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Hydrography, nutrients and plankton abundance in the hot spot of Abu Qir Bay, Alexandria, Egypt

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Abstract

The hydrography, nutrient levels and plankton abundance were investigated monthly for a complete annual cycle in the southwestern part of Abu Qir Bay, the most polluted and biologically productive area on the Egyptian Mediterranean coast. Intense temporal and spatial variability was observed in all measured parameters characteristic of the effects of several effluents discharged into the bay. Based on the present investigation, the southwestern Bay can be divided ecologically and biologically into two parts: one including the near shore strip, which is directly affected by the waste waters, and a second comprising the southwestern part of the coastal strip and the offshore stations, both of which are relatively far away from the land-based effluents.

The Bay water was characterized by low transparency (monthly average: 64-280 cm), dissolved oxygen (monthly average 2.0-6.8 mg/l) and surface salinity (monthly average: 24.8-37.9 ppt), the highest limits usually being in the offshore section. Water fertility and plankton production were high in the Bay indicating an occasionally acute degree of eutrophication, particularly nearshore. Great variations occurred in the concentrations of nutrients throughout the year, with monthly averages of 0.8-50.88 μM for ammonia, 0.42-3.28 μM for nitrite, 1.29-17.36 μM for nitrate, 0.32-3.61 μM for reactive phosphate and 1.09-33.34 μM for reactive silicate. Similarly, the abundance of both phytoplankton and zooplankton showed pronounced temporal and spatial variability, whereas the monthly average chlorophyll-a fluctuated between 2.06 and 52.64 μg/l and zooplankton between $31x10^3$ and $248.6x10^3$ ind./m^3. However, the absolute values of all parameters indicated remarkably wider ranges of variations.

Significant correlation was found between chlorophyll-a and some ecological parameters like temperature, salinity, transparency, dissolved oxygen, nitrite and between zooplankton and temperature, while there was a significant correlation between nutrient concentrations and salinity changes.

Keywords: Abu Qir Bay, Hydrography, Nutrients, Plankton abundance, Land-based effluents.

Introduction

Abu Qir Bay, east of Alexandria City, is one of the most ecologically and biologically important embayments along the Mediterranean coast of Egypt. The ecological importance of the bay is attributed to the fact that it receives various types of agricultural, domestic and industrial wastes causing continuous changes in its water quality. The bay is also classified as highly productive and is considered one of the most highly fertile Egyptian coastal regions, providing a good environment for the breeding of many commercially important fish. Basic information about the morphological feature of the bay has been given by many authors and recently by EL-RAYIS *et al.* (1993) & FAHMY (1997). Due to stress from discharged waste waters, the Bay has become a hot spot area, requiring permanent monitoring of its water quality and inhabiting biota. In this context, many investigations were conducted including hydrographic conditions (EL-SAMRA, 1973; EL-DEEB, 1977; SAAD, 1979; SAID, 1979; DOWIDAR *et al.*, 1983; ANONYMOUS, 1984; OSMAN & DORGHAM, 1987; EL-GINDY, 1988; EL-GINDY *et al.*, 1988; MAHMOUD & ABDEL-HAMIED, 1991; TAYEL, 1992 & NESSIM and EL-DEEK, 1993) pollution problems (ABBAS, 1969; TAYEL, 1981; EMARA, 1982; ABOUL-DAHAB, 1989; EL-NADY, 1991; TAYEL & SHRIADAH, 1991; EL-SHARKAWY, 1991 & ANONYMOUS, 1995) and plankton (DOWAIDAR & EL-MAGHRABY, 1971; DORGHAM & OSMAN, 1987; SAMAAN & MIKHAIL, 1990 & EL-SHERIF & GHARIB, 1994). The great majority of these studies were based upon either seasonal or single cruise sampling. Therefore, the present study was conducted monthly for a complete annual cycle in order to follow up the temporal pattern of hydrography, nutrient levels and plankton abundance in Abu Qir Bay, particularly in the southwestern part, which is exposed to the stress of industrial, domestic and agricultural effluents.

Material and Methods

The study area represents the southwestern part of the Bay, which extends between Abu Qir headland and Boughaz El-Maadiya. This area receives mainly industrial and domestic wastes directly through El-Tabia Pumping Station and from the Abu Qir Fertilizer Company, in addition to agricultural drainage waters from Lake Edku through Boughaz El-Maadiya and cooling water from an electricty power station. The study was carried out monthly from April 1998 to March 1999 on the surface water except for zooplankton, which was collected through vertical hauls from the bottom to the surface (depths: 4-10m) by a plankton net of 55μm mesh size, 30cm mouth diameter and 130cm length. Water temperature, transparency, salinity, dissolved oxygen, ammonia, nitrite, nitrate, reactive phosphate, silicate, chlorophyll-a and zooplankton abundance were determined at 8 stations distributed in the area in order to represent the different water qualities (Fig. 1).

Water transparency was measured by white enamelled Secchi disc, salinity was determined argentometrically and dissolved oxygen by Winkler's method (APHA, 1980). Determination of all nutrients and chlorophyll-a followed the procedures described by STRICKLAND & PARSONS (1975). The zooplankton standing stock was calculated from average counts of three aliquots (5 ml each) of 96 concentrated preserved samples. Correlation coefficients between the different parameters were computed.

Results

Although the study area is small as compared to the whole of Abu Qir Bay, it demonstrated marked variability, both temporal and spatial, regarding the hydrographic conditions, nutrient concentrations and phyto- and zooplankton abundance.

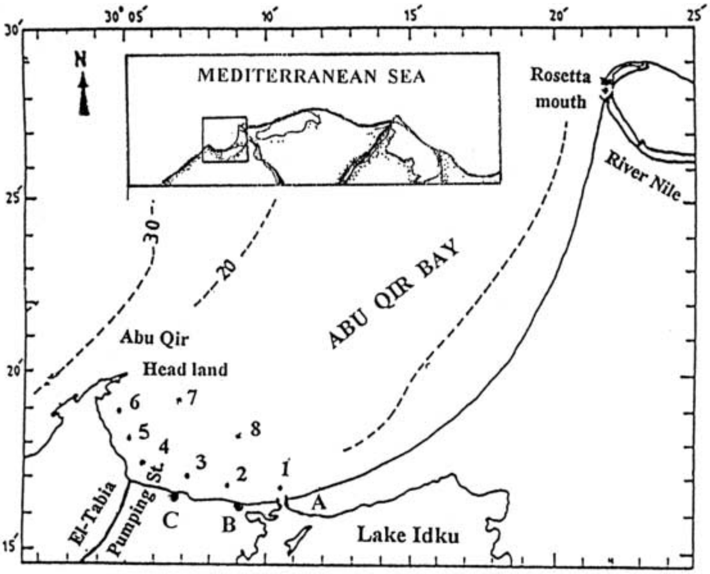

Fig. 1: Abu Qir Bay including the study area and sampling stations. A- Boughaz El-Maadiya, B- Electrical Power Station, C- Abu Qir Fertilizers Compony.

