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IMPACT OF POLLUTION ON PRODUCTIVITY AND FISHERIES OF FISHERIES OF LAKE MARIUT, EGYPT

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ABSTRACT

Water quality characteristics of Lake Mariut (Egypt) were investigated during the period from April 1996 to March 1997. A comparison of nutrient salts and oxygen concentrations during late 1950's with those of the present study, indicated a pattern of increasing eutrophication and organic pollution and dominance of the sewage, industrial and agricultural wastewaters on the ecology of the lake. In the polluted main basin, the water showed much higher concentration of some heavy metals such as iron, copper and zinc. Accumulation levels of heavy metals in fish muscles are within the legal limits of WHO standards.

In response to the heavy pollution, the primary production and fertility of the main basin of the lake were reduced to about $^1/_3$ of that recorded in 1961. The average annual fish production declined from 1850 kg ha^{-1} in 1970's to only 461 kg ha^{-1} in 1996, and more declining is expected in the near future, unless a management programme is applied to conserve this vital ecosystem.

INTRODUCTION

The Egyptian northern Nile-Delta lakes, adjacent to the Mediterranean Sea, are the principal depository for Nile drainage and wastes prior to its outflow in the Sea. These lakes receive the agricultural drainage water and major inputs of municipal and industrial wastes from cities as Cairo, Alexandria and others, in addition to several towns and villages. The National Environmental Action Plan of Egypt (1992) has identified the north-western Lake "Mariut" as the most polluted aquatic ecosystem in Egypt. The lake receives wastes from two major drains, primary treated sewage from Alexandria city, as well as primary treated industrial wastes from about 40 industrial plants. The outflow discharge from the lake is pumped through "Max" pumping station to the Mediterranean Sea with a total amount of about 2.4 billion m^3 $year^{-1}$ with an average salinity of 5,600 ppm (RMP, 1993).

Pollution of the lake has resulted in a considerable decrease of some fish species, disappearance of some valuable ones and reduction of wildlife populations. These deteriorating effects on Lake Mariut have drawn public concern and attention to environmental issues. Therefore, the objective of this study it to investigate the pollutant levels in the lake water and fish muscles as well as to assess the impact of industrial and domestic effluents on productivity and fisheries of the lake.

AREA OF STUDY

Lake Mariut is the smallest brackish water ecosystem along the Mediterranean coast, situated in the northwestern corner of the Nile Delta, at latitude 31° 10' N and longitude 29° 55' E (Fig. 1). It has no connection with neither the Mediterranean Sea nor the River Nile, but there are pumps which discharge water from the lake, at the northern end of Elamoum drain into the sea and the water level in the lake is kept at about 3.8m below sea level (El Sharkawy, 1991).

At the end of the nineteenth century, Lake Mariut occupied an area of about 26,000 hectares (Meininger & Atta, 1994) but since then the lake has been subjected to various changes due to land reclamation projects, which led to a considerable shrinkage of its total area to about 6,070 hectares, with an average depth of about 1.2m. Geographically, the lake is divided into four separated sections by Cairo- Alexandria desert road and Elamoum drain (Fig. 1). They are :

1- The northern-west basin (1214 hectares), which receives its water from Elamoum drain.

2- The southern-west basin (2023 hectares), which also receives its water from Elamoum drain and Noubaria canal and is densely covered with *Phragmites* and *Typha* spp. plants.

3- The fish farm (405 hectares), which receives its water from the drainage waters of Elamoum and Qallaa drains.

4- The main proper basin (2428 hectares), which has been subjected to a serious disturbance in its biological balance, owing to draining of large amounts of municipal and industrial wastewaters from three sources :

a- The Western Collective Treatment Station which discharges the primary treated wastewaters of El-Kabbari, industrial and Gheit El-Ennab drains, at the north west side of the basin.

b- The Eastern Treatment Station which discharges the primary treated wastewater of the Qallaa drain, at the eastern side of the basin.

c- Noubaria Canal which discharges wastewaters at the western side of the basin.

