

EUTROPHICATION IN MEX BAY (ALEXANDRIA, EGYPT) ENVIRONMENTAL STUDIES AND STATISTICAL APPROACH

By

W. LABIB*

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

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ABSTRACT

The influence of physico-chemical factors on time-space variability of phytoplankton standing crop, succession and biomass was assessed during an annual cycle in Mex Bay, west of Alexandria (Egypt). The bay is eutrophic dynamic system, subjected to continuous environmental changes and characterised by distinct structural properties. The normal symptoms and manifestation of eutrophication in the bay included the triggering of heavy algal blooms during summer-early autumn, associated with water discoloration. The statistical approach proved the more significant contribution of the physical parameters (water temperature, density and transparency) affecting chlorophyll a variations, rather than nutrient concentrations. The strong correlation between measured and modelling results of chlorophyll a as a function of the numerical standing crop could be explained by the predominance of diatoms most of the year. Generally, deviation in the model results, occurred at times, is due to the interfering of several factors simultaneously.

INTRODUCTION

Marine eutrophication or simply man-made over fertilisation of an aquatic system is a coastal phenomena restricted to transitional areas, affecting their marine processes (Vollenweider, 1981).

Discharges into Mex Bay of land-runoff rich in organic substances and plant

nutrients from human settlements, urban areas, chemical industries and agricultural activities are largely the cause of eutrophication. The bay receives directly from neighbouring Lake Maryout, through Umum Drain, a daily average of 6×10^6 m³ of agricultural waste waters mixed with pesticides, fertilisers and municipal waste waters.

Intensive attention was paid to investigate physico-chemical characteristics of the bay (e.g. Emara *et al.*, 1984 & 1992; Dorgham *et al.*, 1987; Said *et al.*, 1991; Nessim, 1994). Nevertheless, the previous works on phytoplankton standing crop were rather limited (Dorgham *et al.*, 1987; El-Sherif, 1989; Samaan *et al.*, 1992, Abdalla *et al.*, 1992).

The present study, during an annual cycle, pin points the influence of physico-chemical factors on time-space variability of phytoplankton standing crop, succession and biomass in Mex Bay. It represents an attempt to assess correlation, at a given circumstance, between prevailing environmental physical and chemical variables and chlorophyll *a*, as well as its correlation with the numerical standing crop and community structure. The knowledge gained can help to ameliorate the situation.

MATERIAL AND METHODS

Mex Bay extends for about 15 Km, west of Alexandria. The bay has a mean depth of about 10 m and a surface area of about 19.4 Km.² Sampling collection was conducted at 3 stations; I, II (5-7m depth) and III (12m) from January to December, 1993 (Fig. 1). Samples were taken at 50 cm below the surface. Temperature and salinity were also measured near to the bottom.

Temperature was measured by a thermometer accurate to 0.1°C, salinity (salinity refractometer, S/Mill), water density was calculated on the basis of temperature and salinity data (UNESCO, 1987), transparency (Secchi disk, diameter of 25 cm), pH (pH meter, Extech 607), dissolved oxygen (Winkler method), nutrients (nitrate, NO₃-N, ammonia, NH₄ and phosphate, PO₄) and chlorophyll *a*, here-after Chl. *a* (Strickland & Parsons, 1972) and the quantitative estimation of the phytoplankton by applying the settling method (Utermohl, 1958).

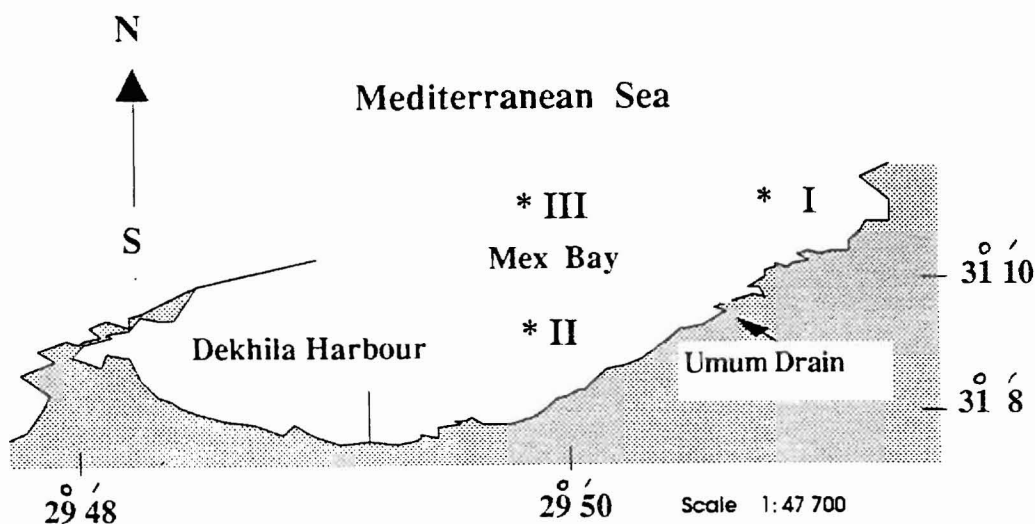


Figure 1. Study area and sampling stations

RESULTS

1-Time-space variability of the physical and chemical parameters:

The hydrodynamic conditions, the land run-off and the algal growth induced large variations in the physico-chemical characteristics in Mex Bay. The measured parameters are shown in Table 1 and Fig. 2&3.

Water temperature, an allogenic factor affects changes in the standing crop and composition (Goldman & Carpenter, 1974). The study area, a part of SE Mediterranean, represents a warm subtropical region. Water temperature varied normally between a minimum of 15.5-15.8°C in January-February to a maximum of 29.8-30.5°C in July. The spring warming started in May. The thermal gradient reached its maximum difference of 3°C between surface and 10m, St. III, in July. In general, water temperature above the bottom followed that of the surface. Limited regional variations were observed.

Salinity has bearing on the temporal development and spatial distribution of the standing crop and succession (Smayda, 1980).

