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PHYTOPLANKTON COMMUNITY STRUCTURE IN EL-DEKHAILA HARBOUR OF ALEXANDRIA, EGYPT

BY

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ABSTRACT

The phytoplankton standing crop, chlorophyll-a and diversity cycle in El-Dekhaila Harbour are studied and discussed in relation to the most effective environmental physico-chemical parameters. The harbour water is affected by huge amounts of brackish wastewater discharged from El-Umoum drain. A total number of 123 phytoplankton taxa were recorded and characterised by different ecological affinities extending from typical marine forms (84 species) to fresh-water euryhaline forms (39 species), often found side by side. Few species were responsible of the main bulk of the community, namely; Skeletonema costatum, Nitzschia microcephala, Rhizosolenia fragilissima and Protoperidinium minutum.

The mean phytoplankton standing crop varied from $1.3x10^6$ to $20.4x10^6$ unit.l^{-1} in the surface layer and between $0.7x10^6$ and $6.6x10^6$ unit.l^{-1} near the bottom layer. Chlorophyll-a content ranged from 2.26 to 69.38 mg.m^{-3} in the surface layer with an average of 24.05 mg.m^{-3} and decreased near the bottom layer (average of 10.50 mg.m^{-3}). The species diversity showed a minimum value at the surface layer, ranging from 0.74 to 2.34 nats and increased with depth. This reflects the pollution effect of fresh-water discharged through El-Umoum drain.

Regression models showing the dependance of standing crop, chlorophyll-a and diversity index on the most effective ecological prameters are given and discussed for the integrated surface layer and near the bottom water.

INTRODUCTION

The newly constructed El-Dekhaila Harbour lies west of Alexandria between El-Mex and El-Agami at a latitude 29°47' and longitude 31°10' with a surface area of about 12.5 Km^2 and a depth ranging from 6-19 m with an average of 12.4 m. El-Dekhaila Harbour was construced to serve Alexandria Iron and Steel Factory. The harbour is a part of El-Mex Bay which is subjected to several sources of wastewaters. A huge volume of brackish water ($7.7x10^6 m^3.day^{-1}$) is discharged through El-Umoum Drain from the neighbouring Lake Mariut and loaded with industrial, agricultural and domestic wastes. El-Mex Bay also receives industrial wastes from a chloro-alkali Plant and other wastes from tanneries and a slaughterhouse. All of these pollutants contaminate the habour water through circulation in the Bay. El-Dekhaila Harbour like other harbours, is also affected by shipping activities (Cargo and Tankers), which also cause hazardous effect on the environment and biota of the harbour water.

During the study period (October 1990-October 1991), the harbour sturcture consisted of four quays, three of them (quay no. 1,2&3) were in use while the fourth (quay no. 4) was under construction (Fig. 1). The north western side of the harbour is bordered by an artificial brake (Ras El-Agami) which is about 2.5 km long.

There are no previous studies known to be done on the phytoplankton community structure in El-Dekhaila Harbour. This work aims to study the spatial and temporal variations in the species composition, chlorophyll-a content and species diversity in order to evaluate the productivity of the harbour water. In addition regression models of phytoplankton standing crop, chlorophyll-a and diversity index as a function of the most correlative environmental condition are also computed.

MATERIAL AND METHODS

Water samples were collected at bimonthly intervals throughout the period from October 1990 to October 1991. Nine stations were chosen covering the ecologicaly different parts of the harbour (Fig. 1). Sampling was made at 3 depths, surface (50 cm), middle (5m.) and near the bottom layer by a three liters capacity plastic Ruttener sampler.