MATERIAL AND METHODS

This study has been conducted in the main basin of Lake Mariut; the most polluted region and the fish farm basin; the relatively stable and clean portion of the lake. Water samples were collected during the period from April, 1996 to March, 1997, at approximately seasonal intervals, at five stations; four in the main basin and one in the fish farm (Fig. 1). Station # 1 is located at the northern portion of the main basin, in between the mouths of the old industrial wastes drain and Qallaa drain. Station # 2 is located in front of the old Gheit El-Ennab drain mouth; while station # 3 is affected by the old El-Kabbari drain. Station # 4 is situated at the south-west region of the main basin, away from the effect of the wastes effluents. Station # 5 is located in the middle of the fish farm.

Water samples were taken from the upper 0.5 m of the water column by plastic water sampler and were analyzed to determine the concentrations of some chemical and biological parameters. These parameters include field measurements of dissolved oxygen (DO), pH values and electric conductivity (EC), in addition to laboratory measurements of chlorides, phosphate, nitrate, nitrite, ammonia, sulphate, hydrogen sulphide, biological oxygen demand (BOD), chemical oxygen demand (COD), total coliform bacteria and the heavy metals; iron (Fe), nickel (Ni), zinc (Zn), copper (Cu), lead (Pb), chromium (Cr) and mercury (Hg). Laboratory analysis of water followed the Standard Methods for Examination of Water and Wastewater (1992). Analysis of heavy metals in fish edible muscles and liver of *Oreochromis niloticus (L)* were carried out according to Chernoff (1975). Metal concentrations were determined using Pye Unicam Sp 191 atomic absorption spectrophotometer.

Primary production experiments were performed at the same stations, using the in situ light-dark bottles method (Strickland, 1960), where duplicate sets of light and dark bottles were filled and suspended at the surface, 0.5 m and 0.8 m.

RESULTS AND DISCUSSION

The chemical and bacteriological analyses of main basin water of Lake Mariut indicated that it has been greatly affected by the input of Alexandria sewage and industrial wastewaters (Tables 1 & 2). The northern sector of the main basin (stations # 1, # 2 and # 3) was the most affected area by these pollutants, where the mean dissolved oxygen concentrations were very low and reached to about 0.5, 0.3 and 1.8 mg l^{-1}, respectively. This reduction in dissolved oxygen at these sites was primarily due to the discharge of the primary treated industrial and municipal wastewaters through the western treatment station, and increasing of ammonia and sulplides (Table 1), which may cause the mineralization of organic matter during eutrophication and induced an enormous oxygen depletion. After an aerobic phase, the microbially-mediated anaerobic decay of plant and animal material was usually malodorous due to production of ammonia and sulphides. These results are in agreement with those obtained by Higgins & Bruns (1975) and Lorenzen (1978).

On the other hand, organic loads have been increased tremendously in this northern sector, therefore the mean biochemical oxygen demand (BOD) reached to about 149.5 mg $O_2 l^{-1}$, while the mean COD amounted to 821.6 mg O_2 l^{-1}, which indicates a high industrial effect in this region. Total coliform bacteria concentrations in these stations (# 1, 2 and 3) were in the range of 3.8 x 10^6, 2.5 x 10^6 and 0.9 x 10^6 MPN l^{-1}, respectively.

