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SEQUENCES AND CONSEQUENCES OF POLLUTION IN NORTHERN EGYPTIAN LAKES. 1. LAKE BOROLLOS.

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ABSTRACT

Egypt northern lakes act as receipients of industrial, domestic and agricultural wastes. The degree of pollution of each lake is different. Lake Borollos is considered the cleanest of them all. However, it is subjected to several changes that may affect its ecology and endanger the life there. The chemical and biological characteristics of this lake are summarised, and the possible effect of the changes in the environment due to eutrophication or excessive use of insectisides are discussed. Also, the effect of changes in the flushing rate of the lake is considedred. It is concluded that the lake needs further coordinated studies since the present data is not suffecient to make any unbiased conclusion.

INTRODUCTION

Egypt's coastal lakes act as temporary reservoirs for drainage water, oftenly, highly contaminated with anthropogenic materials. This is true, particularly for Lake Manzala and Lake Marute and to lesser extent, Lake Edko. Lake Borollos recieves mainly drainge water from agricultural lands with little amounts of industrial and sewage wastes. Thus, all coastal lakes are subjected to an active process of contamination with different pollutants. In each lake, however, the sequences and concequences are not necessarily the same; nevertheless, the final conclusion is similar, that is "we may be killing our lakes and destroying our environment".

Because of the crucial differences between each lake and the other, particularly in terms of water chemistry and nature of pollutants discharged into it, each lake will be delt with separately.

Lake Borollos seems to be distinct, in terms of waste material it receives, since it does not receive any industrial waste, nor it is used as depository for sewage and human refuse, firstly because of the low population density in the neighborhood, and secondly, because of the land reclamation projects in the nearby areas. However, land reclamation may have affected the area and size of the lake to a certain degree, the real extent is not known.

Geographical Setting and General Description

Lake Borollos (Fig. 1) is situated at the northern part of the Nile Delta, between the two branches of the Nile. It extends between Long. 30°30 E and 31 10° E, 60 km east of Rosetta branch and 70 km west of Damietta branch. The Lake is rather narrow and its breadth varies between 5 and 17 km. The lake with an overall area of ca. 546 sq km., is separated from the sea by a stripe of land covered with sand bars and sand dunes of different width and hight. It is connected to the sea through a narrow opening known as Al-Boghaz.

The water depth in the lake is subjected to comparatively large variations from day to day; and the depth varies annually between 42 cm and 207 cms. Generally the depth increases from east to west, and from south to north. The sea level of the lake is affected by both the amount of drainge watre, and the water exchanged with the Mediterranean sea through Al-Boghaz bending on the wind direction. The water depth is maximum during November and minimum during February.

The coasts of Lake Borollos, particularly the southern shores are irregular. Sediments on the bottom of the Lake have a complex nature. Scattered in the lake are many island (ca. 75 islands) of varying areas. The islands near the lake-sea connection are of sandy nature while those far from Al-Boghaz have clayey bottom. Some of the small islands are covered with water during high water periods. These are mostly covered with consolidated calcareous shells.

. The lake receives water from two origins. Sea water enters the lake through Al-Boghaz, at Borg Al-Borollos. Fresh water reaches the lake through six drains, and one fresh water canal (Fig. 1), all discharge water in the southern part of the lake. The lake-sea connection is sometimes closed in the spring due to the movement and accumulation of sand in the sea side.

The shores of the lake are densely covered with **phragmite communis, Jancus maritimus** and **salicornia fruasticosa.** The density of vegetation decreases away from drain openings; it disappears completely about 50 m from shores (recent observations showed much large extent).

The calyay island are covered with potamogeten besides other plants. The sand island are poor in vegetation. However, the drains drift with them water plants like elodia.

The phytoplankton community consists mostly of **Bacillariophyceae, Chlorphyta** and **Cyanophyta.** The zooplankton population comprises copepods, rotifera, cladocera and protozoa.

The fishes of Borollos are mainly **Tilapia nilotica, Tilapia gallili, Latus nilotica, Bagrus bayad** and **Barbus bynni.** Those are mainly fresh water

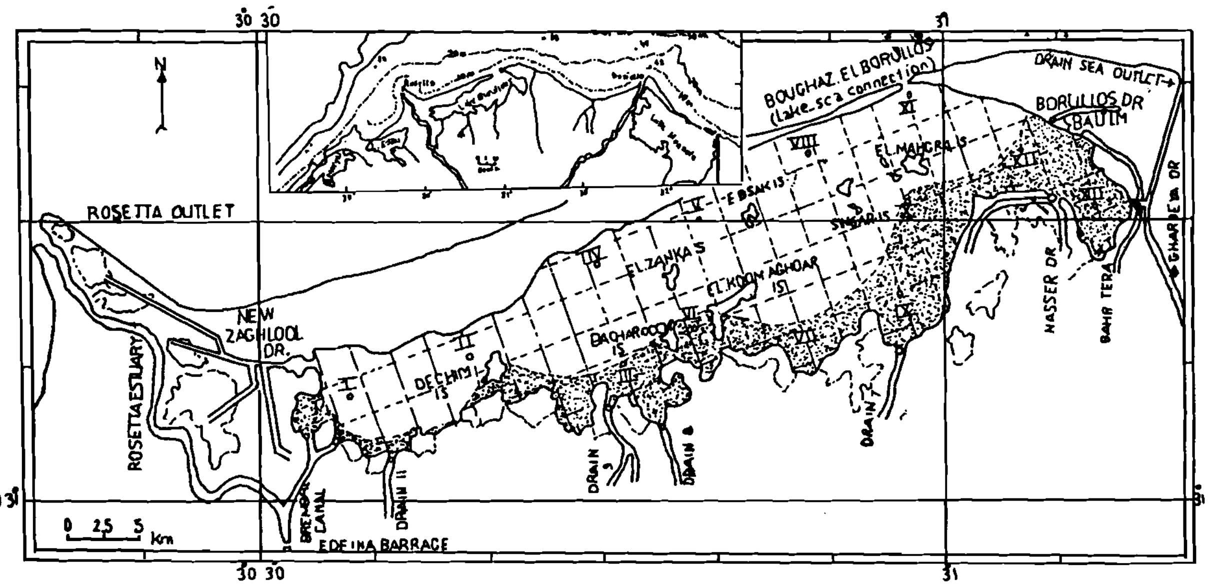

Fig. (1)
Lake Borollos (shaded areas are covered with potamogeton).

fishes. Marine fishes are represented by **Mugil** sp. **Chrysophrys** aur., **Morone labrax** and **Sciaquilla.** The distribution of fish in the lake is mainly controlled by the salinity distribution of the water.

Physical Conditions In Lake Borollos

a- Water temperature

Owing to the shallowness of the lake, the air temperature greatly affcets the water temperature. The lowest water temperature recorded was 12.5°C during the first half of February, the highest water temperature of 29.1°C was recorded during the second half of August. (see Fig.2.).

b- Effcets of wind on the Lake

The wind affects the degree of transparency of water particularly in the open region free of vegetation. Moderate wind can disturb the silty bottom and the water becomes turbid.

