high concentration (3.78 µM/L) reported on 24 December (Fig. 4). Due to the great variability and high concentrations of nitrate, the N/P ratio displayed markedly high values (16.3–194) during many weeks, while it was pronouncedly low (0.9-10) in many other weeks (Fig. 5).

Silicate showed two patterns of weekly distribution, the first occurred during the weeks of summer and autumn which was characterized by narrow variation and low values (1.2–2.1 µM/L). The second displayed wide variation (0.3 – 12.1 µM/L) during winter and spring weeks (Fig. 4).

The phytoplankton community in the Eastern Harbor comprised 151 species, with the dominance of diatoms (76 species) and dinoflagellates (61 species). In terms of the number of species, diatoms were dominated by *Nitzschia* (9 species), *Biddulphia* (7 species) and *Navicula* (6 species), while dinoflagellates was dominated by *Protoperidinium* (27 species). Other algal groups like Cyanophyta, Chlorophyta, Euglenophyta, Chrysophyta and Silicoflagellata were represented by a few species.

During the present study, large number of phytoplankton species seems to be temporal inhabitants of the harbor, appearing occasionally for one week (43 species) or 2-4 weeks (60 species) throughout the year. None of the recorded species was found to be persistent all the year round, but a few species extended their existence for 21-36 weeks, namely *Alexandrium minutum, Actinopticus splendens, Screpsiella trochoidea, Protoperidinium pallidum* and *Prorocentrum triestinum*. The number of phytoplankton species (Fig. 6) showed irregular weekly fluctuation, whereas the highest number (27 - 38 species) was recorded during 6 successive weeks in July

and August, and the lowest number (2-9 species) occurred during several intermittent weeks. In general, the communities of late autumn and winter weeks were the lowest diversified. By the number of species, diatoms overcome dinoflagellates from mid summer to late winter, while dinoflagellates overcome diatoms from 8 April to 15 July. The Shannon-Weaver index reported wide weekly variation between 0.19 and 2.42 nats. Except the high values (>2 nats), which were occasionally observed, the diversity index falls within the range of 1-2 nats for 35 weeks and below 1nat for 11 weeks. There was no clear pattern of temporal variation of the diversity index in harbor (Fig. 6).