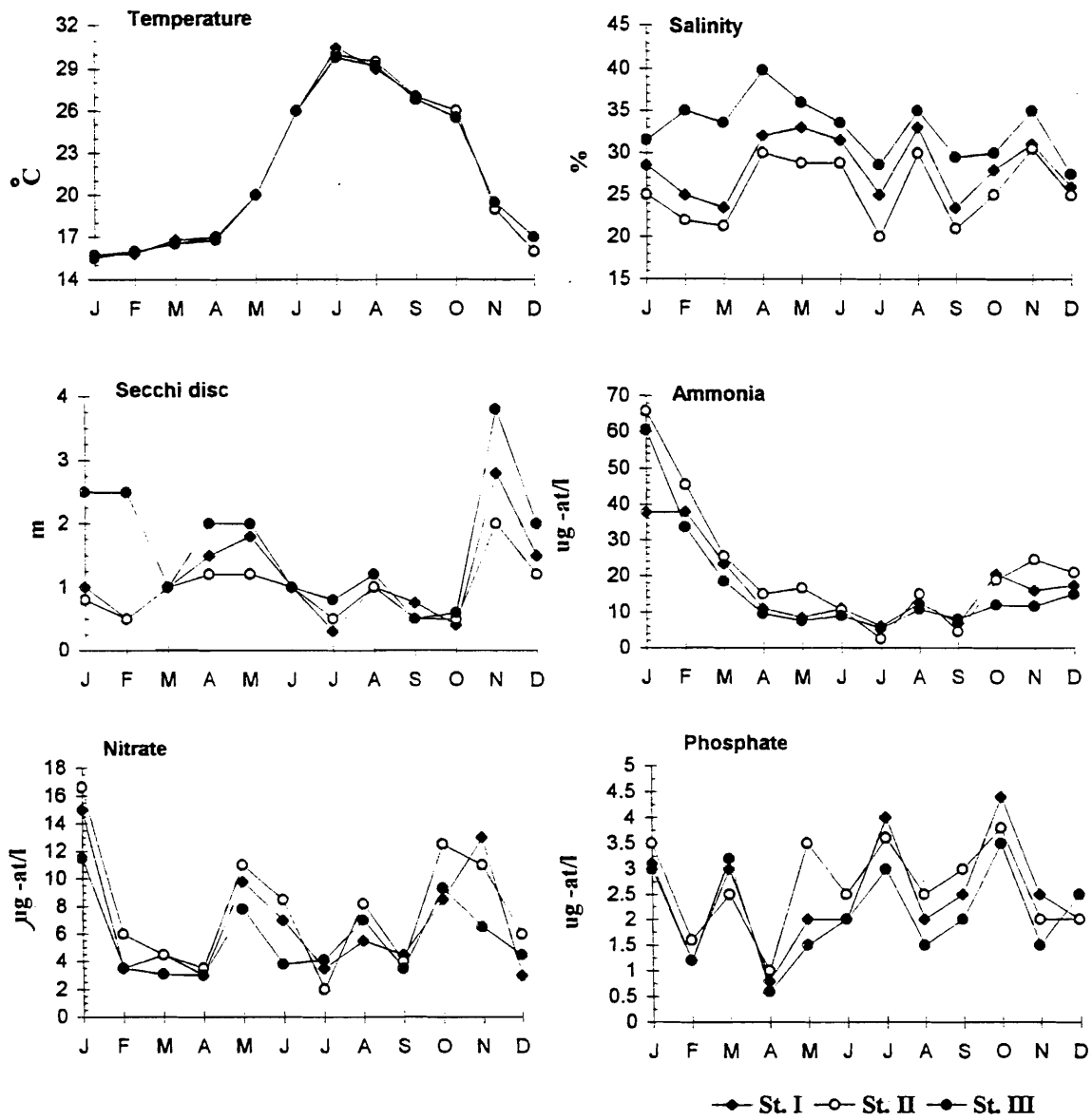


Figure 2. Measured physical and chemical parameters in Mex Bay from January to December 1993.

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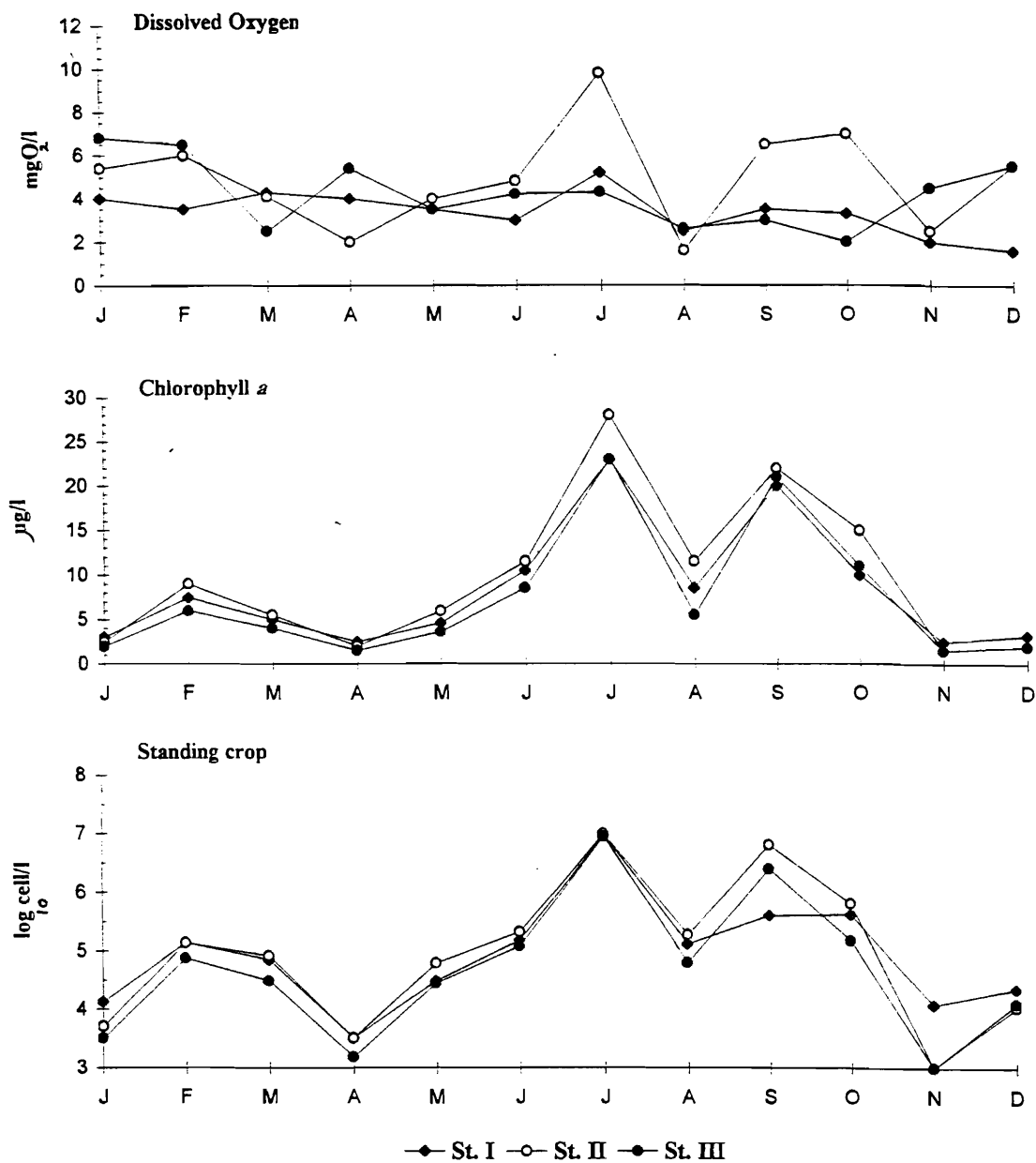


Figure 3. Measured dissolved oxygen, chlorophyll *a* and standing crop in Mex Bay from January to December 1993.

