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PHYTOPLANKTON DYNAMICS IN THE WESTERN HARBOUR OF ALEXANDRIA, EGYPT.

By

FATMA A. ZAGHLOUL*

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

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ABSTRACT

The Western Harbour is subjected to a large amount of untreated domestic, industrial and agricultural waste water beside considerable amounts of oil discarded from ships which altered its water quality. The phytoplankton standing crop displayed wide seasonal variations. The annual averages were of 4.7 x10^6, 1.6 x 10^6 and 0.5 x10^6 unit. l^{-1} respectively at the surface water, 5m. depth and near bottom layer. Sixty eight species were recorded belonging to a wide ecological spectrum extending from typical fresh-water (23 species) to typical marine forms (45 species) often found side by side. However, very few of them formed the main bulk of the community, namely; Cyclotella meneghiniana, Nitzschia delicatissima, Prorocentrum cordatum and Euglena granulata. Generally, the distribution of the dominant species differed from one month to the other. A continuous bloom was observed from June to October, with a peak in June.

The surface chlorophyll a biomass ranged from 0.2 to 11.0 mg/m^3 in the surface water with an annual average of 4.2 mg/m^3. The polluted area sustained lower values. The biomass was related to the size of the dominant species rather than to the total counts.

The Shannon diversity reflects an inverse relationship to the degree of dominance of the main species rather than to the species richness or to the standing crop.

The correlation between standing crop, biomass, diversity and the major environmental parameters and their multiple regression equations are discussed.

INTRODUCTION

The Western Harbour of Alexandria is the main trade harbour in Egypt. It is elliptical in shape with a length of 7.0 Km and a maximum width of 2.0 km.. The depth of the water ranges from 5.5 to 16.0 meters. Its a surface area is about 13 km^2, partially divided into an inner and outer parts with a total length of 9875 m as quays which can station a maximum of 62 ships at one time.

About 90 x 10^3 m^3 /day of domestic, industrial and agricultural drainage water are discharged into the harbour through six outlets (Fig. 1). There is also an intermittent surface inflow from the neighbouring El-Mex Bay which is the recipient of 7.7 x 10^6 m^3/day of agricultural drainage water from El-Umum Drain.

The present investigation deals with the phytoplankton standing crop, chlorophyll a biomass and diversity index. The distribution of the different species in relation to the prevailing environmental conditions was also estimated. The correlation between standing crop, chlorophyll a biomass, diversity and environmental conditions is computed and discussed.

MATERIALS AND METHODS

Water and phytoplankton samples were collected from eight stations, representing the different habitats of the harbour (Fig. 1). Samples were taken from the surface layer, 5 meter depth and near bottom layer at bimonthly intervals during the year 1989, by means of a plastic Ruttner water sampler. Water temperature, Secchi-disc readings, pH values, total alkalinity, salinity, dissolved oxygen, oxidizable organic matter and nutrient salts were measured and discussed earlier by Zaghloul and Nessim (1991).

Estimation of the phytoplankton standing crop was carried out by the sedimentation method (Utermohl, 1936) and the samples were preserved in 4% neutral formalin. The different species were identified and counted as cells per liter. Chlorophyll-a was determined spectrophotometrically as pigment extract according to Strickland and Parsons, (1972), and the results are expressed in mg/m^3.

Species diversity was calculated according to the equation of Shannon and Weaver (1963) on a computer, using Primary Program. The dominance index (d) was calculated using the Bergen - Parker dominance index (C.f. Chellappa, 1989).

$$d = n_{max} / N_T$$

Where

n_{max} = number of individuals of the dominant species.

N_T = total number of individuals of all the species recorded.

Correlation matrix as well as multiple regression equations at a confidence limit 95% ($P \geq 0.05$) were calculated for the surface samples of each month and also for the whole integrated year ($n = 48$) to quantize the standing crop, chlorophyll-a biomass and diversity index in relation to the most correlative environmental factors. The whole set of parameters both biological and non-biological were entered into the models and each of them was tested individually for significance. This stepwise iteration analysis was performed for the three dynamics parameters.

RESULTS AND DISCUSSION

Phytoplankton standing crop:-

The phytoplankton standing crop showed a much higher annual average in the surface water ($4.7X10^6$ unit.l^{-1})as compared with the adjacent area of El-Mex Bay (Dorgham et al, 1987; El-Sherif, 1989), but it is of the same order as that recorded in the Eastern Harbour which averaged $4.3X10^6$ unit.l^{-1}(Zaghloul & Halim, 1990). This is also comparable to most harbours impacted by domestic discharge and industrial effluents (Rao & Mohanchand, 1988).