A -Hydrographic conditions:

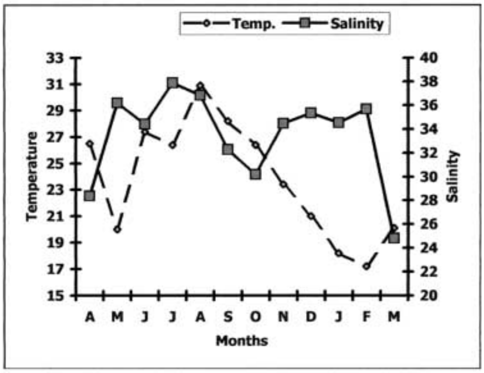

Fig. 2: Monthly average temperature (°C) and surface salinity (ppt) in the hot spot of Abu Qir Bay (April 1998-March 1999).

The water temperature showed the classical seasonal variations (Fig. 2) known in Egyptian coastal waters, but with slightly wider range than that usually recorded in the area, varying between 17°C and 31.5°C (Table 1). In May, the water temperature dropped to 20°C, which is lower than the values usually experienced during spring (23 and 25°C). This was attributed to a similar decrease in the air temperature during May. The spatial distribution revealed that the inshore waters were slightly warmer, by 1-1.5°C, than those offshore.

The surface salinity appeared to be widely variable both temporally and spatially reflecting changes in the volume and dispersion of the discharged wastewater. The measured values fluctuated between a minimum of 6.42 ppt at the inshore station 4 in front of the El-Tabia Pumping Station in March and a maximum of 39.05 ppt at the offshore station 8 in August. The monthly average salinity showed significantly lower values than those usually recorded in Eyptian coastal waters (>38 ppt) reaching its lowest values (24.8-28.36 ppt) during spring, and its highest (36.8-37.9 ppt) during summer (Fig. 2). Spatially, the lowest salinity was found at stations 1 and 4, where the outfalls of agricultural, domestic and industrial discharges are located. It could be generally assumed that the distribution of the surface salinity during the present study led to the occurrence of two water masses in the study area. The first one was in the inshore coastal strip surrounding the outflows of the land-

Table 1
The variation range and annual average of different parameters in the southwestern Abu Qir Bay (April 1998- March 1999).

Parameter	Min.	Max.	Mean	Parameter	Min.	Max.	Mean
Temperature (˚C)	17	31.5	23.5	NO_3(μM)	0.06	51.11	7.17
Salinity (ppt)	6.42	39.05	33.4	PO_4 (μM)	ND	14.64	1.42
Secchi depth (cm)	30	400	124	SiO_4(μM)	0.1	99.8	16.75
Dissolved oxygen (μg/l)	0.6	9.9	3.6	Chlorophyll-a (μg/l)	0.9	90.73	14.9
NH_4 (μM)	ND	338.5	14.1	Phaeopigment (μg/l)	0.2	34.81	3.63
NO_2 (μM)	ND	14.43	2.0	Zooplankton (ind.x10^3/m^3)	11.5	566.2	90.7

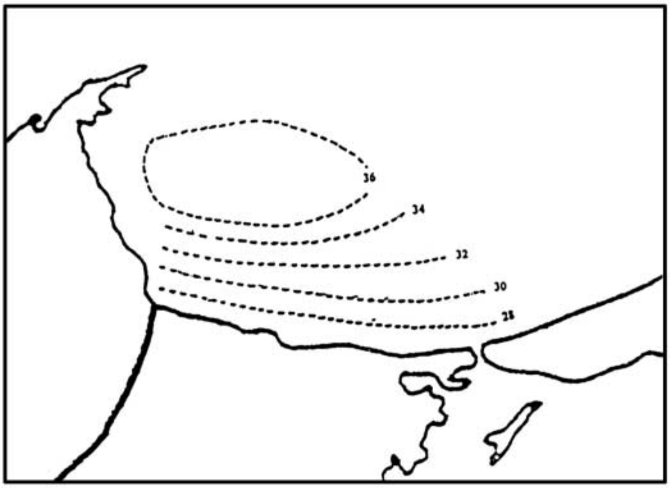

Fig. 3: The spatial distribution of annual average salinity (ppt.) in the hot spot of Abu Qir Bay (April 1998 - March 1999).

based effluents (Sts 1-4), with monthly average salinity less than 33.5 ppt. The second water mass was found in the southwestern part of the bay near the Abu Qir headland (Sts 5 and 6) and the offshore area (Sts. 7 and 8) with average salinity of >35- 36.3 ppt (Fig. 3).

The Secchi disc measurements reflected a dominating low transparency in the whole area. The monthly average transparency (Fig. 4) showed that the bay water was at its most transparent during July, whereas the lowest transparency appeared in February and March. On the other hand, spatial distribution of transparency indicated that the offshore water at stations 7 and 8 was relatively less turbid (annual average: 164-173 cm) than at the inshore ones, particularly at stations 1-4 (annual average: 83-101 cm), which are directly affected by land based effluents.

Dissolved oxygen showed a markedly wide range of variations (0.6 - 9.9 mg/l), the minimum oxygen value (0.6 mg/l) appeared before the Abu Qir Fertilizer Company (St. 3) in September and October and the maximum ones (9.6 and 9.9 mg/l respectively) were found at stations 5 and 6 in April and March respectively. Irrespective to these high values, the monthly averages (2 - 6.8 mg/l) in the area as well as the annual averages (2.4 - 4.3 mg/l) per station indicated clearly low oxygenation in Abu Qir Bay throughout the year. The seasonal pattern demonstrated a slight increase in March and April (average: 5.1 and 6.8 mg/l respectively), while during the rest of year, the oxygen concentrations fluctuated between 2.0 and 4.5 mg/l (Fig. 4). The annual average showed higher values (3.8 -4.3 mg/l) at stations 5 - 8, which are usually far from the discharged