At the southern sector of the main basin (station # 4), the water quality profile indicated a noticeable recovery and a decrease of the pollutants effect which may be attributed to absorption of pollutants by the dense macrophytes; *Phragmites* and *Typha* spp. Khalil and Awady (1990) reported that in the middle and western regions of the lake - which are rich in submerged macrophytes - the water quality profile indicated a remarkable recovery and a decrease of the pollutants effect. The oxygen level increased to 6.3 mgl^{-1}, the COD and BOD decreased to 170 and 45 mg l^{-1}, respectively, and the number of coliform bacteria was decreased to only 4700 MPN l^{-1}. Moreover, the concentrations of ammonia and sulphides decreased sharply (Table 1), which indicated that the wastewaters of the western treatment station were mixed up rapidly with the lake water, due to-primarily-the northern south currents (El-Sharkawy, 1978). At the fish farm basin (station # 5), the water quality profile indicated that concentration values of most parameters, even the heavy metals, were well within the established safety range for unrestricted use in fish culture, compared to standards set by FAO (WHO, 1989).

In the main basin, the water showed much higher concentrations of some heavy metals (Table 3), such as iron, copper and zinc. This reflects the discharge of the industrial and sewage wastes into this sector. Saad *et al.* (1982) have claimed that *Tilapia* spp. fish in the lake have markedly enhanced concentrations of both heavy metals and organochlorine pesticides. This can be explained if we know that during the present study, high concentrations of heavy metals were found in the liver of tilapias (Table 4), which were not complying with the WHO guidelines. But generally, it is found that the accumulation levels of heavy metals in the fish muscles were within the legal limits of different countries and WHO standards (Nauen, 1983; WHO, 1989).

On the other hand, a comparison of nutrient salts and oxygen concentrations during late 1950's with those of the present study at the same sites (Table 2), indicated a pattern of increasing eutrophication and organic pollution, and dominance of the sewage and agricultural drainage water on the ecology of Lake Mariut. During 1996/97 the total phosphate levels were approximately ten times those of the 1950's. The mean nitrate value in 1950's (0.028 mgl^{-1}) has been increased to 0.445 mg l^{-1} in the 1996/97 period. These increases in nutrient salts in Lake Mariut were paralleled by their increases in Lake Manzala, Egypt (Khalil & Salib, 1986; Khalil & El-Awamri, 1988), which receives a huge amount of drainage water besides the sewage of Cairo city. Moreover, the annual mean chlorosity levels in Lake Mariut decreased by 66% since late 1950's. It was about 3670 mg l^{-1} during 1957/58 (Wahby, 1961), then 1367 mg l^{-1} during 1975/76 (El-Sharkawy, 1978), 1280 mg l^{-1} in 1988 (Khalil & Awady, 1990) and finally 1250 mgl^{-1} during 1996/97 (Table 2). This decrease in salinity pattern over the past 50 years is generally attributed to the continuous increase in the input of agricultural drainage water.

In response to the increase of nutrient loading, organic matter, fresh water inputs and the decrease of salinity levels, the productivity and aquatic community have been changed; leading to a less diverse but a high productive ecosystem; tilapia-based fishery. The fish yield has been increased from 167 kg ha^{-1} in 1921-26 (Fouad, 1926) to about 992 kg ha^{-1} in 1961-65 period then to 1950 kg ha^{-1} in 1975-80 (Bishai *et al.*, 1994).

This increase was primarily due to the elevation of nutrient salts levels and consequently primary productivity and plankton; the major diet of tilapia (Bishai & Khalil, 1990). Since the beginning of 1980's the fish production in Lake Mariut began to decrease sharply due to the enormous increase of industrial wastes and sewage of Alexandria discharged into the lake. During the 1983-88 period the fish yield decreased to about 1120 kg ha^{-1} , then to only 461 kg h^{-1} in 1990-96 period (GAFRD, 1997). Table (5) shows the total fish production of Lake Mariut during five periods; from 1921 to 1996.