The wind also has a great effect on the movement of the water in the lake. Sometimes, all the water in the most eastern part of the lake is shifted towards the west under the effcet of the easterly wind, leaving the whole area completely dry. On the other hand, the westerly winds, sometimes, moves great quantities of water from the sea into the eastern part of the lake and at the same time the western part becomes very shallow. The wind movements play an important role in the distribution of salinity in the lake. When it is easterly winds, the drain's fersh water covers most of the lake and decreases the salinity to a large extent. The northerly winds drive sea water southerly and the salinity increases even next to drains. Fig. 3 shows the wind direction and duration over Lake Borollos.

c- Salinity

Salinity distribution in the lake is not constant, depending on the water drained by the drain system and canals, the water invading the lake from the sea and the degree of mixing. However, Beltagy (1966) has shown that the lake during September can be divided into two distinct regions, the central and central-eastern part with salinity over 10‰ (19‰ maximum), and the western part with salinity between 1.5‰ and 10‰.

The distribution of average chlorosity in the lake is shown in Figure.4. The salinity generally decreases going away from Al-Boghaz. The salinity rises from January to reach a maximum in July, due to decrease in the flow of drain water into the lake. Salinity decreases after wards, until it reaches minimum during November.

During November Salinity of water, in all the regions next to drains as well as the lake/sea connection, lies between 0.4‰ and 3‰. Relatively high values are observed in the eastern part of the lake (2.1-1.5‰) increasing to 4-5‰ during December. In other parts of the lake, salinity ranges from 0.8 to 1.8‰ in December.

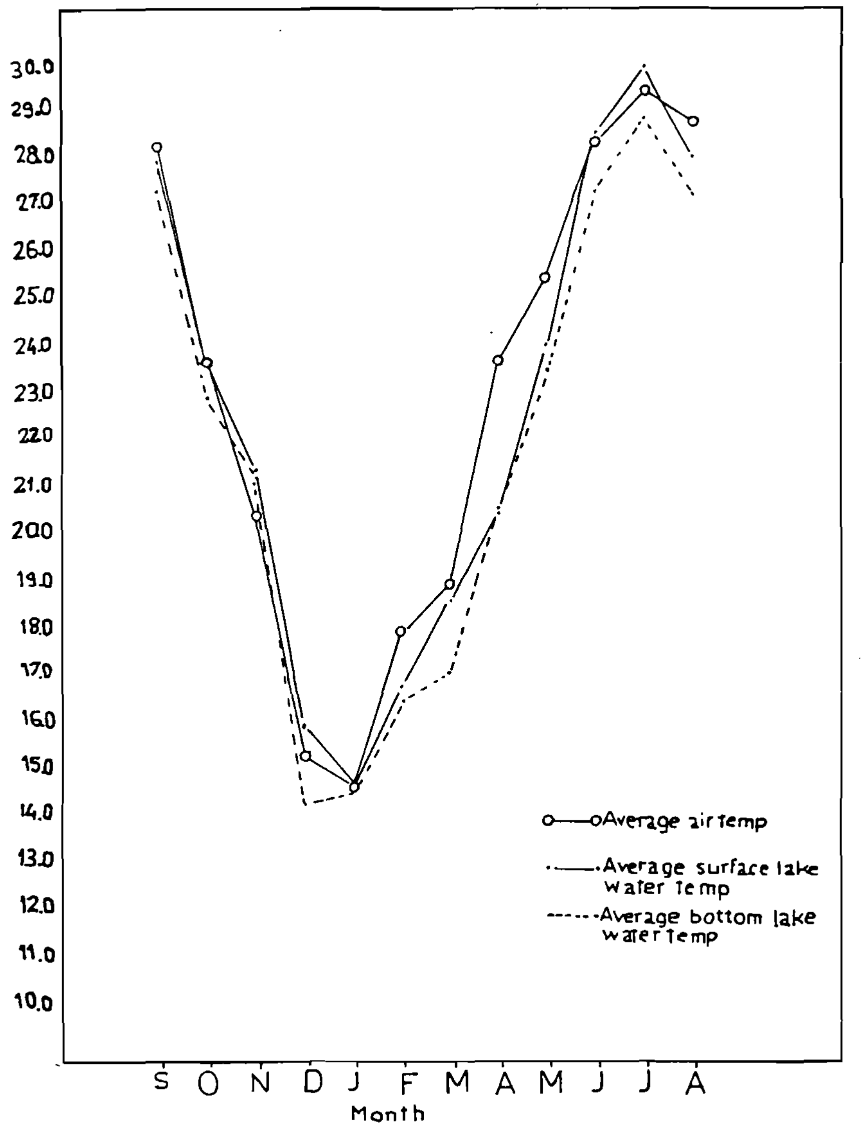

Fig (2)
Average air, surface and bottom water temperatures of Lake Borollos, (1977-1978). [After Darag, 1984].

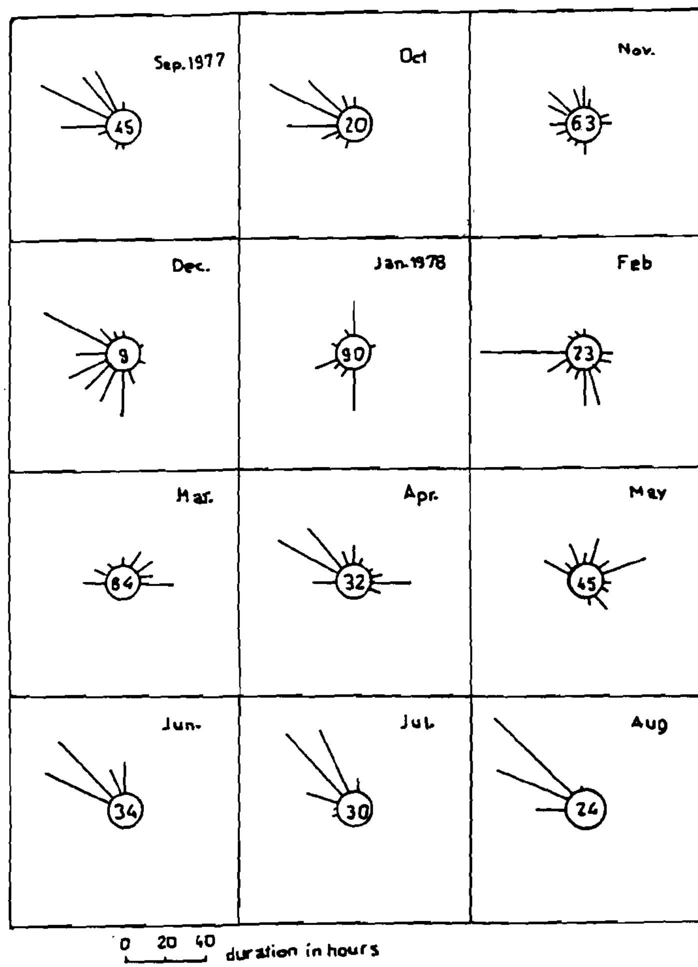

Fig. (3)
Wind direction and duration (hours) in Lake Borollos area, (number inside circles represents hours of calm wind). [After Darag, 1984].