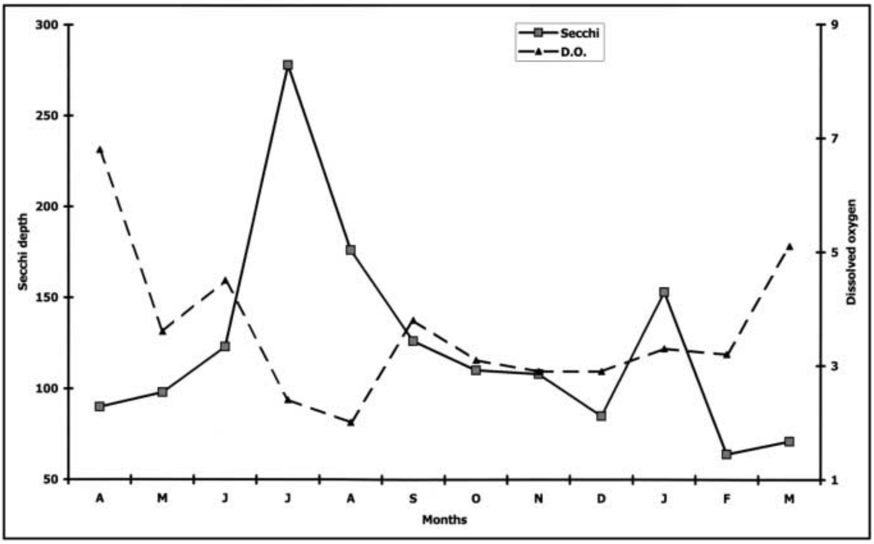

Fig. 4: Monthly average Secchi depth (cm) and dissolved oxygen (mg/L) in the hot spot of Abu Qir Bay (April 1998-March 1999).

waste, while the lowest oxygen (annual average 2.4-2.6 mg/l) appeared close to the waste sources, particularly in front of the El-Tabia Pumping Station and the Abu Qir Fertilizer Company (stations 3 and 4).

Oxygen saturation also showed wide variation (9-145%), but the monthly averages per station reflected low values. Except for the high percent of April (98%), saturation fluctuated between 33 and 69%, while the annual average indicated the lowest value (40-44%) in the area directly affected by land runoff (Sts. 1-4).

B- Nutrient levels:

The absolute values of the measured nutrients demonstrated exceedingly wide variations according to time and space (Figs. 5 - 8).

Nitrate attained significantly high values, varying from 0.06 μM to 51.11μM. Its temporal distribution was slightly different from those of both nitrite and ammonia, whereas three levels of concentration were detected. The highest one (17.36 μM) appeared in August, a moderately high level (7.63-11.25 μM) in April-May, November, January and March and a comparatively low one (1.29-5.96 μM) during the other months of the year. Spatially, all stations near the outfalls (Stations: 1-4) were characterized by markedly higher concentrations (annual average: 9.52-11.6 μM) than those located at a distance from the outfalls (annual average: 1.9-5.4 μM). However, stations 3 and 4 were still the richest in nitrate (annual average: 11.08-11.6 μM).

Although the absolute values of nitrite varied from the undetectable to 14.43 μM, the monthly average concentrations fall within a considerably narrower range of 0.42-3.28 μM (Table 1). April, January and March seem to be the richest months with respect to nitrite. The spatial distribution showed that stations 3 and 4 were characterized by the highest nitrite concentrations (3.92-4.26 μM) and stations 6 and 7, which are relatively far from land runoff, contained the lowest values (0.56-0.97 μM). Station 1 was characterized by comparatively low nitrite (1.69 μM).

Ammonia concentrations were generally high, showing the widest range of variation among all nutrients and fluctuating between an undetectable level and 338.5 μM (Table 1).

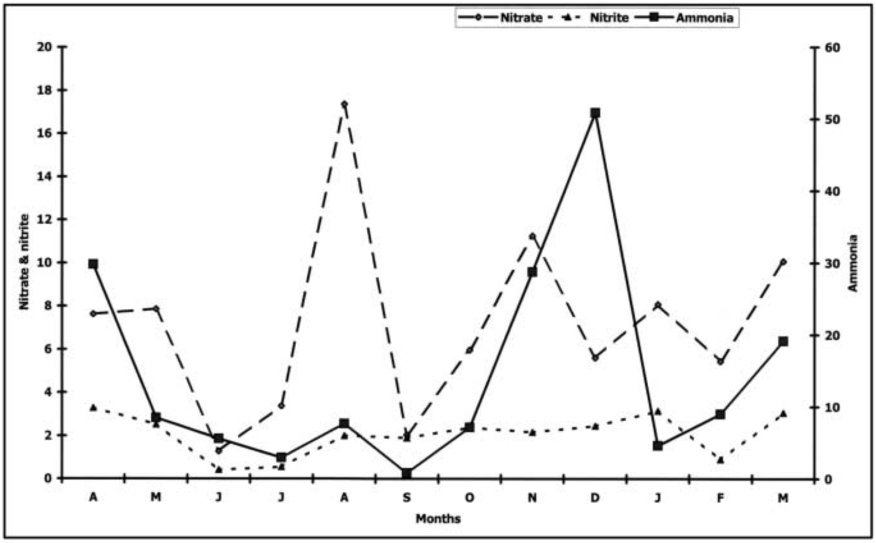

Fig. 5: Monthly average nitrate, nitrite and Ammonia (μM) in the hot spot of Abu Qir Bay (April 1998-March 1999).

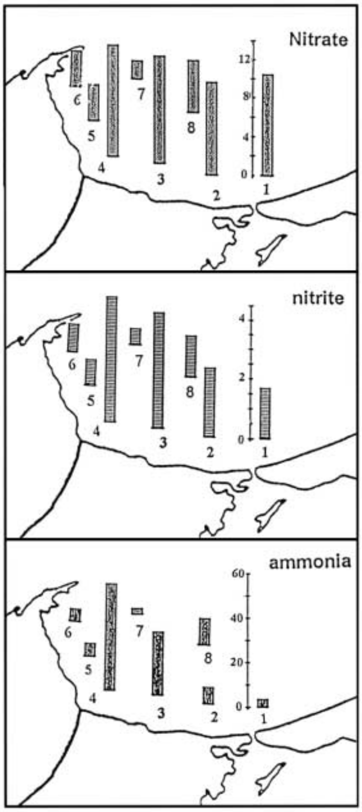

Fig. 6: The spatial distribution of annual average nitrate, nitrite & ammonia (μM) in the hot spot of Abu Qir Bay (April 1988-March 1999).

The monthly average concentrations reached the highest values in April and March (19.16 and 29.78 μM respectively) and in November and December (28.72 and 50.88 μM respectively), but during the rest of the year, they were remarkably lower (0.8-9.01 μM). Regarding the spatial distribution, the highest annual average concentrations (28.32 and 47.85 μM respectively) were found at stations 3 and 4, in front of the Abu Qir Fertilizer Company and the El-Tabia Pumping Station. Near Boughaz El-Maadiya (St. 1), the values were as low as at offshore station 7 amounting to 3.55 and 2.49 μM respectively.

The reactive phosphate concentrations ranged from 0.00 to 14.64 μM. Except for the highest average value in March (3.61 μM), the monthly averages fluctuated between 0.32 and 1.86 μM. On the other hand, the highest phosphate content (annual average: 3.81 μM) was recorded at station 4, followed by station 3 (2.18 μM) and station 1 (1.85 μM). At the other stations, the annual average phosphate was clearly lower (0.53-0.99 μM).