On the other hand, most of the brackish and less tolerant high-valued fish, such as *Mugil cephalus (L.)* , *Labeo niloticus (F.)* , *Bagrus bajad (F.)* , *Lates niloticus (L.)* and *Barbus bynni (F.)* , have been decreased or completely disappeared from the lake (GAFRD, 1997). However, *Tilapia* has been flourished enormously and it represented about 92% of the total yeild in 1980's. Also, *Clarias gariepinus* (Buch.) production has been increased from 80 tons in early 1960's to 300 tons in early 1980's and now it constitutes about 24% (900 tons) of the annual total yield (GAFRD, 1997). The predominance of *Tilapia* and increase of *Clarias gariepinus* production in Lake Mariut is due to their high tolerance to marginal environmental conditions, in terms of oxygen concentrations, high nutrient loading and variation in salinity (Balarin, 1979; Khalil & Awady, 1990). Moreover, because of the herbivorous feeding habit of *Tilapia* spp., they were able to respond quickly and directly to the flourishing of phytoplankton that resulted from nutrient enrichment, especially in the fish farm basin. It is noticed that most of the diversed yield of the lake comes from the fish farm and the western sectors. But, most of fish in the main basin, especially at the northern portion, are very small in size and very low in abundance. This is, definitely, due to the stress of the unfavourable conditions on the fish in this sector which decreased its growth rate.

Other arganisms were also affected by this pollution specially algal flora; the primary producers of the ecosystem. Samaan & Abdalla (1981) have indicated that the efficiency of periphyton growth and production in the polluted main basin was reduced to about 1/4 of the normal growth rate found in the fish farm, besides the community composition was restricted to few forms which were more tolerant to pollution. Also, Abdalla *et al.* (1991) reported a decrease of the species diversity of phytoplankton community and domination of tolerant species in the polluted main basin. The gross primary production measurements during the present study, indicated highest values in the fish farm (8.3 g C m^{-2} d^{-1}) and lowest values in the areas receiving industrial and municipal wastes in the main basin (Table 6). The mean value of production in the polluted main basin was about 1.88 g C m^{-2} d^{-1}. In 1961, when Lake Mariut was less polluted, Samaan (1966) found that the lake was rich in nutrients and has been ranked as one of the most productive lakes in the world. Its biological productivity was more than 3.5 times that of the other Egyptian northern lakes, and its average gross primary production reached to about 6.84 g C m^{-2} d^{-1}. Comparing this value with that of the present study in the main basin (1.88 g C m^{-2} d^{-1}), indicates that fertility of the lake proper has been reduced to about 1/3 of that found in 1961, as a result of pollution, and more declining is expected in the near future, unless a management programme is proposed and applied to conserve the environmental conditions of this vital ecosystem, especially it is considered as one of the most enriched sources of fish production in Egypt.

