FURTHER STUDIES ON THE HYDROGRAPHY AND CHEMISTRY OF LAKE MANZALAH

By

SAAD D. WAHBY

SAMY F. YOUSSEF NABILA F. BISHARA

Alexandria Institute of Oceanography and Fisheries Alexandria, U.A.R.

ABSTRACT

The hydrography and chemistry of Lake Manzalah waters were studied during 1967 after the construction of the Aswan High Dam.

The freshwater formerly discharged through the Nile connections during flood time is thought to be compensated by the increased amount of drainage water discharged at the southern and western parts of the lake.

A comparison between the nutrient level of the lake during 1963 and 1967 is given.

INTRODUCTION

Lake Manzalah is the largest of the Delta Lakes of Egypt. In has an area of about 350,000 feddans (171,000 hectars).

The lake is shallow, the mean depth of water rarely exceeds 1 meter. It is connected with the Mediterranean Sea through an opening at El Gamil lying a little distance to the West of Port Said. The lake is also connected with the Suez Canal through a lock at El Kabouti. This permits the passage of fishermen's ships but no water is exchanged freely between the lake and the Suez Canal (Fig.1).

Three canals: El-Souffara, El-Ratama and El-Enaniya join the lake with the Damietta Nile branch North of Faraskour. Before 1965 these canals permitted the introduction of Nile waters at flood time into the lake. After the construction of a permanent barrage at Faraskour in March 1965, Nile water ceased to flow into these canals except in small quantities.

Several big drains pour into the western and southern parts of the lake. Chief among these are the Serw, Hadous, Ramses and Bahr El-Bakar drains.

The maximum length of the lake extends for 64.5 km, the maximum width being 49.0 km, the length of the shore line is 293 km. The area of the lake is 1275 km^2. The shore development, an indication of the irregularity of the shore line is 2.3 (Welch, 1948).

In a previous work (El-Wakeel & Wahby, 1970) presented a thorough study of the hydrography and chemistry of Lake Manzalah before the construction of the Aswan High Dam and Faraskour barrage. The present work displays the preliminary changes of the hydrographic and chemical conditions of the lake water during 1967 after the construction of the Aswan High Dam.