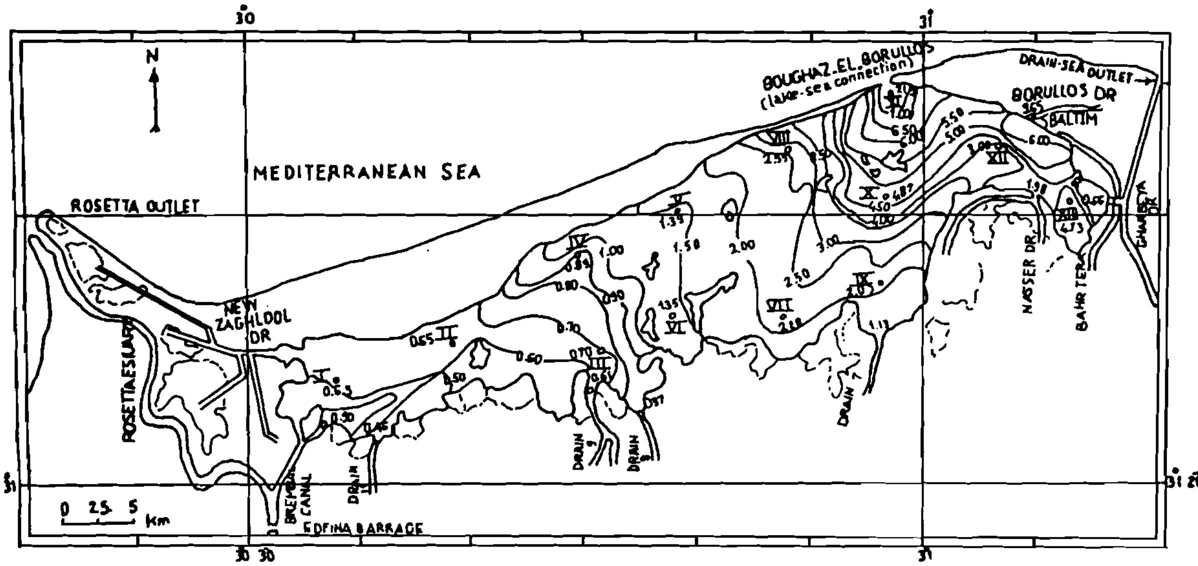

Fig. (4)
Average distribution of chlorosity (mg./l) in lake water
and drain inlets, (1977 - 78).

The drains in the southern region are characterized by high salinity. The water chlorosity in the vicinity of the drains as well as the western region is 0.6-1.4‰.

During August, however, water salinity in the north and north eastern parts was between 3.6 and 21.6‰ (Anon, 1980). The south western part and the drain water, had values as low as 0.8‰. During October the water allover the lake as well as the drains had salinity between 0.8 and 6.0‰ with high values in the eastern part of the lake.

The maximum salinity for drain water is 6‰ with a peak value of 16.9‰ in drain Borollos. Waters of other drains have, however, salinity between 0.6 and 1.4‰.

Hassan (1981) has measured the current at Al-Boghaz and calculated the net inflow and outflow of the lake. He calculated the net daily outflow of the lake to be 1.22 milion cu m/day (an average). However, figures reported on the drains input are much higher.

d- Oxygen

Comparatively low oxygen values are reported for the drain waters during August and September. Maximum oxygen values in the lake are observed in the south and southeastern parts, where they vary between 12 and 9.8 ml/l. Lower values are observed in the north and north eastern parts (range between 6.5 and 8.5 ml/l). The period September-February is characterized by relatively high oxygen content, it ranged between 5.2-10.6 ml/l, with minimum values in the vicinity of southern drains. During March the oxygen content varies between 4.5 and 8.6 ml/l, this is followed by sudden increase during April to 8.9-18.2 ml/l (Anon, 1980). By the end of spring it decreased to 3.5-9.8 ml/l. Very low values of 2.5-5.5 ml/l were observed in the western regions and near the southern drains. The average annual oxygen saturation is shown in Figure 5.

e- Phosphate

The phosphate ion concentration in the lake is relatively high. The southern regions of the lake has an average concentration of ca. 0.54 µg-at/l; while in the northern regions the mean values may be as low as 0.20 µg-at/l. These values drop to between 0.03-0.20 µg-at/l during September and reach maximum of 0.4-1.33 µg-at/l during October. During November they drop again to lower values between 0.3-0.40 µg-at/l. and even to lower values during December. During January there is a characteristic increase of phosphate ion concentration to values between 0.07-0.30 µg-at/l. The lowest absolute concentration is recorded however, during July, where a concentration of ca. 0.02 µg-at/l is dominant over the whole lake, (Figure 6).

f- Nitrite-Nitrogen

The nitrite-nitrogen content in the drain waters during August is reported to be 4.2 µg-at/l. It ranges between 0.33 and 3.98 µg-at/l in the waters

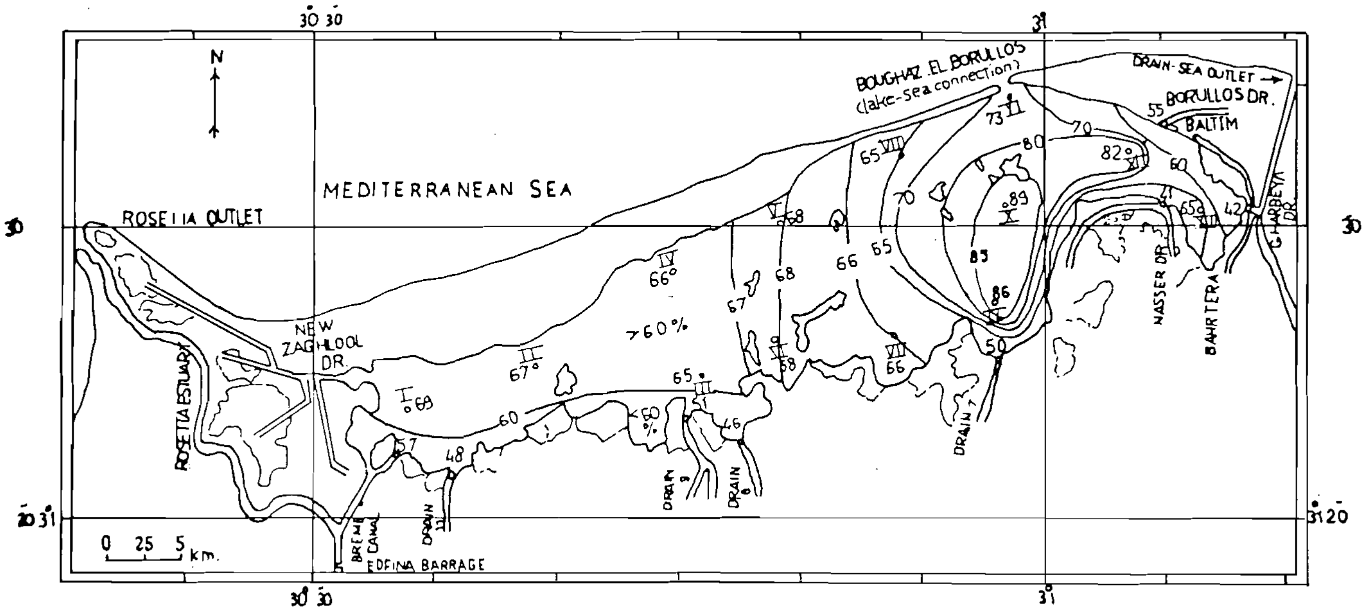

Fig. (5)
Average distribution of oxygen saturation percentage in lake water
and drain inlets, (1977 - 78).

