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# Studies on the Ecology of Lake Qarûn

(Faiyum-Egypt)

Part II.

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Contents



Part I (Kieler Meeresforschungen XIV, 1958, pp. 187—222) dealt with the thermal stratification of "Lake Qarûn" as well as with the salinity, pH-value, bicarbonate concentration, $O_2$-saturation and the occurrance of nitrites, nitrates and phosphates.

In this following part (Part II) the experimental results concerning silicate, iron —, and sulphide contents are presented. Quantitative distribution of phyto- and zooplankton and its roll as food for fishes in "Lake Qarûn" is considered. A general discussion combining part I and part II is given.

## 3. Silicates

The silicate concentration in the surface and bottom water, expressed in µg-at./l. $SiO_3$-Si, estimated at the different stations during the successive seasons of the present study is given in table 11. The monthly average values for the different stations, except 1, 2 and 8, are given in Table 11 A and represented in figure 23. The monthly average values concerning the regions at the mouth of the drains (stations 2 and 8) are given in table 11 B and figure 24.

It could be seen from these data and from the corresponding curves that:

1. The surface silicate concentration, away from the regions of the drains was always lower than the bottom; whereas in the regions at the mouth of the drains the reverse was true. Yet in both cases minimal concentration was observed in late autumn.

2. The bottom silicate concentration showed a progressive increase beginning from late autumn up till the summer months after which it began to decrease till the following autumn where it began to rise again.

The distribution of silicates and its seasonal fluctuations was different from that of the nutrients already mentioned in part I. The succession of events concerning the variation of silicate concentration, in the surface and bottom water layers, could be accounted for as follows:

The drainage water rich in silicates (see table 11) invaded the lake in the drainage flood beginning during autumn till late winter. Low values of silicates at the mouth of the drains during late autumn, indicate that such high silicate content of the drainage water was thrown out of circulation, most probably due to the presence of coagulants or precipitants (TWENHOFEL, 1939). The surface silicates that escaped precipitation at the mouth of the drains and which were subsequently distributed progressively to further regions of the lake, at the end has to undergo the same fate. The fact that a gradual decrease in surface silicate content was observed the further we go away from the drains untill in the far west stations it was almost depleted during autumn and early winter (table 11) supports this assumption. It could also be noticed that the surface silicate concentration in the regions of the double-fed stations were higher than that in the regions of the one-fed stations, at the same time. During late autumn there was a gradual increase in bottom silicates till summer. According to KING and DAVIDSON (1933), who had experimentally proved that the process of redissolution of disentegrating shells of diatoms take place within five months of their deposition, might explain this found increase. Silicates thus produced at the bottom diffused through the upper water layers, especially during summer where vertical mixing occur, as is discussed before.

Unlike their rôle in the cycle on nitrogen and phosphorus, bacteria are probably not directly involved in the resolution of silicon (SVERDRUP, et. al., 1949).

Table 11 A

Monthly average silicate values of the lake proper, in µg-at./l. of $SiO_3$-Si (average of all stations except 1, 2 and 8)

| Year | Month | Surface | Bottom |
|---|---|---|---|
| 1953 | Nov. | 20.1 | 34.8 |
| | Dec. | 10.4 | 35.2 |
| 1954 | Jan. | 19.4 | 43.1 |
| | Feb. | 36.0 | 55.7 |
| | Mar. | 49.6 | 62.7 |
| | Apr. | 59.5 | 75.5 |
| | May | 73.9 | 84.2 |
| | Jun. | 85.7 | 94.6 |
| | Jul. | 98.9 | 101.6 |
| | Aug. | 79.2 | 92.5 |
| | Sep. | 70.9 | 79.8 |
| | Oct. | 60.4 | 67.6 |
| | Nov. | 27.7 | 41.1 |
| | Dec. | 8.2 | 24.9 |
| 1955 | Jan. | 15.7 | 42.4 |
| | Feb. | 39.7 | 54.8 |

See also figure 23

The fact that silicates are only produced from the bottom was clearly demonstrated in the far western more deep regions, where there was a gradual increase of silicate concentration from bottom to surface. A similar remark was noted by SVERDRUP. The bottom and surface silicates, reaching maximum concentration during summer, began to decrease gradually till the following autumn where events repeated itself again.

The fact that there is a coincidence of maximum silicate precepitation with maximum fermentation of bottom sediments during autumn, might suppose that preciptants or coagulants are products of bottom decomposition.

Table 11 B

Monthly average silicate values, in μg-at./l. $SiO_3$-Si, at the mouth of the drains (average of stations 2 and 8)

| Year | Month | Surface | Bottom |
|---|---|---|---|
| 1953 | Nov. . . . . . . . . . | 75.3 | 45.2 |
| | Dec. . . . . . . . . . | 30.7 | 46.9 |
| 1954 | Jan. . . . . . . . . . | 40.5 | 48.8 |
| | Feb. . . . . . . . . . | 65.7 | 58.0 |
| | Mar. . . . . . . . . . | 85.7 | 74.9 |
| | Apr. . . . . . . . . . | 98.5 | 97.8 |
| | May . . . . . . . . . | 115.4 | 105.0 |
| | Jun. . . . . . . . . . | 110.5 | 100.9 |
| | Jul. . . . . . . . . . | 105.6 | 94.8 |
| | Aug. . . . . . . . . . | 102.2 | 85.0 |
| | Sep. . . . . . . . . . | 100.4 | 76.9 |
| | Oct. . . . . . . . . . | 95.9 | 72.4 |
| | Nov. . . . . . . . . . | 80.7 | 41.0 |
| | Dec. . . . . . . . . . | 20.0 | 73.5 |
| 1955 | Jan. . . . . . . . . . | 38.3 | 43.8 |
| | Feb. . . . . . . . . . | 60.2 | 56.3 |

See also figure 24

The average silicate values in lake Qarûn ranged between 8 to 99 μg-at./l. of $SiO_3$-Si, whereas in the region of the drains it varied from 20 to 115 μg-at./l. According to THOMPSON and ROBINSON (1932) the silicate silicon in the sea varied by more than one hundred fold, namely from 0.7 to 110 μg-at./l. THOMPSON, THOMAS and BARNES (1934) and BARNES and THOMPSON (1938) found values amounting to 170 μg-at./l. in the North Pacific. CLOWES (1938) found still higher values in the range of 140 μg-at./l. in the deep waters of the Antarctic. COOPER (1935), for the English Channel, only reported amounts of 0.05 to 4.0 μg-at./l., being much lower than that in Friday Harbor (PHIFER and THOMPSON, 1937).

Seasonal changes were detected by COOPER (1935) in the English Channel, values found higher during winter and lowest during spring. It is almost agreed among different investigators that the seasonal variations in silicate concentration is correlated with the production of organisms utilizing silicon for their shells, particularly diatcms (PEARSALL, 1923; COOPER, 1933; CHANDLER, 1942; SVERDRUP, 1949; SPENCER, 1950). This fact was proved experimentally in laboratory cultures (KING and DAVIDSON, 1933). Particulars concerning that point in lake Qarun will be discussed later when considering phytoplankton production.

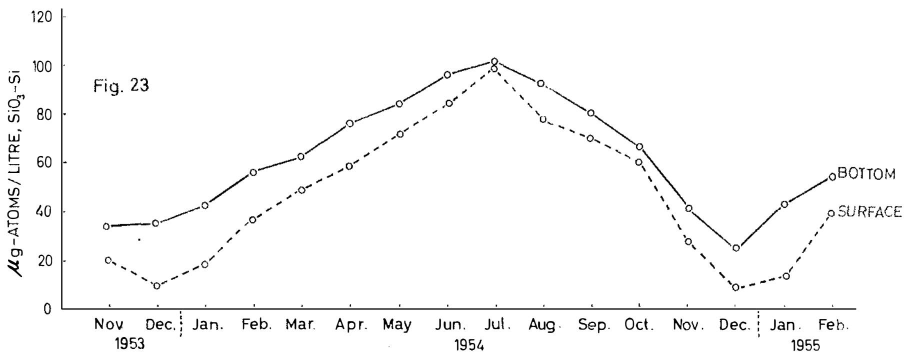
## 4. Iron

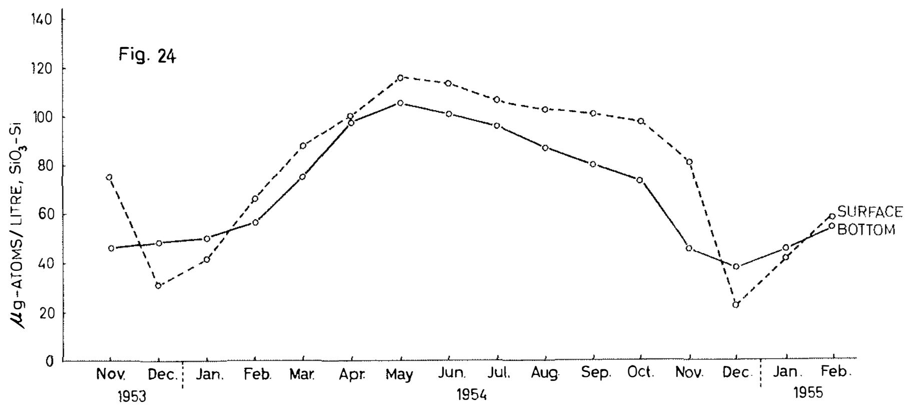
In table 12 is given the concentration of the total soluble iron in the surface and bottom water, expressed in μg-at./l. Fe; estimated at the different stations during the 8 successive seasons of study, from summer 1953 to spring 1955. The monthly average

Legenden zu den nebenstehenden Abbildungen (Tafel 1)

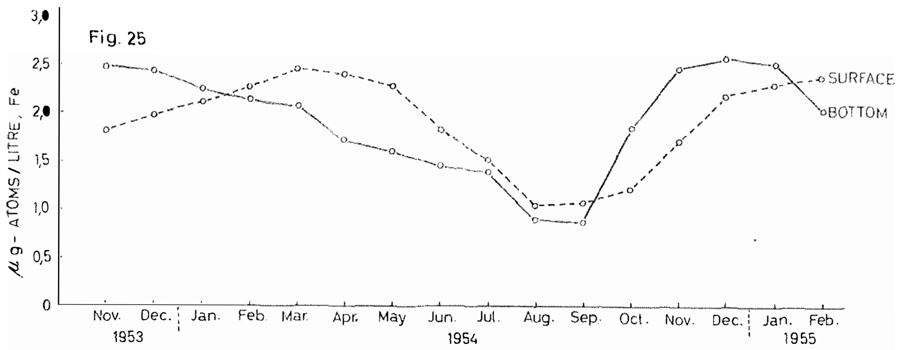
Fig. 23, showing the variation in the monthly average silicate concentration, expressed in μ-at./l. $SiO_3$-Si, in the surface and bottom water ofthe lake proper (in regions away from the drains).

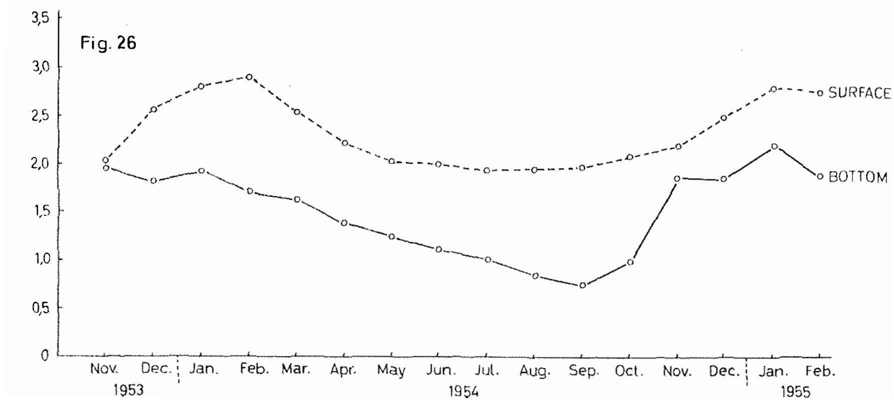
Fig. 24, showing the variation in the monthly average silicate concentration, expressed in μ-at./l. $SiO_3$-Si, in the surface and bottom water in the regions at the mouth of the drains.




**Tafel 1** (zu M. Naguib)




**Tafel 2** (zu M. Naguib)

values for all stations except 1, 2 and 8 are given in table 12 A. The monthly average values concerning the stations at the mouth of the drains (stations 2 and 8) are given in table 12 B. These data are represented in figures 25 and 26 respectively.

It could be seen from these data and from the corresponding curves that:

1. The surface iron concentration, though of different magnitude in the regions of the drains and in the regions away from the drains, showed gradual increase during winter and early spring, decreased during summer to increase again gradually during autumn and the following new year winter.

2. The bottom iron concentration showed a marked increase during autumn, began to decrease gradually during spring and summer and tended to increase again in the following autumn.

In the regions at the mouth of the drains the surface iron concentration was higher than the bottom. Away from the drains this was remarkable during late winter and early spring.

The iron concentration in the water within the drains was high, remarkably higher during winter 1955 (table 12). This character of the drainage water was reflected directly into the surface water at the mouth of the drains. As the invading drainage water, rich in iron, spreaded into the lake, it could be seen on analysing data in table 12,

Table 12 A

Monthly average values of total iron, expressed in μg-at./l. Fe, in the surface and bottom water of the lake proper (average of all stations excluding 1, 2 and 8)

| Year | Month | Surface | Bottom |
|---|---|---|---|
| 1953 | Nov. | 1.78 | 2.49 |
| | Dec. | 1.95 | 2.47 |
| 1954 | Jan. | 2.09 | 2.42 |
| | Feb. | 2.31 | 2.21 |
| | Mar. | 2.45 | 2.11 |
| | Apr. | 2.37 | 1.72 |
| | May | 2.27 | 1.66 |
| | Jun. | 1.85 | 1.50 |
| | Jul. | 1.53 | 1.39 |
| | Aug. | 1.09 | 0.95 |
| | Sept. | 1.11 | 0.91 |
| | Oct. | 1.32 | 1.84 |
| | Nov. | 1.74 | 2.51 |
| | Dec. | 2.27 | 2.56 |
| 1955 | Jan. | 2.38 | 2.51 |
| | Feb. | 2.47 | 2.29 |

See also figure 25

Legenden zu den nebenstehenden Abbildungen (Tafel 2)

Fig. 25, showing the variation in the monthly average soluble iron concentration expressed in μ-at./l. Fe, in the surface and bottom water of the lake proper (in regions away from the drains).