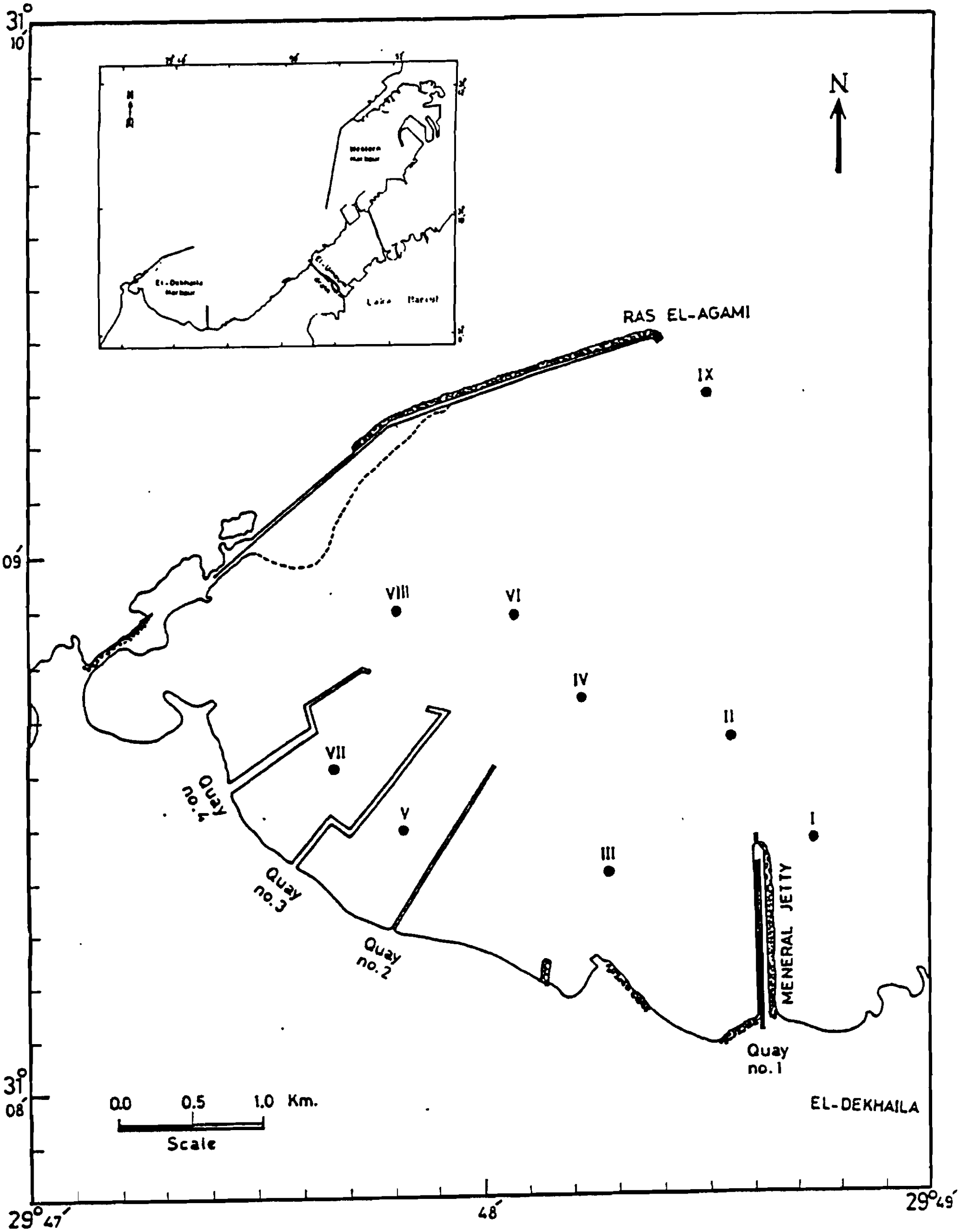

Fig. (1) : Investigated area (EL-Dekhaila Harbour) and position of stations.

The environmental conditions are studied by Abdalla *et al.* 1995. Estimation of the phytoplankton standing crop was carried out by sedimentation method. The phytoplankton species were identified, counted and expressed as unit per liter. Chlorophyll- a concentration was measured following Strickland and Parason (1972). Diversity index was estimated according to Shannon and Weaver (1963) as follows:

$$H = -\sum_{n}^{i=1} P_i \ln P_i$$

where

Pi = n/N is the proportion of the i^{th} (n_i) species to the total number of phytoplankton (N). Diversity index was expressed as nats.

Correlation coefficient between biological (phytoplankton standing crop, chlorophyll-a content and diversity index) and physico-chemical parameters were done for each integrated surface layer (average of surface and 5 meter depth) and near bottom water (n=63). Multiple regression equation at the confidence limit 95% (P=0.05) were calculated at the two layers for the investigation period to quantify the standing crop,chlorophyll-a biomass and diversity index in relation to the most correlative environmental factors. The stepwise analysis was performed for the three dynamic parameters using Number Cruncher Statistical System (NCSS) proposed by Hintze (1993) using a computer.

RESULTS AND DISCUSSION

Phytoplankton standing crop:

1- Community composition:

The phytoplankton community composition in El-Dekhaila Harbour is rich both in standing crop and number of species and also highly diversified in their ecological affinities. The enumerated taxa were 123 species, belonging to a wide spectrum of ecological habitats extending from typical marine forms (84 species) to fresh euryhaline forms (39 species) often found side by side. The species richness (97 species) at surface water was less than near the bottom layer (107 species.). Bacillariophyceae (77 species) were the dominant group, forming 82.7% by number to the total phytoplankton standing crop for the whole water column. Dinophycea (23 species) and Cyanobacteria (10 species), were frequently recorded constituting 7.7% and 6.3% respectively. Chlorophyceae was represented by ten species, while Euglenophyceae by three species, both were rarely recorded. [Table (1)].

Table (1): Mean Average number of different classes of phytoplankton standing crop ($x10^3$unit. l^{-1}) and their percentage frequency to the total phytoplankton in El-Dekhaila Harbour at the integrated surface (average of surface and 5 m depth) and near the bottom layers during October 1990-October 1991.

Depth	Integrate surface layer		Near bottom water	
Class	Average No	%	Average No	%
Bacillariophycea	4911.15	83.67	2378.8	80.7
Dinophyceae	434.05	7.40	247.5	8.4
Cyanobacteria	336.3	5.73	214.4	7.3
Chlorophyceae	107.05	1.82	60.7	2.1
Euglenophyceae	80.85	1.38	44.5	1.5
Total standing crop	5869.4	100	2946.9	100

2- Distribution of phytoplankton standing crop:

The average standing crop in El-Dekhaila Harbour was amounted to be $4.9x10^6$ unit.1^{-1}. Integrated surface layer (average of surface and 5 meter depth) attained an average of $5.9x10^6$ unit.1^{-1}. The phytoplankton decrease with depth is well known phenomenon for coastal water (Rao and Mohanchand, 1988 and Zaghoul 1994 a,b and Zaghoul, 1995). Phytoplankton standing crop was higher at the integrated surface layer of the stations near El-Mex region (Sts. II&IV) and St. VII attaining averages of $8.2x10^6$, $7.3x10^6$ and $6.2x10^6$ unit.1^{-1} at the three stations respectively (Fig. 2), while its lowest count was recorded at the open sea station (St. IX), with an average of $3.91x10^6$ unit.1^{-1}.