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Table 1. Surface measurements in Mex Bay from January to December 1993.

Parameter	Station	Months											
		J	F	M	A	M	J	J	A	S	O	N	D
Temperature °C	St. I	15.7	15.8	16.8	17.0	20.0	26.0	30.5	29.0	27.0	26.0	19.0	16.0
	St. II	15.7	16.0	16.5	17.0	20.0	26.0	30.0	29.5	27.0	26.0	19.0	16.0
	St. III	15.5	16.0	16.5	16.8	20.0	26.0	29.8	29.2	26.8	25.5	19.5	17.0
Salinity ‰	St. I	28.5	25.0	23.5	32.0	33.0	31.5	25.0	33.0	23.5	28.0	31.0	26.0
	St. II	25.0	22.0	21.2	30.0	29.0	28.8	20.0	30.0	21.0	25.0	30.5	25.0
	St. III	31.5	35.0	33.5	39.8	36.0	33.5	28.6	35.0	29.5	30.0	35.0	27.5
Secchi disk m	St. I	1.0	0.5	1.0	1.5	1.8	1.0	0.3	1.0	0.8	0.4	2.8	1.5
	St. II	0.8	0.5	1.0	1.2	1.2	1.0	0.5	1.0	0.5	0.5	2.0	1.2
	St. III	2.5	2.5	1.0	2.0	2.0	1.0	0.8	1.2	0.5	0.6	3.8	2.0
D. oxygen ml/l	St. I	4.0	3.5	4.3	4.0	3.5	3.0	5.2	2.5	3.5	3.3	2.0	1.6
	St. II	5.4	6.0	4.1	2.0	4.0	4.8	9.8	1.6	6.5	7.0	2.5	5.5
	St. III	6.8	6.5	2.5	5.4	3.5	4.2	4.3	2.6	3.0	2.0	4.5	5.5
Nitrate µg-at/l	St. I	15.0	3.5	4.5	3.0	9.8	7.0	3.5	5.5	4.5	8.5	13.0	3.0
	St. II	16.6	6.0	4.5	3.5	11.0	8.5	2.0	8.2	4.0	12.5	11.0	6.0
	St. III	11.5	3.5	3.1	3.0	7.8	3.8	4.1	7.0	3.5	9.3	6.5	4.5
Ammonia µg-at/l	St. I	37.8	38.0	23.5	11.0	8.5	11.0	6.0	12.6	6.9	20.5	16.0	17.5
	St. II	65.8	45.5	25.5	15.0	16.7	10.6	2.5	15.0	4.5	18.8	24.6	21.0
	St. III	60.5	33.5	18.5	9.5	7.5	9.0	5.5	10.8	8.0	12.0	11.6	15.0
Phosphate µg-at/l	St. I	3.1	1.2	3.0	0.8	2.0	2.0	4.0	2.0	2.5	4.4	2.5	2.0
	St. II	3.5	1.6	2.5	1.0	3.5	2.5	3.6	2.5	3.0	3.8	2.0	2.0
	St. III	3.0	1.2	3.2	0.6	1.5	2.0	3.0	1.5	2.0	3.5	1.5	2.5
Chlorophyll <i>a</i> µg/l	St. I	3.0	7.5	5.0	2.5	4.6	10.5	23.0	8.5	20.0	10.0	2.5	3.2
	St. II	2.5	9.0	5.5	2.0	6.0	11.5	28.0	11.5	22.0	15.0	1.5	2.0
	St. III	2.2	6.0	4.0	1.5	3.6	8.5	23.0	5.5	21.0	11.0	1.5	2.0
Standing crop (million cell/l)	St. I	0.013	0.142	0.070	0.003	0.035	0.151	9.50	0.130	4.300	0.420	0.01	0.02
	St. II	0.005	0.138	0.081	0.003	0.068	0.210	10.1	0.185	6.500	0.650	0.01	0.01
	St. III	0.003	0.075	0.031	0.002	0.029	0.121	9.00	0.065	2.500	0.150	0.01	0.01

Salinity variations were closely related to the contribution of the land runoff and the exchange of the water with the adjacent Mediterranean waters. A gradual south-north increasing gradient was seen to be persisted most of the year round. Salinity varied regionally from $>39\text{‰}$ (St. III, April), to 20‰ near to Umum Drain (St. II, July). A salinity range of $20\text{-}30\text{‰}$ dominated the bay during the massive phytoplankton occurrence in July, September and October. Salinity stratification persisted most of the year round. The maximum gradient (11.3‰) was measured between the surface and 10 m, St. III, during July. According to El-Maghraby & Halim (1965), the salinity value of 38.5‰ represents the inner boundary of the Mediterranean neritic waters off Alexandria.

Water density ($\text{Sigma } t$) not only determines the magnitude of phytoplankton production, but ultimately leads to community changes or species succession (Levasseur *et al.*, 1984). Salinity rather than temperature governed the variations in $\text{Sigma } t$ values in either time or space. The spatial distribution showed the surface $\text{Sigma-}t$ values of the near-shore stations (I & II) to be lower than St. III, and there was an increase by depth. The surface $\text{Sigma } t$ values in July, September and October (phytoplankton bloom periods) fluctuated between 19 and 20.7.

Changes in water transparency have been used to assess the rate of eutrophication (Lorentze, 1980). The water transparency in Mex Bay was relatively low, fluctuating between 30-80 cm during the algal bloom periods and >3.5 m in November, associated with low phytoplankton densities. The near-shore stations (St. I & II), directly subjected to the turbid water, generally sustained lower values than observed far-shore.

The pH values were always on the alkaline side, exhibiting a narrow range of variation. The highest value (pH at 8.8) was measured at St. II in October associated with a red tide outbreak, while the minimum (7.8, St. I) in January. There was a gradual increase towards the open sea.

Dissolved oxygen is far known one of the most criteria to assess sewage pollution, organic loading and nutrient input (Redfield, 1958). The lowest value of 1.6 ml.l^{-1} was recorded in August (St. II) and December (St. I). The first station gained the maximum value in July, September and October (9.8, 6.5 and

7ml.l⁻¹, respectively). Except for the periods of massive phytoplankton occurrence, the spatial distribution showed poor values at the near shore stations, and a gradual increase offshore.

Nutrient concentrations, affected by the daily land injection, algal growth and exchange of water, showed wide time-space variations.

Nitrate reached its major peak in January (average 14.37 $\mu\text{g-at.l}^{-1}$) and less so in November. The concentration was also high in October (a red tide period). Nitrate dropped sharply to its minimum in July (2 $\mu\text{g-at.l}^{-1}$, St. II), accompanying a dense phytoplankton bloom. Except for the previous month, there was a gradual decrease towards St. III.

Ammonia exhibited a distribution pattern nearly similar to that of nitrate. However, the major peak in January (average 54.7 $\mu\text{g-at.l}^{-1}$), was followed by another 2 minor ones in February and March. It is hard to consider ammonia limiting the phytoplankton growth. Yet, a concentration of 2.5 $\mu\text{g-at.l}^{-1}$ was measured at St. II in July.