Fig. 26, showing the variation in the monthly average soluble iron concentration, expressed in μ-at./l. Fe, in the surface and bottom water in the regions at the mouth of the drains.

Table 12 B

Monthly average values of total iron, expressed in µg-at./l. Fe, in the surface and bottom water at the mouth of the drains (average of stations 2 and 8)

| Year | Month | Surface | Bottom |
|---|---|---|---|
| 1953 | Nov. | 2.09 | 1.98 |
| | Dec. | 2.60 | 1.82 |
| 1954 | Jan. | 2.81 | 1.92 |
| | Feb. | 2.88 | 1.71 |
| | Mar. | 2.55 | 1.63 |
| | Apr. | 2.38 | 1.38 |
| | May | 2.02 | 1.20 |
| | Jun. | 1.99 | 1.05 |
| | Jul. | 1.90 | 0.97 |
| | Aug. | 1.89 | 0.79 |
| | Sept. | 1.96 | 0.70 |
| | Oct. | 1.98 | 0.94 |
| | Nov. | 2.19 | 1.99 |
| | Dec. | 2.53 | 1.99 |
| 1955 | Jan. | 2.82 | 2.29 |
| | Feb. | 2.74 | 1.96 |

See also figure 26

that there was a progressive increase in the one-fed regions, whether east or west depending upon its relative distance from the fresh water sources; whereas the double-fed regions showed remarkable high iron surface values than in the neighbouring regions.

As regards the iron concentration in the bottom water layers, it was found that it increased relatively during late autumn and early winter. This could be correlated with the decomposition of the bottom material taking place during that period. TWENHOFEL (1939) mentioned that bacteria may be directly involved in the solution and precipitation of iron oxides.

In the shallow northern shores (stations 4 and 11), with a sandy bottom, the surface and bottom iron concentration were almost similar.

The total iron concentration in lake Qarûn varied within the range 0.95—2.5 µg-at./l. Fe. Data on the iron content of lakes are scanty for comparison. However, WELCH in 1935 mentions that Gorham reported amounts of 0.2—1.5 p.p.m. of Fe (i.e. 3.6 to 27.3 µg-at./l. in bog lakes. ORTON (1923), for the English Channel, reported amounts of 0.1 and 0.2 mg. Fe/l. (i.e. 1.9 and 3.6 µg-at./l.). Yet HARVEY (1925), on reanalysing the same water found values as low as 3 and 6 mg./m$^3$ (0.05 and 0.11 µg-at./l. Fe). BRAARUD and KLEM (1931) obtained values ranging from 4 to 9 mg./m$^3$ (0.07 to 0.16 µg-at./l.). WATTENBERG (1927) reported as much as 60 mg./m$^3$ (1.14 µg-at./l. Fe). Seasonal variations in the iron content in the surface water of Friday harbor, found by THOMPSON, BREMNER and JAMIESON (1932) ranged between a maximum of 60 mg./m$^3$ (i.e. 1.1 µg-at./l.) in spring and a minimum of 32 mg./m$^3$ (0.6 µg-at./l. Fe) in summer; the average recorded being 42 mg./m$^3$ (0.84 µg-at./l. Fe). Values up to 280 mg./m$^3$ (5 µg-at./l. Fe) were recorded by the latter authors but for deeper water. COOPER (1937 a) considered that the amount of ferric or ferrous salts in the sea water is probably less than 2 µg-at./l.; while the total iron amounts to 10 times more.

The importance of iron for plant growth has been pointed out by CZAPEK (1920), BRANDT and RABEN (1920), SJÖSTEDT (1921), HOPKINS (1930), GRAN (1931), THOMPSON and BREMNER (1935), HARVEY (1937) and RODHE (1948).

Though the data available in the literature cited do not point to the exact rôle of iron cycle in water, yet it could be seen from the present investigation that it was no very far from the other nutrients; nitrates and phosphates dealt with before.

### Sulphide—Sulphur

Sulphur is present in sea water as sulphate ion. Under stagnant conditions occuring in certain isolated basins, a part of the sulphate may be converted to sulphide ion (SVERDRUP et al.).

The occurrence of hydrogen sulphide in the waters of certain seas, fjords and basins, as well as the presence of black or blue stinking sediments could hardly escape the notice of the investigators (ZOBELL and RITTENBERG, 1948, IVANOV and TEREBKOVA, 1959).

It has been definitely proved that sulphate-reducing bacteria contribute to the formation of hydrogen sulphide (ZOBELL, 1947, IVANOV and TREBKOVA, 1959). However reduction may be carried still further to the free sulphur stage (HUNT, 1915; RIDGWAY, 1930; AHLFELD, 1937; MURZAIEV, 1937; STURM, 1937; IYA & SRYNIVASAYA, 1945). However, these bacteria are considered responsible for the formation of metallic sulphides observed in deposits (MURRAY & IRVINE, 1895; COPENHAGEN, 1934; SCHNEIDERHOHN, 1923; TRASK, 1925; DOSS, 1912; ELLIS, 1925; KINDLE, 1926; STRÖM, 1939; THIEL, 1926; BASTIN, 1933; etc.). The possibility that putrefactive bacteria may be responsible for $H_2S$ production is not to be overlooked. The sharp increase in the number of putrefactive bacteria in response to appearance in waters of readily assimilable organic matter is a fact widely known in microbiological literature (KUSNETSOV, 1952), but declines with the exhaustion of the supply of organic matter. IVANOV and TREBKOVA (1959) ascertain that the main bulk of $H_2S$ in lake Solenoe is formed in the mud sediments through activity of sulphate-reducing bacteria since their number exceeds considerably that of the putrefactive bacteria which forms $H_2S$ from proteins. Sulphate reducing bacteria are found in the bottom deposits; they are active only in strictly anaerobic conditions.

### Experimental results

The total sulphide-sulphur, expressed in mg./kg. in the bottom sediments as well as the hydrogen sulphide content of the bottom water, in mg./liter, which were calculated from the estimated dissolved sulphides in the bottom water, are given in table 13. The estimates were carried out at the different stations during the 8 successive seasons of study. It was noticed that the stations lying in the northern shores (Stations 4 & 11) have a sandy bottom covering black "mucky" sediments. So on calculating the monthly averages, stations 1 (of the drain), 4 & 11 are excluded; and such data are presented in table 13 A and graphically in curves figure 27. As regards stations 4 & 11, samples from the underlying "mucky" bottom were analysed for their total sulphide content and results are given in table 13 B.

From these data and from the curves figure 28, it could be seen that there was a maximum production of sedimentary sulphides during autumn and early winter which decreased gradually during spring till minimal in summer and increased again in the following autumn. This same character was reflected in the bottom water layers, as shown by their content of hydrogen sulphide.

In stations 4 & 11 the bottom is covered with sand which was found almost free of sulphides. However, the underlying sediments (table 13 B) was found to have a large content of sulphides. The $H_2S$ which might be formed in these regions in the water could not be detected, possibly due to the shallowness of the water in which slight agitation would allow $H_2S$ to escape away.

Very few quantitative data as regards the formation of bottom sulphides in lake sediments are available. However, mention was made of the $H_2S$ formation in the bottom water of the black sea having a range of 1.48—6.17 $cm^3$/l. (NIKITIN, 1931); as well as for some Norwegian fjords with values amounting to 22 ml./l. (STRØM, 1936). Recently, IVANOV and TREBKOVA (1959) reported that the rate of $H_2S$ production as due to microbiological reduction of sulphates in the deep part of lake Solenoe amounts to 0.9—3.2 mg. $H_2S$/l. mud per day. In shallow waters this figure is still higher amounting to about 5 mg. $H_2S$/l. mud a day. The authors add further that the progressive $H_2S$ accumulation occurred in the bottom water layers throughout the entire winter, spring and summer, the amount of which reached 100 mg./l. by the end of September, whereas during autumn circulation nearly all $H_2S$ was oxidized.

Table 13 A

Monthly average values of sulphide-sulphur content of the bottom sediments, expressed in mg/kg.; and the unionized $H_2S$ in the bottom water, expressed in mg./l. of the lake proper (average of all stations excluding 1, 4 and 11).

| Year | Month | Sulphide-S. in sediments | Unionized $H_2S$ in bottom water |
|---|---|---|---|
| 1953 | Nov. . . . . . . . . . | 110.03 | 1.05 |
| | Dec. . . . . . . . . . | 96.50 | 0.98 |
| 1954 | Jan. . . . . . . . . . | 88.82 | 0.91 |
| | Feb. . . . . . . . . . | 78.23 | 0.72 |
| | Mar. . . . . . . . . . | 54.60 | 0.54 |
| | Apr. . . . . . . . . . | 50.48 | 0.36 |
| | May . . . . . . . . . | 45.01 | 0.27 |
| | Jun. . . . . . . . . . | 41.09 | 0.18 |
| | Jul. . . . . . . . . . | 37.20 | 0.097 |
| | Aug. . . . . . . . . . | 36.47 | 0.056 |
| | Sep. . . . . . . . . . | 45.05 | 0.076 |
| | Oct. . . . . . . . . . | 65.58 | 0.17 |
| | Nov. . . . . . . . . . | 103.70 | 1.14 |
| | Dec. . . . . . . . . . | 92.72 | 1.01 |
| 1955 | Jan. . . . . . . . . . | 91.10 | 0.79 |
| | Feb. . . . . . . . . . | 79.86 | 0.64 |

See also figure 27

## Phytoplankton and Zooplankton in Lake Qarûn

The quantitative distribution of plankton, both phyto- and zooplankton, in the upper water strata of lake Qarûn was studied. However, no attempt was made for a systematic study of the phyto- and zooplankton examined.

Horizontal plankton collections of surface and subsurface water was obtained each month during a day time of moderate temperature and moderate light intensity, assuming, under these conditions, that vertical migration of plankton was minimal (WELCH, 1935). The relative shallowness of the lake and the fact that the surface water

Table 13 B

Sulphide-Sulphur of the underlying "mucky" sediments of stations 4 and 11, expressed in mg./kg., during 1954.

| Month | Station 4 | Station 11 |
|---|---|---|
| Jan. | 400 | 420 |
| Feb. | 398 | 399.5 |
| Mar. | 410 | 419 |
| Apr. | 449 | 460 |
| May | 381 | 392 |
| Jun. | 385 | 402 |
| Jul. | 410 | 430 |
| Aug. | 439 | 442 |
| Sep. | 395 | 444 |
| Oct. | 405 | 435 |
| Nov. | 430 | 465 |
| Dec. | 450 | 470 |

layers have its supply of nutrients, dissolved gases, etc., gives allowance for considering that such plankton collections represent, in a general way, the plankton crop of the lake.

Microscopic examination of the phytoplankton showed that it was almost formed of diatoms of the genera: *Nitzschia* and *Synedra*. Similar abundance of diatoms composing most of phytoplankton crop was found by DAMANN (1943) in lake Michigan; CHANDLER and WEEK (1945) in Western lake Erie; SPENCER (1950) in Quabbin Reservoir; etc. However, some filamentous blue-green algae (*Lyngbya*, *Oscillatoria*) and red algae (*Polysiphonia*) were occasionally obtained during collection. On the other hand, the zooplankton was almost exclusively formed of copepods, including the different copepodire stages. The larvae of insects (mainly the chironomids) were also present, most abundant during spring. The presence of a large number of Glochidium-larvae, specially pronounced during early winter, did not escape notice; since, as mentioned before, lake Qarûn charakterised by its large populations of molluscs. The most abundant genera of crustaceans present are: *Acartia* sp., *Diaptomus* sp. and, to a lesser magnitude, the different developmental stages of *Leander* sp., as well as the *Gammarus* sp. The latter was observed to be highly aggregated on the shores, specially intermingled with the filaments of the red and blue-green algae densely covering the southern shores. However, GIRGIS (1959), reported that *Diaptomus* sp. were not to be identified in his sample-collections from Lake Qarûn.

The interest of the present work was mainly directed to the interrelation between the zooplankton and the phytoplankton organisms, and their availability as food for fish. Attention was mainly directed to diatoms and copepods since they represent the main bulk of the plankton crop.

It was not found possible to estimate the phytoplankton distribution using HARVEY's pigment analysis method (1934), because certain species of the copepod population had pigmented eyes which interfered with the colour developed from the phytoplankton when extracted with acetone. Furthermore, JUDAY, BLAIR and WILDA (1943) stated that "chlorophyll can hardly be regarded as a good index of the phytoplankton", since this pigment may be affected by several factors such as the different kinds of organisms represented, their age, physiological status and their relation to environmental factors as light and nutrients. RILEY (1941) stated that the total plant pigments are a better index of phytoplankton than chlorophyll. However, JUDAY, et al., estimated the phytoplankton by count. Recently, RODHE (1948), ATKINS and PARKE (1951), ATKINS (1952) evaluated the phytoplankton crop in chlorophyll units, through spectrophotometric estimations. So, quantitative estimation was confined to the count of diatom organisms using the haemocytometer graduated slide, originally deviced for blood count. Although it is not as accurate as the spectrophotometric estimations, yet it was suitable for field work. The quantitative determination of copepods was undertaken by counting the number of animals suspended in a certain volume of water, placed in a petri-dish divided into square areas for controlling the counting. The volume of water estimated during plankton netting by the current meter being known, one can calculate the frequency of these plankton organisms.