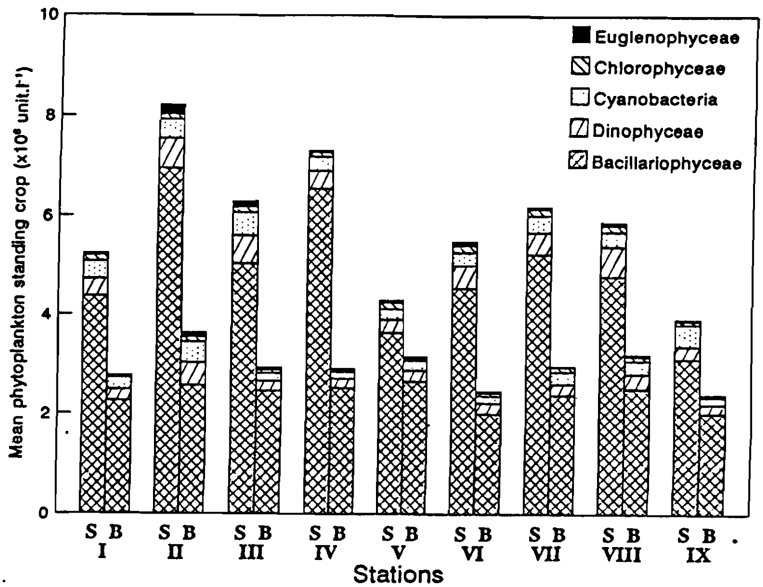

Fig. (2) : Distribution of total phytoplankton standing crop and main classes in El-Dekhaila Harbour at the different stations for both integrated surface layer and near the bottom water (B) during October 1990-October 1991.

The average phytoplankton standing crop in El-Dekhaila Harbour water is higher than that in Western Harbour (Zaghloul, 1994a) and Eastern Harbour (Zaghoul, 1995 & Huessin, 1994) and is also much more than that recorded by Halim (1976), Gergis (1983) Dorgham *et al*, (1987) and Zaghloul (1994b) in the Egyptian Mediterranean waters.

3- Bimonthly variations

The phytoplankton standing crop showed two distinguished peaks; the lower one was in April and the second extended from August to October 1991 (Fig. 3). It is similar to Alexandria coastal water and is related to the high water temperature and the inflow of fresh-water to the area causing eutrophication (Zaghloul, 1994a&b and Nessim, 1994). During the time of the two outstanding peaks, the population was mostly dominated by diatoms especially ***Skeletonema costatum*** which constituted in the upper 5 m about 73.4%, 81.7% and 75.8% by number of the total phytoplankton crop during April, August and

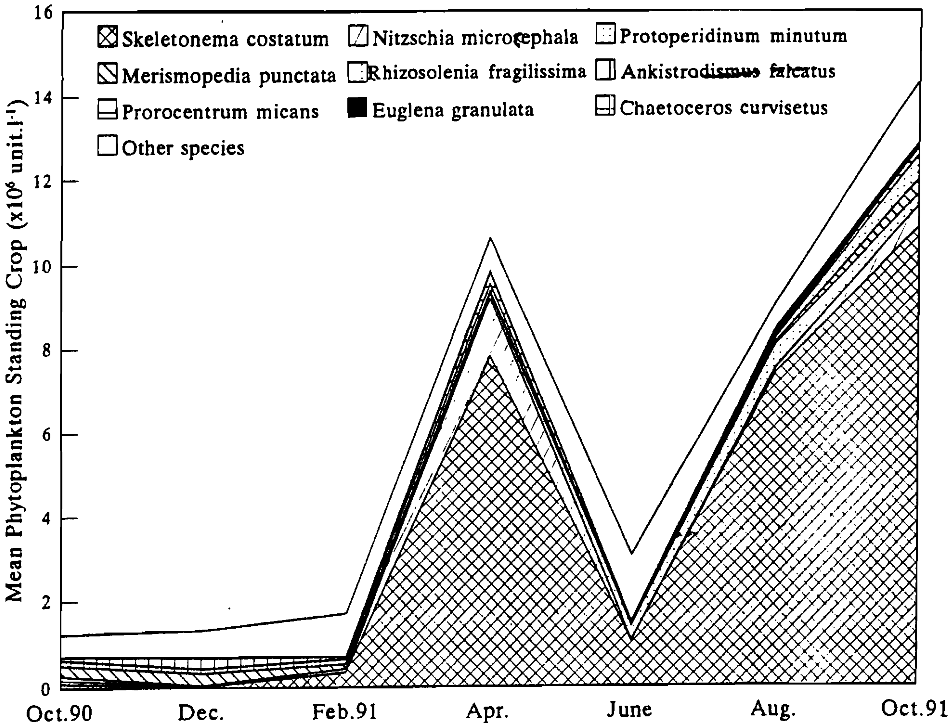

Fig. (3) : Phytoplankton standing crop of the integrated surface layer and its main species in El- Dekhaila Harbour of Alexandria, Egypt.

