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THE HYDROLOGY OF LAKE QARUN, FAYOUM PROVINCE, EGYPT. PART I: PHYSICAL ENVIRONMENTAL CONDITIONS.

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ABSTRACT

Lake Qarun showed in the last 75 years a sequence of changes in its salinity and a decline in its productivity. These phenomena attracted many investigators to explain and discuss them. Most of the results showed great fluctuations in the salt content of the Lake water or its salinity and accordingly many difficulties were found to interpolate the results.

Few trips have been carried out through the period 1981 - 1982, during which water temperature and salinity have been measured while the meteorological conditions and the Lake level have been obtained. The salinity of the Lake is found to be a function of the Lake level (i.e. the inflow water through the drains and the outflow water through evaporation). The salinity values are found to change markedly according to the Lake level and hence it showed a negative correlation with the Lake level. The meteorological factors as well as the hydrographic characteristics were discussed. Moreover, the monthly and annual changes in these parameters were condsidered. The mean salinity of the Lake is ranged between 31.0 - 32.0‰. It is expected to observe an increase in the Lake salinity during the next few decades.

INTRODUCTION

Due to the economic importance of the Egyptian lakes, a series of studies have been made to determine the impact of different pollutants and their levels in these lakes and the aquatic environment in general. The present study deals with the physical environment of Lake Qarun, which is considered to be a very old natural water body that was formed 250 years B.C. or earlier, and was known as Lake Moeries (-50 m depth). This Lake is presently known as Lake Qarun (-4 m depth) and is considered as a closed basin.

The Lake water showed a gradual increase in salinity during the last 75 years. In 1906, the Lake salinity was about 10.95 gm/l (Lucas, 1906), while in 1982 its salinity has markedly increased, amounting to 31.12‰ as an average (Anon.,1984). These high salinity values attained during the last few years greatly affect the bottom fauna and flora of the Lake and its aquatic life in general.

Due to the limited water capacity of the Lake, any increase in the drainage water supply will reduce its salinity greatly. Meanwhile, it will affect the nature of the surrounding lands by the rise of its underground water-level or submerging the land around the Lake when the Lake reaches to a level as that of the land.

At the beginning of the present decade, the Lake was known for its high fish productivity of numerous species. The earliest records on fish production of the Lake are those of the year 1920. At that time, the total catch reached 4,100 tons. From 1921 to 1923 the total catch varied between 1000 and 2000 tons. This apparent drop of production was mainly due to the disappearance of the fresh water fishes from the Lake fauna (El-Zarka, 1961). As the salinity increased, all the Nile fishes disappeared except Tilapia zillii which was able to acclimatize in the saline conditions. In 1962-1963, the total catch was only 273 tons.

To overcome this difficulty, Mullet fry fish (Mugil cephalus and Mugil capito) were transported from Max fish farm near Alexandria in 1928 and continued in the following years but not regularly as at present. In the last few years, a successive increase in the total fish catch was observed. However, Table 1 shows the total catch (in tons) during the period 1974-1983.

Although there is an improvement in the productivity of the Lake, the catch reached 1969 tons only in 1982-1983 (close to that of 1923).

Lake Qarun attracted many workers since the beginning of the present century (Lucas, 1906; Azidian & Hug, 1931; Faouzi, 1933; Wimpenny, 1936; Ball, 1939; Naguib, 1958; Gorgy, 1959; El-Zarka, 1961; El-Wakeel, 1963 & 1964; El-Zarka and El-Serafi, 1970; Meshal, 1973; Ishak et al., 1979; Ishak and El-Malek, 1980; Meshal and Morcos, 1981 and Dowidar and El-Nady, 1982). Several investigators attempted to give the main reasons for the rapid decline in the productivity of the Lake, as due to either physical causes such as temperature and salinity or to chemical causes such as the pesticides dissolved in the drainage water or to both.

Location, Bottom Sediments and Bathymetry of Lake Qarun:

Lake Qarun is confined to latitudes 29° 24′39″N and 29° 32′38″N and longitudes 30° 27′E and 30°44′38″E. The Lake is about 40 km in length and 10 km in width. The average depth of the Lake is about 4 m, with a maximum depth of about 8.5 m to the west of El-Qarun Island. The eastern part of the Lake is shallow (3 m depth) while the western part is deep (5-6 m depth). The Lake bottom is generally greyish slimy clay (El-Wakeel, 1963).