The phytoplankton count demonstrated marked weekly fluctuations from 0.12×10^3 to 258.5×10^3 unit/L (Fig. 7). The period from 15 April to 19 August sustained mostly high counts ($27.2 \times 10^3 – 258.6 \times 10^3$ unit/L), while the rest of the year showed considerably low count (< 4200 unit/L) (Fig. 7). Concerning temporal distribution, the phytoplankton count illustrated several different sized peaks in February, April, May, June, July, August and October. An exceptionally high peak (1209×10^3 unit/L) was observed at the end of April, particularly due to the dominance of *P. triestinum* and *Melosira jurgensii*. In general, dinoflagellates provided more contribution to phytoplankton count (48.7 %) than did diatoms (43 %) and euglenophytes (7.2 %). However, the relative abundance of each of the three groups displayed different weekly patterns throughout the study period. As shown in Figure (8), diatoms dominated for 24 weeks mainly during winter, and intermittently during other seasons, while dinoflagellates dominated for 17 intermittent weeks, mainly during spring, summer and few weeks in winter and autumn. Euglenophytes were dominant for intermittent weeks in April, May, June, September and October.
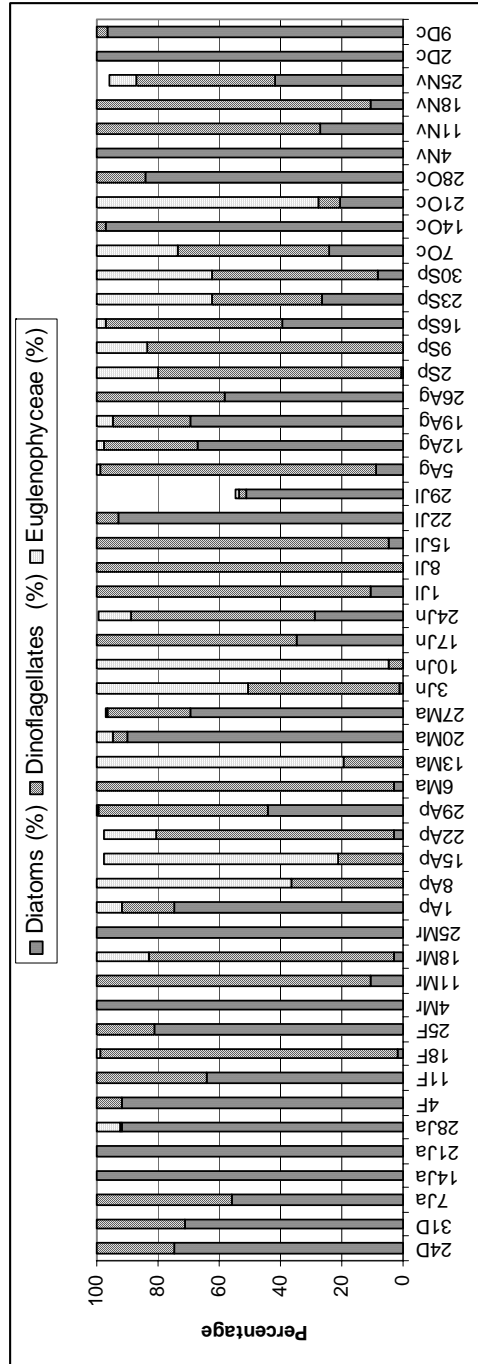
Fig. (8): Weekly relative abundance (%) of the major phytoplankton groups in the Eastern Harbor (24 December 2002 - December 2003).
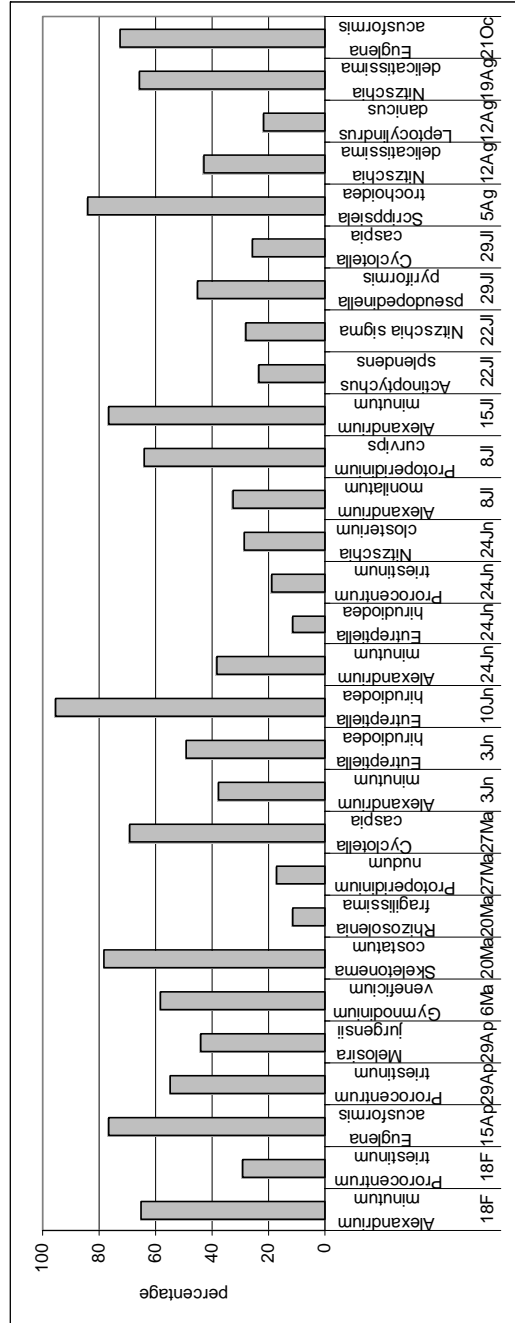
Fig. (9) : Timing and frequency of dominant phytoplankton species in the Eastern Harbor (24 December 2002 - December 2003).

The dominance of species experienced also weekly variations, especially at the flourishing weeks (Fig. 9). Although 18 species contributed actively to the phytoplankton count, many of them (12 species) appeared to be dominant once a year, three dominated for two times. However, the dinoflagellate *A. minutum* was among the dominated species for 5 intermittent weeks in different months at different temperatures. Some species attained the absolute dominance, such as the diatoms *Skeletonema costatum* (78.2% on 20 May), *Nitzschia delicatissima* (65.7% on 19 August) and *Cyclotella caspia* (65% on 27 May), the dinoflagellates *A. minutum* (76.8% on 15 July) and *Scrippsiella trochoidea* (84.2% on 5 August) and the euglenophytes *Euglena acusiforms* (76.4 & 72.4% on 15 April and 21 October respectively) and *Eutreptiella hirundiodes* (95.5% on 10 June).