The phytoplankton density was highest in the surface layer, and it ranged from 0.3×10^6 to 20.0×10^6 unit.l^{-1} compared to 0.08×10^6 to 6.0×10^6 unit.l^{-1} at 5 meter depth and 0.03×10^6 to 2.5×10^6 unit.l^{-1} in the bottom layer (15 m). This is attributed to the rapid attenuation of the incident light with depth particularly in the bottom layer which lies below the euphotic zone during most of the year (Zaghloul & Nessim, 1991).

The harbour can be differentiated into three main habitats according to the degree of contamination. The inlet or "El-Boughaz" area (Sts. IV & V) sustained the highest annual averages of 6.7×10^6 and 6.5×10^6 unit.l^{-1} at the two stations respectively. This is attributed to nutrient enrichment by the inflowing surface water from El-Mex Bay. The highly polluted area is located at the eastern side (Sts VI, VII & VIII) and it sustained both high oxidizable organic matter and nutrient levels which correspond to lower values of dissolved oxygen, salinity and Secchi-disc transparency (Zaghloul & Nessim, 1991) as well as lower phytoplankton standing crop (annual averages of

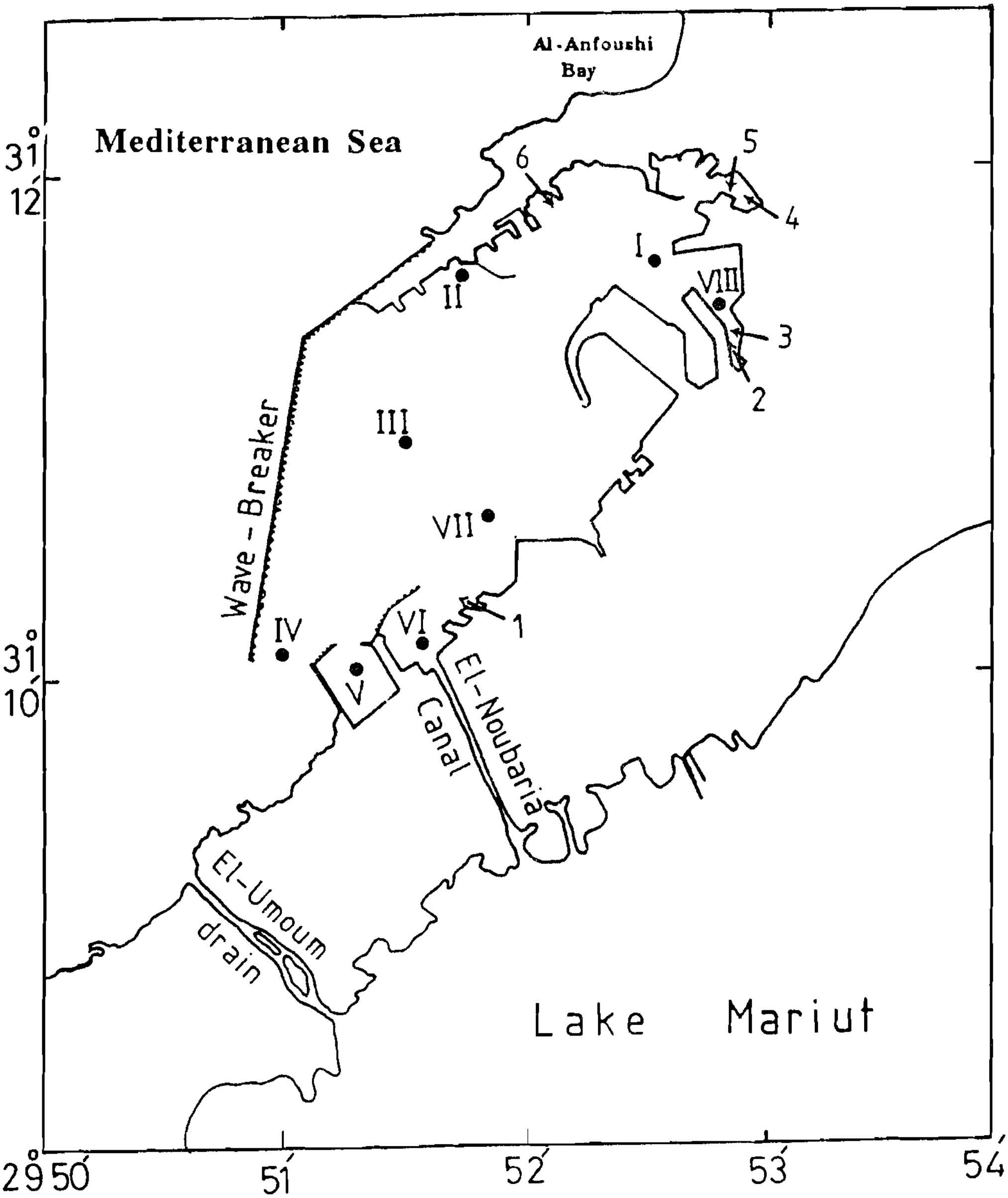

Figure 1: Alexandria Western Harbour, Egypt. Location of sampling stations and sewage outfall (1 - 6)

2.5×10^6, 3.0×10^6 & 3.3×10^6 unit.l-^{1} at stations VI, VII & VIII respectively). The western sector (Sts I, II & III), the least polluted region, sustained high standing crops (annual averages of 5.4×10^6, 5.1×10^6 & 4.7×10^6 unit.l-^{1} at station I, II & III respectively).

Bacillariophyceae (37 species) was predominant, contributing 70%, 87% and 85% by number of the phytoplankton standing crop at the surface, 5 m and 15 m layers respectively. The Dinophyceae (11 species) contributed 25%, 7% and 7.5% respectively. One Euglenophyta was frequently recorded (4.4%, 5.5% & 6.1% respectively). Eleven species of Chlorophyceae and six of Cyanobacteria were rarely encountered.