In tables 14 and 15 are given the monthly counts of diatoms and copepods respectively at the different stations (from station 2 to 13) during the period of the present study, and presented as organisms per liter. The monthly average values for the diatom and copepod counts, for the different stations, except 2 and 8, are presented respectively in tables 14 A and 15 A, and represented graphically in fig. 29.

It is clear from the data given in table 15 A that the phytoplankton showed a marked outburst in late autumn, winter and early spring, followed by a rapid decrease becoming minimal during summer, after which it began to show gradual increase again in the following autumn. The copepods (Table 15 A) were of more frequent occurence during late spring and summer, however, their number decreased markedly during autumn.

The inverse character of the copepod population with that of the diatoms was not so absolute (fig. 29). Both zooplankton and phytoplankton showed gradual increase during winter and spring, after which they reversed each other, markedly during summer. The zooplankton reached its maximum in midsummer, then showed a gradual decrease becoming minimal in mid-autumn (November). This was followed by another zooplankton increase in the following winter.

It could be noticed that the planctonic population wether zooplankton or phytoplankton were less denser in winter 1955 than was the case in the same season of the preceding year. The effect of dilution of the abnormal flood of drainage water which invaded the lake during winter 1955, should be taken in consideration when accounting for such phenomenon.

The planctonic crop of lake Qarûn was relatively poor showing maximum values of 104,300 (during spring) and 56 diatom and copepod organisms per liter respectively. The minimum values were 5,900 diatoms per liter (late summer) and 8 copepod organisms per liter (late autumn). From the data presented by Juday, Blair and Wilda (1943) for Little John lake, it could be seen that it contained an average of 48 diatoms/milliliter for surface water in August 1941. However, lake Qarûn plankton population is of the same order as that found for lake Mendota, Wiscinsin, by Birge and Juday in 1911. These authors studied the vertical distribution of different forms of plankton. Maximum diatom concentration reported as 25,800 organisms per liter of surface water during 11th. October. The minimum was 3,400 during July. For crustacean counts, maximum concentration of organisms in surface water was found to be 90 organisms/liter during June, and minimum of 8 organisms/liter during July.

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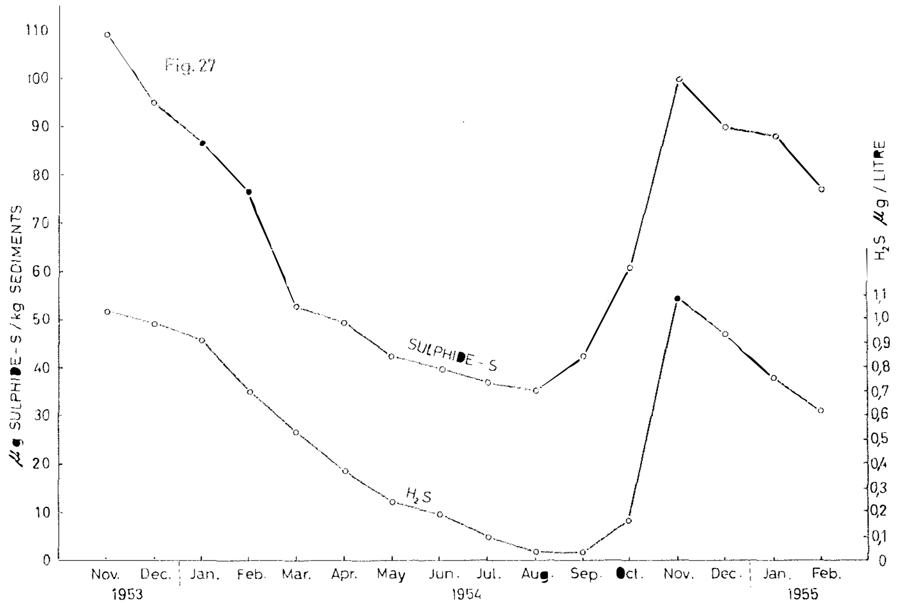
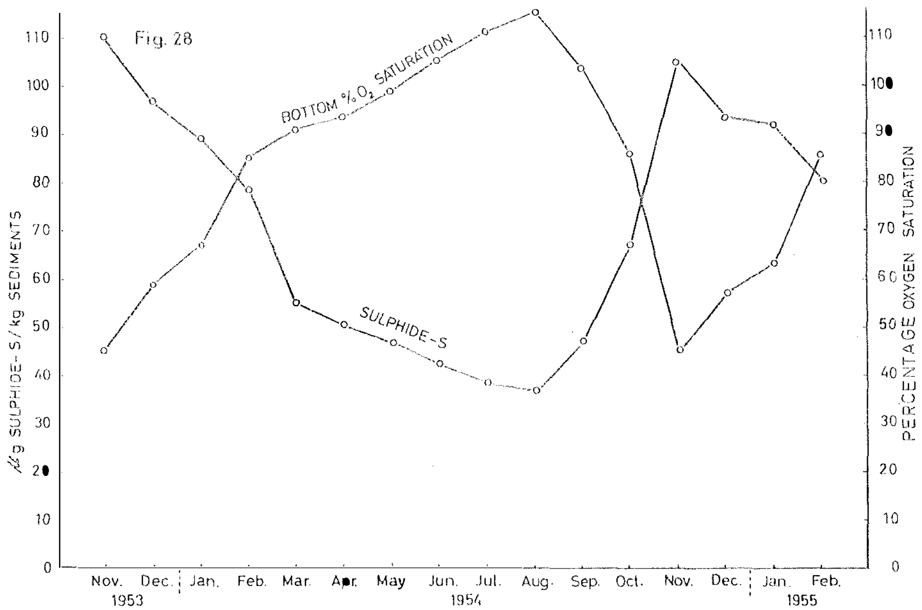
Legenden zu den nebenstehenden Abbildungen (Tafel 3)

Fig. 27, showing the variation in the monthly average concentration of the sulphide content of the sediments (upper curve) and in the bottom water (lower curve), expressed as mg sulphide/kg. sediments and $H_2S$ mg/litre of water respectively, of the lake (in regions away from the drains and the northern sandy shores).

Fig. 28, showing the inverse relation between the bottom water oxygen saturation and the bottom sulphide production of the sediments during the different seasons studied.




**Tafel 3** (zu M. Naguib)

Fig. 29

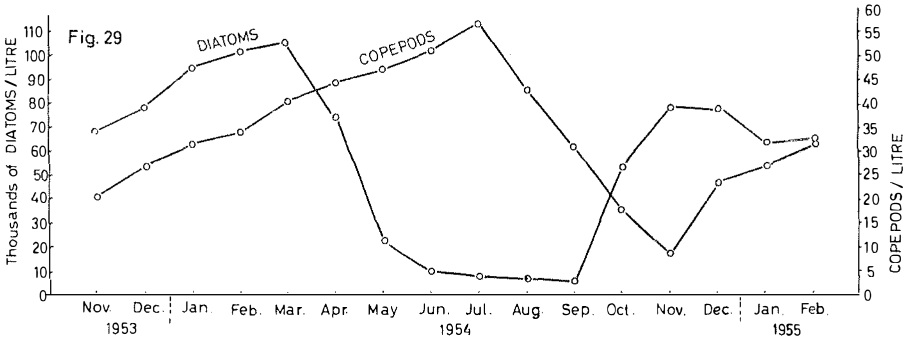
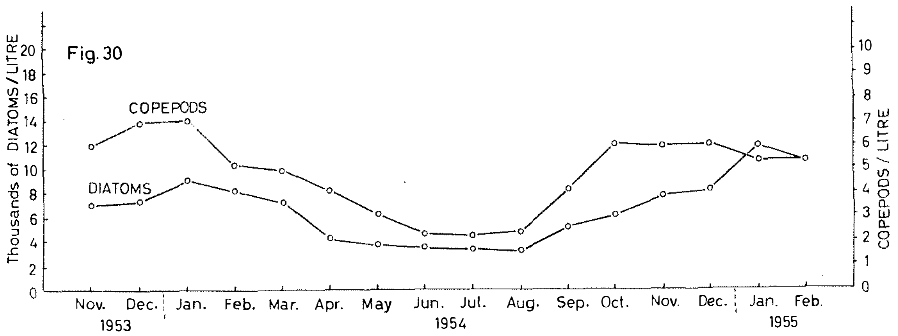



Fig. 30




**Tafel 4** (zu M. Naguib)

Table 14 A

Monthly average values of diatom counts, calculated as organisms per liter of water, of the lake proper (average of all stations except 2 and 8)

| Year | Month | No. diatoms/liter |
|---|---|---|
| 1953 | Nov. . . . . . . . . . . . | 68,480 |
| | Dez. . . . . . . . . . . . | 76,930 |
| 1954 | Jan. . . . . . . . . . . . | 95,091 |
| | Feb. . . . . . . . . . . . | 100,851 |
| | Mar. . . . . . . . . . . | 104,295 |
| | Apr. . . . . . . . . . . . | 73,810 |
| | May . . . . . . . . . . . | 23,690 |
| | Jun. . . . . . . . . . . . | 9,190 |
| | Jul. . . . . . . . . . . | 7,525 |
| | Aug. . . . . . . . . . . . | 6,830 |
| | Sep. . . . . . . . . . . | 5,901 |
| | Oct. . . . . . . . . . . . | 52,490 |
| | Nov. . . . . . . . . . . . | 77,670 |
| | Dec. . . . . . . . . . . . | 76,620 |
| 1955 | Jan. . . . . . . . . . . . | 63,530 |
| | Feb. . . . . . . . . . . . | 64,320 |

See also figure 29

Table 15 A

Monthly average values of copepod counts of the lake proper, calculated as organisms per liter of water (average of all stations except 2 and 8)

| Year | Month | No. Copepods/liter |
|---|---|---|
| 1953 | Nov. . . . . . . . . . . . | 20 |
| | Dec. . . . . . . . . . . . | 27 |
| 1954 | Jan. . . . . . . . . . . . | 31 |
| | Feb. . . . . . . . . . . . | 34 |
| | Mar. . . . . . . . . . . | 40 |
| | Apr. . . . . . . . . . . . | 44 |
| | May . . . . . . . . . . . | 47 |
| | Jun. . . . . . . . . . . . | 51 |
| | Jul. . . . . . . . . . . | 56 |
| | Aug. . . . . . . . . . . . | 42 |
| | Sep. . . . . . . . . . . . | 30 |
| | Oct. . . . . . . . . . . . | 17 |
| | Nov. . . . . . . . . . . . | 8 |
| | Dec. . . . . . . . . . . . | 23 |
| 1955 | Jan. . . . . . . . . . . . | 26 |
| | Feb. . . . . . . . . . . . | 30 |

See also figure 29

Legenden zu den nebenstehenden Abbildungen (Tafel 4)

Fig. 29, showing the variation in the monthly average copepod and diatom counts per litre of water, of the lake proper (away from the regions of the drains).

Fig. 30, showing the variation in the monthly average copepod and diatom counts per litre of water, in the regions at the mouth of the drains.

The total crop of plankton varies from season to season in all waters. WELCH (1952) mentions that in temperate lakes, particularly those of the first and second orders, the total annual production, as a rule, takes the form of a bimodal curve presenting two maxima, one in the spring and one in the autumn, and two minima one during the summer and the other during the winter. BIRGE and JUDAY (1922) for lake Mendota reported values of dry organic matter for total plankton in the spring and autumn maxima amounting to 3,200 and 2,800 mg./m.$^3$ respectively. MCCOMBIE (1953) mentioned a bimodal distribution of phytoplankton in many temperate lakes, with a maximum production in spring and autumn and minimum in winter and summer. A similar bimodal nature of the spring and autumn maxima for phytoplankton outburst could be seen from the data given for the sea by ATKINS (1952); the April maximum and June minimum being 1,32 and 0,15 gm./m.$^2$ clorophyll respectively.

The plankton population in the region of the mouth of the drains was found remarkably low. The monthly average values of the diatom and copepod counts are given in tables 14 B and 15 B respectively and are represented graphically in curves figure 30.

From these data it is clear that the zoo- and phytoplankton concentration was too small to be compared with the plankton population in the other regions of the lake. The corresponding curves for these data, when drawn on basis of a similar proportion between phytoplankton and zooplankton (fig. 30) showed that the zooplankton, though very poor, was relatively higher than the phytoplankton. The zooplankton appear to withstand sudden changes in the environment, resulting from the flow of drainage water, than the phytoplankton.

It is interesting to report that examination of the plankton in the water within the drain showed a fresh water fauna and flora of which *Daphnia* sp. and *Spirogyra* sp. were abundant. These fresh water species were never detected elsewhere in the different regions of the lake, not even at the mouth of the drains. Trials to interprete such observations are dealt with further in the general discussion.

Table 14 B

Monthly average values of diatom counts calculated as organisms per liter of water in the regions at the mouth of the drains (stations 2 and 8)

| Year | Month | Diatoms/liter |
|---|---|---|
| 1953 | Nov. | 6,954 |
| | Dec. | 7,250 |
| 1954 | Jan. | 8,960 |
| | Feb. | 8,020 |
| | Mar. | 6,553 |
| | Apr. | 4,044 |
| | May | 3,245 |
| | Jun. | 2,928 |
| | Jul. | 2,729 |
| | Aug. | 2,227 |
| | Sep. | 4,150 |
| | Oct. | 5,200 |
| | Nov. | 7,200 |
| | Dec. | 7,800 |
| 1955 | Jan. | 11,005 |
| | Feb. | 9,911 |

See also figure 30

Table 15 B

Monthly average values of copepod counts calculated as organisms per liter of water in the regions at the mouth of the drains (stations 2 and 8)

| Year | Month | Copepods/liter |
|---|---|---|
| 1953 | Nov. . . . . . . . . . . . | 6 |
| | Dec. . . . . . . . . . . . | 7 |
| 1954 | Jan. . . . . . . . . . . . | 7 |
| | Feb. . . . . . . . . . . . | 5 |
| | Mar. . . . . . . . . . . | 5 |
| | Apr. . . . . . . . . . . . | 4 |
| | May . . . . . . . . . . . | 3 |
| | Jun. . . . . . . . . . . . | 2 |
| | Jul. . . . . . . . . . . . | 2 |
| | Aug. . . . . . . . . . . . | 2 |
| | Sep. . . . . . . . . . . . | 2 |
| | Oct. . . . . . . . . . . . | 4 |
| | Nov. . . . . . . . . . . . | 6 |
| | Dec. . . . . . . . . . . . | 6 |
| 1955 | Jan. . . . . . . . . . . . | 6 |
| | Feb. . . . . . . . . . . . | 5 |

See also figure 30

## Nature of the ingested food of fishes in the lake

There are four dominating species of fishes in lake Qarûn, namely: *Tilapia zilli*, *Mugil cephalus*, *M. capito* and *Solea vulgaris*. The three latter species mentioned are among the newly introduced species, being transported to the lake regularly each year since 1928; while *Tilapia* is amongst the remains of the original fauna of the lake.