The Chlorophyll *a* displayed irregular weekly variations (figure 7), whereas 14 intermittent weeks sustained values less than 1μg/L, 16 weeks of 1-2 µg/L, and the rest of weeks demonstrated more than 2 µg/L with a maximum of 17.58 µg/L. The lowest concentrations were found during June and July (< 1 µg/L), while markedly high ones (4 – 11.98 µg/L) appeared in different weeks during the period from January to May, August, September, November and December.

4. DISCUSSION

Although the ecosystem of the Eastern Harbor has been intensively studied throughout the past 5 decades, none of these studies concerned with the short–term variations of the ecosystem. The present study made weekly observations for one year on the surface salinity, nutrients and dynamics of the phytoplankton community. The results revealed that the ecosystem of the harbor usually exposed to rapid and frequent pronounced short-term variations, which were not recognizable through the monthly or seasonal records. These variations are driven by several forces inside and outside the harbor, such as the current regime, water exchange with the open sea, direction and speed of the winds, rain fall, discharged wastes reached indirectly to the harbor from Umoum Drain. Abdalla (1979) reported active water exchange between the harbor and the open sea by seasonally variable currents, through Qayet Bey and Silcila openings. These currents are affected by the direction and speed of the winds, which also experienced temporal changes (El-Geziry and Maiyza, 2006). In addition, remobilization of nutrients from sediments to the water column could occur under the effect of variable environmental factors, causing eutrophication condition and abnormal flourishing of phytoplankton and consequently play a crucial role in changing water quality of the harbor (Awad, 2004).

From the present study, it was clear that all nutrient salts as well as qualitative and quantitative structure of phytoplankton suffered from variations on the small-scales of time, but in most cases, these variations showed no clear patterns and each of the measured parameters displayed its own weekly variation pattern.

Regardless of the differences in the sampling time-scale between the present and the earlier records, it is necessary to compare both results to recognize the recent changes occurred in the harbor, particularly in the dynamics of phytoplankton community relative to variations in salinity and nutrient salts. For example, the number of species during the present study (151 species) were double that (75 and 76 species respectively) recorded by Ismael and Halim (2000) and Tawfik (2001). Considering that the number of species in the present study was caught at one station only, which certainly does not represent the community of the whole harbor, this number indicates that the harbor's phytoplankton started to restore its high diversity (229 species) which was recorded

earlier by Ismael (1993). On the other hand, the higher number of dinoflagellates species in the present study (61 species) than those (54 & 31 species respectively) of Ismael (1993) and Tawfik (2001) support the increase of their role in the Eastern Harbor, and their greater contribution to the total phytoplankton count. On the other hand, the values of the diversity index during the present study (0.19 -2.42 nats) was slightly wider than that recorded for dinoflagellates (0.4 – 2.3 nats) by Ismael (1993). The diversity index was significantly correlated to the total number of phytoplankton species in the harbor (r = 0.4337, p = 0.001, n = 51), may be due to the significant correlation with the number of diatom species (r = 0.4285, p = 0.01, n = 51), while it was not significant with the number of dinoflagellates species (r = 0.2311, p = 0.01, n = 51). Furthermore, the present range of diversity index is more or less close to that (1-2.5 nats) observed by Margalef (1964 and 1978) for the actively growing coastal populations and eutrophic lakes.

According to the present study, the word perennial does not mean the existence of a species over the year round, whereas such a species appears for a certain period and disappear for another period, which is usually not documented through the collection of long-term interval. Such interpretation corresponds with the findings of the present study, which missed eight perennial species reported by (Ismael, 1993) and revealed that the maximum time of occurrence for any perennial species in the harbor was thirty intermittent weeks.