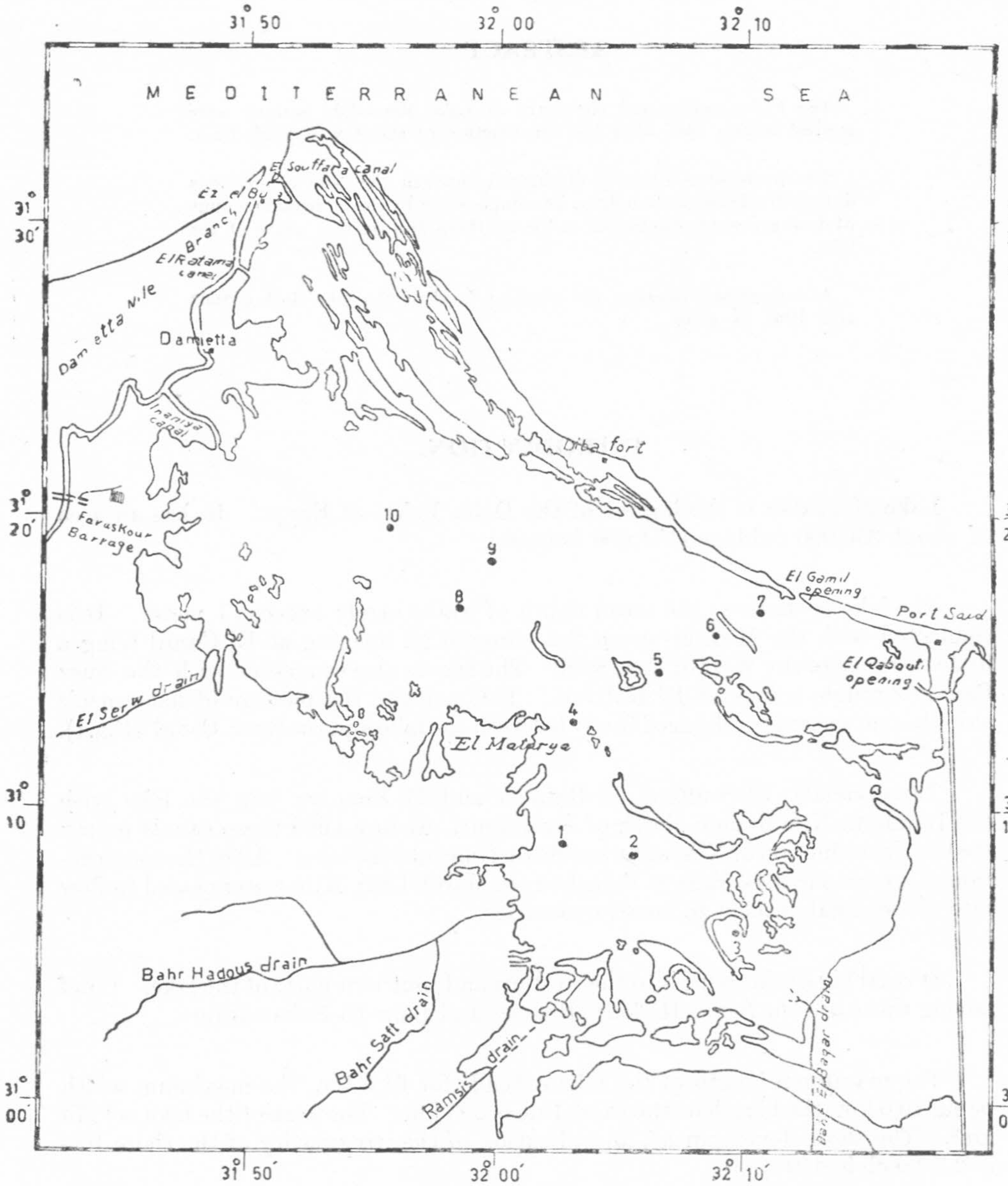


Fig 1 — LAKE MANZALAH
stations of water analysis
SCALE
1 5 K.M

MATERIAL AND METHODS

Samples were collected using a flat type Ruttner sampler one L capacity. The height of the bottle is about 15 cm.

Temperature was measured using a standard thermometer accurate to 0.05°C.

Chlorosity was determined by the ordinary Mohr's method as described by Vogel (1953).

The hydrogen ion concentration was measured by a Helligé pH comparator.

Dissolved oxygen was determined by Winkler's classical method reviewed by Thompson and Robinson (1939). The data are given as ml / L.

Oxygen saturation figures were calculated using Fox's tables (1907).

Phosphates were determined as inorganic soluble phosphates. The method used was that of Deniges detailed and revised by Harvey (1948) and Armstrong (1949).

Nitrates were determined according to Mullin & Riley (1955). Nitrites were determined according to the method of Griess and Ilosvay as modified by Robinson and Thompson (1948).

Soluble silica was determined using Dienert & Wandenbulke method modified by Robinson and Kemmerer (1930).

In all the analyses for nutrients, the results are expressed as ug.at. / L.

Following El-Wakeel and Wahby(1970), the lake was divided into threeregions :

1.—The south-eastern region which receives nearly fresh water from big drains, especially Bahr El-Bakar and Hadous drains.

2.—The north-eastern region of the lake, along the route Mataria - El-Gamil affected by both sea water and fresh water depending upon the level of the lake.

3.—The western region which used to receive fresh water through Suffara, Ratama and Inaniya canals prior to 1965 is now affected by drainage water that pours in the western part of the lake, also by sea water that enters the lake through these canals, in addition to small quantities of fresh water permitted through Faraskour barrage.

In the lake, 10 stations were chosen, 3 in the south eastern region, 4 in the north eastern region and 3 in the western region (Figure 1).

As surface and bottom samples proved to be nearly identical due to the shallowness of the lake and mixing by wind (El-Wakeel & Wahby 1970), in the present work ohly sub-surface samples were collected. Analyses were carried out monthly.

RESULTS AND DISCUSSION

The effect of the physical dimensions of a lake on its population and metabolism is a matter of common observation. The fundamental nature of this relation was expressed by Thienemann (1927) when he demonstrated that the nature of the lake basin and especially its mean depth was a most important factor in determining lake type. The mean depth of a lake is probably as Thienemann believes the most significant dimension. After examining data from many lakes he concluded that most eutrophic lakes have mean depths of less than 18 meters and oligotrophic ones have more.

Lake Manzalah is very shallow, with a mean depth of 120 cm light penetrates to the bottom of the lake and thus the whole volume of water is productive. In addition to the shallowness of the lake, high temperature favours biological productivity. Minimum morning water temperature is 11.3°C in January and the maximum afternoon water temperature is 31.1°C in July.