October 1991 respectively. Cushing (1975) suggested that, the variation in timing, intensity and duration of phytoplankton cycles are mostly related to change in production ratio (compensation rate/depth of mixing) which is in turn largely dependent on seasonal variations in light and wind actions. The production ratio increases in spring with increasing temperature, since incident radiation increased and wind speed tended to decrease reducing mixing.

The species composition of phytoplankton varied from time to the other according to the prevailing environmental conditions. Thus, fresh water forms, such as ***Merismopedia punctata*** (which formed 20.3%, 21.5% and 6.5% by number to the total phytoplankton during October & December 1990 and February 1991 respectively) and ***Ankistrodismus falcatus*** (9.0%, 8.3% and 6.1% at the same three months respectively) were frequently recorded during the period October 1990 till February 1991 as shown in Fig (3). ***Euglena granulata*** was also frequently recorded most of the year with a high percentage frequency during August (2.7%) and October 1990 (1.0%) at a relatively high organic matter concentration. This agrees with the results of Kyselowa (1973) and Zaghloul (1994 a,b). In the present study ***E. granulata*** is positively correlated with organic matter content (r = 0.25) and water temperature (r = 0.30). ***Euglena granulata*** is considered as biological indicator for organic pollution (Munawar, 1972, Palmer, 1969 and Zaghloul, 1994 a,b).

4- Phytoplankton and water quality relationships:

Phytoplankton standing crop was significantly correlated with water temperature (r = 0.46). On the other hand, phytoplankton growth also depends on the level of nutrients in marine ecosystem (Raymont, 1980). In El-Dekhaila Harbour, phytoplankton standing crop at the integrated surface layer, was negatively correlated with all measured nutrient salts, ammonia (r = -0.47), nitrate (r = -0.33), nitrite (r = -0.34) and phosphate (r = -0.45). Silicate was not significant correlate with phytoplankton standing crop which can be attributed to its excessive amount in the harbour. It is to be noted that silicate concentration during the outstanding peaks was at lowest level due to its consumption by the increased numbers of diatoms especially ***Skeletonema costatum***. Also phytoplankton standing crop was negatively correlated with total alkalinity (r = -0.30) which reflects the presence of fresh-water discharge. This is also confirmed by the presence of 39 fresh water taxa of allochtonous origin. As a result of phytoplankton growth, standing crop was also negatively correlated with water transparency (r = -0.62) but positively with oxidizable organic matter (r = 0.42). Therefore, phytoplankton accumulation is associated with the removal of inorganic nutrients, suggesting that nutrient uptake by phytoplankton is the major process responsible for their removal (Fisher ***et al***, 1988 and Zaghloul ***et al***, 1995).

Concerning the relation between phytoplankten standing crop (St. crop) and the environmental parameters, a series of statistical regression models were calculated. These models describe the dependence of standing crop on the most effective measured abiotic factors at both integrated surface layer (S) and near the bottom water (B) are as follows:

St. crop $_{(S)}$ = - 1116994 - 2681091 **Transparency** + 334893.3 **Organic matte**
+ 2528060 **Dissolved oxygen** + 352779.4 **SiO_4** (M.R. = 0.56

St. crop $_{(B)}$ = 7335274 - 77329.5 **S‰** + 1638732 **NO_3** - 0.108 X 10^8 **PO_4**
+ 74233.5 **O_2%** (M.R = 0.58).

These models are adequate at a significant level of 95% (P = 0.0: Comparison of actual phytoplankton to the models, Fig. 4, shows a sma average error, which may be due to the interference of other factors (such a trace elements and vitamins or biological factor such as grazing) that are n included in the model equations.

Diversity

1- Diversity cycle:

The species diversity of the phytoplankton assemblages recorded in E Dekhaila Harbour fluctuated between a minimum of 0.74 nats in the integratec surface layer during August to a maximum of 2.34 nats in June. Phytoplankto diversity increases with depth at most stations all the year round. This reflec the pollution effect which is more pronounced at the surface water. Th estimated diversity at near the bottom layer showed the same trend for th integrated surface layer, it also varied from a minimum of 0.83 nats in Augu to a maximum of 2.40 nats in June.

Diversity index in the harbour water showed an inverse relationship wi phytoplankton standing crop, this result holds for the whole area, and wa clearly evident all the year round both at the integrated surface layer (r = -0.7 and near the bottom layer (r = -0.68). A reverse relationship to the relati frequency was also detected rather than to the number of species. This type relationship was previously recorded by Abdalla *et al* (1992), Zaghloul (199 a,b) and Zaghloul (1995).

The diversity index decreased significantly in surface layer during April, Augu and October 1991 (1.10, 0.74 and 1.21 nats at the three months respectivel when the bloom was dominated by the diatom ***Skeletonema costatun*** constituting 73.4%, 81.7% and 75.8% during the three months respectively well as with higher standing crop (10.6x10^6, 9.06x10^6 and 14.3x10^6 unit. l-