It is obvious that phytoplankton abundance in the Eastern Harbor has passed distinctive changes throughout the past decade, in both the maximum values and the frequency of peaks. The present study recorded several peaks over the year, while Ismael (1993) reported unimodal peak in January and Tawfik (2001) observed trimodal peak in February, June and October. This indicates that the actual number of peaks could not be recognized within macro time scale like seasons or months. On the other hand, the drastically low phytoplankton count in the present study compared to the earlier ones (Fig. 10) was attributed to pronounced changes in nutrient concentrations, especially the relative abundance of both nitrate and phosphate, which caused abnormal variations in the N/P ratio over the year. However, the low cell count did not serve as indication of the phytoplankton growth in the harbor, since chlorophyll *a* demonstrated high values due to active contribution of picoplankton which could not be counted by normal microscope. The pronounced role of picoplankton in chlorophyll *a* was reported in the Western Harbor (Gharib and Dorgham, 2006), Dekhaila Harbor (Dorgham, Unpublished data) of Alexandria, and Abu Qir Bay (Shams El-Din and Dorgham, in press). However, the values of chlorophyll a in the present study were pronouncedly lower than those reported earlier (Fig 11), mainly due to clear changes in the water quality of the harbor (Table 1). Further, chlorophyll a in the Eastern Harbor appeared to be low compared to other areas of Alexandria Coast as a result of regional ecological differences (Table 2).

It is worth to mention that, the changes of the phytoplankton in the Eastern Harbor have occurred not only in the count but also in the dominance of species. During the present study, twenty two species were reported as dominant, ten of which belong to dinoflagellates, and most of them bloomed once or twice a year, except *Alexandrium minutum* which dominated for six intermittent weeks. Although twelve dominant dinoflagellate species were reported by Ismael (1993), only two of them were found among the dominant species during the present study, namely, *Prorocentrum triestinum* and *Protoperidinum curvipes*.

The comparison of nutrient salts levels in the Eastern Harbor throughout the past decade (Table 1) revealed serious changes in all nutrients, whereas inorganic nitrogen forms (ammonia and nitrate) displayed pronounced increase, while both phosphate and silicate dropped clearly. In addition to the

high salinity most of the year, this is a good indication of stopping waste discharge to the harbor during the past few years. On the other hand, the high concentrations of ammonia indicate rich organic matter in the harbor, which may be formed from local pollution, resulting from the activities of the hunting club, or brought together with nitrate through the waste waters discharged from Umoum Drain to the Mex Bay and transported by the eastward current to the harbor. Al-Dughiem (2005) reported up to 7.22 mg/g of organic matter in the bottom sediments of the Eastern Harbor. The statistical analysis indicated that there were no significant correlation between the phytoplankton count or chlorophyll a and nutrient salts during the present study, except that with ammonia ($r = 0.783$, $p < 0.001$)

However, the weekly variations of phytoplankton standing crop showed reverse relationship with the different nutrient salts, which indicate the variation in their uptake by phytoplankton throughout the present study. In addition, significant correlations were reported between the different nutrient salts (Table 3), illustrating that the relationship between each two salts may affects the phytoplankton growth. This is clearly indicated from the wide range of variations of both N/P (0.5 – 96.5) and Si/P (0.6 – 100.8) as compared to ratios found in the open sea.
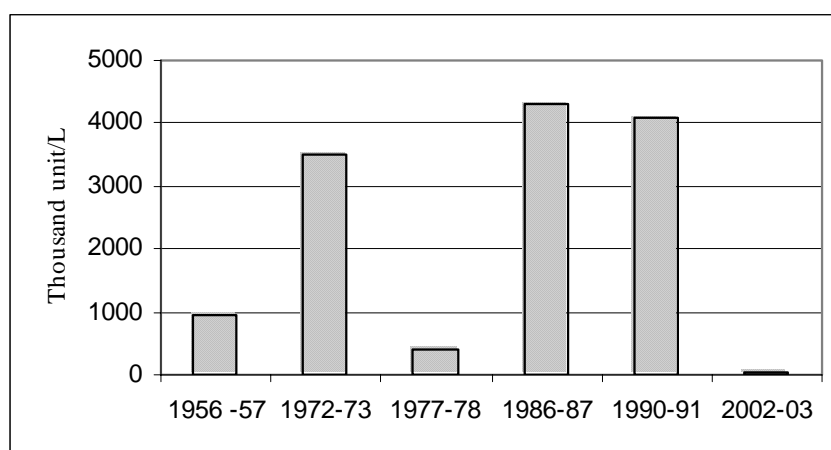