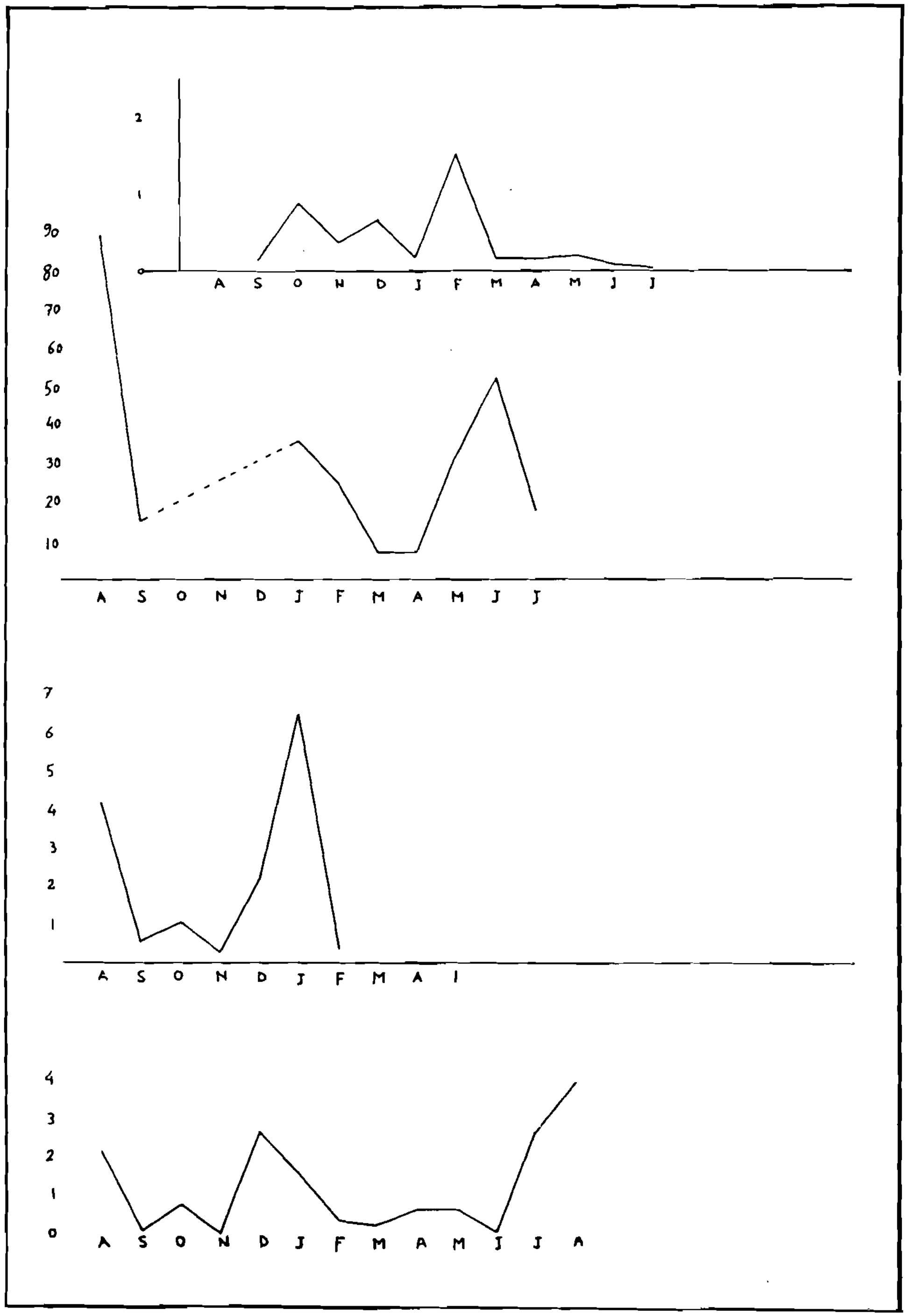

Fig. (6)
Dominant phosphate concentrations over the whole Lake Borollos.

of the lake. The concentration reaches 0.0-0.13 μg-at/l during September. The drainage water raises these values to ca. 0.35 μg-at/l in the vicinity of the drains. In October nitrite content increases to 0.2-1.3 μg-at/l, it reaches zero concentration during November, however, higher values of 0.3-10 μg-at/l are noticed in the region surrounding the southern drains during December. On average the nitrite concentration during December is 2.6 μg-at/l. In January it is 1.5 μg-at/l more, i.e. 4.1 μg-at/l, in February it is 0.43 μg-at/l; in March it is 0.2 μg-at/l, this concentration sustaines during April. In June it decreases to zero and in July it is 2.5 μg-at/l, that increase to 3.9 μg-at/l, during August.

g- Nitrate-Nitrogen

The nitrate values are relatively high in August and range from ca. 4.9 μg-at/l near the drains to ca. 1.4 ug-at/l in the north and north east. In September it decreses to 0.46 μg-at/l and it is 1.06 μg-at/l in October. In November, it is 0.75 μg-at/l, and during December it is 4.6 μg-at/l in the northeast. In the north and northwest it is 11 μg-at/l, and in the west it is exceptionally high.

The annual maximum of the nitrate of about 6.5 μg-at/l in the lake is observed in January, with comparable high values in the drain waters. Drain waters contain as high as 15.5 μg-at/l. During February it is 0.26 μg-at/l that increases to 1.75 μg-at/l and then to 7.5 μg-at/l during July.

h- Silicate

The silicate concentration of the lake water is high in August, it has an average of 90 μg-at/l while in September it is ca. 16 μg-at/l. Minimum concentration observed in January is 36 μg-at/l. The drain water has an average concentration of 55 μg-at/l. In the northeast region during January, the lake water had silicate concentration of ca. 90 μg-at/l. In February the average silicate concentration of the lake water is ca. 25 μg-at/l. In March and April it has even lower concentrations, ca. 7.5 μg-at/l. During May the silicate content increases to ca. 33 μg-at/l in the north west; while the drain water however has ca. 12 μg-at/l. During June the lake water has silicate content of ca. 24 μg-at/l in the south east, it is ca. 81 μg-at/l in other parts of the lake. During July, the over all average is ca. 18 μg-at/l, (Figure 6).

i- Hydrogen Ion Concentration

The pH values in the lake varies from 8.3 to 8.02. The drain watres has pH values ranging between 7.55 and 7.05 Northern parts has higher pH than southern parts. During January northern parts of the lake has pH range of 8.05-8.5, the drain watres has pH of 7.5 to 7.9. During March, the pH increased to values between 8.5 and 9.0, particularly, in the southeast. The southwest region attained minimum values of 7.3 to 7.7 due to drain watre influx. Normal values of 8.0 to 8.2 are found in the northern region. By the end of Spring season, the pH in thje southeast are about 9.2, the drain waters attained values of ca. 7.5 to 8.2, that sustained during summer months, (see Fig. 7).