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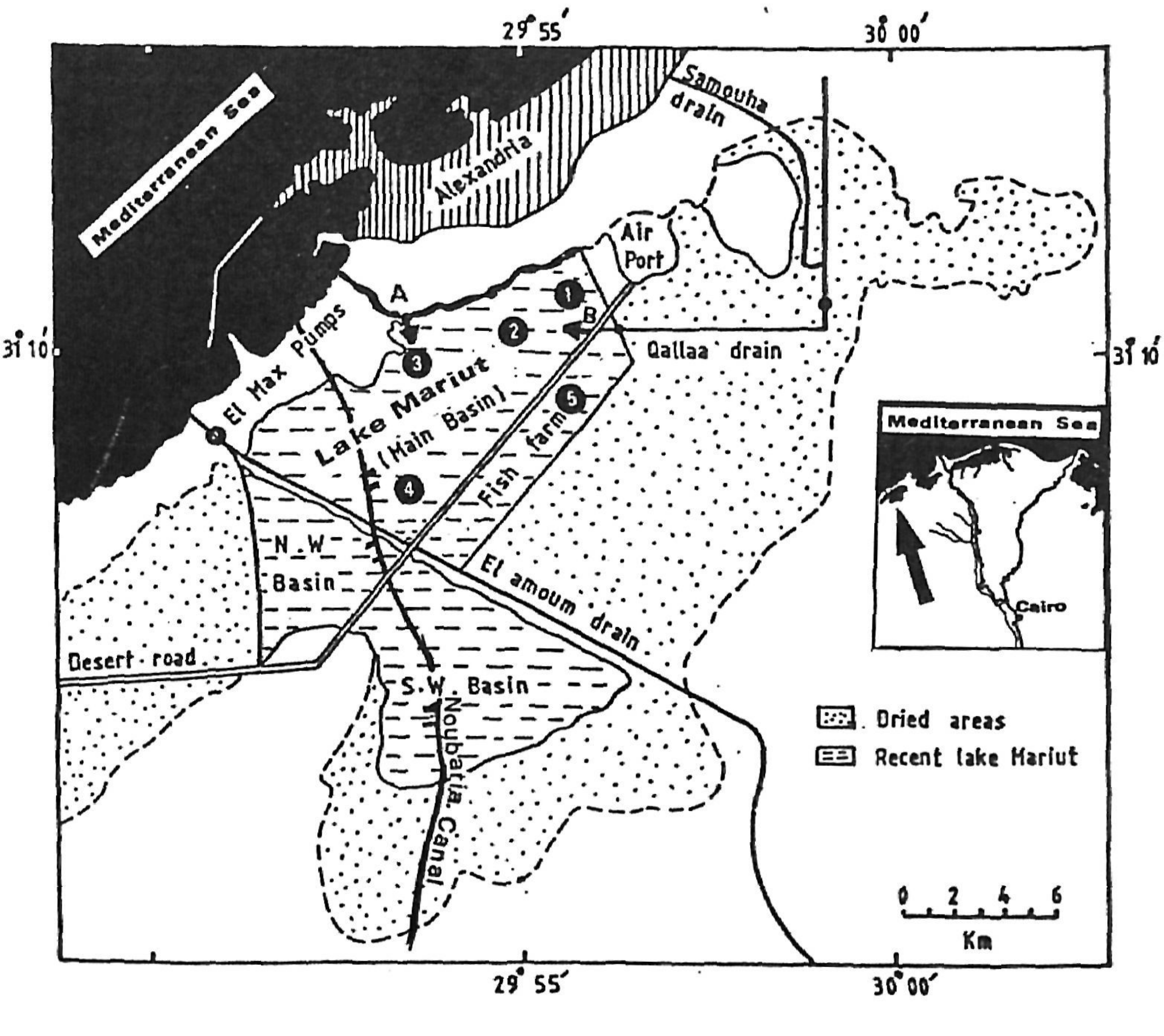

Fig. (1) : Area of study; Lake Mariut, showing the water sampling sites.

A- The western collective treatment station

B- The eastern treatment station

Table (1). Water quality characteristics of Lake Mariut during 1996/97 (seasonal mean values)

Parameter	Stations				
	1	2	3	4	5
pH	7.4	7.5	7.8	8.5	8.1
Ec (μmhos cm^{-1})	6.5	4.2	2.9	1.1	1.8
SO_4 (mg l^{-1})	610	550	510	297	230
H_2S (mg l^{-1})	15	30	16	2.8	3.5
NH_3 (mg l^{-1})	26.9	28.1	26.3	10.8	5.9
NO_2 (mgN l^{-1})	0.020	0.030	0.025	0.39	0.6
BOD (mgO_2 l^{-1})	175	182	93	45	15
COD (mg O_2 l^{-1})	940	985	540	170	85
Faecal coliform (MPN x 10^3 l^{-1})	3,800	2,500	900	4.7	1.4

Table (2). Water quality characteristics of Lake Mariut during the period 1957/58 and 1996/97 (seasonal mean values).