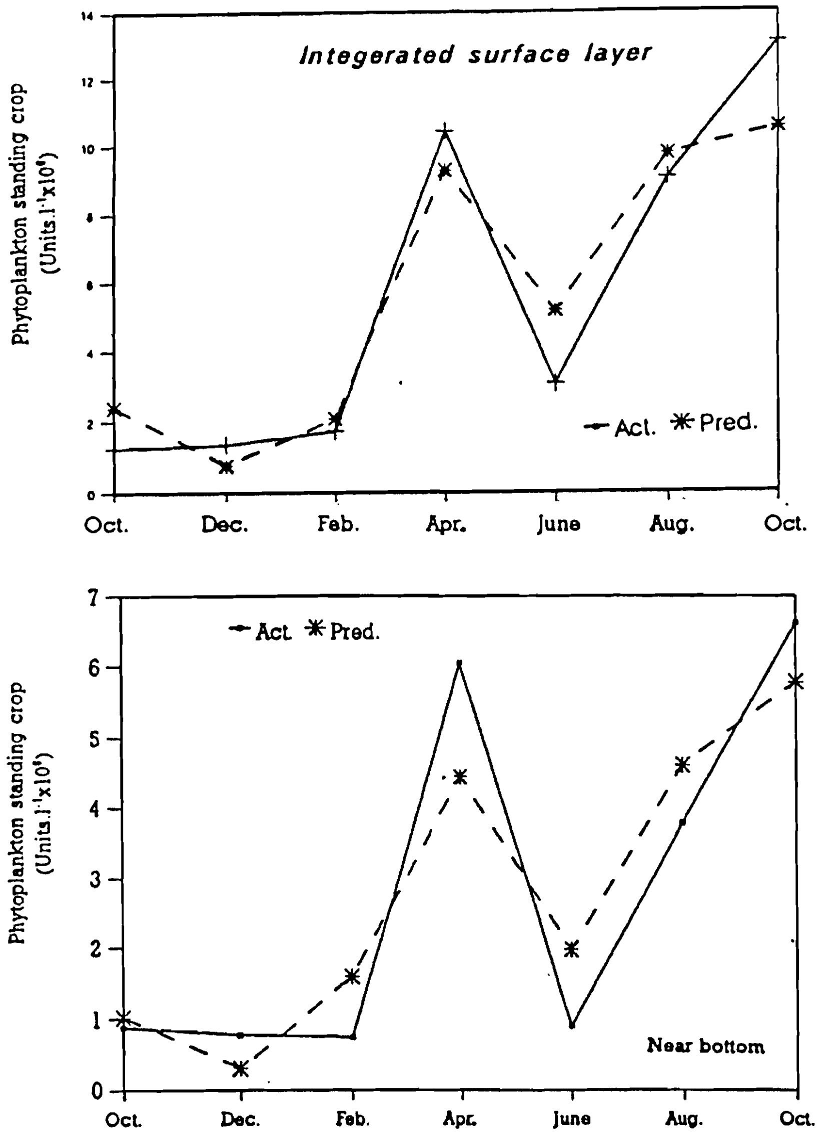

Fig. (4) : The actual phytoplankton standing crop compared with the predicted values as calculated by a multipe regression analysis of the relationship between phytoplankton and the most correlative environmental parameters.

On the other hand, the diversity index reached its maximum when the dominance shared by several species as in the case of the rest of the year. In October 1990, the co-dominance of ***Merismopedia punctata*** (20.3%), ***Ankistrodesmus falcatus*** (9.0%), ***Skeletonema costatum*** (8.2%), ***Nitzschia microcephela*** (6.9%) and ***Chaetoceros curivisetus*** (5.3%) resulted in high diversity index with low phytoplankton standing crop ($1.3x10^6$ unit.l^{-1}).

2- Diversity and habitat structure relationships:

Species composition of a phytoplankton community and/or the dominance depend on the interaction between ecological; biological and evolutionary processes in the surrounding habitat (Margalef, 1978 and Hallegraeff & Reid, 1986). So the availability of resources is one of the most important ecological factors affecting species diversity. This was emphasized by numerous workers who reported correlation between diversity and same aspects of habitat structure (Mac-Arthur, 1964; Borowitzka, 1972; Basson *et al.*, 1976; Fogg; 1978; Margalef, 1978; Cosser, 1988; Abdalla *et al.*, 1992; Zaghloul 1994 a,b and Zaghloul 1995).

Phytoplankton diversity in surface layer of El-Dekhaila Harbour was positively correlated with water transparency (r = 0.63) and most of the nutrients salts (NO_3, r = 0.39; NO_2, r = 0.39; NH_3, r = 0.38; PO_4, r = 0.60). Such correlation may be related to the role of these nutrients in the eutrophication of the area most of the year and its effect on phytoplankton growth. Negative correlations were found between phytoplankton diversity and each of water temperature (r = -0.43), organic matter, (r = -0.32) and dissolved oxygen (r = -0.58), which may reflect the presence of these parameters in the harbour waters in excess (table 2). The same correlation existed also near the bottom layer.

Stepwise multiple regression equations showed that the relation between phytoplankton diversity (H) and the most effective measured abiotic factors at the different layers are as follows.

$H_{(S)}$ = 2.58 + 0.22 **Transparency** - 0.30 **Total alkalinity**- 0.35 **Dissolved oxygen** + 1.74 **PO_4**. (M.R. = 0.65).

$H_{(B)}$ = 1.8 + 0.06 **Organic matter** + 4.0 **PO_4** - 0.02 **O_2%** (M.R. = 0.61).

Table (2): Range and mean values of some water quality at the surface layer and near bottom water in El-Dekhaila Harbour of Alexandria, Egypt during the period October 1990 - October 1991.