Bathymetric charts of the Lake have been made by Gorgy (1959), Irrigation Department at the Barrage in 1968, and then recently by Abd-El-Hady et al. (1982) using remote sensing techniques (Fig. 1).

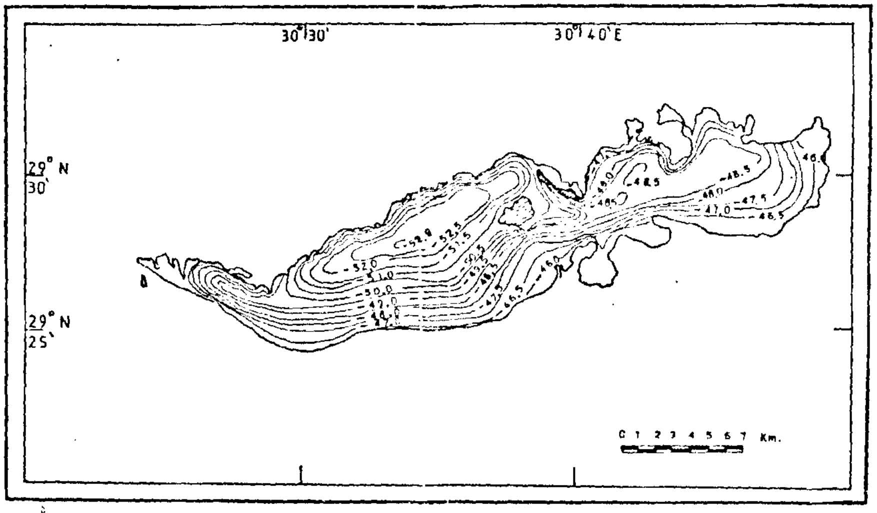

Fig. (1)
Bathymetric Chart of Lake Qarun (after Abd-El-Hady et al., 1982.

MATERIAL AND METHODS

Figure 2 presents the location of 11 stations which were selected to cover the whole Lake. Surface and bottom water samples were collected during 1981-1982. Temperatures were measured using reversing and ordinary thermometers.

Salinity was obtained using Mohr's-Method and applying Meshal's formula (1973):

$$S = 2.47 * Cl + 0.21$$

Meteorological Conditions

1- Air Temperature:

The climate of Egypt has been steady over the past few thousands years (Ball, 1939). The mean monthly and annual

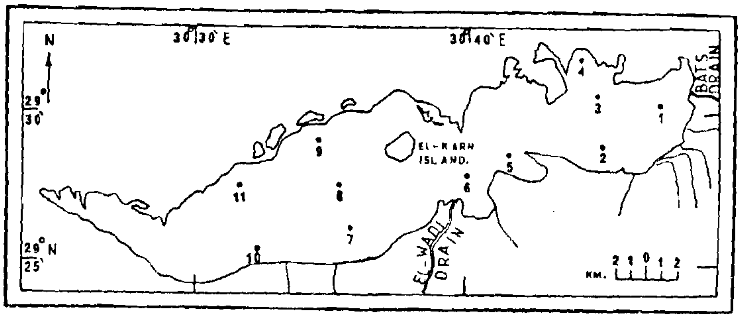

Fig. (2)
Location of stations

air temperature above the Lake for a long period of time is presented in Figure 3 (Anon., 1931-1960). Ball (1939) stated that the average daily oscillation of the air temperature above the Lake is about 13°C, while the mean annual variation amounted to about 17.9°C during the period 1928-1935. It was found to be about 17.2°C during the period 1931-1960 (Anon., 1931-1960). The maximum value observed was 36.7°C in August and the minimum value was 6.3°C in January.

2- Relative Humidity:

The higher values of relative humidity are encountered in winter (December and January), reaching about 65%, and the lower values are in spring and early summer (May-June), which reach about 45% (Fig. 3).

3- Wind Conditions:

Figure 4 shows the overall average of wind frequencies above the Lake during the period 1981-1982. In winter the wind blows from all directions but dominantly from the southeast. In spring, the area is characterised by the northerly wind but sometimes from the southeast. The northerly wind and westerly wind prevail in summer.In autumn, the north and northwest winds dominate.