The uptake of nitrate and ammonia by phytoplankton was proved by several authors (e.g. Walfer *et al.*, 1986).

Phosphate is an essential growth controlling factor (e.g. Marchetti *et al.*, 1988). Surface phosphate in Mex Bay fluctuated between 0.6 $\mu\text{g-at.l}^{-1}$, St. III, April and 4.4 $\mu\text{g-at.l}^{-1}$ St. I, October. The last month was a period of a red tide bloom caused mainly by a dinoflagellate species. Relatively higher levels were also recorded in January and July (average of 3.2 & 3.5 $\mu\text{g-at.l}^{-1}$, respectively). Generally, the spatial distribution showed the near-shore stations to be relatively rich. The highest surface phosphate level in the open Mediterranean was estimated at 0.3 $\mu\text{g-at.l}^{-1}$ (Halim *et al.* 1995).

2- Time-space variability of the phytoplankton standing crop, species composition and chlorophyll *a* content:

The phytoplankton standing crop, community structure and chlorophyll *a* in Mex Bay exhibited marked variability, in space and time (Table 1, Fig. 3). The near-shore stations (I&II) were always richer than St. (III).

The phytoplankton community included fresh, brackish and marine species. Diatoms contributed the main bulk of the community (89.6% to the total standing crop), followed by dinoflagellates (3.8%), Euglenophyceae (2.6%, maximum abundance during January and February), Cyanophyceae (2.5%, main occurrence in June) and Chlorophyceae (1.5%, mainly in August). Generally, the fresh and brackish water forms were transferred to the bay from Lake Maryout.

Except for the relatively high standing crop in February, low densities were observed during winter till May, as well as in November and December. Temperature could be considered limiting, despite density stratification of the water column and nutrient availability. The increased numbers in February (average 0.12×10^6 cell.l⁻¹) were mainly due to the proliferation of diatoms, mainly *Chaetoceros* species (*C. affine*, *C. breve* and *C. decipiens*), with the minor constituents of the community; *Lauderia borealis*, *Leptocylendrus danicus*, *Asterionella glacialis*, and the euglenophycean, *Phacus triquetus*. Chl. *a* reached $9 \mu\text{g.l}^{-1}$ at St. II. The crop started to increase remarkably by June (0.16×10^6 cell.l⁻¹), due to the growing diatoms, *Rhizosolenia fragilissima* (overwhelmingly dominant, 78% to the total standing crop) and to a lesser extent; the dinoflagellates, *Prorocentrum triestinum*, *Scrippsiella trochoidea*, *Protoperdinium depressum* and the fresh-water forms, *Euglena granulata*, *E. acus*, *Oscillatoria tenuis* and *Spirulina princeps*. The last two species, despite their relatively low numbers, contributed the high Chl. *a* at St. I&II (10.5 & $11.5 \mu\text{g.l}^{-1}$, respectively). A water discoloration was observed in July, the centric diatom, *Skeletonema costatum* was the causative organism (average of 8.7×10^6 cell.l⁻¹, 89.2% to the total standing crop), followed by *R. fragilissima* (average of 0.56×10^6 cell.l⁻¹), *S. trochoidea* and *P. triestinum*. The bloom covered the 3 sampling stations, raising Chl. *a* to its year maximum ($23-28 \mu\text{g.l}^{-1}$). The density dropped dramatically in August (average 0.13×10^6 cell.l⁻¹). The numerically important species included *Coscinodiscus excentricus*, *Cyclotella meneghiniana*, *S. trochoidea*, *P. triestinum* and the chlorophycean species, *Ankistrodesmus falcatus*, *Crucigenia rectangularis* and *Scenedesmus acuminatus*. Chl. *a* reached $11.5 \mu\text{g.l}^{-1}$ at St. II. Again, multi-species red tide bloom appeared in September (average 4.4×10^6 cell.l⁻¹). The causative organisms were *Skeletonema costatum* (60.7%), *Nitzschia longissima* (25.1%) and *Prorocentrum minimum* (8.9%). Chl. *a* attained an average of $21 \mu\text{g.l}^{-1}$. A yellow, slightly brown water was observed in October

representing the last red tide period. The dinoflagellate, *Gymnodinium catenatum* (maximum density of 0.55×10^6 , St. II, 78.9% to the total), associated with *S. costatum* (11.5%) and *R. fragilissima* were the responsible species. Chl. *a* fluctuated between 10-15 $\mu\text{g.l}^{-1}$. There was a sharp drop in the phytoplankton densities during November and December. The community comprised mainly of *Thalassiosira subtilis* and *Cyclotella meneghiniana*.

3- Statistical Model

The statistical program system (NCSS, Hintze, 1993) was used. The model was computed to fit a line through a set of observations, seeking to analyse how a dependent variable is affected by the values of one or more independent variables. The model was run to understand the correlation between Chl. *a* (dependent variable) and measured physico-chemical parameters (independent variables), as well as its correlation with the phytoplankton standing crop and community structure.

Chlorophyll *a* as a function of pH and temperature (Fig. 4 a, b) showed expected positive, significant correlation with temperature, confirming the conclusions of Labib (1994, a) for the neritic waters of Alexandria. It was relatively less with pH values. The combination of these two parameters strongly affects Chl. *a* variations, but mainly due to the influence of temperature ($R^2=0.58$, Fig.4c,d). Deviations between the measured and calculated data of Chl.*a* with temperature could be attributed to the predominance of diatoms in a wide range of temperature, as previously mentioned by Bonin & Maestrini, 1981.

Chlorophyll *a* as a function of Secchi disk readings and Sigma *t* is shown in Figure 5. The water density and transparency were inversely, significantly correlated with Chl. *a*. The latter parameter was more effective, confirming the present field observations that the low transparency values were always associated with the phytoplankton blooms. The role of water density affecting Chl. *a* variations is well documented in Alexandria waters (Labib & Halim, 1995, Labib, 1996) and elsewhere (e.g. Franco, 1984). Deviation in the model results between the measured and calculated Chl. *a* and Sigma *t* (Fig. 5, d) is mainly due to the fact that the land runoff caused the water column to be always density stratified into two layers; a surface diluted water layer and a subsurface water layer of higher salinity.