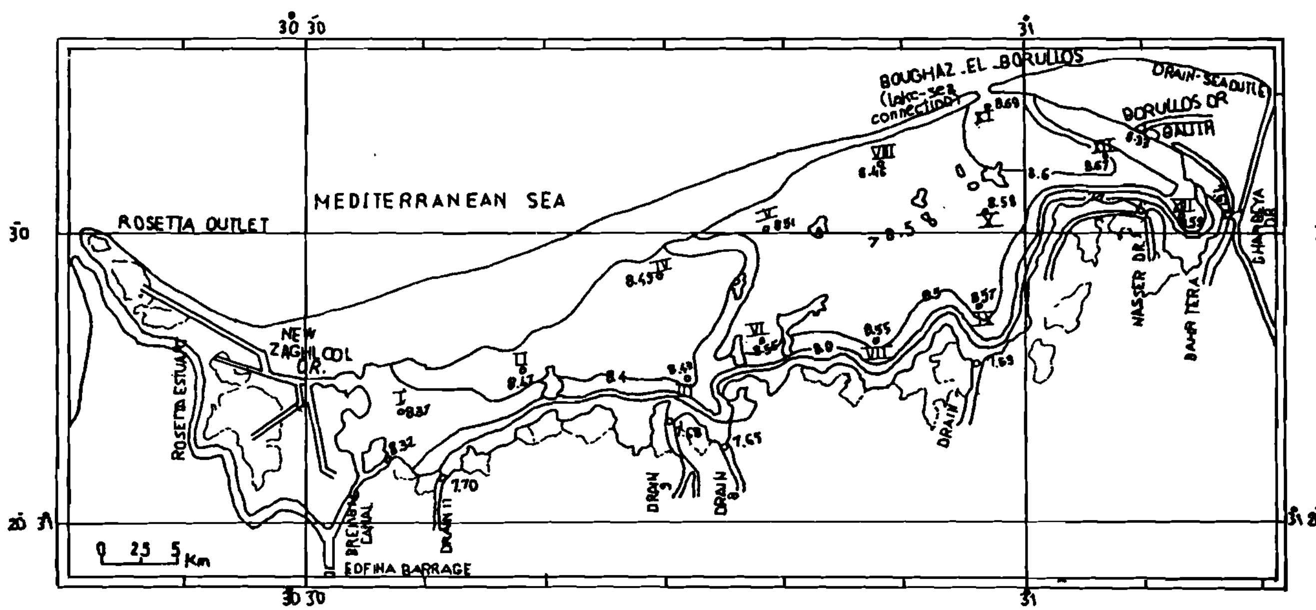

Fig. (7)
Average distribution of pH in lake water and drain inlets,
(1977 - 78). [After Darag, 1984].

j- Heavy Metals

Iron and copper were determined in the lake waters. The Cu concentrations varies between 0 and 4 µg-at/l, with an average of 1.74 µg-at/l. Iron concentration was, on the average 0.25 µg-at/l. Results indicate that the origin of these two elements is the water coming from the drains. High copper is observed before Brimbal Canal (3.0 µg-at/l). The lowest concentration is observed in the northern part of the lake. Little variations are always detected with no seasonal trend. Other drains show, values more than 1 µg-at/l. During Autumn. drain waters of the eastern part have higher value(more than 2 µg -at / l).

The distribution of Cu shows marked reduction in November, September and October, particularly, in the central and eastern parts of the lake. In winter (December, January and February), much higher concentrations of copper are observed (ca 5 µg-at/l) with an average of 2.66 µg-at/l for the whole lake. Stations near the drains show lower concentrations (not exceeding 2 µg-at/l). In February the drainage water shows higher values of ca. 4 µg-at/l.

The iron concentration during June shows values between 0.1 and 1.2 µg-at/l in the lake water. Near Brimbal Canal high concentrations are observed (0.60 µg-at/l). In July, distinct increase takes place and an average concentration of 0.4 µg-at/l is observed, compared to an average of 0.12 to 0.21 µg-at/l during August. In the area of Al-Boghaz, the water have concentrations of ca. 0.5 µg-at/l.

The highest concentration during Autumn is 1.5 µg-at/l, the lowest is 0.20 µg-at/l. In October, the western part of the lake shows values around 0.20 µg-at/l, while the western parts shows relatively higher values (0.70 µg-at/l). The Boghaz area shows abnormal low content.

In winter iron concentration shows a maximum value of 1.4 µg-at/l

k-PCB's

The concentration of 14 PCB is determined in the water of the drains as well as the lake itself. lake Borollos is mainly considered as an agricultural discharge area and there is no industrial pollution sources to the lake. This may explain the low content of PCB's found in the samples (less than 5% of the total chlorinated hydrocarbons). The total concentration of BHC, a-BHC, b-BHC, Heptachlor , d-BHC, Aldrin, o.p. DDE, pp DDE, Dieldrin, o.p. DDD, o.p. DDT, pp. DDD and pp DDT all together is found to vary between 76 x 10^{-6} ppm. The lake water contained between 144 x 10^{-6} ppm and 1421 x 10^{-6} ppm, with an average of 825 x 10^{-6} ppm. Brimbal Canal, a fresh water discharge has 835 x 10^{6} ppm. Individual compounds shows much concentration in Brimbal Canal and Al-Boghaz area and BHC and . BHC show the highest concentration. Also, drain 11, El-Kodea and Al-Borollos drain show high concentration of p. DDE.

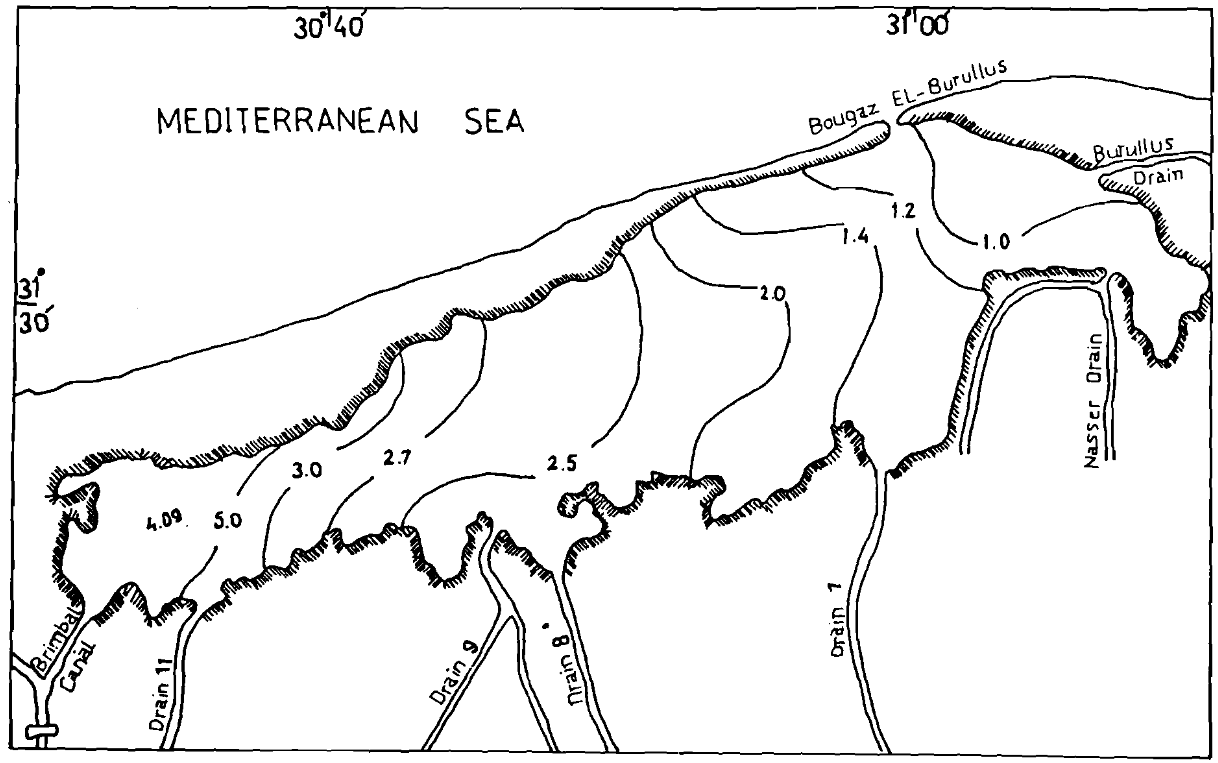

Fig. (8)
Distribution of the total numbers of phytoplankton in million μ / l
recorded in Lake borollos during years 1978 - 79.