Parameters	surface layer		Near bottom water	
	Range	Mean	Range	Mean
Transparency (m)	0.3 - 4.5	1.73		
Temperature (°C)	17.5 - 30.0	24.0	18.5 - 29.0	23.4
Salinity (‰)	16.57 - 39.69	29.10	35.5 - 41.85	39.2
PH	8.09 - 8.97		7.88 - 8.92	
Total alkalinity (mill.eq.l^{-1})	2.52 - 5.52	3.6	2.06 - 3.84	2.8
Dissolved oxygen (ml.O_2.l^{-1})	0.67 - 4.77	2.91	0.38 - 3.94	2.0
Percentage oxygen saturation (%)	12.5 - 98.6	58.9	7.8 - 88.6	42.5
Oxidizable organic matter (mg.O_2.l^{-1})	4.13 - 26.49	11.50	1.54 - 10.14	4.7
Nitrate (μg-at.l^{-1})	0.12 - 12.07	2.46	0.01 - 7.43	1.18
Nitrite (μg-at.l^{-1})	0.77 - 2.56	1.52	0.07 - 1.79	0.97
Ammonia (μg-at.l^{-1})	2.69 - 17.37	8.12	1.00 - 8.94	3.50
Dissolved Phosphate (μg-at.l^{-1})	0.22 - 0.71	0.40	0.18 - 0.45	0.30
Reactive silicate (μg-at.l^{-1})	1.56 - 13.98	5.70	1.15 - 4.38	2.20

These models are adequate at a significant level of 95% (P = 0.05). Comparison of actual phytoplankton diversity to the models (Fig. 5), showed a small average error. This may be due to the interference of other factors (such as trace elements or vitamins) which are not included the model equations.

3- Diversity - Frequency relationship:

Shannan Weaver diversity index reflects an inverse relationship to the degree of dominance or relative frequency rather than to the number of species contributing to the standing crop. This conclusion holds for each surface layer and near the bottom water throughout the year. Figure (6) represents the relationship between diversity (H) and the degree of dominance (F%). The simple regression equation describing this dependence are as follows:

$H_{(S)} = 2.67 - 0.02\ F\%$ (r = - 0.89)
$H_{(B)} = 2.82 - 0.02\ F\%$ (r = - 0.55)

Chlorophyll- a Biomass:
1- Distribution and bimonthly variations:-

Surface chlorophyll.-a varied widelly between 2.26 and 69.38 $mg.m^{-3}$ while near the bottom the variation range was narrower, 1.20 and 41.23 $mg.m^{-3}$. The average value of chorophyll-a in the water column was 10.50 $mg.m^{-3}$. Its average in the integrated surface layer of the harbour was high (24.05 $mg.m^{-3}$) and mainly attributed to high phytoplankton standing crop and suitable environmental conditions (Table 2) such as water temperature as well as enrichment of surface water with nutrient salts brought into the harbour with sewage and drainage waters from El-Mex pumping station. It is significantly higher than that recorded by Nessim and Tadros (1992) in Western Harbour (6.12 $mg.m^{-3}$).

As regards to the regional distribution, higher values of chlorophyll-a were recorded at the surface water of stations II and III (near El-Mex pumping station) with an average of 33.3 and 30.3 $mg.m^{-3}$ at the two stations respectively. This was met with a higher phytoplankton standing crop. The minimum values of chlorophyll-a (average of 11.25 $mg.m^{-3}$) as recorded at open sea station (St. IX), which was characterized by relatively low phytoplanktan counts (Fig. 2).