It was thought interesting to determine how far the plankton crop, phytoplankton and zooplankton, partake in the feeding of fishes present in the lake.

A thorough review of the literature dealing with this subject has been dealt with in a previous publication (NAGUIB, 1954).

Experimental results:

During the regular visits made to lake Qarûn in the course of the present investigation, ten specimens of every species of fish, each visit, were taken out and dissected the moment they were brought out of the water. The alimentary tracts were ligatured off at the oesophagus, next to the pylorus and at the end of the rectum. The alimentary tracts were removed from the body of the fish and transferred to tubes containing 10% formalin solution, to preserve the material for alter examination.

Qualitative estimations through examination of the alimentary tract contents were confined to *Mugil cephalus*, *M. capito*, *Tilapia zilli* and *Solea vulgaris* the most common fishes of the lake. For each species of fish, the contents of the alimentary canals were examined by a binocular microscope and a rough estimation of the different forms constituting the plant and animal portions of food were recorded. Results are presented in table 16 A, B, C, and D.

It is clear from these tables that the four species of fish dominating in the lake are omnivorous although the ratio of the phytopart to the zoo-part differs in the different species. Fishes were found to devour plankton organisms, both phyto- and zooplankton, filamentous algae: red and blue-green, higher plant fragments and insect larvae. It is rather striking that mollusc shells were regularly found among the food contents of *Solea*. One cannot say definitely from this observation that molluscs represent an item

Table 16 A

Qualitative estimation of forms constituting the plant and animal food during the different months of the year 1954; of *Mugil cephalus*

| Month | Diatoms | Fil. Red | algae Blue-green | Crustacea Copepod | Crustacea Amphipod | Glochidium larvae |
|---|---|---|---|---|---|---|
| Jan. | ++++ | + | ++++ | + | — | ++ |
| Feb. | ++++ | + | ++++ | + | — | ++ |
| Mar. | ++++ | + | ++++ | + | + | + |
| Apr. | ++++ | + | ++++ | + | + | + |
| May | ++++ | + | ++++ | ++ | — | — |
| Jun. | +++ | + | ++++ | +++ | ++ | — |
| Jul. | +++ | ++ | ++++ | ++++ | ++ | — |
| Aug. | ++ | ++ | ++++ | +++ | ++ | — |
| Sep. | ++ | ++ | ++++ | ++ | ++ | — |
| Oct. | +++ | + | ++++ | + | + | — |
| Nov. | ++++ | + | ++++ | + | + | — |
| Dec. | ++++ | + | ++++ | + | + | — |

\+ Present occasionally
\++ Present in small quantity
\+++ Present in fair quantities
\++++ Present in abundance

Table 16 B

Qualitative estimation of forms constituting the plant and animal food during the different months of the year 1954; of *Mugil capito*

| Month | Diatoms | Fil. Red | algae Blue-green | Crustacea Copepod | Crustacea Amphipod | Glochidium larvae |
|---|---|---|---|---|---|---|
| Jan. | ++++ | + | ++ | + | — | ++++ |
| Feb. | ++++ | + | ++ | + | — | ++++ |
| Mar. | ++++ | + | ++ | + | — | ++++ |
| Apr. | ++++ | + | +++ | ++ | — | ++ |
| May | ++++ | + | +++ | ++ | — | ++ |
| Jun. | +++ | + | +++ | +++ | — | + |
| Jul. | +++ | + | +++ | +++ | + | + |
| Aug. | ++ | + | ++++ | +++ | + | — |
| Sep.[1]) | ++ | + | ++++ | ++ | + | — |
| Oct. | +++ | + | +++ | + | — | — |
| Nov. | ++++ | + | ++ | + | — | — |
| Dec. | ++++ | + | ++ | + | — | ++ |

\+ Present occasionally
\++ Present in small quantity
\+++ Present in fair quantities
\++++ Present in abundance

[1]) Many alimentary canals, during that month were found empty.

Table 16 C

Qualitative estimation of forms constituting the plant and animal food during the different months of the year 1954, of *Solea vulgaris*

| Month | Diatoms | Fil. Red | algae Blue-green | Crustacea | | Insect larvae | Mollusc larvae | Fish larvae |
|---|---|---|---|---|---|---|---|---|
| | | | | Copepod | Amphipod | | | |
| Jan. | ++ | + | +++ | — | ++++ | ++ | ++ | — |
| Feb. | ++ | ++ | ++ | — | ++++ | +++ | ++ | — |
| Mar. | +++ | + | ++ | — | ++++ | ++ | ++ | — |
| Apr. | +++ | + | ++ | — | ++++ | ++ | + | — |
| May | +++ | + | ++ | + | ++ | — | — | + |
| Jun. | ++ | + | ++ | + | +++ | — | — | + |
| Jul.[1]) | + | ++ | +++ | ++ | +++ | — | — | ++ |
| Aug.[1]) | + | + | +++ | ++ | +++ | — | — | ++ |
| Sep. | + | ++ | ++ | + | +++ | — | — | ++ |
| Oct. | + | ++ | +++ | + | +++ | — | — | + |
| Nov. | ++ | + | ++ | — | +++ | — | — | — |
| Dec. | ++ | + | ++ | — | +++ | — | + | — |

+ Present occasionally
++ Present in small quantities
+++ Present in fair quantities
++++ Present in abundance

Table 16 D

Qualitative estimation of forms constituting the plant and animal food during the different months of the year 1954, *Tilapia zilli*

| Month | Diatoms | Fil. Red | algae Blue-green | Higher plants | Crustacea | | Insect larvae | Mollusc |
|---|---|---|---|---|---|---|---|---|
| | | | | | Copepod | Amphipod | | |
| Jan. | ++++ | ++ | + | ++++ | ++ | + | ++ | — |
| Feb. | ++++ | + | ++ | +++ | ++ | + | ++ | + |
| Mar. | ++++ | + | ++ | +++ | ++ | + | ++ | — |
| Apr. | ++++ | + | +++ | ++ | ++ | + | ++ | — |
| May | ++++ | + | +++ | ++ | ++ | + | + | — |
| Jun. | +++ | ++ | +++ | ++ | +++ | + | + | — |
| Jul.[1]) | ++ | ++ | ++++ | ++ | ++++ | + | + | — |
| Aug.[1]) | ++++ | ++ | ++++ | ++ | ++++ | + | + | — |
| Sep.[1]) | ++ | ++ | ++++ | ++ | +++ | + | — | + |
| Oct. | +++ | + | +++ | ++ | ++ | + | — | — |
| Nov. | +++ | + | +++ | ++ | + | + | — | — |
| Dec. | +++ | + | +++ | +++ | + | + | — | — |

+ Present occasionally
++ Present in small quantities
+++ Present in fair quantities
++++ Present in abundance

in the diet of that fish. The fact that this species is a bottom feeder might be responsible for the presence of these shells which usually cover the whole bottom of the lake. In this report one has to mention that although *Tilapia* is often a bottom feeder, yet the

[1]) Many alimentary canals during that month were found empty.

presence of shells in its alimentary canal was comparatively very seldom. One wonders wether these observations may indicate that *Solea* is really feeding on molluscs. Settling this question is left for future investigation. The contents of the *Solea* were also charakterised by the presence of a larger number of amphipods (*Gammarus* sp.) and mosquito larvae as well as chironomid larvae, than observed in the contents of the other species of fish examined.

The only reference in the literature which mentions the blue-green algae as food of fishes is that of WALCH and SCHUURMAN STEKHOVEN (1929) and NAGUIB (1954).

From this examination it could be observed that the species of *Tilapia zilli* and *Mugil cephalus* tend to utilize more plant material than animal food. Their alimentary canal contents usually greenish. The reverse was observed for the *Solea*. *Mugil capito* seems to utilize both animal and plantmaterial in almost the same proportion.

It is of interest to note that diatom consumption was less during summermonths during which time the diatom crop of the lake was poor (fig. 29). On the other hand the copepod utilization was greater during summer when the lake was richer in zooplankton population.

## General discussion

The physical and chemical factors that operate in lake Qarûn just described are discussed in a way to show their interrelations and their influence on biological productivity.

It does not seem possible to designate any single factor or influence as the sole cause of the periodic maxima and minima observed for the planktonic crop of lake Qarûn. Doubtless they were the result of the interplay of a combination of factors acting at different intensities. There are reasons for considering the multiple enents, concerned in the productivity if the lake, as having some intimate relations to the nutrients present on the one hand, and to some other chemical and physical factors on the other hand; the biological productivity being the end result of the interaction of the organisms present with the surrounding environment.

An outburst of phytoplankton was conspicous during winter and early spring, followed by a sudden marked decline during summer. Lake Qarûn, of the tropical type, did not show the bimodal nature usually described for temperate lakes (McCOMBIE, 1953).

It is not easy to generalize and designate any one factor as being more important than any other, in a complex natural environment where all of the numerous known factors operate simultaneously.

As regards temperature, it certainly plays an important rôle in the manifestation of life in water. Lake Qarûn did not show a proper thermal stratification. According to the classification, modified lately by THIENEMANN (1922), lake Qarûn is to be considered among tropical lakes of the third order[1]). The maximum surface water temperature recorded was 32,5° C; 10,7° C being the minimum, i.e. the water surface temperature undergoes a seasonal change within a range of 22 ± 1° C, corresponding to a change of 27 ± 1° C of air temperature (Table 1). Moreover, in the regions of the shores the maximum temperature reached was more than 40° C.

The higher summer temperature had a direct bearing on the lowering of the lake level (fig. 2), and on the increased salinity in summer (fig. 6), as caused by the excessive evaporation.

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[1]) However, according to the most recent classification of REMANE and SCHLIEPER (1958) lake Qarûn is to be considered among the polyhalines (= brachyhalines Wasser-Polyhalinikum) having salinities ranging from 18—30 ‰. Furthermore, the term (Mixo-)polyhaline was given to indicate the same salinity range of water bodies in the "Venice-System" (1958) for the classification of marine waters according to salinity.

Apart from the possible strain to which the flora and fauna in the lake are probably submitted and "were forced" to tolerate a difference in temperature within a range of 22$^0$ C; the inhabitants of the shore regions are subjected to still more extreme temperature fluctuation. This great change in temperature seems to affect the fish adversely, particularly as it is known that fish larvae and young fish invade the peripheral shallow parts of the lake which are subjected to greater temperature fluctuations. This important feeding ground of the lake is totally inaccessible as it is dried up during summer because of the high temperature which lowers the level of the lake.

The controlling effect of water temperature on the growth rate of phytoplankton is indicated in the frequent reports concerning the increase of phytoplankton in spring with rise in water temperature (RICKER, 1937 for Cultus lake, British Columbia; DAILY, 1938 for lake Michigan; WELCH, 1938 as cited from MCCOMBIE; LUND, 1949 in experimental work; SPENCER, 1950 for Quabbin reservoir; etc.). However MCCOMBIE, (1953) surveying earlier work, pointed out the lethal effect of high temperatures on phytoplankton production.

The harmful effect, and sometimes lethal, of high temperatures on the different developmental stages of fishes was pointed out by many investigators (JOHANSEN and KROGH, 1914; EMBODY, 1921; HUNTSMAN, 1942; SILLIMAN, 1943; MANKOWSKI, 1948; BRETT, 1952; BLACK, 1953; BISHAI, 1954; GIBSON, 1954; GIBSON and FRY, 1954; etc.).

As regards salinity, the mean salinity value of lake Qarûn for the year 1954, could be given as 22%. Accordingly, this when compared with the salinity values of other lakes (CLARKE, 1924; ABBRUZZESE and GEVONESE, 1952; WELCH, 1952; etc.), as well as the salinity of the ocean being 35$^0/_{00}$ (SVERDRUP, et al., 1949), puts lake Qarûn among the "highly brackish" water lakes. The earliest determination of the water salinity of this particular lake was made by LUCAS in 1906. This author found a value of 13.42 grm./liter and 5.584 grm./liter of total dissolved solids and chlorides respectively. Later, BALL (1939) reported the salinity values of this lake, from 1919 to 1933, clearly showing a gradual increase. The values presented varied from 16.2 and 11.2 grm./liter of total dissolved solids and sodium chloride respectively in 1919, to 25.5 and 17.7 grm./liter in 1933. This progressive increase of the salinity of the lake with the lapse of years is due to the fact that continuous quantities of dissolved salts are poured into the lake via the drains, while no salts are leaving the lake, since it has no outlet. Consequently, if the volume of water in the lake remains constant its salinity would steadily increase.

The general distribution of salinity was controlled by two main factors: The influx of the drainage water, invading the lake through the drains, mainly the "Bats" drain from the east, and the "Wadi" drain from the mid-south (see fig. 1) is the cause of the relatively less saline surface layers, specially obvious at the mouth of the drains. This charakter manifested itself progressively throughout the different regions in the lake, as the fresh drainage water fans from the drains; less marked at the far west, but more conspicuous in the double-fed regions receiving water from either drains and lying about the middle of the lake.