Flora and Fauna of Lake Borollos

Quantitative studies are made on plankton and bottom fauna of the lake. Eighteen stations were sampled and studied in the main different regions of the area. The phytoplankton community in lake Borollos comprises: **Chlorophyta, Cyanophyta** and **Chrysophyta.** Members of **Euglenophyta** and **Pyrophyta** are also present. The lake sustaine a relatively rich community which tends to increase form east to west. The average total phytoplankton is about 2.3 x 10^6 u/l. The percentage composition of different groups during a period of two years of study shows that diatoms flourished over blue green algae in the lake during 1979 (the second year of study). In other parts of the lake, the middle and western, diatoms and green algae are dominant over the blue green algae. Figure 9 shows phytoplankton distribution in the lake. Seasonal variations of different species were described by Anon. (1980).

The zooplankton population in lake Borollos is mainly represented by **Copepoda, Caldocera** and **Rotifera. Protozoa, Ostracoda Malacostrata, Nematodes, Cirriped** larvae and aquatic insects are also present. The lake sustained a relatively rich community of zooplankton. The highest concentrations are in the western region. Al-Boghaz area sustained also a high density of zooplankton. The lowest numbers of zooplankton were recorded near to the northern margin of the lake. The annual mean value of the total zooplankton in the lake amounted to 122.828 org./m^3 during 1978 with **Copepode** constituting over 65% of the total population. The number of organisms reached 45.883 org./m^3 with **Copepode** forming ca. 36.5% of the community. The zooplankton shows definit seasonal variation with maximum during February. Individual species shows also seasonal variations, however, different parts of the lake maintained their relative richness or poverty with respect to each other, (Fig. 9).

The lake hosts a moderate standing stock of benthic fauna. The community there comprised **Mollusca, Ancylus, Cardium, Melania, Neritina, Amphipoda, Corphium, Gammarus, Polychaete neris, Oligochaete** sp., **Isopod** sp. and **Chironomous** larvae. The average numbers and biomass recorded for the different groups in ,the lake are shown in Table 1. From this table it is apparent that the lowest biomass of benthic fauna is observed in the eastern part of the lake which has an average of 3.44 g/m^2. It increases gradually westwards to 10.44 g/m^2 in the middle and 26 g/m^2 in the western part of the lake. Distribution of different organisms are also given in Table 2.

The seasonal variation of the total biomass of bottom fauna in the lake shows a peak in winter and early spring, however, different groups shows different seasonal pattern in the lake.

The fish fauna of lake Borollos comprised **Tilapia** sp., **Mugil** sp.. These have been studied in details by several authors (sea for ex. El-Sedafy, 1972).

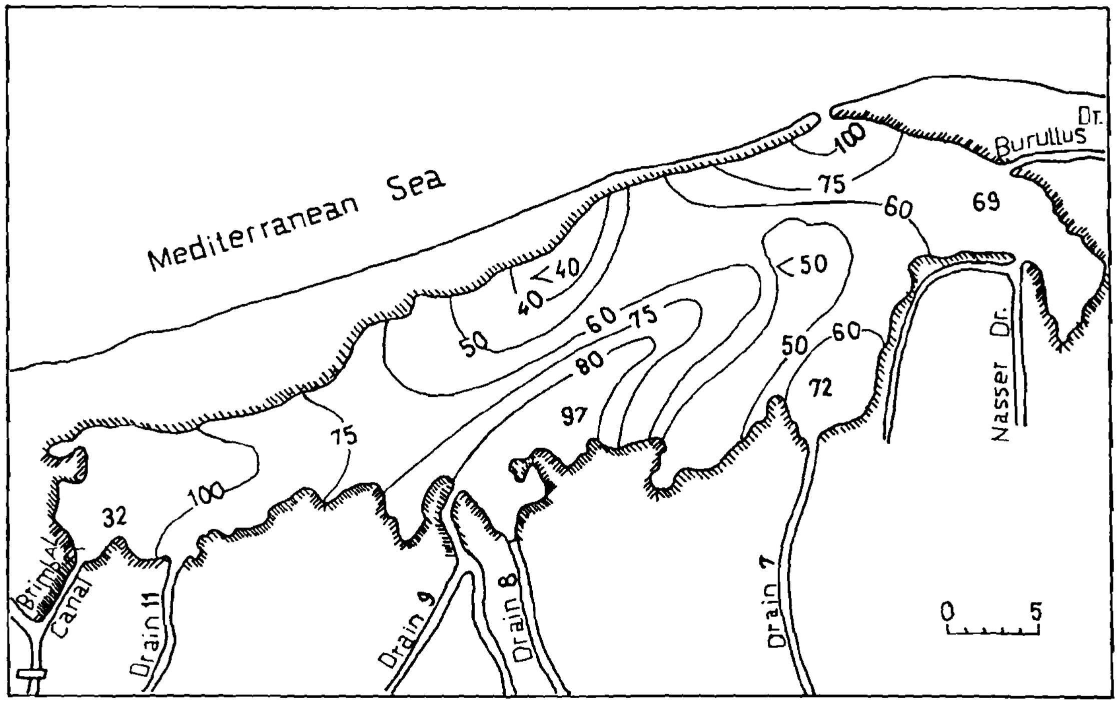

Fig. (9)
Horizontal distribution of the total zooplankton in thousand org./m
in Lake Borollos during years 1978 - 79.

TABLE 1

Average numbers (org./m^2) and biomasses (gm fresh wt./m^2) of the different groups of benthos recorded in Lake Burullus during 1978.

Benthos	Eastern Lake		Middle Lake		Western Lake		Average	
	No/m^2	Gm/m^2	No/m^2	Gm/m^2	No/m^2	Gm/m^2	No/m^2	Gm/m^2
Mollusca	32	2.78	44	10.29	78	25.63	51	12.90
Crustacea	204	0.38	317	0.46	67	0.25	196	0.36
Polychaeta	29	0.27	7	0.07	trace	---	12	0.12
Oligochaeta	15	0.01	163	0.10	337	0.10	176	0.10
Chironomus L.	6	0.01	2	0.02	2	0.02	3	0.03
Average Annual	386	3.45	533	10.94	484	26.00	438	13.51

TABLE (2.a)

Distribution of phytoplankton in Lake Burullus (μ / L) during the year 1978.

Phytoplankton	Eastern Lake	Middle Lake	Western Lake	Average
Diatoms	554,902	696,471	601,119	617,497
Chlorophyta	401,743	968,364	1,214,513	861,540
Cyanophyta	146,520	351,836	1,856,802	785,053
Other gps.	43,099	11,547	6,015	20,220
Total	1,146,264	2,028,227	3,678,447	2,284,310

TABLE (2.b)
Distribution of phytoplankton in lake Burullus
(μ / L) during the year 1979.

Phytoplankton	Eastern Lake	Middle Lake	Western Lake	Average
Diatoms	683,861	715,669	1,821,888	1,073,806
Chlorophyte	273,117	1,110,821	1,393,484	922,474
Cyanophyta	108,099	342,699	453,273	307,356
Other gps.	99,444	7,760	22,358	43,187
Total	1,154,521	2,176,949	3,691,003	2,349,823

TABLE (2.c)
Distribution of zooplankton in lake Burullus
(org./m^3) during 1978.