TABLE 1.—AVERAGE MONTHLY AIR TEMPERATURES TOGETHER WITH THE AVERAGE SURFACE WATER TEMPERATURE FOR LAKE MANZALAH DURING 1967 (IN °C)

Month	8 a. m.		2 p. m.	
	Air temperature	Water temperature	Air temperature	Water temperature
January	12.4	11.3	12.7	12.6
February	14.3	14.2	15.4	16.7
March	15.3	15.5	16.1	19.1
April	20.0	20.5	21.3	25.7
May	24.4	25.1	25.1	29.5
June	26.2	26.5	26.9	30.8
July	27.5	28.1	28.3	31.1
August	26.5	27.0	27.4	30.4
September	25.0	25.4	25.9	28.9
October	23.6	23.7	24.2	25.7
November	20.2	20.4	20.6	21.0
December	15.3	15.0	15.5	16.1

The direct effect on the metabolic activities of phytoplankton caused by temperature variations is controlled by Vant Hoff's law according to which the rate of biological processes may increase two or three times with a rise of temperature of 10.0°C within the tolerable limit (Clarke, 1954). In Lake Manzalah the shallowness of the lake together with high water temperature work in harmony to increase the production of organic matter.

Temperature not only affects the survival and distribution of fish, but also their growth rate, rate of development, activity, activation of reproductive processes and susceptibility to diseases. The sensitivity of fish to various temperatures had been carried out by many investigators (Fry, 1951 ; 1959; Baily, 1955, and Bishai, 1960).

Rainfall occurs only in winter from October to March, while the summer months are dry. The prevailing wind in the lake district ranges between 5-13 knots, such winds usually blows from North to North west in summer.

The direct effect of wind on a shallow body of water as Lake Manzalah is manifested by the continuous mixing of water that permits no thermal stratification to develop. This accelerates heat transfer between air and water and adds to the dissolution of atmospheric oxygen in the water. Accordingly, Lake Manzalah may be classified either as a swamp or a tropical lake of the third order (Whipple, 1918; Welch, 1948).

Salinity is one of the most important factors which affects the survival and distribution of fish at different stages of their life.

TABLE 2.—Ranfall, Relative Humidity And Average Wind Velocity In Lake Manzalah Area During 1967.

Month	Total rainfall mm	Relative Humidity %	Average wind velocity (knots)
January	6.3	71.0	7.7
February	13.3	70.0	10.3
March	18.3	64.0	13.6
April	0.3	71.0	10.3
May	1.1	71.0	7.8
June	zero	68.0	8.2
July	zero	72.0	6.5
August	zero	71.0	6.3
September	zero	68.0	6.0
October	2.0	67.0	5.4
November	18.2	68.0	7.3
December	8.3	72.0	7.0

The effect of salinity may be direct by affecting the survival of fish or indirect by affecting the amount of plankton which constitutes the main food of the early larval stages.

Three mainfactors affect salinity variations in Lake Manzalah :

1.—Drain water discharge.

2.—High summer temperature which accelerates evaporation.

3.—The introduction of sea water into the lake through the lake-sea connection.

The south-eastern region which receives large quantities of fresh water from the drains situated at the southern side of the lake has the lowest chlorosity values ranging between 0.68 g / 1 in December and 2.00 g / 1 in June. The North eastern part has the highest chlorosity values because it is affected by the lake-sea connection. It has chlorosity values ranging between 2.9 g / 1 in October and 10.1 g /l in July. The western region, now mainly affected by drainage water pouring in the Western part of the lake after the construction of Faraskour barrage, has chlorosity values ranging between 1.21 g / 1 in December and 3.12 g / 1 in August.

Chlorosity variations during 1967 are compared with the corresponding values for 1963 (El Wakeel and Wahby 1970) in Figure (2). In 1967 chlorosity values are slightly higher than during 1963 in the South eastern region, slightly lower in the North eastern region and also lower in the western region. The construction of Faraskour barrage deprived the western part of Lake Manzalah of a big part of the fresh Nile water which poured in this region through Souffara, Ratama and Inaniya canals during the Nile flood before 1965. Nevertheless the chlorosity values in the western region did not increase in 1967, this is due to a big increase in the drainage water discharged in the lake since 1965 as a result of big land reclamation projects. Also to fresh-water permitted through Faraskour barrage and introduced into the lake through Enaniya canal which amounted in 1967 to 113 $\times$ 10^6 cubi meters. The total fresh water discharged in Lake Manzalah in 1963 including the previous Nile connections was 5, 858 $\times$ 10^9 cubic meters / In 1967 the total water discharged in the lake was 5,809 $\times$ 10^9 cubic meters, i.e., nearly the same quantity. The quantities of Nile waters previously introduced into the lake through Souffara, Ratama and Inaniya canals are now compensated by drainage water.