The minimum value estimated for the salinity of the water during the year 1954, was 17.9$^0/_{00}$ (in December) for the surface, and 21$^0/_{00}$ (December) for the bottom; while the maximum value was about 25.5$^0/_{00}$ for both surface (in August) and bottom (August and September). In other words, the lake was submitted to a seasonal change in salinity within a range of 7.5% and 4.5% for surface and bottom water respectively.

The salinity of the water is important in maintaining the proper osmotic relationship between the protoplasm of the organisms and the water. Stenohaline animals "succumb" quickly when subjected to small changes in salinity, in contradistinction from euryhaline animals having a higher degree of tolerance to wide range changes in salinity. Many interesting have been made concerning the ability of animals to survive changes in salinity (PACKARD, 1918; BLUM, 1922; THORPE, 1927; SCHLIEPER, 1932; BEAUFORT, 1936; PEARSE, 1939; etc.). However very few studies have been made on the osmotic relations of diatoms (GROSS, 1940). This represents a very interesting field for future investigation in this lake. The effect of salinity on the survival and distribution of marine and fresh water fishes has been studied by many authors. Its effect may be direct by affecting the survival of fish or indirect by affecting the amount plankton which constitute the main food of the plankton feeders and the early larval stages of fishes JOHANSEN, 1927; POULSEN, 1930, 1931, 1937; HENSCHEL, 1936; GUNTER, 1945; WALFORD, 1946; MANKOWSKI, 1948; KÄNDLER, 1950; ALÄNDER, 1952; JENSEN, 1952; LAUZIER, 1952; etc.). The lethal effect on increasing the salinity on fishes was demonstrated by BERT (1871), RAMULT (1927), HUNTSMAN and HOAR (1939), CHAISSON (1934), AUVERGNAT and SACONDAT (1941), BUSNEL et al. (1941, 1946), BISHAI (1954) etc.

The degree of resistance of fresh water fishes (predisposition) to increased salinity of water medium can be increased by acclimatization as shown by many investigators (BERT, 1871, 1873, 1883; RAMULT, 1927; CHAISSON, 1934; BLACK, 1951; etc.).

As has been already pointed, the salinity of lake Qarûnis progressively increasing year after year. It is of interest to remark that *Tilapia zilli*, which is very dominant in the lake today, is the only remnant of the original fresh water fish fauna of the lake. The extinction of the fish fauna, which had once inhibited the lake (*Tilapia nilotica*; *Anguilla vulgaris*; *Lates niloticus*) may be related to the gradual increase of the salinity of the lake.

It appears, therefore, that variations in salinity operate mainly as a selective agency determining the composition of species that make up the population (SVERDRUP, et al., 1949).

Regarding the hydrogen ion concentration, the average pH value of the water of the lake was about 8.2, lying within the range of the pH values observed for the ocean (SOUTHAGATE, 1948), most drainage lakes described by JUDAY, BIRGE and MELOCH (1941), for lake Sweeny (WILSON, 1937), for lake Idko (SALAH, 1947), for Great Slave lake (RAWSON, 1950), for Cowichan lake (CLIFFORD, 1953), etc. However, it is remarkably different from the highly acidic lakes described by JUDAY and BIRGE (1941).

The seasonal fluctuations of the hydrogen ion concentration varied within very narrow limits. However, the surface water pH was in general more sensitive to changes in carbonate concentration. The photosynthetic activity of phytoplankton during winter and spring, with the corresponding utilization of free and half-bound carbon-dioxide and thus tending to increase the pH values, was counterbalanced by the supply of fresh drainage water rich in bicarbonate. The bottom water pH, on the other hand, was observed to decrease in autumn where fermentation processes in the bottom were at a maximum. This was accompanied by a corresponding decrease in oxygen content, an increased organic nitrogen concentration (fig. 20), and increased sulphide production (fig. 28). Similar observations were recorded by HEINRICH (1934) and SEIWELL and SEIWELL (1938) relating oxygen deficiency with decreased decomposition of organic matter; and by WATTENBERG (1937) and STROM (1936) concerning increased sulphide production.

The pH of the lake sediments was slightly lower than that of the water, having an average value of about 7.8 and is still lower in late autumn and early winter, showing a pH of about 7.1. This may be due to the products of fermentation taking place in the bottom sediments during that period.

The hydrogen ion concentration in the aquatic environment may act on the phytoplankton as a "controlling" or as a "lethal" factor, according to its level (McCOMBIE, 1953).

The effect of low and high pH on the survival of fish has been a subject of great interest to many investigators. Low pH was found to be unfavourable for fish survival (JACOBS, 1920a, b; PEREIRA, 1924; JEWELL and BROWN, 1924; PRUTHI, 1927; HALL, 1931; ELLIS, 1937; SOUTHAGATE, 1948; etc.). High pH values were also recorded to be unfavourable (WELLS, 1915; HARVEY, 1928; SCHACH, 1939; BISHAI, 1954, etc.). However, one wonders wether it is possible for fish to be acclimatized to waters of high or of low pH values.

Due to the fact that the pH of lake Qarûn varied within narrow limits and never reached really low or high pH, one is inclined not to regard the prevailing pH values of water as having a limiting effect on the production of phytoplankton and survival of different fauna in the lake.

Concerning the carbonate and bicarbonate alkalinity, lake Qarûn is to be considered of the bicarbonate type. The amounts of carbonate present were found to be too small when compared with the bicarbonate, and in some regions, especially at the mouth of the drains, surface carbonate was almost absent reflecting the character of the fresh drainage water.

The value of carbonate and bicarbonate estimated in lake Qarûn, in terms of $CaCO_3$ for surface water, ranged from 27.0 to 60.5 mg./liter (average: 43.8); and 143 to 175 mg./liter (average: 159) respectively, corresponding to an average of 19.3 and 42.3 mg./liter bound and half-bound carbon dioxide. However for bottom water, values ranging from 24 to 64 (av. 44) and from 137 to 168 (av. 152.5) mg./liter $CaCO_3$ were found for carbonate and bicarbonate respectively. Corresponding of an average, to 19.4 and 41.2 mg./liter of bound and half bound $CO_2$. It could be seen that the changes in carbonate and bicarbonate concentrations for surface and bottom waters occurred within almost similar limits; the range of change in the bound and half-bound $CO_2$ being almost the same.

The average value of bound carbon dioxide for lake Qarûn is higher than that reported for some Wisconsinlakes (JUDAY and BIRGE, 1941), and for the series of the Charlotte County lakes (SMITH, 1952); lower than other Wisconsin lakes (JUDAY, BIRGE and MELOCH, 1941); and apparently of the same order as that of Little John lake (JUDAY, BLAIR and WILDA, 1943).

The fresh drainage water invading lake Qarûn is almost entirely free of carbonate but rich in bicarbonate. CAMPBELL and FUNK, in 1953, that while Black River was almost free of carbonate, it contained a bicarbonate concentration of 110 p.p.m. in terms of $CaCO_3$.

It seems that out of the different factors mentioned by WELCH (1952) affecting the changes in bicarbonate and carbonate concentration and their intertransformation evaporation and shell forming organisms are the most important factors operative in lake Qarûn. The importance of photosynthesis, as one of WELCH's factors, in this respect, is not clear as the lake receives a large quantity of drainage water and continuous fresh supply of bicarbonate during the season of plant outburst. It is of interest to mention that *Lyngbya* sp., of the blue-green algae and present in lake Qarûn, are among the algal forms described by POLLOCK (1919) as being responsible for lime deposition. KINDLE (1927), likewise, presented some evidence which suggest the deposition of lime by diatoms. It is also interesting to note that a large number of Glochidium-larvae were present during winter. These larvae settle down in the following spring forming their shells. The shell formation, as WELCH pointed out, is a process of detachment of the half-bound $CO_2$ causing precipitation of carbonate. This might be taken in consideration when accounting for the decrease in bottom water bicarbonate during spring.

Excessive evaporation during summer, more effective in the shallow regions of the lake, should be regarded as the possible cause of the decreased bicarbonate concentration (WELCH, 1935).

During late autumn and early winter, the $CO_2$ evolved during the fermentation processes taking place in the sediments (ALLGEIER, PETERSON, JUDAY and BIRGE, 1932) should account for the increase in bottom water bicarbonate during that period.

WELCH (1935) considered that continuous removal of the bound $CO_2$ in any lake, particularly that of calcium, without being compensated through fresh supplies, tends to reduce the productivity of the lake, eventhough other consitions tend to increase the availability of other fundamental substances. In time, such lake may become one of the poverty-stricken marl lakes in which the paucity of life is sometimes so conspicuous. The fact that lake Qarûn, in its present state, is not of such type, a continuous supply of $CO_2$, bound and half-bound, being conveyed into it, excludes the possibility that such factor is responsible for the present low productivity of the lake.

Lake Qarûn did not show, as pointed before, thermal stratification, but, on the other hand, it showed a chemical stratification as regards oxygen, particularly during autumn and early winter. It was found, during that period, that the bottom water layers were deficient in oxygen, showing an average saturation of 45 per cent; however in some regions there was complete bottom oxygen depletion. Associated with this oxygen deficiency there was a large increase in organic material (fig. 20), as well as sulphides (fig. 28). Evidence were reported by HEINRICH (1934); SEIWELL and SEIWELL (1938) and WELCH (1952) relating oxygen deficiency with increased organic decomposition. The deficient oxygen bottom favoured the activity of the sulphate reducing bacteria (DANILTCHENKO and TSCHIGRINE, 1926; ZOBELL and RITTENBERG, 1948) thus producing sulphides.

The surface water layers were almost saturated with oxygen except during summer months, high temperature (WELCH, 1952) and increased salinity (FOX, 1907, 1909; PEARSE, 1939) being responsible for the decreased solubility of oxygen. BALL (1939), for lake Qarûn, reported a similar observation. The average minimum and maximum oxygen saturation estimated were 71.5 and 104 per cent respectively.

During the fall and early winter, continuous supply of fresh water through the drains seems to leave the lighter more fresh surface layers on the top of the lake. Since no turn over takes place, the the bottom is stagmated. In such a stagnant bottom, bacteria's action is felt, particularly the sulphate-reducing bacteria, which cause the bottom sediments to stink.

Although this work is not concerned with bacteriological investigations, yet some observations might throw some light on the causes responsible for the oxygen deficiency in the bottom water layers. During autumn there was a sudden and rapid drop in the zooplankton population (fig. 29), apparently not entirely through their consumption, but through their "death". Also it was observed that a huge number of molluscs present at the bottom were "dying" and empty shells were frequently found everywhere in the bottom. So during this "death season" there occurred a "mucky" bottom, caused by the sedimentations of this miscellaneous array of dead organisms, mixed with the original bottom material. It is likely that oxygen deficiency may be the result of bacterial activity in the decomposing sediments, as the ALSTERBERG's theory explains. WELCH (1952) trying to combine the "microstratification theory" of ALSTERBERG and the opponent theory put forward by KUSNETZOW and KARZINKIN (1931), mentions that bacterial action goes on both in the bottom and in the water and that prevailing circumstances in one lake may make bottom decomposition more influential, while in another lake, the suspended bacterial population may play a greater part. However confirmation of this contention needs precise bacteriological studies.

The irregularities in oxygen content and distribution are none the less highly important, and in many restricted instances, the low supply of oxygen, and the hydrogen sulphide associated with this condition, exclude all but anaerobic organisms on or near the bottom. Under these circumstances, there may be not only an exclusion of animal life, but a whole sale destruction of aerobic forms living in higher levels when temporary disturbances resulting from storms or surface cooling cause an upward displacement of these poorly aerated water (SVERDRUP, et al., 1949). JUDAY et al. (1943) pointed out that in Little John Lake the metabolic activities of the phytoplankton in summer are concentrated in the upper three meters, since deeper layers are found depleted of oxygen.

The effect of low oxygen content on the survival and distribution of fish was extensively studied, both under natural and laboratory conditions (KUPZIS, 1901; PATON, 1902, 1904; PACKARD, 1907; WINTERSTEIN, 1908; GARDNER and LEETHAM, 1914; POWERS, 1921, 1922; GARDNER and KING, 1922; THOMPSON, 1925; GARDNER, 1926; GUTSELL, 1929; HALL, 1930; ROOT, 1931; SOUTHGATE, 1933; WIEBE et al., 1934; TOMLINSON, 1935; SEARS, 1936; HUTCHINSON, 1936; WILDING, 1939; MOORE, 1942; PRIVOLNIEV, 1947; HASLER and EINSELE, 1948; GRAHAM, 1949; GANAPATI et al., 1950; FRY, 1951; GIBSON and FRY, 1954; SHEPARD, 1955).

Unfortunately for lake Qarûn there was no available statistical data as regards the monthly fish catch. But more observations of the fish caught during late autumn and early winter showed a marked decrease.

Although light intensity is a factor which deserved recording in the present work, yet the lack of a suitable apparatus for quantitative measurement of light intensity, has confined our observations with regard to that point to a rough qualitative consideration. The fact that there is a shining sun almost all the year round and that the lake makes exact quantitative determination not very necessary.

The presence of the nutrient salts, mainly the nitrogenous compounds, Phosphates, "silicates" and iron were studied.

The nitrate values varied, on an average, between 39 and 54 μg-at./liter of $NO_3$-N. These values are remarkably high when compared with the values reported for the ocean: 0.1—43.0 μg-at./l. (SVERDRUP, et al., 1949); for lake Mendota: 30 μg-at./l., and for some Wisconsin lakes: 0.6—3.7 μg-at./l. (DOMOGALLA, JUDAY and PETERSON, 1925). However the seasonal fluctuations of nitrate concentration in lake Qarûn, varied within 15 μg-at./l. of $NO_3$-N.

The rich nitrate content in lake Qarûn is due to the nitrate rich supply of drainage water of lands fertilized with nitrogenous manure, which during the successive years accumulated to such high values. This nitrate, which is normally consumed by plants (WELCH, 1935; CHU, 1943; RODHE, 1948) and by denitrifying bacteria (GRAN, 1901; BAUR, 1902; BRAARUD and KLEM, 1931; WELCH, 1935) seems to be present in such quantities that are not totally utilized by these consumers.