4-Rain-fall:

The rainfall is nearly negligible. Its rainy season strats in November and ends in April-May. During the period

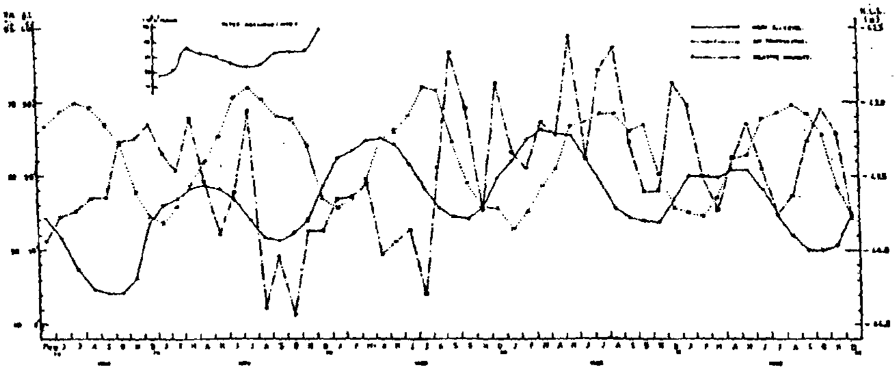

Fig. (3)
Mean lake level, air temperature, relative humidity and water discharge during the period 1978-1982.

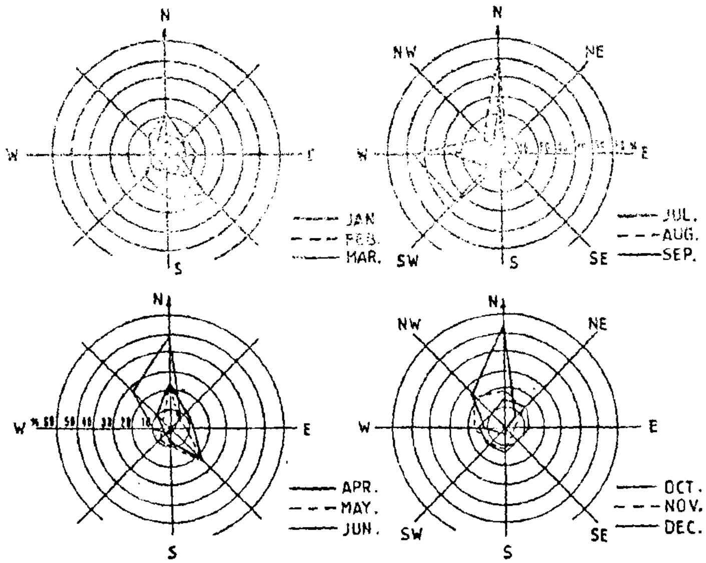

Fig. (4)
Wind frequency above the lake during 1981-1982.

TABLE 1
The total catch (in Tons) during the period 1974-1982.

Year	Total catch (Tons)
1974-1975	885
1975-1976	1787
1976-1977	1193
1977-1978	1367
1978-1979	1563
1979-1980	1700
1980-1981	1696
1981-1982	1633
1982-1983	1969

1928-1935, the annual rainfall amounted 7.9 mm with maximum of 2.8 mm in December, while the annual rainfall amounted 9.2 mm during the period 1931-1960, with maximum 3.0 mm in December. Generally, the amount of rainfall on Fayoum Province is less than 1.0 cm/year, which is of negligible effect on the water level of the Lake.

5- Evaporation:

Evaporation is considered as one of the main reasons responsible for the continuous changes of the water level of the Lake. Several investigators attempted to estimate the amount of water evaporated from the Lake in order to determine the water balance in the Lake (Ball, 1939, Gorgy 1959; Meshal, 1973; and Meshal and Morcos, 1981). Ball (1939) mentioned that, by using the two tanks experiment in a pool (one of which was a meter square and the other 2 m^2), the evaporation ratio between the evaporation rates of the two tanks was 0.88. He added, if an exceedingly large dimension tank or the Lake itself was considered, the evaporation ratio could be taken as 0.8. Accordingly, he estimated the evaporation rate in the Lake using an evaporation ratio 0.8. Gorgy (1959) criticized Ball's procedure and attempted to calculate the rate of evaporation using the energy equations based on the assumption that heating and cooling processes, in a water-mass, must balance each other. He concluded that the calculated value of evaporation is less than that estimated by tank observations. Meshal and Morcos (1981) gave another estimation of the evaporation in the Lake by bulk aerodynamic method. Table 2 shows the comparison between the results of the above three works.