Due to the abnormal increase of ammonia and nitrate and the decrease of phosphate the N/P ratio attained exceptionally high values up

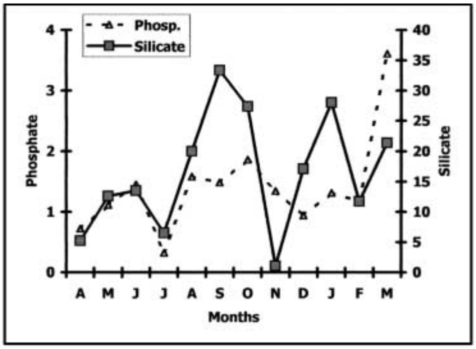

Fig. 7: Monthly average reactive phosphate and silicate (μM) in the hot spot of Abu Qir Bay (April 1998-March1999).

to 453 at station 4 in December and abnormally low value 0.9 at station 1 in June. The monthly average ratio demonstrated high values in November (96.9), December (75) and April (54.4), but during the rest of the year, it varied between 4.4 and 24.8. On the other hand, annual average N/P ratio showed that stations 3, 4 and 8 presented the highest values (42.3, 52.2 and 52.1 respectively), while at other stations it fell within a range of 14.8-23.2.

Silicate concentrations (0.1-99.8 μM) reflected wide temporal and spatial variations. The greatest monthly average values (33.34, 27.38 and 28.01 μM respectively) were found in September, October and January. Regardless of low concentrations (1.09- 6.48 μM) in April, July and November, silicate showed high values during the other months (11.6-21.38 μM). Spatial distribution indicated the highest content (17.22 - 35.32 μM) at stations 1- 4, and the lowest values (5.46-8.55 μM) at stations 5-8.

C-Plankton abundance:

Chlorophyll-a was measured as an index of the phytoplankton biomass. Its values indicated high primary production in the area all year round, with wide temporal variations (monthly average: 2.06 to 52.64 μg/l) and three distinguished peaks in April, September and

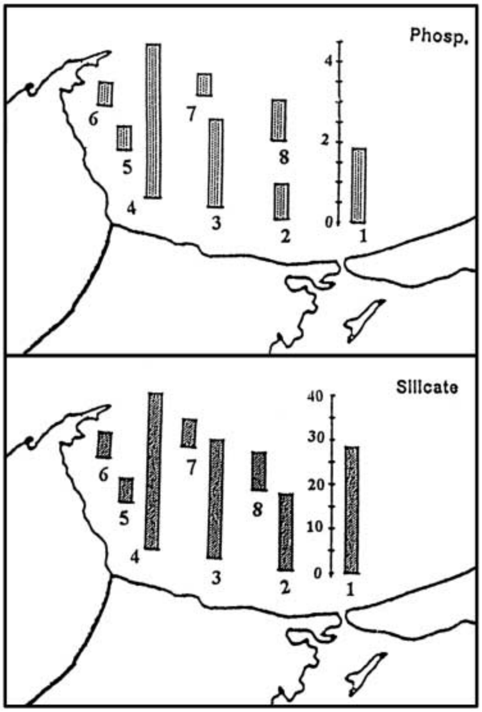

Fig. 8: The spatial distribution of the annual average reactive phosphate and silicate (μM) in the hot spot of Abu Qir Bay (April 1998-March 1999).

March (Fig. 9). The absolute values showed markedly higher chlorophyll-a (90.73 μg/l) at station 2 in April. Great differences were recorded between the stations, therefore four groups of chlorophyll concentrations can be considered in the area, representing different rates of primary production. The highest biomass at stations 1 and 2 (annual average: 19.4-24.8 μg/l) was associated with the fresh water discharge from Lake Edku, whereas the relatively high biomass at stations 3 and 4 (15.4-17.4 μg/l) was related to the industrial and domestic wastes through the El-Tabia Pumping Station and the Abu Qir Fertilizer company. The other two groups of phytoplankton biomass were lower and recorded in the area away from the direct impact of the different wastes, either nearshore (12.1-13.9 μg/l) at stations 5 and 6 or offshore (7.6-8.7 μg/l) at stations 7 and 8 (Fig. 10).

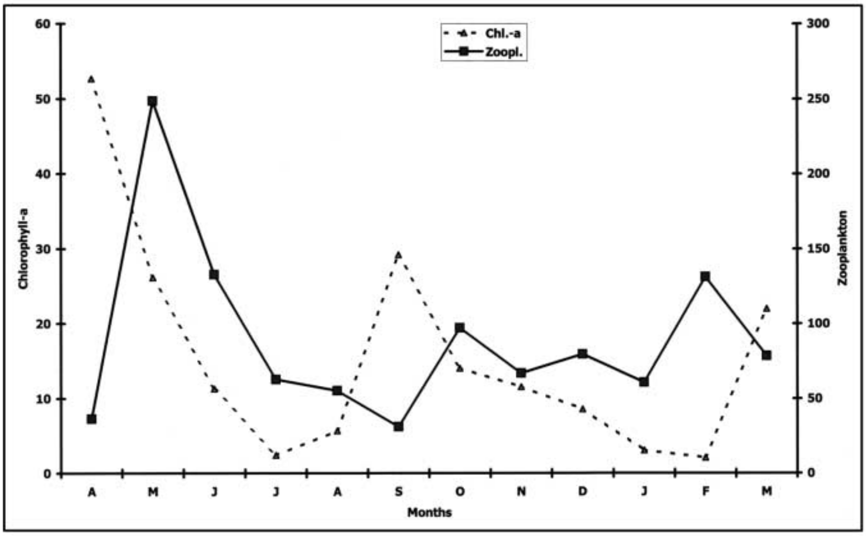

Fig. 9: Monthly average chlorophyll-a (μg/l) zooplankton abundance (ind.x10^3/m^3) in the hot spot of Abu Qir Bay (April 1998-March 1999).

Clear indication of high secondary production was revealed from the high abundance of zooplankton over the year (11.5x10^3-566.2x10^3 ind./m^3). The temporal and spatial patterns of zooplankton abundance were different from those demonstrated by chlorophyll-a. The abundance cycle of zooplankton demonstrated three peaks in May, October and February (Fig. 9). From the spatial distribution, the offshore water (Sts. 7 and 8) and the area in the vicinity of fresh water outflow (St. 1) harboured the lowest zooplankton densities (54.5x10^3 - 72.8x10^3 ind./m^3), while the density appeared to be the highest (Fig. 10) in the area adjacent to the industrial outflow (St. 4),

The statistical treatment of data revealed the occurrence of several significant correlations between the different parameters. Salinity showed negative significant correlation with most of the nutrients (nitrite, nitrate, phosphate and silicate), chlorophyll-a and phaeopigments (Table 2). Apart from temperature, zooplankton abundance showed no correlation with any of the measured ecological parameters.