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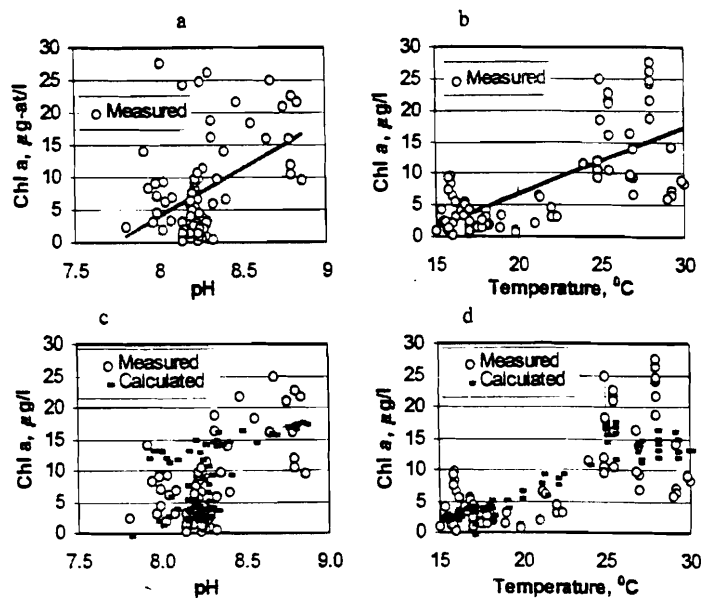


Figure 4. Chlorophyll *a* as a function of pH and temperature
 a - $\text{Chl. } a = -113.629 + 14.701 * \text{pH}$ ($R^2 = 0.44, F = 18.20$)
 b - $\text{Chl. } a = -14.114 + 1.0425 * T$ ($R^2 = 0.50, F = 76.14$)
 $\text{Chl. } a = -93.889 + 0.940 * T + 9.918 * \text{pH}$ ($R^2 = 0.58, F = 51.03$)

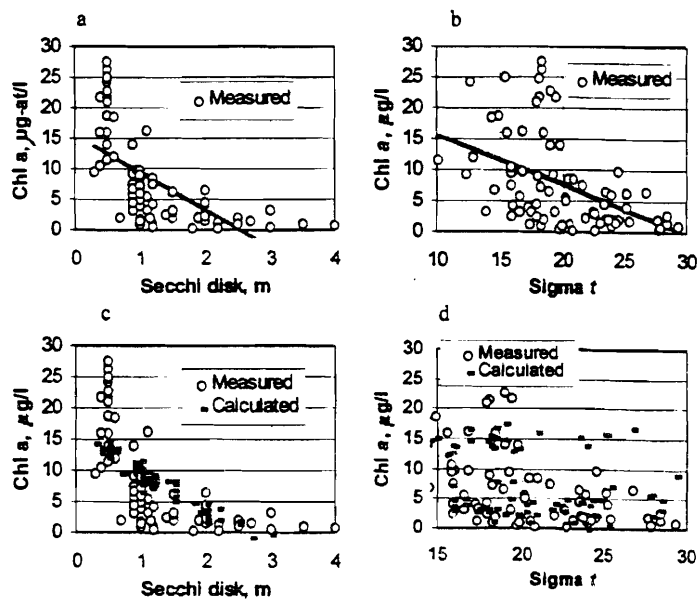


Figure 5. Chlorophyll *a* as a function of Secchi disk readings and Sigma t
 a- $\text{Chl. } a = 15.662 - 6.144 * \text{Secchi}$ ($R^2 = 0.41, F = 52.45$)
 b- $\text{Chl. } a = 23.677 - 0.800 * \text{Sigma } t$ ($R^2 = 0.21, F = 20.56$)
 $\text{Chl. } a = 20.317 - 0.290 * \text{Sigma } t - 5.282 * \text{Secchi}$ ($R^2 = 0.43, F = 28.11$)

Very weak correlation was found for chlorophyll *a* with nitrate and ammonia, negatively with the latter parameter (Fig. 6 a, b). However; Chl. *a* showed a positive, significant correlation with phosphate (Fig. 6 c), signalling its importance to stimulate the phytoplankton growth, in agreement with other observations, west of Alexandria ((Nessim, 1990). Phosphorus is assumed limiting growth factor in the Mediterranean (Casabianca, 1979).

Chlorophyll *a* was significantly correlated with the numerical standing crop ($R^2= 0.69$, Fig. 7 b). The model results showed the measured and calculated chlorophyll *a* as a function of the numerical standing crop to be closely related, explaining such strong correlation. Deviation could be due to species composition interaction.

As diatoms were the main component of the community, dominating during the different months, the statistical analysis showed nearly similar results to that of the standing crop (Fig. 7, a).

Chlorophyll *a* as a function of the counts of chlorophytes and dinoflagellates (Fig. 8 a, b) showed a very weak correlation as a result of their frequent occurrence, but relatively higher with the former group.

Comparison of the monthly changes of measured and calculated data

The measured and calculated data of Secchi disk as function of Chl. *a* and salinity (Fig. 9) showed these two parameters to be the major factors affecting its variations. Deviations occurred at times are being the result of interfering of other factors as the contribution of discharge water, the standing crop, community structure and species composition.

Strong relations were found between the measured and calculated chlorophyll *a* as a function of temperature, Secchi disk and pH, reflecting their importance (Fig. 10, a). Deviations occurred some times are due to other factors previously mentioned.

Deviations between the measured and calculated chlorophyll *a* as a function of Sigma *t* and Secchi disk readings (Fig. 10 b) were mainly restricted to periods of algal growth during summer, accompanied with abnormal chlorophyll *a* increase. The phytoplankton structure is also responsible. Very close relation was observed in autumn-early winter, a period of limited growth.