TABLE 2
Estimate values of evaporation (in cm) as given by: Ball (1939); Gorgy (1959); and Meshal and Morcors (1981).

Month	Ball (1939)	Gorgy (1959)	Meshal and Morcos (1981)
January	6.5	3.49	5.99
February	8.2	7.16	9.12
March	12.6	12.67	13.83
April	15.9	15.57	19.19
May	20.6	25.42	24.59
June	22.5	28.29	28.21
July	23.2	26.66	21.90
August	21.9	24.03	21.25
September	17.8	21.56	20.43
October	13.7	11.25	14.93
November	8.7	5.67	6.61
December	5.8	1.16	4.03
Total	177.4	183.83	190.08

Hydrological Controls Affecting Lake Qarun

The hydrographic structure of Lake Qarun is discussed in the present study, Part I, while Part II will show the successive increase of salinity in the Lake. Later, in Parts III and IV the chemical and biological impact on the Lake fisheries will be discussed.

1- Water drainage:

The Lake receives drainage water of irrigation supplied from the Nile through Bahr Yusef and Wasif Canal. These two canals are controlled by two openings. The openings are partially closed during January for cleaning from silts.

Most of the drainage water reached the Lake in the past by two main channels: El-Wadi Drain (near the midpoint of the southern shore) and El-Bats Drain (at its northeastern end). The remaining drainage water reached the Lake by a number of small drains. Presently, El-Wadi-Drain conveys its water partially to Wadi-El-Rayan Lake.

2- Water level:

Historically, Fayoum depression was in the form of a huge lake. The Lake at that time was used as a natural reservoir for the Nile water during the flood season. During the drought season, the Lake was used to supply the country with the required water. In Herodotus time, the Lake was very deep, and the maximum depth exceeded 50 m. However, the water level had shown a successive decrease, e.g. 2 m below sea level (at Alexandria) at the end of Ptolemaic period (250 B.C.), 7 m below sea level (S.L.) in the second century A.D., 36 m below S.L. in late Roman times 300 A.D., 40 m below S.L. in 1906. Between 1906 and 1982, the waterlevel in the Lake fluctuated between 46 m and 43 m below sea level.

The variations in the flow rate of drainage water into the Lake and in the rate of evaporation from its surface are supposed to be the main two factors responsible for the fluctuation of the Lake water level.

The volume of the drainage water, which flows into the Lake carrying a small amount of silt, is estimated to be about 100,000 cubic meters per year. The continuous deposition of silt brought into the Lake with time is responsible for raising its bottom (El-Wakeel, 1963).

Hydrographic Structure of Lake Qarun

Since the Lake is a closed and relatively shallow water body, the distributions of temperature and salinity show a particular pattern. Those changes in the temperature and in particular the salinity of the Lake are very important ecological factors. Accordingly, the horizontal and vertical distributions of temperature and salinity as well as their monthly and annual fluctuation are of a prime importance.

1-Temperature:

Due to the shallowness of the Lake (4 m depth), its water warms rapidly in summer and cools quickly in winter as its temperature markedly approaches the air temperature (Fig. 5). The increase of the water temperature above a certain limit (32°C) influences greatly the physiological behaviour of the fish and may reduce the fish abundance and accordingly the fish catch.

The horizontal distribution of temperature at the surface (Fig. 6) shows that during February and March of 1981 the water temperature along the southern boundary shows a clear positive temperature gradient across the Lake. Meanwhile, from April and up to the beginning of the autumn season the reverse pattern is observed with a negative temperature gradient as a result of the warm water discharging from the drains. Generally, strong temperature gradient occurs at the surface during February, April and June, while a weak gradient appears in March, August and December. The Lake nearly showed a homothermal condition during August 1981 with a mean temperature of about 28.0°C and December 1981 with a mean temperature of about 16.0°C.