The community composition in the three layers was almost similar during the different seasons. A continuous phytoplankton bloom was observed from June to October with a peak in June (Fig. 2).

The community harboured different dominant species within the different months as affected by the prevailing physico-chemical conditions. Thus, the months June and August were characterized by a gradual increase in water temperature (26.5 & 28.0°C), high stability, high values of pH, reactive silicate and dissolved oxygen but the other parameters including water salinity, Secchi-disc readings and nitrate concentration remained low (Zaghloul & Nessim, 1991). The bloom within these two months was dominated by Cyclotella meneghiniana and to a lesser degree of Nitzschia longissima and Prorocentrum cordatum (Fig. 2). The October bloom attained its highest density at stations VII & VIII and it consisted mainly of the marine diatom Nitzschia delicatissima and coincided with higher water salinity, nitrite, nitrate, pH values, ammonia and also Secchi disc transparency. Dissolved oxygen, water stability and silicate content were low.

Prorocentrum cordatum was the main plankter in February. This coincided with higher phosphate content which was positively strong correlated with the species counts ($r = 0.95$, $P \geq 0.05$) and this agree with the findings of Casabiana (1979) and also with higher values of reactive silicate ($r = 0.86$, $P \geq 0.05$) and lower water salinity ($r = -0.94$, $P \geq 0.05$). Euglena granulata prevailed in April and was positively correlated with oxidizable organic matter ($r = 0.92$, $P \geq 0.05$) and chlorophyll a ($r = 0.73$, $P \geq 0.05$).

Regression equations were developed statistically to find out possible correlations between standing crop fluctuations and environmental conditions. The models obtained for each month are given in Table (1).