The fluctuation in the surface water nitrate concentration, as has been described before, followed the distribution of the invading drainage water to the different regions of the lake. The bottom water nitrates, on the other hand, showed a marked increase during autumn and early winter, apparently as the resukt of the decomposition of the organisms settling down to the bottom.

The nitrite concentration was very low, varying on an average within a range of 0—0.125 μg-at./liter of $NO_2$-N.

Nitrite is not a stable end product, so its absence or presence in small quantities might not be so unexpected; (HARVEY, 1926; REDFIELD and KEYS, 1938). SVERDRUP, et al. (1949) gave a range of 0.01 to 3.5 μg-at./l. for nitrite nitrogen in the sea.

The surface water nitrite concentration in lake Qarûn, was almost negligible, varying from 0.045 μg-at./l.; slightly higher in the regions of the mouth of the drains amounting to 0.28 μg-at./l. of $NO_2$-N. On the other hand, the bottom water layers of the lake were almost depleted of nitrite, except during summer where it showed an increase amounting to 0.125 μg-at./l., higher than the amounts recorded for the surface in the same season.

It has already been pointed out, that the surface water nitrites followed the distribution of the fresh drainage water rich in nitrite concentration, throughout the lake. On the other hand, the bottom water nitrites, being higher in summer than that in the surface, indicated its liberation and production at the bottom through some agencies, most probably bacterial. The rôle of nitrite in the nitrogen cycle is discussed later on.

The amounts of organic nitrogen present in lake Qarûn were remarkably high, varying within the range 173—340 μg-at./l. N. For the ocean, the total nitrogen was reported to have an average value of 7.2 (ROBINSON and WIRTH, 1934a and b) and 10 μg-at./l. N (MOBERG and FLEMING, 1934). However, for some Wisconsin lakes, DOMOGALLA, etc. (1925) found the organic nitrogen to range from 300 to 600 mg.-N/$m^3$ (21.5—43 μg-at./l. N).

The surface water organic nitrogen, similar to nitrates and nitrites, followed the distribution of the drainage water supply rich in nitrogenous substances. However, increased concentration of organic nitrogen in the bottom water coincided with the bottom oxygen deficiency observed (fig. 20). HEINRICH (1934); WELCH (1935) and SEIWELL and SEIWELL (1938) have emphasised this oxygen depletion phenomena as a result of bottom material decomposition.

As has already been stated, the nitrite is not a stable end product and its very instability makes it a possible indicator of the state of the equilibrium between the oxidation and reduction making up the nitrogen cycle. The formation of nitrite is either the result of oxidation or reduction processes, through the activity of certain agents mainly the bacteria. Diatoms may contribute to that process of reduction of nitrates to nitrites (ZOBELL, 1935). The presence or absence of the necessary organisms is a bacteriological problem, yet there are a number of considerations from the observed chemical data which might throw some light as regards the position of nitrite in the nitrogen cycle prevailing in the lake.

The formation of nitrite through the agency of bacteria, either nitrifying or denitrifying is the result of either oxidation process from ammonia or organic matter directly (ATKINS, 1926; RAKESTRAW, 1936), or reduction process of nitrates (BRANDT, 1899; BRUJEWICZ, 1931; BRAARUD and KLEM, 1931 etc.). It is generally believed that the process of nitrate reduction should be carried out under strictly anaerobic conditions or at least very poor in oxygen content. The fact that nitrite production in the bottom water of lake Qarûn, was during the summer months, in which the bottom was rich in oxygen points to the impossibility of nitrite formation as a result of reduction of nitrate by denitrifying bacteria. Therefore, it looks very probable that nitrites were formed in the lake through oxidation of ammonia or organic nitrogenous substances. ATKINS (1930) and RAKESTRAW (1936) came to a similar conclusion in their investigations in the sea.

The phosphate concentration in lake Quarûn varied, on an average, between 0 and 0,7 μ-at./l. of $PO_4$-P during the successive months of the year 1954. For the sea, it was reported to vary between 0 and 0,3 μ-at./l., whereas in the ocean it varied between 0,20 and 3,5 μ-at./l. JUDAY et al. (1928) found that in 15 Wisconsin lakes, the total phosphorus content ranged from 0,012 to 0,040 mg./l. of surface water 0,4—1,3 μ-at./l., whereas for deep water, from 0,017 to 0,75 mg./l. 0,54—24,3 μ-at./l.) were detected. These authors, however, considered these values to be small. The same authors, in 1931, for some other Wisconsin lakes reported the mean quantity of soluble phosphorus in surface water to be 0,03 mg./l. (0,1 μat./l.), ranging from 0 to 0,015 (0—0,5 μ-at./l.). The ranges reported by the latter authors are apparently of the same order as the phosphate concentration estimated by FULLER and COOPER (1946) for the lakes in Mount desert island region of Maine; by HAYES (1947) for the Nova Scotia Fisheries and by SMITH (1952) for the Charlotte County lakes.

The surface phosphate concentration in lake Qarûn showed a gradual increase from late autumn to early spring, dependant upon the distribution of drainage water, relatively rich in phosphates, in the different regions of the lake. RILEY (1937) also pointed that phosphates are supplied by the rivers. However, during summer, surface water was free of phosphate. As for the bottom phosphates, it showed increase during autumn and early winter, then began to decrease, together with the surface phosphates, till depleted completely during summer. In the following autumn the phosphates began to increase again. It is noticed that phytoplankton outburst coincided with the high concentration of phosphate which occurred during winter and early spring; e.g. maximum phosphate utilization by phytoplankton took place during that time. Phosphate concentration after that decreased gradually, and was noticed, by analysis, to be completely absent during summer. In the following autumn, the fresh supply of drainage water and the decomposition of bottom sediments accounted for the observed reincrease and bottom phosphates respectively.

For the seasonal variation in phosphate concentration, PHIFER and THOMPSON (1937), at Friday Harbor, found maximum values in winter and lowest in summer, due to phytoplankton utilization. Similar observations were recorded by SAWYER in 1947 in the Madison lakes he studied.

Regeneration of phosphates from the decaying dead plants and animals was proved by COOPER (1935a), finding a more rapid regeneration from animal plankton than from diatoms. However, SVERDRUP, et al. (1949) emphasises that in nature regeneration requires three to four months. This might explain the observed maximum phosphate concentration in Lake Qarûn during winter from the decaying sediments in autumn.

Investigators in their studies on the nitrogen and phosphorus distribution in water, attempted to find out the ratio N : P. REDFIELD (1934) showed that, regardless of the absolute concentrations, a constant ratio exists between the nitrate-nitrogen and phosphate-phosphorus content of sea water, amounting to N : P = 20 : 1. He added further that these elements are apparently removed from the water by organisms in the same proportions in which they occur and that on the death and decomposition of the organisms these elements are returned to solution simultaneously. COOPER (1938a) proposed a modified ratio (N : P = 16 : 1), pointing out that the phosphorus data used by REDFIELD has not been corrected for salt error.

The average nitrate-N and phosphate-P values — calculated from tables 9 A and 12 A, showing values of the successive months of the year 1954 — were 43.3 and 44.2 μ-at./l. of $NO_3$-N and 0.31 and 0.41 μ-at./l. $PO_4$-P for the surface and bottom water respectively in lake Qarûn. It could be seen that the ratio between the concentration of nitrate-N and phosphate-P present in the lake was of the order 140 : 1 for the surface and 110 : 1 for the bottom water (giving an average ratio 125 : 1 for the whole lake). The high nitrate concentration was due to the continual accumulation of this nutrient richly supplied by the drainage water. It should be emphasised, however, that according to the following discussion, this ratio should not be taken to represent the ratio of utilization of nitrates and phosphates.

In lake Qarûn there are so many variables: — the fresh drainage water supply rich in nutrients which invades the lake during certain seasons and which affects phytoplankton outburst; the zooplankton grazing the phytoplankton; the animal omnivores, particularly fishes, devouring both zoo- and phytoplankton; apart from the other direct factors as temperature and salinity, etc. Under these prevailing conditions, it looks rather difficult to resort to a method which would calculate in an exact way the ratio N : P utilization by plankton. Yet, calculations made on basis of the difference between the maximum and minimum concentrations of surface nitrate-N and surface phosphate-P during the successive months of the year 1954 (see tables 9A and 12A), would point to the fact that surface nitrate and surface phosphate values varied within limits of 9.6 $\mu$-at./l. N and 0.6 $\mu$-at./l. P. On such basis, the utilization ratio between nitrate-N and phosphate-P could thus be taken roughly as 16 : 1. Similar interpretation to find the N : P ratio based on the difference between the winter maxima and summer minima in $PO_4$-P and $NO_3$-N was undertaken by COOPER (1938a) who found the ratio N : P to be also 16 : 1, i.e. of the same order detected in lake Qarûn.

It is clear then, that the ratio between the concentration of nitrate-N and phosphate-P present in lake Qarûn was totally different from that of their utilization. However, this does not seem to agree with the view presented by REDFIELD (1934) who stated that nitrates and phosphates are removed from the water by organisms in the same proportion in which they occur. On the other hand, the present finding in lake Qarùn gives further support to the view of EINSELE (1941) who experimentally proved that the ratio of nitrogen to dry matter in phytoplankton is almost the same whether the plankton comes from nitrate rich or nitrate poor media. The author adds further that "phytoplankters do not appear to store nitrogen but take up sufficient for there immediate metabolic requirements". It looks apparent that N : P utilization by phytoplankton is of the order 16 : 1 irrespective of the actual prevailing nutrient concentrations. SVERDRUP, et al. (1949) stated that "the utilization of nitrates and phosphates in the synthesis of organic substance proceeds at an aproximatly parallel rate, so that although might become markedly reduced by plants, the ration of the two approaches 15 atoms of nitrogen to one atom of phosphorous with some deviation called "anamoly of the nitrate phosphate ratio". One has to add further that in order to establish definitely the actual N : P utilization ratio, one has to analyse the proper consumers of these nutrients.

As regards silicates, the average value in lake Qarûn ranged between 8 and 99 $\mu$-at./l. $SiO_3$-Si. It is almost agreed among the different investigators that difference in silicate concentration is correlated with organisms utilizing silicon for their shells, particularly diatoms (PEARSALL, 1923; KING and DAVIDSON, 1933; CHANDLER, 1942; SPENCER, 1950; etc.).

The silicate cycle in lake Qarûn showed a rather different rythm from the nitrate and phosphate cycles discussed. The main cause of that difference lies in the fact that while nitrate and phosphate content of drainage water flows freely to the different regions of the lake, the silicates, on the other hand, undergoes gradual precipitation on coming in contact with the lake water (see TWENHOFEL, 1939). This explains the difference in the time of fluctuations observed in the concentrations of nitrates, phosphates and silicates in surface water. On the other hand, the bottom water nitrates and phosphates showed increase during late autumn and early winter (figs. 14 and 21), while gradual increase of bottom water silicates was observed during late autumn till summer.

Regeneration of phosphates and nitrates from the decaying dead animals: zooplankton, molluscs, fishes, etc. (see COOPER, 1935a) a process which in nature requires three to four months would account for the observed increase in the bottom water concentration of these two nutrients. Redissolution of sedimentary silicates should account for the gradual increase in bottom water silicates observed in late autumn till summer. Since KING and DAVIDSON (1933) has proved that redissolution of diatom shells takes place within five months from their deposition, might explain the gradual increase of bottom water silicates observed in late autumn resulting from the decaying diatom shells in summer. Furthermore, the observed continuous increase of bottom silicates till summer. points to the presence of another source of bottom silicates. This might be the result of the redissolution of the contained diatoms in the alimentary tracts of the dying animals during autumn, the diatom shells being undigested (NAGUIB, 1954), or of the precipitated silicates or of both. The fact that silicates were only produced in the bottom would be seen clearly in the far more deep western regions, where there was a gradual increase of silicate concentration from bottom to surface. A similar observation was reported by SVERDRUP, et al. (1949).

It was found not possible to calculate the amounts of silicates utilized in the phytoplankton production in winter and spring, since during that period silicate concentration showed a gradual increase outranging utilization.

As regards iron, it was found that the total soluble iron concentration varied within the range of 0.95 and 2.5 $\mu$-at./l. Fe. COOPER (1937a) considered that the amount of ferrous or ferric salts in the sea was probably less than 2 $\mu$-at./l. while the total iron amounted to 10 times more.

The fluctuation in the total soluble iron content in the surface water of lake Qarûn followed the distribution of the fresh drainage water throughout the different regions of the lake. The total soluble iron content in the bottom water was found, on the other hand, to be produced within the bottom layers, together with the nitrates and phosphates, as a result of the decomposition of the sediments during late autumn and early winter. That bacteria may be directly involved in the solution and precipitation of iron oxides, is mentioned by TWENHOFEL (1939).

The importance of iron for plant growth has been demonstrated by CZAPEK (1920), BRANDT and RABEN (1920), SJÖSTEDT (1921), GRAN (1931), THOMPSON and BREMNER (1935), HARVEY (1937), RODHE (1948), etc.

Though the earlier data available about iron do not point to the exact rôle of iron cycle in natural waters, yet it could be seen from the data of the present investigation that it was not very far from the other nutrients nitrates and phosphates.

The characteristic odour of hydrogen sulphide in the water of the lake, and the presence of black stinking sediments in some regions of the lake, could hardly escape notice.

The maximum production of sulphides in the lake sediments was found to be during autumn and early winter. The same picture was reflected in the bottom water as shown by its content of hydrogen sulphide (see table 13 A).