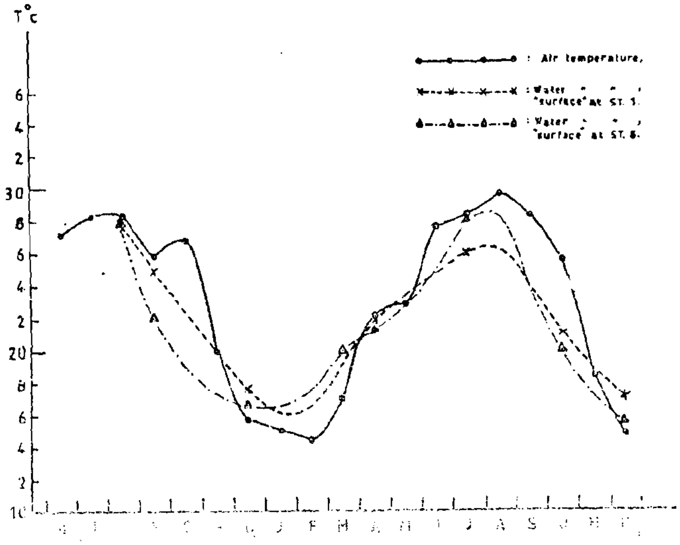

Fig. (5)
Air temperature above the lake and water temperature at stations 1 & 5.

The minimum observed [illegible] the [illegible] period 1981-1982 was less than 10.0°C in [illegible] the maximum value was more than 33.3°C in June. The range of change was about 23.0 [illegible] over the whole year [illegible]

2- Salinity:

The salinity pattern (Fig. 7) is so far similar to the temperature distribution, in particular the homogeniety of water in March with a mean salinity 33.0 ‰. The minimum salinity observed of less than 18.0 ‰ was in December in front of the outlet of El-Wadi Drain and the maximum salinity of more than 36.0 ‰ was in September and October.

Considering the salinity pattern over the vertical sections taken along the Lake, Figs. 10 and 12 show a clear picture of the infuence of the fresh water discharged from

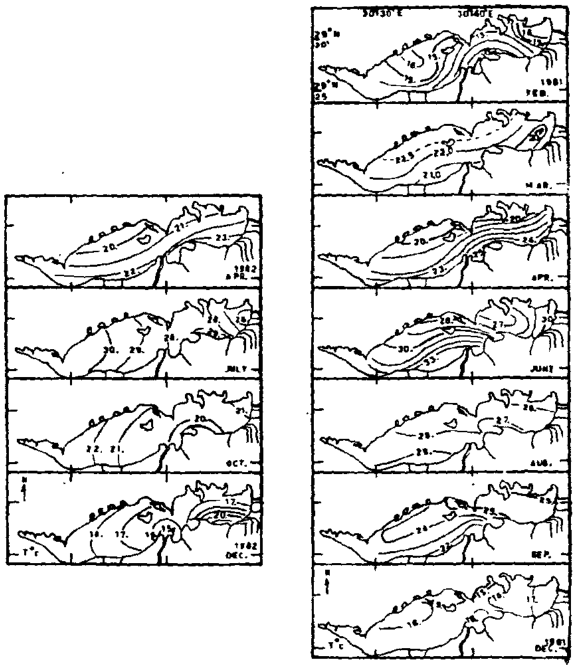

Fig. (6)
The horizontal distribution of the lake water temperature during 1981-1982.

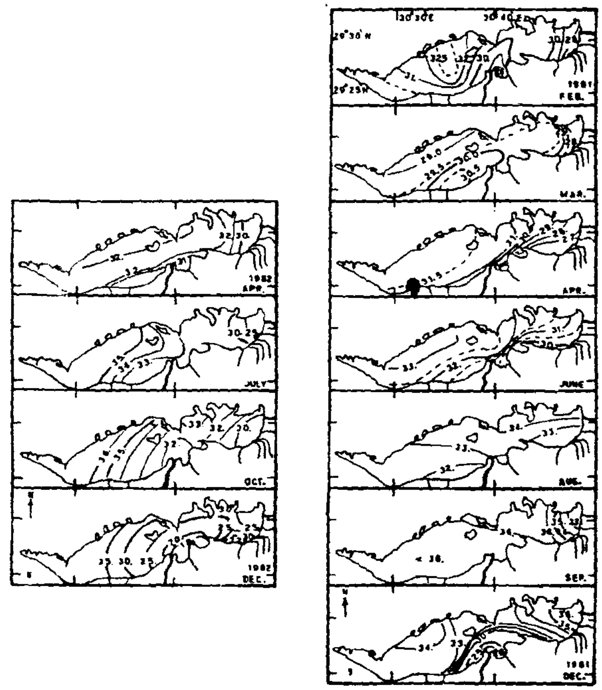

Fig. (7)
The horizontal distribution of lake water salinity during 1981-1982.