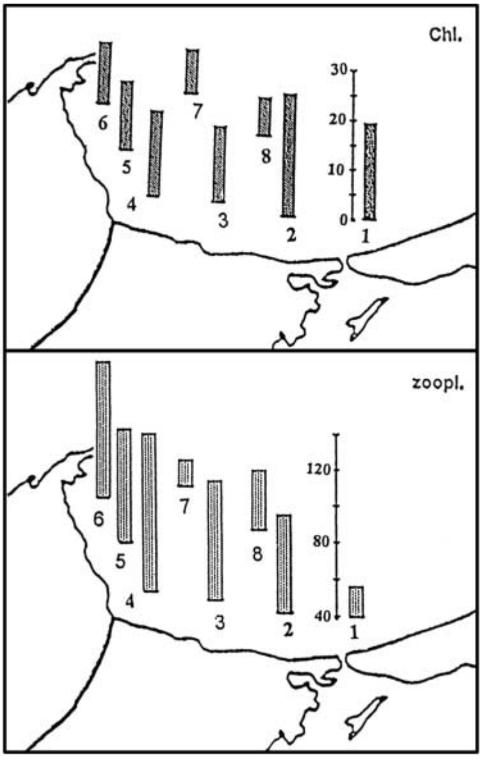

Fig. 10: The spatial distribution of the annual average chlorophyll-a (μg/l) and zooplankton abundance (ind.x10^3/m^3) in the hot spot of Abu Qir Bay (April 1988-March 1999).

Discussion

Abu Qir Bay has its own uniquely characteristic ecological conditions, since it receives variable pollutants through discharged agricultural, domestic and industrial wastes mainly in the southwestern part. The seasonal variability in the quantity and quality of these wastes and their dispersion is of great importance in the dynamics of the hydrographic conditions, nutrient concentrations and plankton density in the bay. This means that the growth of planktonic organisms in Abu Qir Bay is stimulated directly and indirectly by nutrients and may be inhibited by the discharged pollutants.

The first clear effect of such variations was shown in the hydrographic conditions, particularly water transparency, dissolved oxygen and salinity. According to the present study the southwestern bay was characterized by low water transparency all year round, due to the mixing processes. Although chlorophyll-a was generally high, dissolved oxygen was usually low. The low oxygenation of the coastal waters in Abu Qir Bay has been a characteristic feature for a long time (EL-DEEB, 1977; ANONYMOUS, 1984; TAYEL, 1992; GHARIB & SOLIMAN, 1998 & AHDY, 1999). This results mainly from oxygen consumption in the oxidation of a heavy organic matter load in the bay, particularly in the southwestern part which is directly exposed to industrial and domestic wastes and characterized by intensive plankton production. HOPPE (1978) reported that the concentration of oxidizable organic matter is produced as a result of decomposition of domestic sewage, decaying of organic detritus, and planktonic organisms by bacterial action. This is in agreement with the measurements of the oxidizable organic matter in Abu Qir Bay (3 - 40 mg O_2/L) recorded by the authors mentioned above. Although no bacterial count has been made in Abu Qir Bay, those made in adjacent waters may be used as a guide for the bacterial density of the bay. In the Eastern Harbour of Alexandria, which receives domestic sewage, bacterial densities ranges of 0.47 - 5.4 x 10^6 cells/ml and 540 - 5400 CFU/ml were recorded over the year for the total and for saprophytic bacteria (SIAM, 1998a), while along a distance of 20 km of Alexandria beaches, the total bacterial count varied seasonally between 0.2 and 5.07 x 10^6 cells/ml and the saprophytic bacteria ranged from 632 to 1673 CFU/ml (SIAM, 1998b). Therefore, it could be supposed that bacteria play an important role in the oxidation of organic matter in Abu Qir Bay. According to TAYEL (1992), the amount of dissolved oxygen after complete oxidation of the organic matter in

Table 2
Significant correlation between different parameters at different values of p(n=96).

Temp. # Secchi depth	0.01	Dis. oxygen # Chl.	0.001
Temp. # Chlorophyll	0.1	Dis. oxygen # Phaeop.	0.001
Temp # Zooplankton	0.01	Dis oxygen # Nitrate	0.01
Salinity # Secchi depth	0.001	Nitrite # Nitrate	0.010
Salinity # Chl	0.001	Nitrite # Ammonia	0.001
Salinity # Phaeop	0.02	Nitrite # Phosphate	0.001
Salinity # Nitrite	0.001	Nitrite # Silicate	0.001
Salinity # Nitrate	0.001	Nitrite # Chl	0.05
Salinity # Phosphate	0.001	Nitrite # Phaeop.	0.1
Salinity # Silicate	0.001	Nitrate # Phosphate	0.001
Secchi depth # Chl	0.01	Nitrate # Silicate	0.01
Secchi depth # Phaeop.	0.01	Phosphate # Silicate	0.001
Chl # Phaeop.	0.001		

the surface water of the bay was about 47.8%, which was lower than that recorded in areas with similar ecological conditions, like the Eastern Harbour and Mex Bay (EMARA *et al.*, 1989, c.f. Tayel, 1992) and the Western Harbour (SHRIADAH & TAYEL, 1992). The oxygen saturation in the polluted part during the present study (40-44%) was in agreement with that given by TAYEL (1992).

The surface salinity showed distinctive zonal distribution with the lowest values in the vicinity of land-based runoff and gradual increase towards the offshore stations. Similar zonation was also observed by OSMAN & DORGHAM (1987) who recognised that the extent of zones is governed not only by the nature and magnitude of the discharge, but also by mixing processes and water circulation. However, the volume and nature of the waste waters appeared to play an active role in the water quality as well as in salinity variations in the Bay, especially in the coastal strip. Said (1979) found that the circulation pattern in Abu Qir Bay depends largely on the mixing of the Mediterranean water with the land-based effluents. According to the surface salinity three types of water were identified in the Bay representing different degrees of mixing between the sea water and the discharged wastes, namely: Mediterranean water (>38.5 ppt), diluted sea water (35-38.5 ppt) and mixed water (<35 ppt). The extent of each water mass varied monthly due to the mixing processes and the wind action, which showed monthly variations (Table 3).