That the sulphate reducing bacteria contribute to the formation of hydrogen sulphide has been definitely proved (HUNT, 1915; RIDGWAY, 1930; AHLFELD, 1937; MURZAIEV, 1937; STURM, 1937; IYA and SRYNIVASAYA, 1945a& b). Also these bacteria are responsible for the formation of metallic sulphides observed in deposits (MURRAY and IRVINE, 1895; DOSS, 1912; SCHNEIDERHOHN, 1923; TRASK, 1925; ELLIS, 1925; BASTIN, 1933; COPENHAGEN, 1934; etc.). However, putrefacturi bacteria might be a possible cause for the formation of $H_2S$ (IVANOV and TREBKOVA, 1959). These authors ascertain that the main bulk of $H_2S$ in lake Solenoe is formed in the mud sediments through activity of sulphate returing bacteria, since their number exceeds considerably that of the putrefacturi bacteria which form $H_2S$ from proteins. ZOBELL and RITTENBERG (1948) found that sulphate-reducing bacteria are active only in strictly anaerobic conditions. This might explain the increased production of sulphides and hydrogen sulphide in lake Qarûn sediments and bottom water during late autumn and early spring (fig. 28), where the bottom was found to be deficient in oxygen. Also the same reason could account for the high production of sulphides in the sediments which lie under a sandy cover in the northern sandy shores (table, 13B) where conditions below this sandy cover are almost anaerobic.

COPENHAGEN (1934) reported that the hydrogen sulphide might be lethal to flora and fauna if produced in sufficient quantities.

In the Black sea, the hydrogen sulphide was reported to be as high as 3,000 mg./l. (DANILTSCHENKO and TSCHIGRINE, 1926), whereas a range from 1.48 to 6.17 cm./l. of bottom water was given by NIKITIN (1931). IVANOV and TREBKOVA in 1959 reported amount of 0.9—3.2 mg. $H_2S$/l mud per day in the deep parts of lake Solenoe and amount of 5 mg./l. in shallow regions. However, in some Norwegian fjords, STRÖM (1936) reported its presence in values amounting to 22 ml.l/. The highest value estimated in the bottom waters of lake Qarun was 1.14 mg./l. Although this concentration of the hydrogen sulphide in the bottom water of this lake looks rather low as compared with the amounts dedected in other waters, as mentioned above, yet the effect of these sulphides in lake Qarûn cannot be finally established before future thorough investigation.

The phytoplankton production is dependant upon many factors which act together in a coordinating manner. The presence of a factor or factors in minimal quantity may limit the phytoplankton growth, according to the LIEBIG's law of minimum.

The importance of nutrients in regulating and — under certain conditions — limiting the growth of phytoplankton has long been emphasised by BRANDT (1899), MARSHALL and ORR (1927), SCHREIBER (1927), GRAN (1930), HENTSCHEL and WATTENBERG (1930), CHU (1943), RODHE (1948), GERLOFF (1950 & 1952), etc.

The importance of nitrogenous substances in their inorganic forms, particularly nitrates, for phytoplankton growth was pointed out by PHIFER and THOMPSON (1937), EINSELE (1941), CHU (1942, 1943), RODHE (1948), WELCH (1952), etc. Nitrogen deficiency may result, not only in a limitation of phytoplankton growth but also in a limited chlorophyll production and yellowing of the cells (CHU, 1943; RODHE, 1948). CHU (1942) found that phytoplankton survived and grew in nitrogen concentration up to a least 100 p.p.m. (about 7,000 $\mu$-at./l. N). On the other hand, the same author in 1943 proved experimentally that an increase in nitrogen concentration was accompanied by increased inhibition of phytoplankton growth.

Lake Qarûn is richly supplied with nitrates. The maximum nitrate concentration estimated for surface water amounted to 50 $\mu$-at./l. of $NO_3$-N, the minimum to 40 $\mu$-at./l. These amounts, according to CHU's data (1942) are much below the lethal concentration. The fact that nitrates were never exhausted from the lake at any time of the year indicates that nitrates could not be looked upon as a possible limiting factor.

The main nitrate consumers are the plants, including algae, weeds and phytoplankton (CHU, 1943; RODHE, 1948; WELCH, 1952; etc.), as well as denitrifying bacteria (GRAN, 1901; BAUR, 1902; BRAARUD and KLEM, 1931; WELCH, 1935; etc.). It should be noticed that maximum utilization of surface nitrates by phytoplankton in lake Qarûn during winter and early spring, was masked by the supply of drainage water, its nitrate content outranging the amounts utilized. However, the utilization of nitrates and phosphates in the lake was roughly calculated to be within the ratio N : P = 16 : 1 by atoms.

The changes in phytoplankton crop almost followed the same rythm shown by the surface nitrates.

The important rôle played by the phosphates in controlling, and sometimes considered limiting, for the phytoplankton growth has been pointed out by CHU (1943) RODHE (1948), McCOMBIE (1950), GERLOFF (1950, 1952).

RODHE (1948) observed that the content of assimilable phosphorus in lakes varies with an interval below 0.06 p.p.m. (1.9 μ-at./l. $PO_4$-P), and on the basis of his field and laboratory studies he classified phytoplankton according to their phosphorus requirements. His data indicated that the green algae requirements was higher than that of the diatoms, agreeing in this respect with CHU's data (1943). McCOMBIE (1950) noticed the abundance of green algae when the nutrient supply (including phosphorus) was increased by fertilization. Inspite of the fact that phosphates occur in insufficient concentration in lake Qarûn, it is shared by both diatoms and blue-green and red algae. This adds more to the deficiency of phosphates available for diatoms.

The seasonal changes in the seasonal phosphate concentration was shown to be maximal in winter and early spring and depleted in summer. The phytoplankton crop (as shown by diatoms, fig. 29) followed the same rythm. The fact that the phytoplankton concentration became minimal during summer, in almost the same time when the water was almost free of phosphates, points to the important rôle of phosphates as being a limiting factor for phytoplankton growth.

The importance of silicate in building the skeletal shells of diatoms, was pointed out by PEARSALL (1923), ATKINS (1926), HARVEY (1928), KING and DAVIDSON (1933), COOPER (1935), CHANDLER (1942), SPENCER (1950), etc.

The seasonal rythm of the silicate concentration did not coincide with that of phytoplankton, for some reasons already discussed page 00. The maximum utilization of silicates by diatoms should occur during the phytoplankton outburst in winter and early spring. Apparently the silicate production exceeded utilization by diatoms, since silicates showed gradual increase during this period of utilization. Silicates, therefore, should not be regarded as a limiting factor.

Little has been written about the importance of iron for phytoplankton growth, though iron is known to be an important constituent of plants. The importance of iron for phytoplankton was clearly demonstrated in the work of GRAN (1931), THOMPSON and BREMNER (1935), HARVEY (1937), RODHE (1948), etc. Moreover GRAN and RODHE believed that low concentration of iron might result in limiting or causing poor growth of phytoplankton.

As for lake Qarûn, the total soluble iron content, though small, yet it was never exhausted at any time of the year. This should point to disregard iron as a limiting factor for phytoplankton production.

The plankton crop of lake Qarûn was relatively poor. Diatoms and copepods were found to form the largest bulk of plankton catch. The maximum average values of 104,300 diatoms and 56 copepods were found per liter of water. The plankton population in lake Qarûn is almost of the same order as that found for lake Mendota, Wisconsin, by BIRGE and JUDAY (1911). From the data presented by the same authors, together with WILDA in 1943 for Little John Lake, it could be seen that it contained an average of 48 diatoms per milliliter for surface water in August 1941.

The plankton population in lake Qarûn did not show the general bimodal nature exihibiting two maxima (one in spring and one in autumn) and two minima (one during summer and one during winter) as described for dome temperate lakes by many investigators: BIRGE and JUDAY (1922), McCOMBIE (1953), ATKINS (1952), WELCH (1952), etc.

The plankton population in the region of the mouth of the drains was found to be remarkably low.

It is interesting to report that examination of the plankton population in the water within the drains, showed a fresh water fauna and flora of which *Daphnia* sp. and *Spirogyra* sp. were abundant. These fresh water species were never detected elsewhere in the different regions of the lake, not even at the mouth of the drains. This means that the planktonicfauna and flora in the lake are not derived from that contained in the drainage water invading the lake, since these seem to perish on their admixture with the more saline water of the lake.

No attempt was made for a systematic classification of the phytoplankton and zooplankton of the lake. But a general microscopic examination of the phytoplankton showed that it was almost formed of diatoms of the general *Nitzschia* and *Synedra*. Similar abundance of diatoms composing most of the phytoplankton crop was found by DAMANN (1943) in lake Michigan, CHANDLER and WEEKS (1945) in western lake Erie, SPENCER (1950) in Quabbin reservoir and McCOMBIE (1953) on reviewing some earlier investigations in different lakes. On the other hand, the zooplankton was almost exclusively formed of copepods, including the different copepodite stages. The larvae of chironomids were also present, remarkably abundant during spring. The presence of a large number of Glochidium-larvae, specially pronounced during early winter, did not escape notice, since, as mentioned before, lake Qarun is characterised by its large population of molluscs. The most abundant genera of Crustacea present are: *Acartia* and *Diaptomus* and to a lesser magnitude the different developmental stages of Leander and Gammarus sp. The latter form was observed to by highly aggregated on the shore, specially intermingled with the algal filaments, red and blue-green, densely covering the southern shores.

Trials to explain the presence of these planktonic forms in the lake, which are mainly marine, has lead to the supposition that in ancient times a connection existed between the mediterranean and the lake. But the fact that as mentioned before, young fish breeds are caught from the sea and are transported alive within waters from their original habitat and are introduced into the lake since 1928, throws doubt that this is the only explanation. However, to prove the origin of the planktonic fauna and flora in the lake needs informations about the different species present in the lake before 1928. WIMPENNY (1936) gave a somewhat detailed account concerning the zooplankton population in lake Qarûn during the period 1930—1931. He mentioned the presence of only three species: *Diaptomus salinus*, *Leander squilla* and *Moina salinarum*. *Acartia*, one of the abundant and dominating species present nowadays in the lake was not present since 1930. It seems probable then, that presence of this latter species, a marine form and newly introduced into the lake, supports the idea that it was mechanically transported to the lake during the process of introducing the marine fish breeds, and was apparently able to be acclimated to the new environment. It is worth mentioning, in that connection, that *Balanus* species, which is a typical marine form, is found in abundance in that lake.

The vital importance of the phytoplankton organism as producers of the primary food supplyofnatural waters, being drawn upon the countless number of herbivorous plankton animals has long been recognised (HENSEN, 1887; LOHMANN, 1908; DAKIN, 1908; ESTERLY (1916); LEBOUR (1922); MARSHALL (1924); etc.

The two hypotheses — grazing (HARVEY, 1934; HARVEY, COOPER, LEBOUR and RUSSEL, 1935) and animal exclusion (HARDY, 1936) — were put forward to account for the fact that there is, by no means always, an inverse relationship between the quantities of zooplankton and phytoplankton. An attempt to resolve between the hypotheses of grazing and exclusion or to determine which may be the more important was undertaken by BAINBRIDGE (1953). This author obtained results from which he suggested that the exclusion mechanism, as a means of producing the inverse relationship, is of much more restricted occurrence.

In the present investigation horizontal plankton collections from surfaces and subsurface water were obtained under "conditions" which would make vertical escape of plankton organisms minimal. It was considered that such plankton collection would, in a way, represent the actual crop of the lake. The relative shallowness of the lake would favour this consideration. An inverse relation between zooplankton and phytoplankton, though not so absolute, yet it was all the same observed. Therefore, it can be assumed that the grazing of the copepods devouring the phytoplankton should be considered as more possible than the exclusion phenomenons.

During the present work it was found that the dominating species of fish in lake Qarûn are: *Tilapia zilli*, *Mugil cephalus*, *M. capito* and *Solea vulgaris*. These forms were found to be of the omnivorous predators on phytoplankton and zooplankton feeding as well on any diet available in their surrounding, with a preferential plant diet (of phytoplankton, filamentous algae and fragments of higher plants) in case of *Tilapia zilli* and *Mugil cephalus*. *Solea* sp. on the other hand, seem to utilize more of the animal diet composed of *Gammarus* sp. and mollusc forms.

As it is expected, the phytoplankton consumption, as observed on analysing the alimentary tract contents of fishes of the lake (table 16), was found to be less during summer months when the phytoplankton crop of the lake was poor (fig. 28). On the other hand, the zooplankton utilization was greater during summer when the lake was richer in zooplankton population. It is apparent that the different species of fish in the lake seem to depend to a certain extent on a planktonic diet, consequently, fish production is influenced by shortage in phytoplankton and zooplankton crop in the lake.

Unfortunately there are no statistical data available for the monthly catch of fishes which feed on plankton. Such data, if available, would help, by simple calculation, to decide whether the drop in plankton population has resulted from fish consumption or from their death, as discussed before. In spite of that, most of the evidence available seem to indicate that the sudden fall in plankton population happened principally as a result of the death of plankton.

Many of the problems involved in the direct utilization of dissolved organic matter await solution. The conclusion that such direct utilization does occur seem now to have more positive support than in the past. That there is some absorption of substances from the water by the smaller soft bodied forms seems established. Possibly forms as high as the fishes may absorb a slight amount of dissolved substance, but the securing of a large proportion of their nutriment in this way, as has been postulated, appears very doubtful.

## SUMMARY AND CONCLUSION
(Part 1 and Part II)

1. Lake Qarûn, the field of the present investigation, occupies the lowest part in the Faiyum depression which lies about 100 kilometers to the southwest of Cairo. The lake is a closed basin with no apparent outlet. It receives drainage water of the neighbouring cultivated lands through a system of twelve drains among which the "Bats" and "Wadi" drains are the main channels joining the lake at the east and middle south sides respectively, while the rest of the drains are very small and add comparatively little water to the lake.

2. The important physical and chemical factors that are thought to affect the biological productivity of the lake were studied and discussed:

3. a. Lake Qarûn did not show a proper thermal stratification to justify BIRGE's rule which formulates a vertical decrease of $1^0$ C for each one meter of water, for lakes to be considered as undergoing thermal stratification.

b. Lake Quarûn is to be considered, according to the classification of THIENEMANN (1922) as a tropical lake of the third order.

c. The high summer temperature has a direct bearing on the lowering of the lake level (fig. 1) and on the increased salinity in summer (fig. 6), as caused by the excessive evaporation.

d. The possible strain to which the flora and fauna of the lake are probably submitted and have to tolerate a difference in temperature of $22^0$ C (maximum temperature $35.7^0$ C and min. $10.7^0$ C) is discussed page 196.