the main drains (El-Wadi Drain near station 6 and El-Bats Drain near station 1), during January and April 1981 and their impact on the salinity of the whole Lake. In January 1981, it is clear that the water influx started first from El-Wadi Drain. The flow is directed northwards. Taking into consideration the SSW and SSE winds which dominate during January and also the rotation of the earth, the outflow water is deflected towards north-northeast, and accordingly flows partially eastwards in the eastern part of the Lake and the rest towards northwest in the western part. As the El-Bats Drain starts to convey its water to the Lake in April, the discharged water pushes the existing water in the eastern part to the west, reducing its salinity and helping in circulating the water in the western part and hence showing an apparent decline in its salinity. In reality, the total salt content in the Lake increases gradually with the lapse of time (which will be discussed in Part II), while the salinity of the water shows apparently a decrease tendency.

From June to October (Figs. 8), the salinity in the Lake often shows values higher than 30.0 ‰ which increases westwards. This indicates that the water sources which

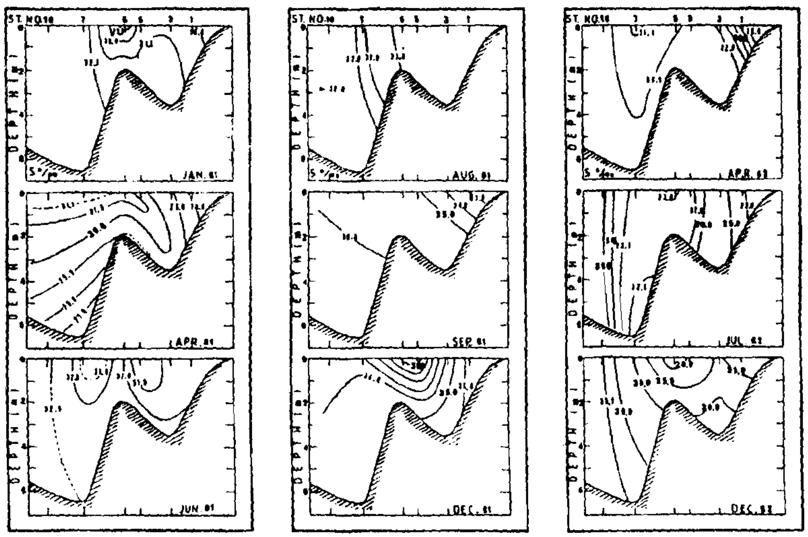

Fig. (8)
The vertical distribution of salinity along a section (west-east) during 1981-1982.

supply the Lake with the fresh water are apparently stopped completely and accordingly the salinity of the water starts to increase steadily from June up to November. In fact and as shown in Figure 3 the water influx exists over the whole year but its amount differs from one month to another. On the other hand, a huge amount of the Lake water leaves the Lake at the surface as vapour through evaporation which reaches its peak in summer. The difference between the inflow (drainage water) and the outflow waters (due to evaporation) is positive quantity in winter while it is negative in summer.

3- Oxygen:

High dissolved oxygen content is found along the southern bank of the Lake all year - round as a result of the existence of weeds which cover mostly the shallow areas along the southern bank in comparison to the northern one which is steep and sandy (Fig. 9).

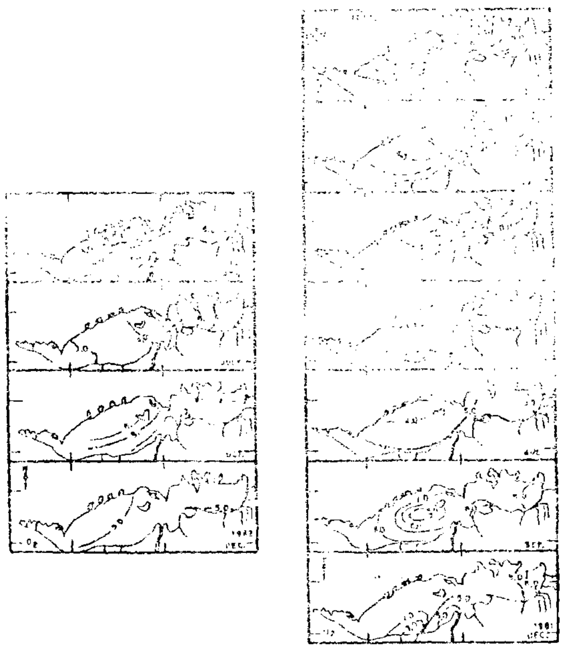

Fig. (9)
The horizonatal distribution of dissolved oxygen during 1981-1982.