Zooplankton	Eastern lake st. (1-6)	Middle Lake st. (7-12)	Western Lake st. (13-18)	Average st. (1-18)
Copepoda	50,641	61,518	129,355	80,505
Cladocera	2,220	8,171	27,474	12,588
Rotifera	10,899	9,831	38,530	19,588
Protozoa	4,705	1,954	2,363	3,174
Nematoda	4,699	593	490	1,927
Malacostraca	5,003	430	322	1,918
Cirripede larvae	4,412	52	---	1,844
Ostracoda	1,376	955	573	968
Insecta	222	444	508	406
Other groups	249	10	44	64
Total	84,426	83,901	200,159	122,828

TABLE (2.d)
Distribution of zooplankton in Lake Burullus
(org./m^3) during 1979.

Zooplankton	Eastern Lake st. (1-6)	Middle Lake st. (7-12)	Western lake st. (13-18)	Average st. (1-18)
Copepoda	12,635	14,911	22,670	16,739
Cladocera	7,309	11,593	14,754	11,219
Rotifera	13,031	3,549	9,383	8,654
Protozoa	2,842	1,954	5,841	3,546
Nematode	6,041	1,114	205	2,543
Malacostraca	759	1,156	42	652
Cirripede larvae	948	352	--	433
Ostracoda	342	224	42	203
Insecta	472	231	52	252
Other groups	3,466	1,591	139	1,732
Total	47,845	36,675	53,128	45,883

Chemical analysis of some biological material of the lake indicates that fish (Tilapia) of the lake has concentrations of Hg (19.8-69.3 PPb) with an average of 38.97 ppb Hg. It has also high concentrations of Cd that ranges between 2.8 and 9.4 ppb with an average of 5.08 ppb. Fishes collected from drain 9 have the highest concentration of Hg, while samples collected from drain 8 have the highest concentration of Cd.

Biological materials analyzed for PCB's shows that fishes collected from the lake as well as the drains contained ca. 1000 times the concentrations reported for the lake water, however, fishes of different species and from different locations shows different concentration factors. Average concentration of PCB's in fishes of the lake ranges between 418 ppb and 10.56 ppb. Individual compounds shows different patterns (AsKar, 1982).

Sediments of Lake Borollos

The bottom sediments in lake Borollos have a specific textural composition. Shells and shell fragments constitute a significant part of the sediments. These shelly materials seem to be a determining factor in the distribution of grain size within the sediments of the lake. Sands are represented mostly by shells, shell fragments, quartz, feldspar, ostracods and foramineferal tests. Little amounts of heavy minerals form the minor part of sand. The fine fraction of the sediments is composed of silt and clays characterizing the Egyptian soils together with fine carbonate particles, (Fig. 10).

Calcium carbonate content of the sediments in the lake is less than 30%. In the central and western regions of the lake, the carbonate contents reach higher values (up to 75%). The major source of carbonates to Lake Borollos is calcareous matter of mollusc shells. The sediments in the eastern part of the lake has the lowest carbonate content.

The organic matter content of the sediments of Lake Borollos (Fig. 11) varies between 1 and 2 %, (Anon, 1980). The organic matter content becomes higher near the southern eastern and western parts of the sediments.

Water and Salt Budgets and Fulshing Time of the Lake

According to Anon (1980) the average daily outflow of Lake Borollos is 1.22 mi cu m/day (446 mi cm/year). The drains and canals discharge 2,120 m cm/year (Anon, 1939). However according to El-Sherief (1983) the drains discharge amounts to 2463 m cu m/day. The Lake recieves also ca. 100 m cm/year as precipitation. Thus, compared with the total size of the lake, the drains discharge 5 times the lake size and the flushing time should be about 2.5 months. This contrasts with the measured amount of water leaving the lake annualy. Which is only 446 m cm/year, through Al-Boghas. That leaves about 2000 m cu m in excess that has to find another way to leave the lake, partially by evaporatio and possibly through the bottom.

Another way of calculating the amount of water discharged into the lake is by assuming the following:

i) The drainage area of the lake is estimated to be 400,000 Fed.
ii) It is also estimated that the amount of water drained daily/fed. is about 10 cu m.

Thus, the drainage water from the neighbouring areas would amount to 1460 m cu m/year, which is still far more than the amount of water leaving the lake through Al-Boghaz, particularly if the amount of rainfall and fresh water discharged through Briambal Canal are aded.

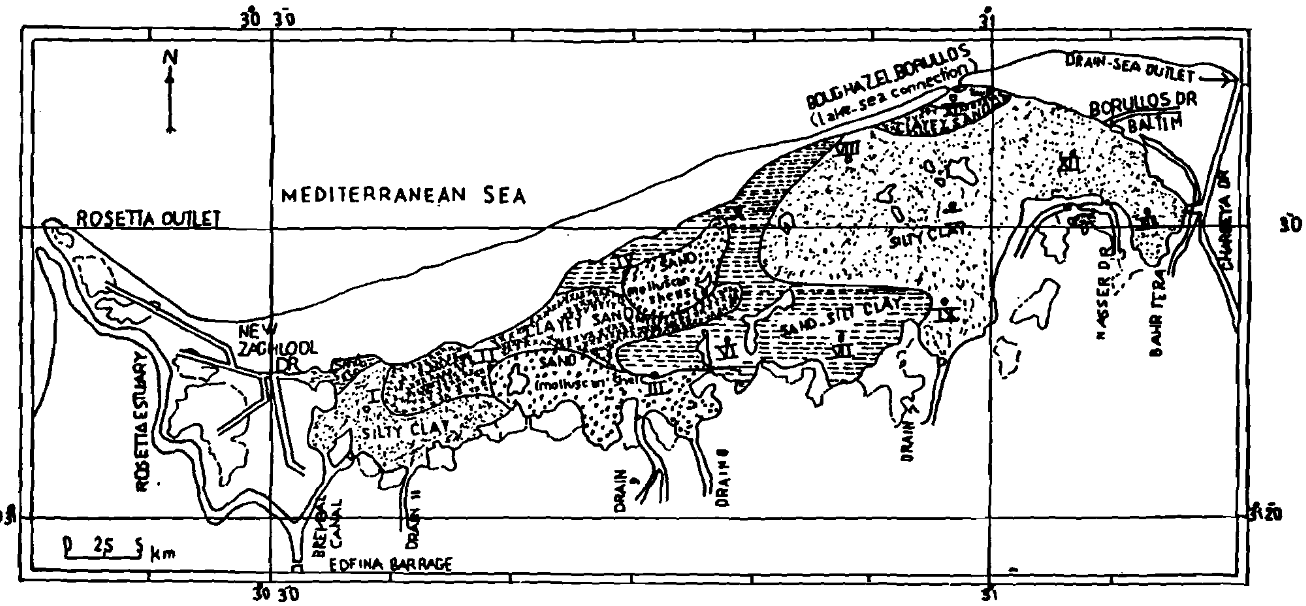

Fig. (10)
Bottom nature of Lake Borollos (After Zazou, 1974).