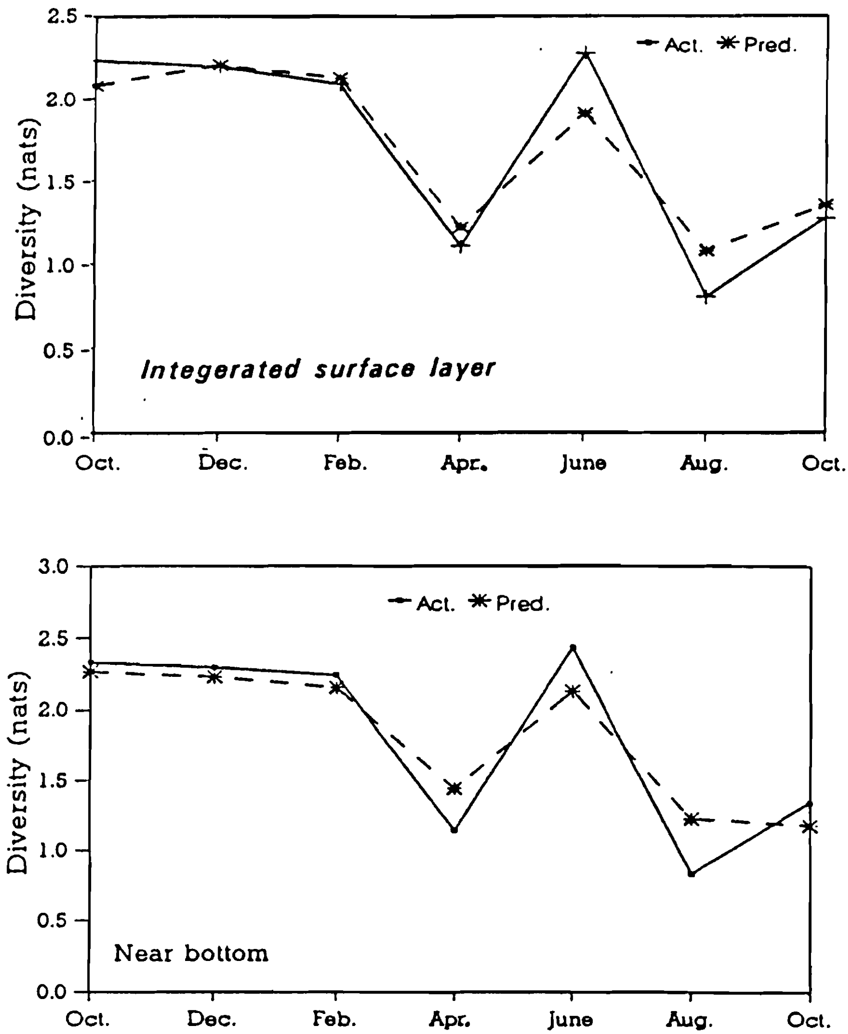

Fig. (5) : Comparison of the actual diversity values with the predicted values as determined by a multiple regression analysis of the relaionship between diversity and environmental factors.

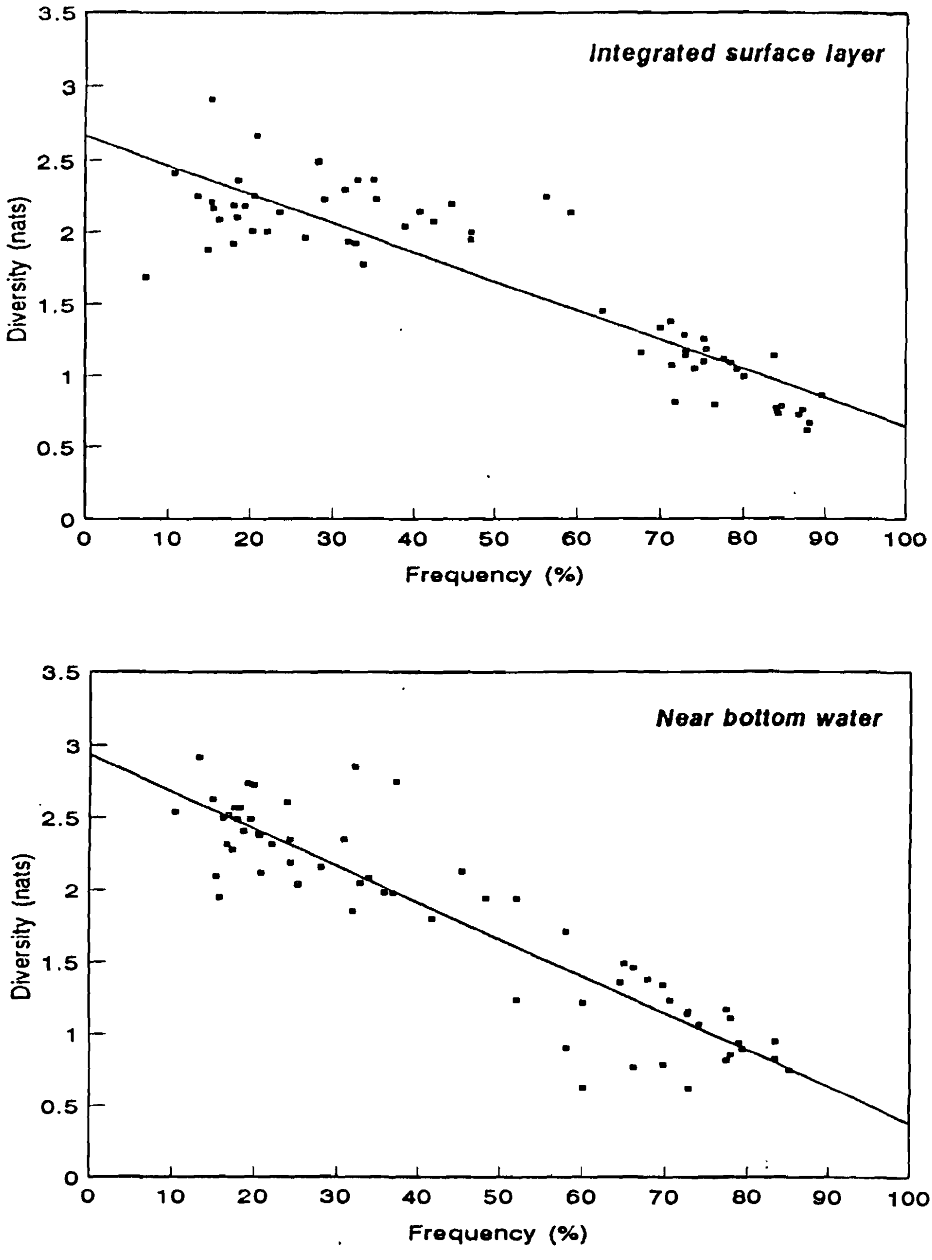

Fig. (6) : Regression of diversity (H) on dominancy (F%) in the integrated surface layer and near the bottom water at El-Dekhaila Harbour of Alexandria, Egypt.