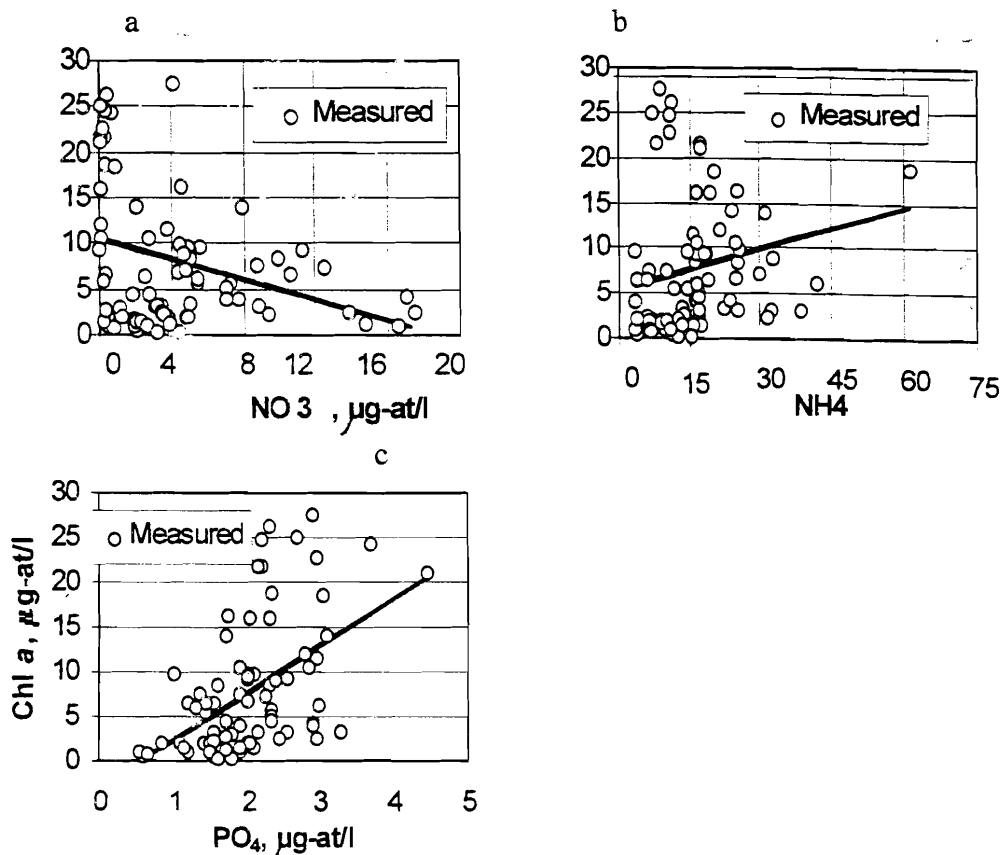


Figure 6. Chlorophyll *a* as a function of NO₃, NH₄, PO₄ and N:P ratio

a - $\text{Chl. } a = 5.289 + 0.462 * \text{NO}_3$ ($R^2 = 0.10, F = 3.70$)

b - $\text{Chl. } a = 10.222 - 0.074 * \text{NH}_4$ ($R^2 = 0.50, F = 8.83$)

c - $\text{Chl. } a = -3.013 + 5.303 * \text{PO}_4$ ($R^2 = 0.26, F = 26.21$)

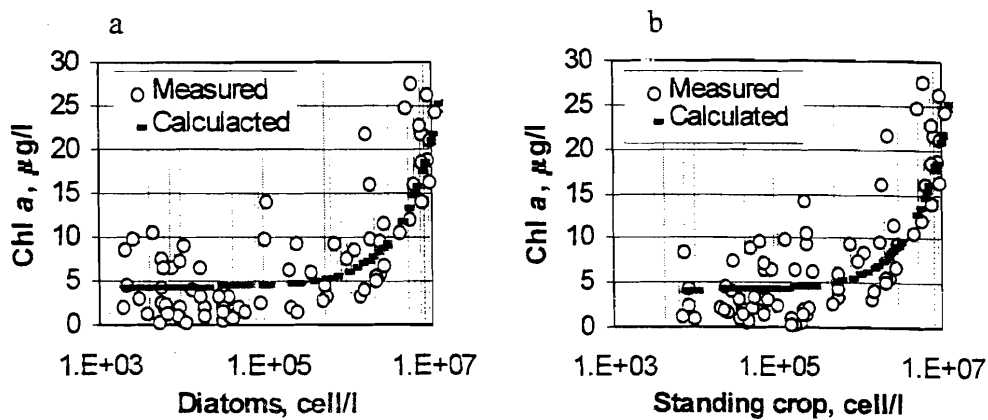


Figure 7. Chlorophyll *a* as a function of diatoms and standing crop

a - $\text{Chl. } a = 4.327 + 1.86\text{E-}6 * \text{Diatoms}$ ($R^2 = 0.68, F = 160.04$)

b - $\text{Chl. } a = 4.168 + 1.84\text{E-}6 * \text{St.crop}$ ($R^2 = 0.69, F = 171.96$)

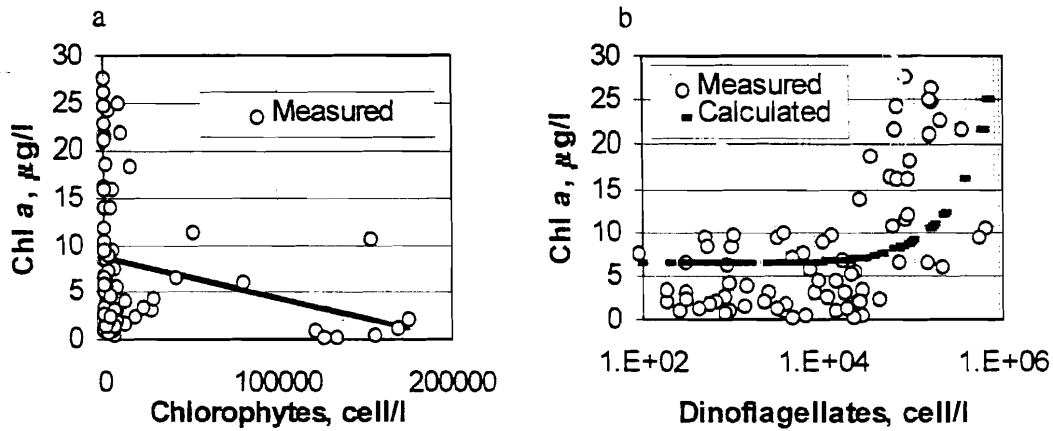


Figure 8. Chlorophyll *a* as a function of dinoflagellates and chlorophytes.

a - $\text{Chl. } a = 8.666 - 4.3\text{E-}5 * \text{Chlorop.}$ ($R^2 = 0.06, F = 4.98$)

b - $\text{Chl. } a = 6.396 + 2.84\text{E-}5 * \text{Dinofl.}$ ($R^2 = 0.17, F = 15.99$)

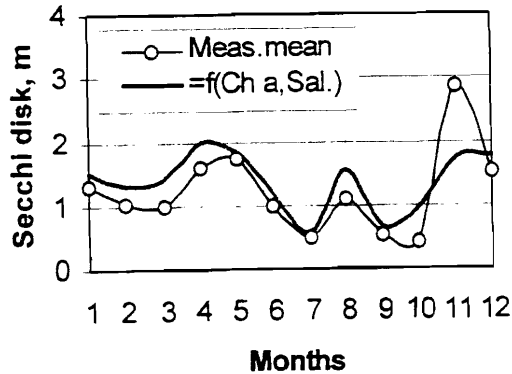


Figure 9. Measured and calculated Secchi disk readings

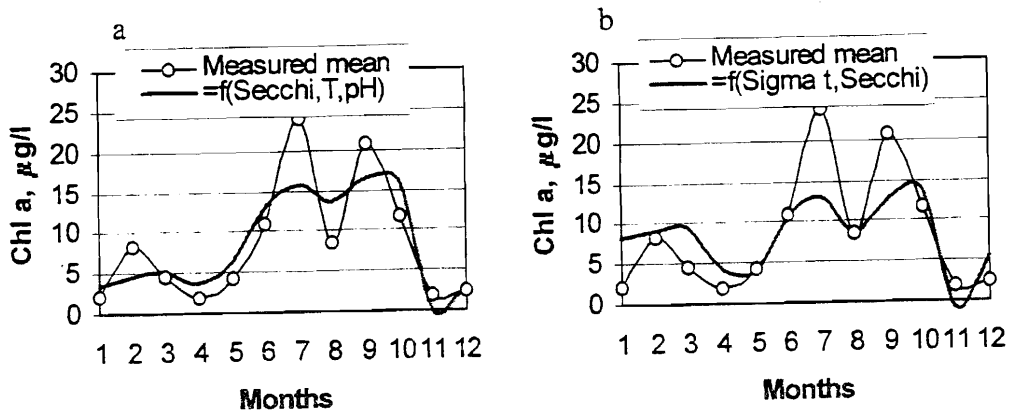


Figure 10. Measured and calculated chlorophyll *a* as a function of Secchi, Sigma *t*, Tem. and pH

A weak relationship was found as a function of phosphate. Deviations occurred during algal outbreaks (Fig. 11, a).