Fig. (10): Historical changes of the average phytoplankton count in the Eastern harbor. (1956-57: El-Maghraby and Halim, 1965; 1972-73: Halim et al., 1980a; 1977-78: Halim et al., 1980b; 1986-87: Zaghloul and Halim, 1992; 1990-91: Hussein, 1994; 2003-03: Present study)
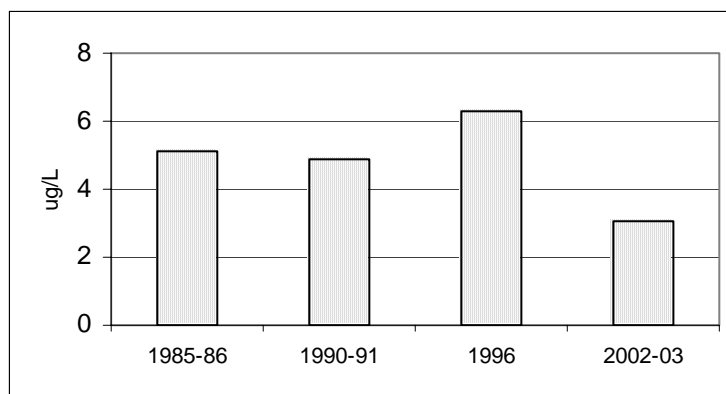
Fig. (11): Historical changes of the average chlorophyll *a* (µg/L) in the Eastern Harbor. (1986-87: Aboul-Kassim (1987); 1990-91: Hussein (1996); 1996: Anonymous (1997); 2002-03: Present study)

Table (1): Historical changes of the annual average concentrations of nutrient salts (µM/L) in the Eastern Harbor during the past 5 decades.

Date	NH_4	NO_3	PO_4	SiO_4	Reference
1956-57	----	----	0.23	----	El-Maghraby and Halim (1965)
1979	----	12.35	0.82	----	El-Nady (1981)
1985-86	3.76	7.12	0.56	----	Aboul-Kassim (1987)
1989	1.5	4.12	1.08	11.2	Ibrahim (1999)
1990 - 91	----	3.78	0.58	----	Hussein (1994)
1999-2000	3.2	2.71	0.66	4.3	Tawfik (2001)
2002-2003	5.33	10.48	0.6	3.36	Present study

Table (2): The annual average concentrations (µM/L) of nutrient salts and chlorophyll _a_ (µg/L) in different areas of Alexandria Coast.

Area	NH$_4$	NO$_3$	PO$_4$	SiO$_4$	N/P	Chl. _a_	Reference
Abu Qir Bay	14.55	7.16	1.41	16.74	9.6	15.7	Abdel-Aziz _et al._ (2001)
Western Harbor	14.5	5.73	1.17	9.03	11.81	33.82	Dorgham _et al._ (2004)
Dekhaila Harbor	38.69	19.22	6.43	49.52	4.4	107.49	Abdel-Aziz _et al._ (2006)
Eastern Harbor	5.33	10.48	0.6	3.36	18.2	3.08	Present study

Table (3): Correlation coefficient between the different parameters in the Eastern Harbor (n = 51). (Significant at p = 0.001, * Significant at p = 0.05).**

	NH$_4$-_N_	NO$_3$-_N_	PO$_4$-_P_	NO$_3$/ PO$_4$	_SiO$_4$-Si_	_Si/P_	_Chl a_	_Salinity_
NH$_4$-_N_	1							
NO$_2$-N	0.2436							
NO$_3$-N	0.0114	1						
PO$_4$-P	**0.3522** *	**0.3446** *	1					
NO$_3$/PO$_4$	-0.1825	**0.8414****	-0.05	1				
SiO$_4$-Si	-0.0379	**0.899 ****	0.0708	**0.8067 ****	1			
Si/P	-0.1428	**0.42** *	-0.113	**0.6154 ****	**0.6184****	1		
Chl a	0.0297	-0.1317	-0.075	-0.1138	-0.0638	-0.097	1	
Salinity	-0.096	-0.160	-0.242	-0.094	-0.098	-0.115	0.212	1
Phyto.count	**0.7483****	-0.0567	0.026	-0.092	-0.0421	-0.087	0.096	0.032

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