Generally, the water movements in the Lake are mostly influenced by the following factors:

a-The influx of drainage water from the main drains. Their effects are clearly observed during winter when the inflow exceeds the outflow markedly.
b-The local wind effect at the surface.
c-Density gradients due to the extensive evaporation in summer and the deep cooling in winter.

The water movement mostly appear to be cyclonic in its character in the horizontal domain. Mixing processes also take place in the vertical as sinking or upwelling. These movements help in renewing the physical, chemical and biological characteristics of the Lake water and hence the redistribution of nutrients over the whole Lake. In addition, they prevent the accumulation of the salts in the extreme western part of the Lake.

Monthly and Annual Variability of The Different Parameters:

Figure 5 shows the monthly mean air temperature above the Lake as recorded at Shakshouk Meteorological Station (Anon., 1931-1960) and the surface water temperature at station 1 and station 6 during the period June 1981 - December 1982. It is clear that the monthly temperature domain for both media are nearly similar. Air is relatively warmer in summer than the Lake water, while in winter is much cooler. Moreover, the water temperature rises slowly during spring and summer but falls rapidly in autumn and winter. The rise in air temperature during October (Fig. 5) is related to the west wind prevailed during September.

Figure 3 shows the monthly and annual mean of the Lake level, relative humidity, drainage water and air temperature over the period 1978-1982. The relative humidity is generally hign in winter and low in summer. It can be taken as a measure for evaporation noting that high evapration occurs when the relative humidity is low and vice-versa. Lowest Lake level was observed in summer 1978 showing a level below -44.3 m. The level started to increase steadily with time attaining the highest level observed of about -43.18 m in March 1980. During that time the water of the Lake flooded to the neighbouring lands. Hence, the irrigation water supplied to the province has been reduced and accordingly the drainage water. From that time onwards, the Lake water fluctuated about the level of -43.7 m and -44.0 m. Although the quantity of drainage water discharging into the Lake varies widely from month to month with a range of 20-50 x 10^6 m^3 /month, the water discharging in summer and autumn is quantitatively much less than the water evaporated at the surface (50-70 x 10^6 m^3 per month in summer and autumn).

The annual mean air temperature shows insiginficant variability from year to year. The maximum temperature of

30.0°C is often observed in June - July, while the minimum values of 12.0°C - 14.0°C are observed in January.

Figures 10a,b shows the monthly salinity values for different stations over the same period in the eastern and western parts of the Lake. Station 6 has been represented in both figures to facilitate the comparison between the two parts. During the period June 1978 - August 1979 (Anon., 1978 & 1980), the surface salinity in the eastern part showed clear fluctuation particularly at stations 1, 3 & 6 while at the other two stations 2 & 5 the fluctuation is less pronounced having a maximum in July - August and a minimum in March - April. Moreover, the range of variation of salinity at station 3 is 22.0 - 42.0‰ while at station 6 it is 13.0 - 42.0 ‰. During the rest of the period, the

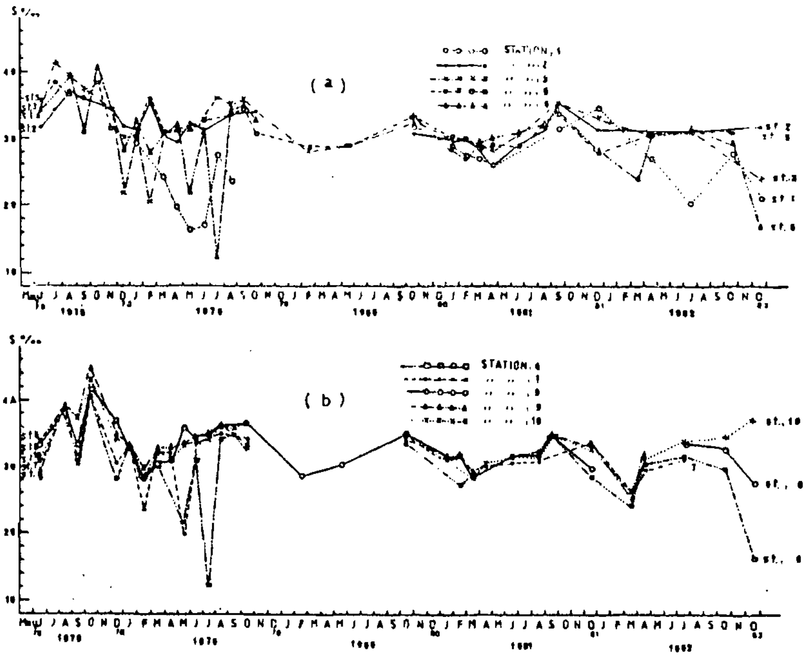

Fig. (10)
Monthly and annual variation of salinity values for different stations in:
a- The eastern part of the Lake.
b- The western part of the Lake.