Drastic variability of nutrients in the study area reflects the stress of different land-based effluents. One clearly apparent stress is caused by the continuous increase of nutrient supply to the bay, as indicated from the markedly greater concentrations found in the present study (NO_3-N: up to 51.11 μM, NH_4-N: up to 338.5μM, PO_4-P: up to 14.64μM and SiO_4-S: up to 99.8μM) than in the previous records (NO_3-N: up to 20.74 μM, NH_4-N: up to 22.13μM, PO_4-P: up to 2.36μM and SiO_4-S: up to 40.28μM)/ (EL-DEEB, 1977; DOWIDAR *et al.*, 1983; ANONYMOUS, 1984; OSMAN & DORGHAM, 1987; NESSIM & EL-DEEK, 1993; ANONYMOUS, 1995; FAHMY, 1997 & GHARIB & SOLIMAN, 1998). The present study revealed that the industrial and domestic wastes discharged through the El-Tabia Pumping Station play a greater role in nutrient supply to the Bay than that of the agricultural drainage waters from Lake Edku. This is clearly indicated from the fact that the concentrations of nutrients at station 4, which is very close to the El-Tabia Pumping Station were signicicantly higher than those found at station 1 in front of the Lake Edku outlet. However, the latter station contained compatible amounts of nitrate and silicate indicating its significant role in the nutrient enrichment of the Bay. The drainage water of Lake Edku sometimes reached the outer boundaries of the study area, where comparatively high concentrations of nutrients were recorded at offshore station 8. A similar pattern was found in the area by FAHMY (1997). Furthermore, significant variability was observed in the temporal distribution of all nutrients with the seasonal peaks of each one differing in timing from the others. Such differences may be attributed to the variability of nutrient levels in the discharged waters, which are exposed to seasonal quantitative and qualitative changes. On the other hand, abundance of the different inorganic nitrogen forms at most stations in the study area was in the order NH_4-N > NO_3-N > NO_2-N. This may suggest a relative increase of ammonia production when compared to its uptake rate by phytoplankton as the preferred source of nitrogen (MAHMOUD, 1985 & ABOUL KASSIM, 1987).

The N/P ratio varies with trophic state and decreases with increased eutrophication (Welch, 1980). In the study area, the N/P ratio reached unusually high values (up to 453:1), with the monthly average fluctuating between 14.8:1 and 52.2:1. This indicates that the nitrogen supply is remarkably greater than that of phosphorous. As compared with previous

Table 3
Monthly areas (km^2) of mixed and diluted waters and wind direction in Abu Qir Bay (SAID, 1979).

Month	Area		Source	Wind direction
	Mixed	Diluted		
January	-	407	Rosetta Mouth	SW
February	-	693	Lake Edku	NE
March	-	705.7	Rosetta Mouth	NE
May	154	513.2	Lake Edku	NE
June	70	500	Lake Edku	NW
July	154	258.5	Lake Edku	NE
September	247.5	302.5	Lake Edku	NW
November	51.2	307	Lake Edku	SW

N.B. The discharge from the EL-Tabia Pumping Station was not included in this study.

studies, the levels of dissolved inorganic nitrogen and phosphorous, as well as the N/P ratio in the present study, seem to be significantly higher than those recorded by ANONYMOUS (1984), MAHMOUD & ABDEL-HAMIED (1991), NESSIM & EL-DEEK (1993), FAHMY (1997) & GHARIB & SOLIMAN (1998). This may confirm the role of the terrestrial sources in nitrogen supply, particularly through the widespread utilization of nitrogenous fertilizers in agriculture rather than the phosphorous compounds and waste products of the Abu Qir Fertilizer company. Based on the annual average values of different parameters, the southwestern part of Abu Qir Bay, that is directly affected by the land-runoff, is classified among the highly eutrophic locations in the world oceans (WETZEL, 1983).

The increased nutrient supply led to abnormal flourishing of phytoplankton and consequently high abundance of zooplankton, which were several times higher than the values recorded during the past three decades by DOWIDAR *et al.* (1983), ANONYMOUS (1984), DORGHAM & OSMAN (1987) & SAMAAN & MIKHAIL (1990). Such situation may raise a question: How can phytoplankton and zooplankton flourish in an area exposed directly to different pollutants? The answer to this question requires the knowledge of levels and types of pollutants in Abu Qir Bay. The extent of the pollution problem in the bay is not clearly defined, particularly from the chemical point of view, since the chemical structure of the industrial wastes is not well known. The available information (SALEH, 1982) indicated that the raw waste water through the El-Tabia Pumping Station contained lead (62.5 μg/L), zinc (79.26 μg/L), copper (11.58 mg/L), and cadmium (3.4 μg/L), while in the bay water, lead and cadmium were the only measured metals having a maximum concentration of 2.95 and 3.58 μg/L respectively (AHDY, 1999). The major part of the metals appeared to be accumulated in the bottom sediments, where markedly higher concentrations were found (Pb: 14 μg/g, Zn: 141μg/g, Cu:51μg/g) (EIMP, 1999). When comparing with the inhibiting levels of lead and cadmium (100 mg/L) given in the literature (TKACHENKO *et al.*, 1974, c.f. PATIN, 1982), one would expect the lead and cadmium contents in the bay water to have no inhibiting effect on the growth of phytoplankton, but that they may act as enhancing factor (TKACHENKO *et al.*, 1974; KUIPER, 1982; MURAMOTO & OKI, 1983; AHDY, 1999). For zooplankton, the inhibiting concentrations of lead and cadmium was at least 250 and 85μg/L (PATIN *et al.*, 1978). However, lack of information about the other unmeasured pollutants which may occur in the bay water makes it difficult to ignore their role.

Furthermore, the inhibiting effect of toxicants on the phytoplankton growth proved to be of a seasonal pattern related to the seasonal variations in the cell division and physiological state of the cells and their resistance to toxicants (LANSKAYA, 1971), and the taxonomic diversity of the phytoplankton population due to the effect of metals, could affect the growth and development of herbivorous assemblages of high trophic levels, which are selective in their feeding (THOMAS & SEIBERT, 1977, c.f. PATIN, 1982). On the other hand, the resistance of marine invertebrates to toxicants varies greatly with their developmental stage and with the conditions (especially duration) of exposure to the action of toxicants, at an early stage and over prolonged periods of exposure the resistance of animals to toxicants is reduced (PATIN, 1982).

Regardless of such complexity, the effect of nutrients appeared to be more pronounced than that of the pollutants. This was clearly shown from the high production of both phytoplankton and zooplankton in the inshore area adjacent to the industrial outflow at the El-Tabia Pumping Station as compared to clean waters and even to the area around the Lake Edku runoff. However, at the El-Tabia Pumping Station, chlorophyll-a content was relatively higher than that in the vicinity of freshwater outflow, indicating the stress of grazing in the former area, where zooplankton attained the greatest abundance in the whole area. On the other hand, the relatively high chlorophyll-a in the offshore waters revealed that these waters are also affected by terrestrial discharges.

The high nutrient levels and plankton production reflect the high fertility of the south-western part of Abu Qir Bay, a characteristic feature which has been recognised for a long time (SAMAAN & MIKHAIL, 1990; NESSIM & EL-DEEK, 1993; EL-SHERIF & GHARIB, 1994), particularly for phytoplankton. It seems therefore, that nutrients are not limiting factors for phytoplankton growth and the effect of pollution is not very clear in the study area.