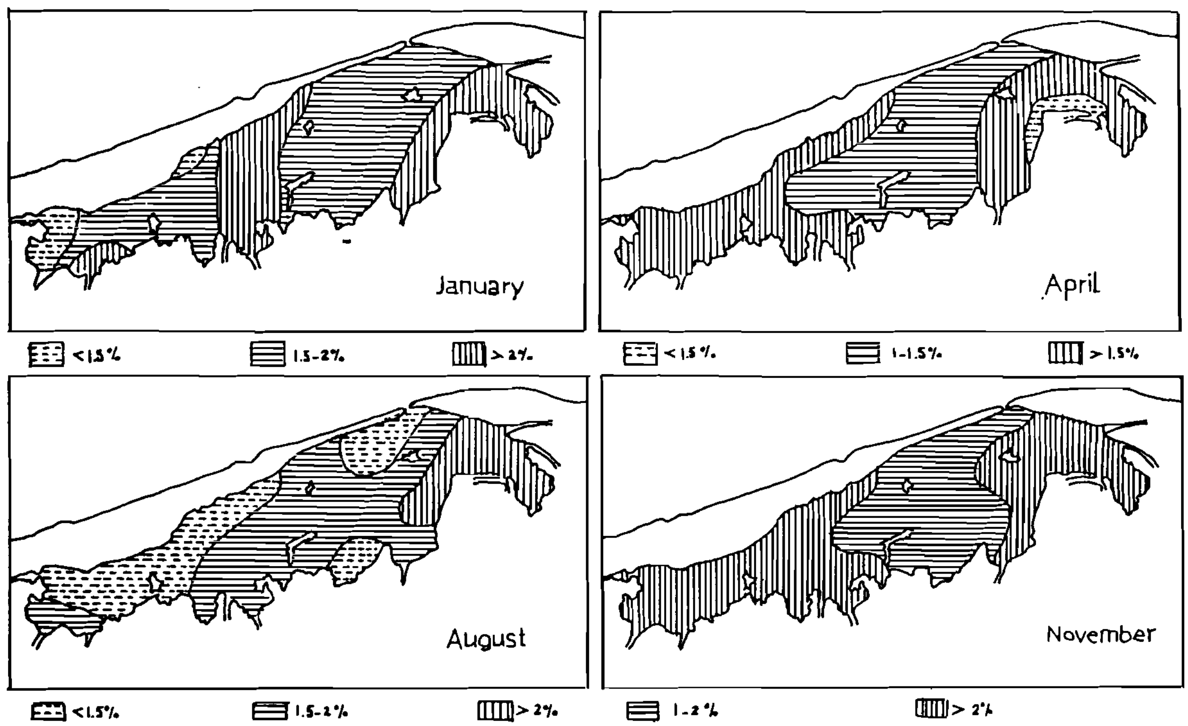

Fig. (11)
Distribution of organic matter content in the bottom sediments of Lake Borollos, (Anon, 1980).

Based on the obeve values, the total salt input to the lake would amount to 10.9 x 10^8 gm/year. The salt output from the lake is about 9.4 x 10^8 gm/year (based on calculating water salinity about 2.1 ‰), which is quite close to the input values. However, if we assume that the total salt will leave the Lake through Al-Bougas, and the average salinity is 2.1 ‰, the amount of water would then be ca 520 mi cu m/year.

Thus it seem; that the water budget of the lake still poses a problem and needs special attention.

Regarding the salt budget , the problem even more coplicated., since it is primarily connected with the water budget. However, based on the above values, the total salt input to the lake would amount amount to 10.9 x 10^8 gm/y; the salt output from the Lake is estimated to be 9.4 x 10^8 gm/y, (assuming an average slinity of 2.1‰ for the water leaving the Lake to the Sea). Thus, there is a net gain of salt of ca 1.5 x 10^8 gm/y.

The total salt content in the lake is stimated as 30 x 10^8 gm, which means that the lake could have aquired its salinity in 20 years, befor it reached its present day salinity, and the lake water salinity should increase until it reaches equilibrium at an average salinity of ca 2.44 ‰ which may be the case, now. On the other hand, that means that excess water leaving the lake through the bottom must have a very low salinity.

Thus if we take then, the values of incomming and outgoing water and assuming an average value for evaparution of 1.60 m/y, we can arrive to the fact that more then 60% of the drain waters is transferred to the sea by seapage, with out complete mixing with the lake water. This may possibly happen considering the nature of the sediment of the bottom, and the shallow subsurface structures, which, according to Anon (1963) is mainly compesed of fine sand.

Another route could be the permeable sand dunes constituting the barier between the lake and the sea.

The point of having water leaving a lake through the bottom is not by itself a serious problem, and there are many examples from allover the world to this phenomenon, but what makes it potential problem is the effect of the perculating water through the bottom on the sediments charactristics.

Bottom Sediments and Accumulation of Pollutants in Lake Borullus:

Bottom sediments have certain limited capacity to absorb different ions from waters perculating through it (see for ex. Beltagy et al, 1985). This capacity is lowest for carbonate-sandy fractions of sediment, and highest for clayey-organic matter rich sediments. Not only the capacity of the sediment to absorb different materials, but also its ability to release again these sorbed material to the environment due to changes in the physico-chemical conditions within the sediments is greatly affected by the perculating water in the sediment. Perculating lake water is always rich in oxygen, thus there will be relatively high rate of oxidation of organic matter of the sediments. This is indicated in lake Borullus by the low organic content of the sediments, despite the fact of the high organic productivity in the lake. Oxidation of organic matter in the sediments, not only decreases the capacity of the sediment to absorb different material, but it also introduces further complications by lowering the pH, thus favouring the release of metalic ions from the sediments into the water column and enhancing the conditions for migration of different ions through the water column and the interstitial waters of the sediments.

However, the direction of migration of any released component is not easy to determine, thus it is expected that ions may move with the water perculating the sediments and leaving the lake through the bottom to the Mediterranean Sea, i.e. enhancing the purifying capacity of the lake; or it may migrate to the surface and return back to the water in the lake and creat high concentrations at the surface of the sediment. This later case may occur as a result of changes in sea level under the effect of tides and heavy storms and winds.

Another problem may be evolved, that is the dissolution of calcium carbonate components of the bottom sediments leaving the clayey and silty material to predominate. The ultimate result of this process is the decrease of the permeability of bottom sediments , and the clogging of the way out of the water leaving the the lake through the bottom which is about 70%, thus exposing the lake to the possibility of sudden flooding , or the complete transformation of the lake into fresh water lake. This could also result in the invasion of water to the narrow sand bar separating the lake from the sea.

Lake Borullus is highly eutrified with respect to PO_4^- and NO_3^- ions compared with other natural lakes, nevertheless the biological productivity is comparitively low; particularly the bottom fauna. Further addition of nutrients will increase phytoplankton population with the result of much higher increase in dissolved oxygen content, as it is happening now in some places of the lake. Oxygen will be used to oxidize more organic matter, hence the bottom sediments may become poor enough , thus unable to sustain benthic life, which may be the case now.

The process will also help to maintain high nutrient concentration in the lake, even if we were able to regulate the amount of nutrients being added by the drains and canals.

However,the problem still simple with nutrients, but it is not with respect to pollutants like Hg, Cd, Cu or PCB's.

CONCLUSION

Lake Borollos is a moderately productive lake. It is facing the problem of eutrophication that may affect the whole ecology of the lake. Studies on the lake showed that organisms contained relatively high concentrations of Hg, Cd, Cu, and PCB's. Any change in the regime of the lake might lead to drastic change in the environment, with the concequences that can not be assessed from the data available. Further studies on the levels of pollutants and their sources is required, and the effect of changing the water quality and the flushing time must be evaluated.

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