March and April. The lowest levels were observed in August and September of 1932 and 1933 (46.22 m - 46.25 m below sea). At present the water in the Lake stands nearly at -43.7 m. The annual drainage water amounts 350 x 10^6 m^3.

The hydrological elements of the Lake, particularly temperature and salinity, have been studied. Since the Lake is a shallow water body, it warms and cools rapidly in summer and winter respectively. The northern regions are warmer than the southern in winter and cooler in summer. The daily fluctuation of water temperature ranges from 2^{o} to $5.5^{o}C$. Morever, the annual variation in the water temperature amounts $15.0^{o}C$, approximating the air variations. The maximum water temperature of about $33.0^{o}C$ was obseved in June while the minimum temperatyre of about $15.0^{o}C$ was measured in January and February. There is no significant variation in the monthly average water temperature from year to year.

Regarding salinity, the Lake showed in the past wide fluctuations from one season to another and from year to year. During the period 1981 -1982, the Lake showed a mean value of salinity less than 30.0‰ in winter, while in summer the mean salinity was about 33.0‰. Salinity values less than 18.0‰ were observed in December while values of more than 36.0‰ were found in September and October. The drainage water discharged into the Lake in winter influenced greatly its salinity reducing markedly its value, while in summer and due to the excessive evaporation the salinity showed high values.

Although, there is a continuous addition of salt to the Lake with the drainage water, the salinity changed within a very narrow limite in the last two decades in comparison to the changes observed during the period 1906 - 1935. In fact, the increases of the Lake level mask any increase of the salinity of the Lake.

As the Lake presently stands at a fixed level of 43.7 m ± 0.3 m, it is expected to observe a gradual increase of its salinity during the next few decades.

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range of salinity variation lies between 27.0 - 37.0‰, except near the mouth of the drains, the salinity drops to values less than 18.0‰.

In the western part, the fluctuations observed during the first period 1978 - 1979 could be traced at station 6, while at the other stations the high salinity values generally occurred in October and the low values in February. Meanwhile, during the period 1980 - 1982 salinity values fluctuated between 28.0 and 36.0‰ except in winter when the salinity decreased markedly to less than 25.0‰. It is worth mentioning that the mean salinity in the eastern part of the Lake during the last period is nearly constant of about 31.0‰, while in the western part it showed a mean value of about 31.5‰.

SUMMARY AND CONCLUSION

During the ancient times, Lake Qarun was utilized as a reservoir for the water of the River Nile during flood season through Bahr-Yousef and gave it back to the Delta during drought.

Presently, the drainage water is conveyed into it. Due to the extensive evaporation from the Lake, its salinity started to increase progressively from 1906 to the present time which was destructive to its fresh water fishes and accordingly disappeared. As a result efforts have been exerted to acclimatize some of the marine fishes in the Lake.

The meteorological conditions such as: air temperature, relative humidity, rainfall, evaporation, wind conditions, water drainage into the Lake and its water level have been considered. The air temperature attains its maximum of 30.0°C in July and Auguts and its minimum of 14.0°C in Junuary. There is no significant variation in the monthly average air temperature on annual bases. The relative humidity fluctuated greatly due to the continuous variation occurring in the meteorological conditions of the area. Precipitation is nearly negligible and amounts to about 7-9 mm per year, while the evaporation rate is very high and is considered to be one of the two principal factors responsible for the continuous changes in the water level of the Lake, the other being the volume of drainage water flowing into the Lake. The wind conditions possess great variability over all Fayoum Province. Its complicated character over the area has a great influence on the water movement and circulation in the Lake and at the same time it is more effective due to the shallowness of the lake (about 4 m). Changes of the water level in the Lake is almost of a sinusoidal shape, which is closely related to the evaporation rate at the surface and the volume of drainage water conveyed to the Lake. The minimum level occurs during September and October while the maximum level occurs during

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