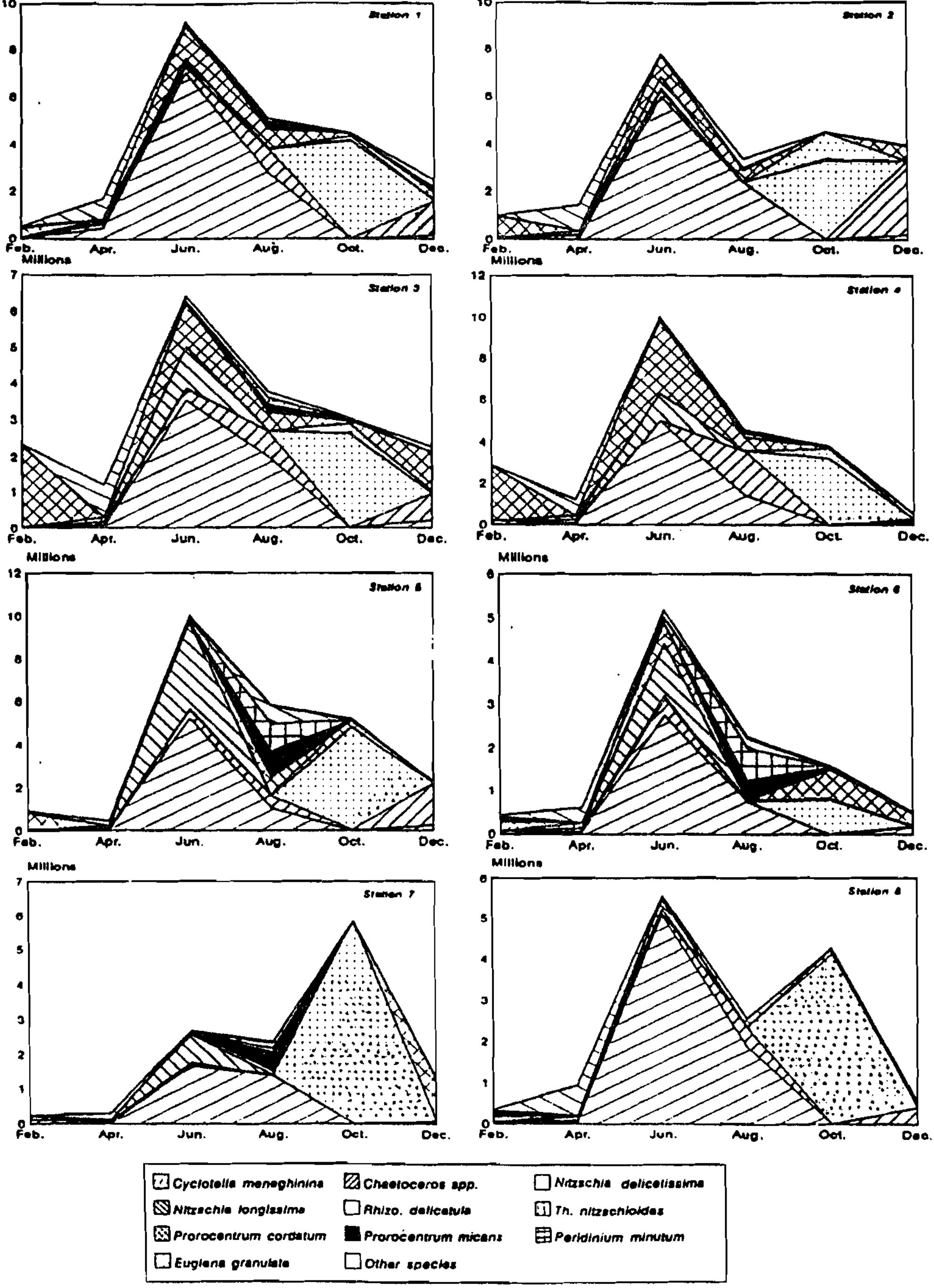

Figure 2: Phytoplankton standing crop at the integrated surface layer (average of surface and 5 meter depth) and its main species at the different stations in Western Harbour of Alexandria, Egypt, during 1989.

Table (1): Multiple regression equations of phytoplankton standing crop at the surface water of the Western Harbour during the different months of 1989.

Month	Phytoplankton standing crop models (St. crop)	Multipte Regression M.R.)	Compiled error (e%)
February	St.crop = 1497584.06 PO_4 -173112.9 N/p -1925337.51	0.98	18.7%
April	St.crop = 318646.85 trans -707517.77 temp. +350031.64	.86	17.8%
June	St.crop = 11719316.64 trans+15387857.25 pH-105595930.37	0.89	2.4%
August	St.crop = 20099981.28 pH -1062441.63 S%. -1490639.8 DO-123173873.83	0.94	0.97%
October	St.crop =1261330.0 trans +4283508.65 Alk +10462704.42	0.64	7.65%
December	St.crop =1658253.77 trans -2237603.19 temp +4398850.46 PO_4 -805704.27 SiO_2 + 44085647.7	0.98	3.62%

Where

Trans = Secchi-disc transparency (cm)
DO = Dissolved oxygen ($mlO_2.l^{-1}$)
Alk = Total alkalinity (milli. $Eq.l^{-1}$)
Temp. = Water temperature (°C)
PO4 = Phosphate concentration (u gm- $at.l^{-1}$)
SiO2 = Silicate content (u gm-$at.l^{-1}$)