Concerning the bimonthly variations of chlorophyll-a biomass, it showed a similar trend to that of the total phytoplankton standing crop all the year round. Two outstanding peaks were also recognised, one during April 1991 and the second extended from August to October 1991. During April 1991, ***Skeletonema costatum*** and ***Nitzschia microcephala*** were the main phytoplankton species constituting numerically about 74.4% & 13.0% (Fig. 6) respectively of the total phytoplankton standing crop. The peak of August-October 1991 was coused by ***Skeletonema costatum*** and ***Protoperidinium minutum*** forming 81.7% and 6.0% by number to the total phytoplankton standing crop during August 1991 and 75.8% & 2.0% during October 1991.

2- Chlorophyll-a biomass and habitate structure relationships.

Surface chlorophyll-a biomass was significantly correlated with water temperature (r = 0.57); pH (r = 0.61) and organic matter (r = 0.63), while negatively correlated with salinity (r = -0.41) indicating the effect of fresh-water rich in nutrient in the formation of Chlorophyll-a (Chl-a). Michael ***et al.***, (1983) recorded high Chl-a values with the low transparency which agree with the results of the present work, as Chl-a was negatively correlated with water transparency (r=-0.64). Chlorophyll-a biomass was positively correlated with ***Skeletonema costatum*** (r=0.83), ***Protoperidinium minutum*** (r = 0.48) and ***Euglena granulata*** (r = 0.48).

A series of statistical regression models were calculated to describe the dependence of chlorophyll-a biomass on the most correlative physico-chemical parameters at both integrated surface layer (S) and near the bottom water (B). They are as follows:

Chl.a $_{(S)}$ = - 293.4 - 0.55 **S‰** + 44.9 pH - 11.5 **Transparency** - 6.1 **Total alkalinity** (M.R. = 0.70).

Chl. a $_{(B)}$ = 128.0 - 3.1 **S‰** + 3.9 **Dissolved oxygen** + 6.8 $\mathbf{NO_3}$ + 1.3 $\mathbf{NO_2}$ - 1.1 $\mathbf{NH_3}$ - 25.7 $\mathbf{PO_4}$ (M.R. = 0.58).

These models are adequate at confidence limit 95%. Comparison of actual chlorophyll a-biomass to the models are shown in Fig. 7.

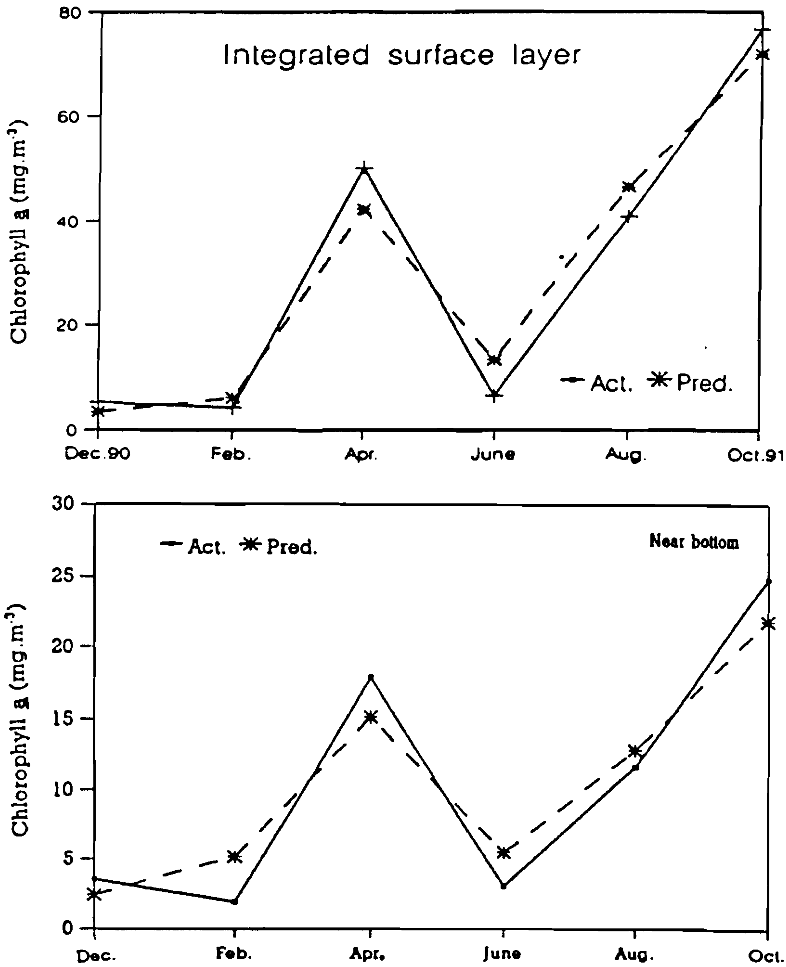

Fig. (7) : The actual chlorophyll-a biomass compared with the predicated values as calculated by a multiple regression analysis of the relationship between chlorophyll-a and the most correlative environmental parameters.

Conclusion

The investigated area is characterized by receiving huge quantities of brackish water from El-Umoum drain causing the eutrophication of the water. According to the extention of El-Umoum drain eflluent fresh water forms ***Merismopedia punctata*** and ***Ankistrodesmus falcatus*** were sometimes found as codominant with marine forms.

Eutrophic conditions resulted in higher phytoplankton standing crop, higher chlorophyll-a biomass and lower species diversity particularly at the surface layer as well as the appearance of species tolerant to eutrophication such as ***Skeletonema costatum, Rhizosolenia fragilissima, Nitzschia microcephela Protoperidinium minutum*** and ***Prorocentrum micans.***

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