Both phytoplankton and zooplankton showed three peaks of abundance throughout the year, but with different timing (Fig. 9). Therefore, two types of relations between chlorophyll-a and zooplankton could be expected, a direct one appeared during June, July, November and January, and another reverse relation dominated during the rest of the year. Such relations may be explained by the significant effect of grazing or by the theory of animal exclusion (c.f. RAYMONT, 1980). On the other hand, the low density of zooplankton nearby Boughaz El-Maadiya reflects the negative impact of fresh water on the population growth, since salinity in this area is exposed to daily variations (ABDEL-AZIZ & DORGHAM, 1999) which inhibit the growth of marine species (ABDEL-AZIZ, 2000). Meanwhile, the high chlorophyll-a concentration at the outlet of Lake Edku was caused mainly by freshwater phytoplankton (GHARIB & DORGHAM, 2000). In eutrophic waters, phytoplankton production exceeds zooplankton consumption, because of the growth of large algae that are relatively unutilized by filter feeding zooplankton, while in other situations, high zooplankton production is unrelated to phytoplankton production because of large influx of detrital allochthonous matter (WELCH, 1980).

Zonation of the surface salinity was reflected in the spatial distribution of nutrients and consequently plankton abundance in the study area, where two areas were distinguished. The former was confined to the inshore water around the different outfalls containing higher nutrients and more abundant plankton. The latter comprised the area near the Abu Qir headland and the offshore water having lower concentrations of nutrients and plankton. The boundary of each area was variable according to the variability of the water discharge (SAID, 1979). The significant correlation of salinity to nitrite, nitrate, phosphate, silicate and chlorophyll indicated salinity variations as one of the major factors influencing several biotic and abiotic components of the ecosystem in the study area. Moreover, the significant correlation between salinity and these parameters is mainly attributable to the quantity and quality of the discharged terrestrial wastes, which are usually loaded with large amounts of nutrients and different pollutants.

It could be further said that the effluent from Lake Edku showed a very limited effect on the southwestern part of the Bay, since the incoming fresh water current is usually directed eastward and a rarely westward (EL-GINDY, *et al.*, 1988). On the other hand, the waste waters discharged from the Electrical Power Station and the Abu Qir Fertilizer Company exhibited localized impact on the water quality of the surrounding area. The greatest role in such a context is played by the runoff from the El-Tabia Pumping Station, which on some occasions extends westward to the Abu Qir headland. However, the surface circulation regime in the Bay restricts water exchange between the inshore and offshore regions, especially in the western part (OSMAN & DORGHAM, 1987) preventing the spread of the terrestrial effluents to the outer part of the bay. According to EL-RAYIS *et al.*, (1993), the less saline water extends seaward during the period when the sea is calm in spring and the period of prevailing S-SE winds in winter. In summer, these waters are directed eastwards due to the prevailing NW winds and westwards during autumn due to N-NE winds.

Conclusions

The continuous discharge of different waste waters into the southwestern part of Abu Qir Bay has caused drastic changes in the hydrographic conditions, abnormal increase of nutrients and high plankton production, which together have led on several occasions to an acute degree of eutrophication and low oxygenation in the study area. The temporal and spatial variations of the measured parameters were strongly related to similar changes in the quantity and quality of the discharged wastes. Industrial and domestic wastes play a greater role in nutrient supply to the Bay than agricultural waste. The inhibiting effect of industrial waste on plankton production was not clear, and this requires a more detailed study of the chemical structure of these wastes.

References

ABBAS, M.M., 1969. Industrial waste pollution and its effect on the physical, chemical and biological character of sea water. M.Sc. Thesis, Fac. Sc., Alex. Univ.

ABDEL-AZIZ, N.E., 2000. Weekly observations on zooplankton community in a Sea-Lake connection (Boughaz EL-Maadiya), Egypt. *Bull. Fac. Sci.,* Alex. Univ., 40(1,2):68-83.

ABDEL-AZIZ, N.E. & DORGHAM, M.M., 1999. Ecological characteristics of plankton in brackish water, Egypt. Egypt. *J. Aquat. Biol. and Fish.,* 3(4): 215-242.

ABOUL-DAHAB, O.T., 1989. Chromium biogeochemical cycle in Abu Qir Bay, east of Alexandria, Egypt. *Est.cstl. and Shelf Sci.,* 29:327-340.

ABOUL-KASSIM, T., 1987. Cycles of carbon, nitrogen and phosphorous in the marine environment in Alexandria region. M.Sc. Thesis, Alexandria University, 232pp.

AHDY, H.H.H., 1999. Dynamics of Cadmium and Lead in Abu Qir Bay and their effect on marine organisms. Ph.D. Thesis, Fac.Sci., Alexandria University, 555 pp.

ANONYMOUS, 1984. Pollution status of Abu Qir Bay. Report, Nat. Inst. Oceanogr. & Fish.

ANONYMOUS, 1995. Effect of water circulation on pollutant transport in Abu Qir Bay area. Report submitted by Nat. Inst. Oceanogr. & Fish. to ICSC-World laboratory, 1-22 pp.

APHA, 1980. Standard methods for the examination of water and wastewater. American Public Health Association, New York.

DORGHAM, M.M. & OSMAN, M.M., 1987. Environmental conditions in Abu Qir Bay, east of Alexandria. II- Plankton distribution, downstream from land-based effluents. *Chemosphere,* 16(2/3): 559-564.

DOWIDAR , N.M. & EL-MAGHRABY, A.M., 1971. Observations on the neritic zooplankton community in Abu Qir Bay during the flood season. *Rapp. Comm. Int. Mer. Medit.,* 20(3): 385-389.

DOWIDAR, N.M., GERGES, M., EL-SAMRA, M.I. & EL-DEEB, M.K., 1983. General review of the ecological conditions of Abu Qir Bay. Unesco reports in marine sciences, 20: 124-133.

EIMP, 1999. Sediment and benthos monitoring. Report of Environmental Information and Monitoring Programme (EIMP) of the Coastal sea water of Egypt. Egyptian Environmental Affairs Agency.

El-DEEB, M.K., 1977. Hydrography and chemistry of Abu Kir Bay. M.Sc. Thesis, Fac. Sc., Alex. Univ.

El-GINDY, A.A.H., 1988. On the dynamic features and the possible mechanisms of the vertical mixing in Abu Qir Bay. *Rapp. Comm. Int. Mer. Medit.,* 31(2): 200.

El-GINDY, A.A.H., SHEREET, S. & EL-SHIEKH, S., 1988. Circulation and water masses. Their complications of shore processes and pollution transport in Abu Qir Bay. *Rapp. Comm. Int. Mer. Medit.,* 31(2): 200.