Considering all results for the surface layer, strong positive correlations were obtained between phytoplankton abundance and water temperature ($r = 0.56$, $P \geq 0.05$) on one hand and negative correlations with water salinity ($r = -0.35$, $P \geq 0.05$) and ammonia concentration ($r = -0.3$, $P \geq 0.05$) on the other. This indicates that the influx of fresh-water causes an increased eutrophication level. The corresponding evaluated model equation is

Standing crop = 16760794.87 + 382629.85 temp. - 552147.47 S%. - 102918.25 NH_3.
(M.R. = 0.66, e% = 19.2%)

Chlorophyll-a Biomass:

Chlorophyll-a biomass showed wide variations in the surface water, ranging from 0.2 mg/m^3 (St. VIII, February) to 11.0 mg/m^3 (St.I, August) with annual average of 4.2 mg/m^3. Such concentrations are lower than the surface records of El-Mex Bay which averaged 16.2 mg/m^3 (Dorgham et al 1987). The highest annual average biomass was recorded at station I (5.93 mg/m^3) and the lowest at the polluted station VIII (2.87 mg/m^3). Comparing the monthly averages, the highest value was recorded in December (6.23 mg/m^3) and August (5.16 mg/m^3), deceasing gradually through April (4.8 mg/m^3)and June (4.92 mg/m^3). However, the month of December harboured relatively low phytoplankton standing crop (2.6 x 10^6 cells.l^{-1})which consisted mainly of diatoms (60% by number to the total phytoplankton). The chlorophyll a biomass was correlated with Peridinium minutum ($r = 0.82$, $P \geq 0.05$) and Euglena granulata ($r = 0.73$, $P \geq 0.05$) in April. Prorocentrum micans ($r = 0.89$, $P \geq 0.05$) during June. Results indicate that the chlorophyll a biomass is mainly related to the size of the dominant species rather than to the total phytoplankton count.

Strong positive correlation exists between the chlorophyll a biomass and pH values ($r = 0.5$, $P \geq 0.05$), while a negative correlation appears with N/P ratio ($r=-0.26$, $p \geq 0.05$). The corresponding model equation is

Biomass = - 26.33 + 2.7432 pH - 0.0113 N/P. (M.R. = 0.56, e% = 14.2%).

Phytoplankton diversity:

The estimated diversity reflects an inverse relationship to the degree of dominance of the main species recorded rather than to the number of species or the magnitude of the standing crop. Such conclusion is more clear in the surface water of the harbour throughout the whole year. For example, the highest average diversity value was recorded during both April (1.22 nats) and August (1.39 nats) although the phytoplankton density in April (average 1.3 x 10^6 unit.l-^{1}) was much lower compared to that of August (5.9 x 10^6 unit.l-^{1}).

These two months showed also big differences in the species richness (34 & 28 species in April and August respectively). Such high diversity values are attributed to the dominance of several species which comprised mainly Euglena granulata (59% by number to the total phytoplankton), Cyclotella meneghiniana (9%) and Nitzschia delicatissima (7%) in April and Cyclotella meneghiniana (7%), Chaetoceros spp. (20%), Prorocentrum cordatum (13%) and Prorocentrum micans (11%) during August. On the other hand, the lowest average diversity values were obtained in February (0.67 nats) and October (0.52 nats), and the species richness were 40 and 32 respectively, in spite of the wide difference in the phytoplankton standing crop (0.07×10^6 & 1.2×10^6 cells.l^{-1} in February and October respectively). The community was dominated by only one significant species, namely Prorocentrum cordatum which formed 91% of the total standing crop in February and Nitzschia delicatissima which contributed 84% in October.

Fig. (3) illustrates an inverse relationship between diversity (H) and the dominance index (d) in the surface water. The simple regression equation describing this dependence is

$$H = 2.2805 - 2.0518\ d \quad (M.R. = -0.89).$$

Negative correlations were recorded between diversity and Secchi-disc reading ($r=-0.3$, $P \geq 0.05$) and nitrate concentration ($r=-0.39$, $P \geq 0.05$), while a positive one was obtained with dissolved oxygen ($r=0.37$, $P \geq 0.05$). The representative diversity model equation is

$$\text{Diversity} = 0.8822 - 0.1238 \times \text{transparency} + 0.0815 \times \text{dissolved oxygen} + 0.0188 \times NO_3. \quad (M.R. = 0.53,\ e\% = 6.6\%).$$

In conclusion, biological indices of eutrophication in the Western Harbour are indicated by a heavy phytoplankton standing crop particularly in the surface layer and the presence of allochthonous fresh-water species in abundance, with high percentage of Euglena granulata. The seasonal cycle of phytoplankton is correlated with some environmental factors which varies from one month to the other.