Parameter / Station	Period	
	1957/58*	1996/97
Oxygen (mg O_2 l^{-1})		
1.		0.5
2.	4.6	0.3
3.		1.8
4.	10.4	6.3
5.	14.9	6.5
Mean	9.26	3.08
Chlorosity (mg l^{-1})		
1.		1080
2.	3650	1040
3.		1120
4.	3690	1160
5.	3680	1850
Mean	3670	1250
Phosplate (mg P l^{-1})		
1.		3.6
2.	0.347	2.72
3.		2.93
4.	0.049	1.94
5.	0.011	0.41
Mean	0.249	2.32
Nitrate (mg N l^{-1})		
1.		0.621
2.	0.011	0.352
3.		0.461
4.	0.041	0.390
5.	0.032	0.401
Mean	0.028	0.445

* Wahby, 1961

Table (3). Heavy metals content (mg l^{-1}) in water of Lake Mariut during 1996/97 (seasonal means values)

Stations	Fe	Ni	Zn	Cu	Pb	Cr	Hg
1	9.22	0.46	0.30	0.66	0.32	0.52	0.02
2	10.20	0.30	0.25	0.52	0.21	0.33	0.01
3	8.21	0.22	0.22	0.49	0.22	0.21	0.02
4	4.80	0.09	0.10	0.21	0.08	0.15	ND
5	3.50	0.05	0.08	0.12	0.03	0.10	ND

Table (4). Heavy metals content (µg g^{-1} dry wt.) in *Oreochromis niloticus* of Lake Mariut during 1996/97

Location / Fish organ	Fe	Zn	Cu	Pb	Hg
Fish farm					
muscles	8.5	6.5	1.95	0.43	ND
liver	15.3	27.3	8.9	2.10	ND
Main basin					
muscles	35.3	19.2	9.3	0.97	ND
liver	1230	194	56	15.2	0.05

Table (5). Fish production of Lake Mariut during five different periods.

Item	Period				
	1921-26*	1961-65	1975-80	1983-88	1990-96
Average annual yield (tons)	4,339	7,400	13,800	6,800	2,800
Fish production in kg ha^{-1}	167	992	1850	1120	461
% catch of *Tilapia* spp.	72.6	89.7	92.3	86.9	68
% catch of other Nile fishes	12.1	7.5	2.5	11.2	30.7
% catch of marine fishes	15.3	2.8	5.2	1.9	1.3

* Fouad (1926)
- Other data from Bishai *et al* (1994) and GAFRD (1997).

Table (6). Annual average values of gross primary production in different areas of Lake Mariut during 1996/97 (seasonal means values).

Station		Gross Primary Production ($g\ Cm^{-2}\ day^{-1}$)
Main basin	1	0.90
	2	1.32
	3	2.40
	4	2.9
	Mean	1.88
Fish Farm	5	8.3
Mean GPP in 1961 (Aleem & Samaan, 1969)		6.84

تأثير التلوث على إنتاجية وأسماك بحيرة مريوط بمصر

مجدى توفيق خليل
قسم علوم الحيوان–كلية العلوم–جامعة عين شمس

تم دراسة خصائص مياه بحيرة مريوط بمصر، خلال الفترة من ابريل ١٩٩٦ الى مارس ١٩٩٧، بمقارنة تركيزات الأملاح المغذية والأكسجين خلال الخمسينات بمثيلاتها فى الوقت الحاضر، نجد أن التلوث العضوى قد زاد بمعدل ملحوظ، وقد أثر التلوث الصناعى وكذلك المعادن الثقيلة مثل الحديد والنحاس والزنك سواء فى المياه أو عضلات أسماك البلطى نتيجة زيادة التلوث فى الجزء الرئيسى بالبحيرة، كما انخفضت الانتاجية الأولية وخصوبة المياه الى ثلث ما كان مسجلاً خلال عام ١٩٦١.

وقد تدهور الانتاج السمكى كثيراً، فبعد أن كان ١٨٥٠ كجم/هكتار خلال السبعينات، اصبح ٤٦١ كجم/هكتار خلال عام ١٩٩٦، ومن المتوقع أن يقل هذا الانتاج كثيراً إذا لم تتخذ عدة تدابير وحلول جذريه لتقليل ووقف هذا التلوث فى هذه البحيرة الهامه.