EL-NADY, F.E., 1991. Impact of the land runoff on the nitrogen species and organic matter in the Mediterranean waters of Alexandria (Abu Qir Bay). Proc. 1st Int. Conf. "Environmental Protection is a Must", 11-14 March 1991, Alexandria, 27-34.

EL-RAYIS, O.A., SAAD, M.A.H. & EL-NADY, F.E.(1993. Dispersion pattern of freshwater in Abu Qir Bay, Egypt. Proc. 3rd int. Conf. "Environmental Protection is a Must", 13-15 April 1993 Alexandria, 103-109.

EL-SAMRA, M.I., 1973. Chemical and physical properties of the waters of Lake Edku and the mixed waters between the lake and the sea (Abu Qir Bay). M.Sc. Thesis, Fac. Sc., Alex. Univ.

EL-SHARKAWY, M.F., 1991. Management of Abu Qir Bay pollution. Proc. 1st Int. Conf. "Environmental Protection is a Must", 11-14 March 1991, Alexandria, : 80-88.

EL-SHERIF, Z.M. & GHARIB, S.M., 1994. Phytoplankton production and composition in Abu Qir Bay (Egypt). Proc. 4th int. Conf. "Environmental Protection is a Must", 10-12 May 1994 Alexandria, 291-306.

EMARA, H.I., 1982. Study of some heavy metals in Abu Qir Bay and Lake edku. *Ves Journees Etud.Poll. Cannes.* C.I.E.S.M.,: 395- 399.

FAHMY, M.A., 1997. Hydrochemistry and nutrients of Abu Qir Bay during summer 1995. *Bull. Fac. Sc.,* Alex.Univ., 37(2): 171-186.

GHARIB, S.M. & DORGHAM, M.M. (2000. Weekly structure and abundance of phytoplankton in Boughaz EL- Maadiya, Egypt. Egypt. *J. Aquat. Biol. and Fish.,* 4(2): 183-210..

GHARIB, S.M. & SOLIMAN, A.M., 1998. Some water characteristics and phytoplankton-zooplankton relationship in Lake Edku (Egypt) and adjacent sea. *Bull. Fac. Sc.,* Alex. Univ., 38(1,2): 25- 44.

HOPPE, H.G., 1978. Relations between active bacteria and heterotrophic potential. *J. Netherlands Sea Res.,* 12(1): 78-98.

KUIPER, J., 1982. Fate and effects of cadmium in marine plankton communities in experimental enclosures. *Mar. Ecol. Prog. Ser.,* 6:161-174.

LANSKAYA, L.A., 1971. Algae culture. In *Ecological Physiology of marine planktonic algae,* pp: 5-21, Kiev.

MAHMOUD, TH.H., 1985. Phosphorous and nitrogen dynamics in the polluted coastal waters of Alexandria. Ph.D. Thesis, Alexandria University.

MAHMOUD, Th.H. & ABDEL-HAMIED, O.H., 1991. The distribution and the relationship between Nitrogen and Phosphorous compounds in Abu Qir Bay, Alexandria, Egypt. *Bull. High Inst. Public Health,* 21(2): 361-370.

MURAMOTO, S. & OKI, Y., 1983. Removal of some heavy metals from polluted water by water hyacinth *(Eichhornia crasssibes). Bull. Environ. Contam.* Toxic, 30:170-177.

NESSIM, R.B. & EL-DEEK, M.S., 1993. Eutrophication in Abu Qir Bay. Proc. 3rd int. Conf. "Environmental Protection is a Must", 13-15 April 1993, Alexandria, 115-130.

OSMAN, M.M. & DORGHAM, M.M., 1987. Environmental conditions in Abu Kir Bay, east of Alexandria. I- Physico- chemical characteristics and water circulation. *Chemosphere,* 16(2/3): 361-368.

PATIN, S.A., 1982. Pollution and the biological resources of the oceans. Butterworth Scientific, London, 286pp.

PATIN, S.A., PETUKHOV, S.A. & MOROZOV, N.P., 1978. Distribution and differentiation of metals in ecosystems of the pelagic zone of the ocean. *DAN SSSR,* 240(2):445:447.

RAYMONT, J.E.G., 1980. Plankton and Productivity in the Oceans. I- Phytoplankton (2nd ed.), Pergamon Press.

SAAD, M.A.H., 1979. A study on mixed water between Lake Edku and the Mediterranean Sea. *Rapp. Comm. Int. Mer. Medit.,* 25/26: 115-116.

SAID, M.M., 1979. Effect of oceanographical and meteorological factors on the transport of pollutants in Abu Qir Bay. M.Sc. Thesis, Fac. Sc., Alex. Univ.

SALEH, H.H., 1982. Mortality of fish exposed to water from the Tabia Pumping station, Egypt. Vies Journees d' études sur les pollutions marines en Méditerranée, Cannes, 2-4 December, 1982

SAMAAN, A.A. & MIKHAIL, S.K., 1990. Distribution of phytoplankton in Abu Qir Bay (Egypt). *Bull. Nat. Inst. Oceanogr. & Fish.,* A.R.E., 16(1): 65-73.

SHRIADAH, M.M.A. & TAYEL, F.T.R., 1992. Environmental condition of the Western Harbour of Alexandria. Physico-chemical characteristics. *Bull. High Inst. Publ. Health,* 22(1): 213-223.

SIAM, E.E., 1998a. A synoptic survey on number of bacteria and biomass in relation to physico-chemical parameters in the Eastern Harbour of Alexandria, Egypt. *Bull. Nat. Inst. Oceanogr. & Fish.,* 24:103-119.

SIAM, E.E., 1998b. Enumeration and biomass of bacterial indicator saprophytic community in Alexandrian coastal water. *Bull. Nat. Inst. Oceanogr. & Fish.,* 24:127-139.

STRICKLAND, J.D. & PARSONS, T.R., 1975. A handbook of seawater analysis. *Fish. Res. Bd* Canada, 167, 310pp.

TAYEL, F.T.R., 1981. Effect of pollution by pesticides on some marine animals in Abu Qir Bay, M.Sc. Thesis, Fac. Sc., Alex. Univ.

TAYEL, F.T.R., 1992. The physical and chemical conditions of Abu Qir Bay waters, Alexandria, Egypt. *Bull. High Inst. Public Health,* 22(1): 87-99.

TAYEL, F.T.R. & SHRIADAH, M.M.A., 1991. Effect of pollution by hydrogen sulphide on the hydrobionts in both Abu Qir Bay and Western Harbour of Alexandria. A technical report submitted to FAO.

WELCH, E.B., 1980. Ecological effects of wastewater. Cambridge Univ. Press. Wetzel, R.G. (983. Limnology 2nd ed. Sounders College Publishing, Philadelphia: 66-98.