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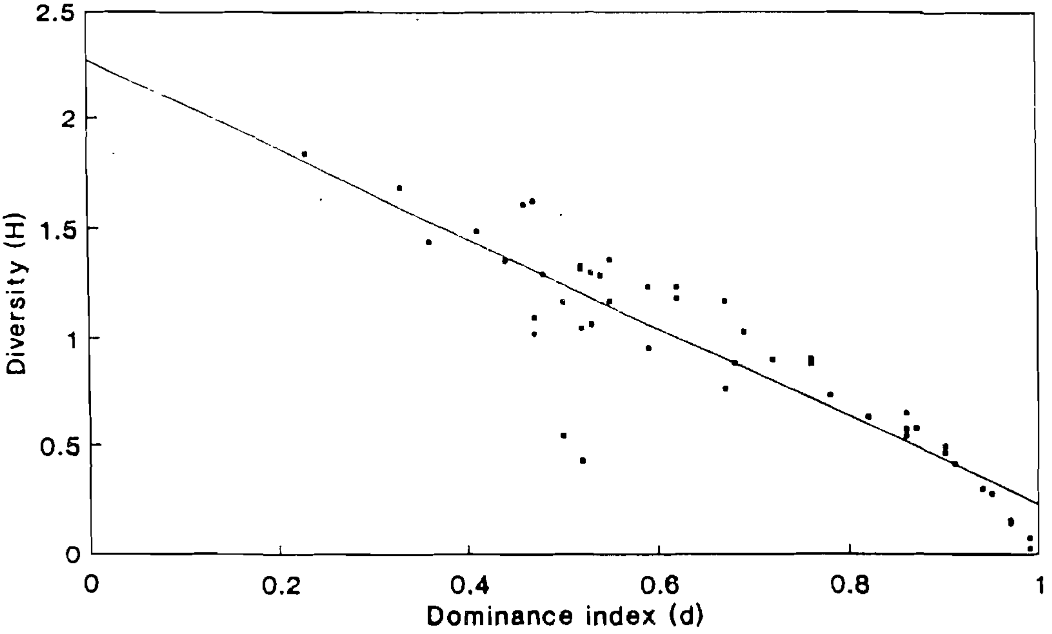

Figure 3: Regression of diversity (H) on dominance index (d) in the surface of the Western Harbour of Alexandria, Egypt, during 1989.

REFERENCES

Casabianca, M.C. 1979. Phosphates dans less etances Mediterraneens; Hautes teneurs, teneurs criliques-Drevision et declenchement des " Eaux decolorees" Rapp. Comm. Int. Mer. Medit. 25/26, 105-108.

Chellappa, N.T. 1989: Phytoplankton species composition, chlorophyll biomass, and primary production of the Jundiai Reservoir (northeastern Brazil) before and after eutrophication. Acta Hydro. Vol. 32 No 1/2: 75-91.

Dorgham, M.M, M.I. El. Samra, & Th. Moustafa, 1987. Phytoplankton in an area of multi-polluting factors west of Alexandria, Egypt. Qatar Univ. Sci. Bull. Vol. 7: 393-419.

El-Sherif, Z.M. 1989. Distribution and ecology of phytoplankton in El-Mex Bay (Egypt). Bull. Inst. Oceanoger. and Fish., ARE. Vol. 15.

Rao, M.U. & V. Mohanchand, 1988. Water Quality characteristics and phytoplankton of polluted Visakhapantanam Harbour. Marine Environmental Research. Vol. 25: 23-43.

Shannon, G.E. and W. Weaver, 1963 . The mathematical theory of communication. University of Illinois Press, Urban pp 125.

Strickland, J.D.H & T.R. Parsons, 1972. A practical handbook of sea water analysis. Fish. Res. ed. Canada. Bull. 167, 2nd ed. 310 pp.

Utermohl, H. 1936. Quantitative methoden untersuchung des nannoplankton in adderheldens. Handbuch der Biolog. Arb-Methoden Abt. IX(I).

Zaghloul, F.A. & Y. Halim, (1990). Phytoplankton flora and its dynamics in the Eastern Harbour of Alexandria. Bulletin of the High Institute of Public Health. Vol. 20 (4): 875-886.

Zaghloul, F.A. & R.B. Nessim, (1991). Eutrophication syndrome in the Western Harbour of Alexandria, Egypt. Bulletin of the High Institute of Public Health. Vol. 21(2): 257-271.