Reasons to explain the logic result of the large deviations between the measured and calculated values of chlorophyll *a* as a function of nitrate (Fig. 11, b) are mainly due to the daily injection of nitrate and its fast regeneration.

There is strong correlation for chlorophyll *a* with the numbers of diatoms and the standing crop (Fig. 12 a, b). Deviations are attributed to the contribution of the species compositions. Their similar variation pattern is due to the dominance of diatoms.

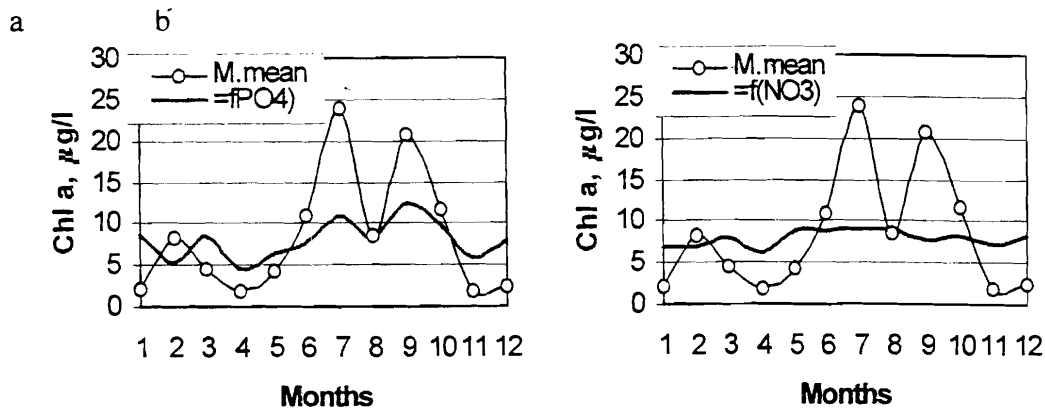


Figure 11. Measured and calculated chlorophyll *a* as a function of PO₄ and NO₃

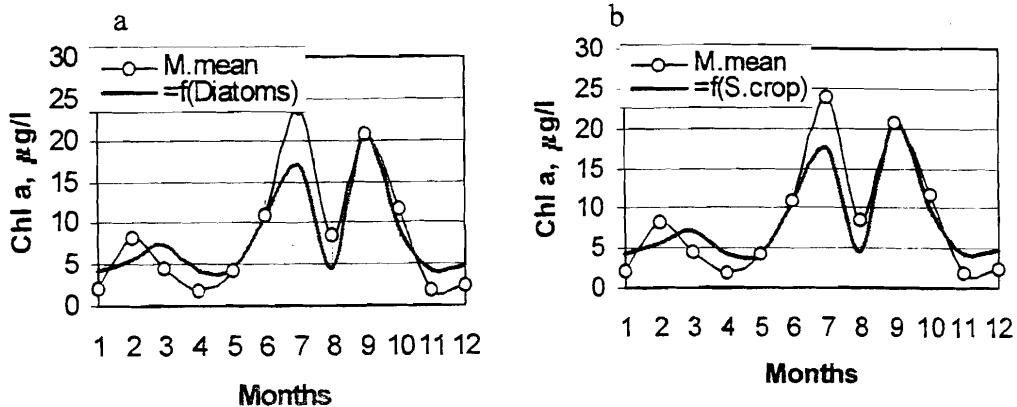


Figure 12. Measured and calculated chlorophyll *a* as a function of diatoms and standing crop

DISCUSSION

Mex Bay is a dynamic system, subjected to continuous environmental changes, with distinct structural properties.

Land-runoff caused the water column to be always density stratified, accelerating the phytoplankton growth.

The high daily nutrients injection to the bay leads to continuous replenishment of nutrient elements throughout the year. However, the consumption by phytoplankton growth reduced the concentration at times (June and September). Neither nitrogen nor phosphorus seems limiting factor for the phytoplankton growth.

The normal symptoms and manifestation of eutrophication in Mex Bay included the increased ammonia concentration compared with earlier records and the triggering of 3 heavy algal blooms during summer-early autumn, accompanied with water discoloration.

The centric diatom, *Skeletonema costatum* was the major component of the community, dominating mainly in July and September. This species is very common in the Egyptian Mediterranean waters (Sultan, 1975; Zaghloul & Halim, 1992), previously recorded in Mex Bay as numerically significant component of the community (Dorgham *et al.*, 1987; El-Sherif, 1989; Samaan *et al.*, 1992). It was recorded a red tide species, with occurrence closely related to land drainage in the Eastern Harbour of Alexandria (Labib, 1994 b), as well as elsewhere (e.g. Revelante & Gilmartin, 1985). *Skeletonema costatum* is known as an indicator of eutrophication (e.g. Mihnea, 1985).

The *Gymnodinium catenatum* outbreak took place under typical environmental conditions for a red tide bloom, similar to that reported for other dinoflagellate species in Alexandria waters (Labib, 1992; 1994 a,b; 1996; Labib & Halim, 1995).

Chlorophyll *a* content corresponded well with the numerical standing crop. However, deviation, occurred at times, is certainly a result of species composition interference. Generally, according to recommended Chl. *a* concentration by the OECD (1982), Mex Bay is considered eutrophic marine basin.

The statistical approach showed salinity, due to the daily discharge water input with heavy turbidity, strongly influenced Secchi disk readings. Also chlorophyll *a* represents a major affecting factor. The strong correlation between the measured and modeling Chl. *a* data as a function of the numerical standing crop is mainly attributed to the predominance of diatoms most of the year. However, deviation occurred at times is a result of species composition. The significant contribution of the physical parameters (water temperature, density and transparency), rather than nutrients, affecting Chl.*a* variations was proved. Generally, deviations in the model results occurred at times are due to the interfering of several factors simultaneously. The interpretation of simple correlation is not always easy and any conclusion must be remain tentative.

The practical implication of the present study leads to a conclusion that the supply of nutrients, mainly from Umum Drain must be curtailed to improve the situation in Mex Bay and to avoid toxic algal blooms in future. What is certain, however, is that without drastic reduction of nutrients supply from external sources, eutrophication in Mex Bay and probably in the coastal areas of Alexandria can't be brought under lasting control. From the point of view of predictability of algal blooms, the interaction of nutritional factors with hydrodynamic conditions and the sediment release and exchange also requires further evaluation.