4. a. Lake Qarûn is considered to be of the "highly brackish" lakes; the mean salinity value, during the year 1954, was found to be about $22^0/_{00}$ (max. salinity for surface and bottom: $25.5^0/_{00}$; salinity for surface: $17.9^0/_{00}$ and for bottom: $21^0/_{00}$).

b. The general distribution of salinity in the different regions of the lake and its fluctuations during the successive seasons is controlled, on the one hand, by the influx of the fresh drainage water which invades the lake during autumn and early winter, and, on the other hand, by temperature.

c. The salinity of lake Qarûn has been found to increase year after year, due to the accumulation of salts conveyed into it through the drains, the lake being a closed basin. The effect of salinity on the survival and distribution of the fauna and flora is discussed page 198. It is noteworthy to mention, in that connection, that *Tilapia zilli* is almost the only remnant of the original fresh water fishes of the lake, which included formerly *Tilapia nilotica, Mugil cephalus, Mugil capito* and *Lates niloticus.* Apparently *Tilapia zilli* was the only species able to tolerate, till now, the progressive increase in the salinity of the water of the lake.

5. The pH of the water of the lake varied within narrow limits, the average pH value during the year 1954, was about 8.2. The factors affecting changes in the hydrogen ion concentration are discussed (see pages 201). The pH values of the sediments were found to be lower, especially during late autumn and early winter (pH = 7.1). This may be due to the products of increased fermentation taking place in the bottom during that period. One is inclined to disregard the prevailing changes in pH in lake Qarûn, being within narrow limits, as having a limiting effect on the production of phytoplankton or on the survival of the different fauna in the lake.

6. Lake Qarûn is to be considered of the "bicarbonate type", the amounts of carbonate present were found to be too small when compared with the bicarbonate (average carbonate concentration: 43.8 mg./l. and av. bicarbonate 159 mg./l., in terms of $CaCO_3$). The fresh drainage water invading the lake is rich in bicarbonate and is almost free of carbonate. The main factors, operative in lake Qarûn, affecting the changes in carbonate and bicarbonate concentration and their intertransformation, as well as the corresponding changes in the bound and half-bound carbon dioxide, is discussed (see page 202 and 203).

7. Lake Qarûn exhibited chemical stratification as regards oxygen saturation, especially marked during autumn and early winter. During that period the bottom water layers were deficient in oxygen, showing an average saturation of 45%; however, in some regions, there was complete bottom water oxygen depletion. Associated with this bottom oxygen deficiency there was an increase in the bottom water organic material

(fig. 20) and increase suphide production in the sediments (fig. 28). The possible factors operating in the lake and which might cause such phenomenon, and the theories put forward to explain the bottom oxygen deficiency, as well as the influence of this low oxygen content on the survival and distribution of the fauna and flora, are discussed page 205. The surface water layers, on the other hand, were almost saturated with oxygen, except during the summer months, the high temperature and increased salinity being responsible for the decreased solubility of oxygen.

8. The seasonal oscillations of the concentrations of the nutrient salts studied: nitrates, phosphates and iron, were found to follow, in a general way, in their surface fluctuations, the distribution of the fresh drainage waterrich in these nutrients-invading the lake during autumn and early winter. Regeneration of these nutrients seems to be produced from the decaying organisms during the fermentation processes taking place in the lake sediments during late autumn and early winter.

9. The presence and distribution of the nitrogenous compounds in lake Qarûn: nitrites, nitrates and soluble organic nitrogen were studied. The lake was found to be rich in nitrate (average: 46 $\mu$-at./l. $NO_3$-N) and organic nitrogen (av. 256 $\mu$-at./l. N). The rich content of nitrates and organic nitrogen in Lake Qarûn is due to the rich supply of drainage water of lands fertilized with nitrogenous manure, which, during the successive years, accumulated to such high values. The nitrite, on the other hand, was very low, varying on an average within a range of 0—0.125 $\mu$-at./l. $NO_2$-N. The position of nitrite as a link in the nitrogen cycle in lake Qarûn, discussed before page 211 favours the view that nitrites are formed through a process of oxidation of ammonia or organic nitrogenous substances by nitrifying bacteria, rather than through a process of oxidation of ammonia or organic nitrogenous substances by nitrifying bacteria, rather than through a process of reduction of nitrates by denitrifying bacteria.

10. The phosphate concentration in lake Qarûn varied, on an average, between 0 and 0.7 $\mu$-at./l. $PO_4$-P. The water of the lake, surface and bottom, was depleted of phosphates during summer.

11. The ratio between the concentrations of nitrate-N and phosphate-P present in lake Qarûn, during the year 1954, was of the order 125 : 1. On the other hand, the utilization ratio of these two nutrients was found to be of the order N : P = 16 : 1. This, as has been discussed page 217, seems to oppose the view that nitrates and phosphates are removed from the water by organisms in the same proportion in which they occur.

12. The silicate cycle in lake Qarûn showed a rather different rythm from the nitrate and phosphate cycles. The main cause of this difference lies in the fact that while nitrate and phosphate content of the fresh drainage water flows freely to the different regions of the lake, the silicates, on the other hand, undergo gradual precipitation when coming in contact with the lake water. Silicates were found to be produced in the bottom as a result of the redissolution of the shells of the dying diatoms and most probably of the precipitated silicates.

13. The total soluble iron in lake Qarûn varied within the range of 0.95 and 2.5 $\mu$-at./l./Fe.

14. The maximum sulphide production in the lake sediments was found to be during autumn and early winter. The same picture was reflected in the bottom water as shown by its content of hydrogen sulphide. The possible causes affecting sulphide production are discussed (see page 100).

15. The plankton crop of lake Qarûn was relatively poor. Diatoms and copepods were found to form the largest bulk of the plankton crop. The phytoplankton population

in lake Qarûm did not show the bimodal nature usually described for the plankton in temperate lakes. The diatom outburst in lake Qarûn was found to be during winter and early spring-during which time the surface water was rich in nutrients. The sudden drop in the phytoplankton population in summer was coincidant with a similar decrease in the nutrient salt concentrations in the surface water layers. Phosphate is the only nutrient depleted during summer, while the other salts: nitrates, iron and "silicates" were not. Therefore, it was considered possible that phosphates form a limiting factor in the phytoplankton production.

An inverse relation, though not absolute, between the phytoplankton concentration and the zooplankton was observed. From the present investigation the grazing effect of zooplankton on phytoplankton looks a rather possible cause for this inverse relationship than the animal exclusion phenomenon (see page 102).

16. As regards the origin of the plankton fauna in the lake, (as is discussed before page 103 and 104), these forms are not derived from the fresh water plankton forms coming in the lake through the drains, but more possibly they were mechanically transported to the lake during the process of introducing the marine fish breeds, caught from the sea, and transported to the lake. These marine planktonic forms were apparently acclimated to the new environment.

17. The alimentary canal contents of the fishes dominating in the lake: *Tilapia zilli*, *Mugil cephalus*, *M. capito* and *Solea vulgaris* were examined. These fishes seem to depend to a certain extent on a planktonic diet and consequently fish production is influenced by shortage in the phyto and zooplankton crop in the lake.

It seems that the idea of rearing fish in the lake is not wrong in principal though not yet completely successful in lake Qarûn. The introduction of new species in lakes is a process followed, up till now, in different lakes in the world as mentioned by RAWSON (1945) for lakes of the Prince Albert National Park; SCHUSTER (1952) for some lakes in Java; DYMOND (1955) for some lakes in Canada; etc. The choice of the species to be introduced should be based on the knowledge of the new biological environment, and it needs a series of experiments to assure its successful acclimation to this new environment. Moreover, introduction of big numbers of fish breeds into the lake, if not carefully controlled, might lead to the disturbance of the natural equilibrium generally attained in natural waters.

## Zusammenfassung[1])

11. Das Verhältnis der Konzentrationen an Nitrat-N und Phosphat-P in „lake Qarûn" lag im Jahre 1954 bei 125 : 1. Die beiden Nährstoffe wurden dagegen im Verhältnis 16 : 1 verbraucht. Wie auf Seite 217 diskutiert wurde, scheint diese im Gegensatz zu stehen zu der Ansicht, daß Nitrate und Phosphate von den Organismen im gleichen Verhältnis verbraucht werden wie sie im Wasser vorkommen.

12. Der Silikatzyklus in „lake Qarûn" zeigte einen vom Nitrat- und Phosphatzyklus unterschiedlichen Rhythmus. Der Hauptgrund für diesen Unterschied liegt in der Tatsache, daß die Nitrate und Phosphate des Frischwassers unverändert zu den verschiedenen Regionen des Sees gelangen, während die Silikate in zunehmendem Maße ausfallen, wenn sie mit dem Seewasser in Kontakt kommen. Es wurde festgestellt, daß auf dem Grunde Silikate produziert werden infolge des Wiederauflösens von Schalen abgestorbener Diatomeen und wahrscheinlich auch ausgefallener Silikate.

[1]) Teil I der vorliegenden Arbeit (Kieler Meeresforschungen Band XIV, Heft 2, 1958) enthält bereits eine deutsche Zusammenfassung der dort beschriebenen Untersuchungen.

13. Das gesamt-lösliche Eisen in „lake Qarûn" variierte zwischen 0,95 und 2,5 μ-at/l Fe.

14. Die maximale Sulfidproduktion in den Ablagerungen des Sees vollzog sich während Herbst und Winter. Das gleiche Bild zeigte sich an dem Schwefelwasserstoffgehalt des Grundwassers. Mögliche Ursachen, die die Sulfidproduktion beeinflussen, wurden diskutiert (siehe Seite 100).

15. Die Plankton-Ernte von „lake Qarûn" war relativ gering, wobei Diatomeen und Copepoden am häufigsten gefunden wurden. Die Phytoplankton-Population in „lake Qarûn" zeigte nicht die bimodale Natur wie sie gewöhnlich für Plankton in temperierten Seen beschrieben wird. Die Hauptmenge an Diatomeen wurde im Winter und beginnenden Frühjahr gefunden, eine Zeit, in der das Oberflächenwasser reich an Nährstoffen war. Der plötzliche Abfall in der Phytoplankton-Population im Sommer war übereinstimmend mit einer ähnlichen Abnahme der Nährsalzkonzentrationen in den oberflächlichen Wasserschichten. Phosphat war der einzige Nährstoff, der während des Sommers völlig erschöpft war, im Gegensatz zu den anderen Salzen: Nitraten, Eisen und „Silikaten". Aus diesem Grunde wird es für möglich gehalten, daß Phosphate einen begrenzenden Faktor in der Phytoplankton-Produktion darstellen. Ein umgekehrtes Verhältnis — wenn auch nicht absolut — wurde zwischen der Konzentration des Phytoplanktons und der des Zooplanktons beobachtet. Nach der vorliegenden Untersuchung scheint vielmehr der „grazing effect" von Zooplankton auf Phytoplankton als das „animal exclusion phenomenon" die Ursache für dieses inverse Verhältnis zu sein. (Siehe Seite 102.)

16. Was den Ursprung der Plankton-Fauna im See betrifft (wie auf Seite 103 ff diskutiert wurde), so stammen diese Formen nicht von denen des Frischwasserplankton, das durch die Kanäle in den See gelangt, sondern viel wahrscheinlicher wurden sie mechanisch in den See transportiert mit den marinen Fischbruten, die im Meer gefangen und in den See gebracht wurden. Diese marinen Planktonformen adaptierten offenbar an die neue Umgebung.

17. Der Inhalt des Verdauungskanals der im See dominierenden Fische *Tilapia zilli, Mugil cephalus, M. capito,* und *Solea vulgaris* wurde untersucht. Diese Fische scheinen bis zu einem gewissen Grade von einer planktonischen Nahrung abhängig zu sein. Folglich wird die Fischproduktion von dem Angebot an Phyto- und Zooplankton im See beeinflußt.

Es scheint, daß die Idee, Fische im See zu züchten im Prinzip nicht abwegig ist, obwohl sie sich in „lake Qarûn" noch nicht zufriedenstellend ausführen läßt. Die Einführung neuer Arten in Seen ist ein Vorgang, der in verschiedenen Seen der Welt ausgeführt wurde, wie erwähnt von Ramson (1945) für Seen im Prince Albert National Park, Schuster (1952) für einige Seen auf Java, Dymond (1955) für einige Seen in Kanada, etc. Die Wahl der einzuführenden Fische sollte auf der Basis des Wissens um die neue biologische Umgebung geschehen. Es erfordert eine Reihe von Untersuchungen, um die erfolgreiche Akklimatisierung an diese neue Umgebung sicher zu stellen. Darüberhinaus mag das Einführen einer großen Menge von Fischlaich in den See, wenn es nicht sorgfältig kontrolliert wird, zur Zerstörung des natürlichen Gleichgewichtes führen, das sich in natürlichen Gewässern gewöhnlich einstellt.

Acknowledgment!

The author wishes to express his deep gratitude for Professor Dr. F. Khalil, Prof. of Zoology and Head of the Department, under whose supervision this work has been undertaken, for his continuous help and encouragement. The author also acknowledges

his great indebtness to Dr. R. Said, Department of Geology, for identifying the types of molluscs and for his valuable advice during the preparation of this thesis. Thanks are also due to Dr. M. Salah and Mr. M. A. Refät, from the Fisheries Dept. at Alexandria, and Dr. S. Gaid, from the Dept. of Botany, Fac. of Science, Univ. of Cair●, for helping in the identification of the diatom, zooplankton and algal forms respectively. The author is also indebted to the Coast Guard ●ffice and Ministry of Agriculture, for offering facilities and transport in the lake.

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