REFERENCES

- Abdalla, R. R., Halim, Y., Gergis, W. L and Assad, F. N.,1992. Phytoplankton diversity in the oligotrophic waters, west of Alexand(Egypt). Bull. Nat. Inst. Oceanog. & Fish., A.R.E. 18: 73-84.
- Bonin, D. J. and Maestrini, S. Y., 1981. Importance of organic nutrients to phytoplankton growth in natural environment: implications for algal species succession. Can. Bull. Fish. Aquat. Sci., 210: 279-291.

- Casabianca, M. C., 1979. Phosphate dans les etances Mediterraneens, Hautes teneurs, teneurs Cnliques. Drevision et declenchement des Eaux de colorees. Rapp. Comm. Int. Mer. Medit., 25/26, 105-108.
- Dorgham, M. M., El-Samra, Moustafa, M. I., 1987. Phytoplankton in an area of multi-polluting factors west of Alexandria, Egypt. Qatar Univ. Sci., Bull., 7: 393-419.
- El-Maghraby, A. M. and Halim, Y., 1965. A quantitative and qualitative study of the plankton of Alexandria waters. Hydrobiologia, 25, 1-2: 221-238.
- El-Sherif, Z.M., 1989. Distribution and ecology of phytoplankton in El-Mex Bay (Egypt). Bull. Inst. Oceanogr. Fish., A.R.E. 15 (2): 83-100.
- Emara, H.I., Iskandar, M.F. and Assad, F.N., 1984. Chemistry of the water west of Alexandria. Bull. Nat. Inst. Oceanog. & Fish., 10: 35-49.
- Emara, H. I., Shiradah, M.A., Moustafa, T. H. and El-Deek, M. S., 1992. Effect of sewage and industrial wastes on the chemical characteristics of the Eastern Harbour and Mex Bay waters of Alexandria, Egypt. In: Marine Coastal Eutrophication, Proc. Int. Conf. Bologna, Italy, 21-24 March, 1992. Elsevier, 773-784.
- Franco, P., 1984. Fattori influenti sulla productivita primaria dell Adriatico settentrionale. Boll. Oceanol. Teor. Appl., 2: 125-140.
- Goldman, J.C. and Carpenter, E.J. (19). A kinetic approach to the effect of temperature on algal growth. Limnol. Oceanog. 19: 756-766.
- Hintze J. L., 1993. Number cruncher statistical system (NCCS). Version 5.03 5/1993.
- Labib, W., 1992. Amphicrysis compressa Korshikov red tide bloom off Alexandria. Biology of the bloom and associated water chemistry. CERBOM, Centre d'etudes et de recherches de biologie et d'Océanographie. 107-108: 13-23.

- 1994 a. Ecological studies of spring-early summer phytoplankton blooms in a semi-enclosed estuary. *Chemistry and Ecology*, 9: 75-85.
- 1994 b. Massive algal pollution in highly eutrophic marine basin, Alexandria, Egypt. The 4th Conf. of the Environ. Prot. is a must, 10-12 May, 1994, 181-194.
1996. Water discoloration in Alexandria, Egypt, April 1993. I- Occurrence of *Prorocentrum triestinum* Schiller (Red Tide) bloom and associated physical and chemical conditions. *Chemistry and Ecology*, 12: 163-170.
- Labib, W. and Halim, Y., 1995. Diel vertical migration and toxicity of *Alexandrium minutum* Halim red tide, in Alexandria, Egypt. *Mar. Life*, 91: 11-17.
- Levasseur, M.E., Therriault, J.C. and Legendre, L., 1984. Hierarchical control of phytoplankton succession by physical factors. *Mar. Ecol. Prog. Ser.*, 19: 211-222.
- Lorentze, M.W., 1980. Use of chlorophyll-Secchi disc relationships. *Limnol. Oceanogr.*, 25 (2): 371-372.
- Marchetti, R., Gaggino, G.F. and Provini, A., 1988. Case study: red tides in the northwest Adriatic. *UNESCO Rep. Marine Sci.*, 49: 133-139.
- Mihnea, P.E., 1985. Effect of pollution on phytoplankton species. *Rapp. Comm. Int. Mer. Medit.*, 29 (9): 85-88.
- Nessim, R. B., 1990. Nutrient levels and chlorophyll a in Alexandria coastal waters, *Bull. Instit. Oceanogr. Fish. Egypt*, 17 (1): 129-140.
1994. Environmental characteristics of Mex Bay. 1st Proc. Arab cof. On Marine Environ. Protec. Alexandria, 5-7 February: 221-243.
- OECD, Vollenweider, R.A. and Kerekes, J. J., 1982. *Eutrophication of Waters. Monitoring Assessment and Control*, Paris.

- Revelante, N. and Gilmartin, M., 1985. Possible phytoplankton species as indicators of eutrophication in the northern Adriatic Sea. *Rapp. Comm. Int. Mer. Medit.*, 29 (9): 89-91.
- Redfield, A.C., 1958. The biological control of chemical factors in the environment. *Amer. Sci.*, 46: 205-222.
- Said, M.A., El-Deek, M.S., Mahmoud, Th. H. and Shridah, M.M.A., 1991. Physicochemical characteristics of different water types of El-Mex Bay, Alexandria, Egypt. *Bull. Nat. Inst. Oceanogr. Fish., A.R.E.*, 17 (1): 103-116.
- Sana'an, A.A., Abdella, R.R. and Gergis, W.L., 1992. Phytoplankton population in relation to hydrographic conditions along the west-coast of Alexandria (Egypt). *Bull. Nat. Inst. Oceanogr. Fish., A.R.E.*, 18: 53-71.
- Smayda, J., 1980. Phytoplankton species succession. In: *The physiological ecology of phytoplankton*, Morris, I. (ed.), Blackwell, Oxford. 493-570.
- Strickland, J.D. and Parsons, T.R., 1972. A practical hand book of sea water analysis 2nd Ed. *Bull. Fish. Res. Bd. Can.*, 167: 310 pp.
- Sultan, H.A., 1975. Preliminary investigation on the primary production of marine phytoplankton of the Egyptian Mediterranean Coast around Alexandria. M. Sc. Thesis. Alexandria University. 151 pp.
- Strickland, J. D. and Parsons, T. R., 1972. A Practical Handbook of Sea Water Analysis, 2nd Ed. *Bull., Fish., Res., Bd., Canada*, 167:310 pp.
- UNESCO, 1987. Technical papers in Marine Science. *International Oceanographic Tables*, 4, 128-131.
- Utermohl, H., 1958. Zur vervollkommnung der quantitativen phytoplankton Methodik, *Mitt. int. Ver. theor. angew. Limno.* 9: 1-38.
- Vollenweider, R.A., 1981. Eutrophication- algal problem. *WHO water Qual. Bull.*, 6.
- Walfer, M.V.M., Walfer, S. and Devassy, V.P., 1986. Nitrogenous nutrients and primary production in a tropical Oceanic environment, *Bull. Mar. Sci.*, 38 (2): 273-284.