Hydrogen ion variations :

In Lake Manzalah, the South eastern region has pH values ranging between 7.9 in April and May and 8.46 in October. In the North eastern region it varies between 8.00 in April and May and 8.46 in February, March and November. In the Western region pH values range between 8.00 in March, April and August and 8.5 in December. Small changes of pH are recorded at the different

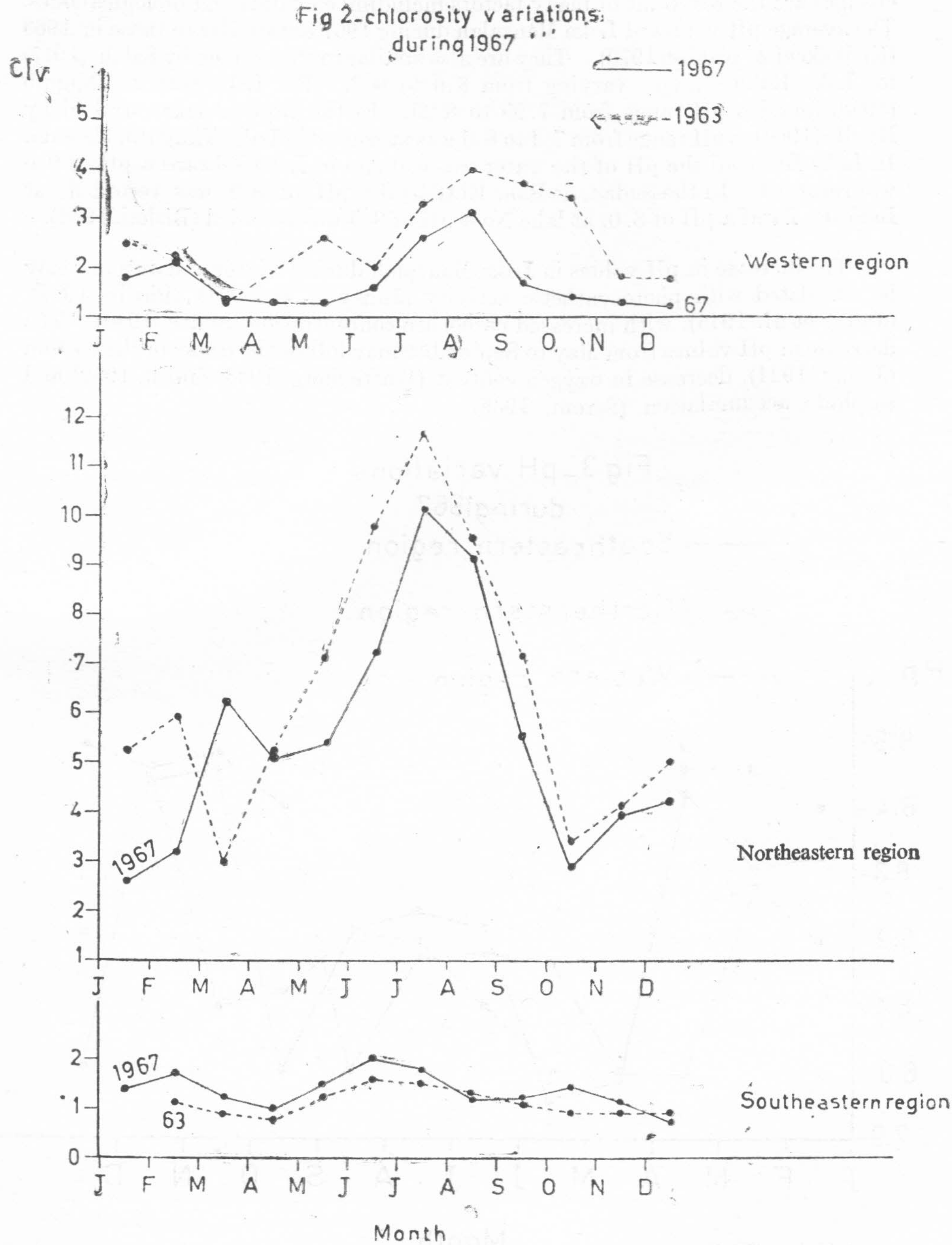
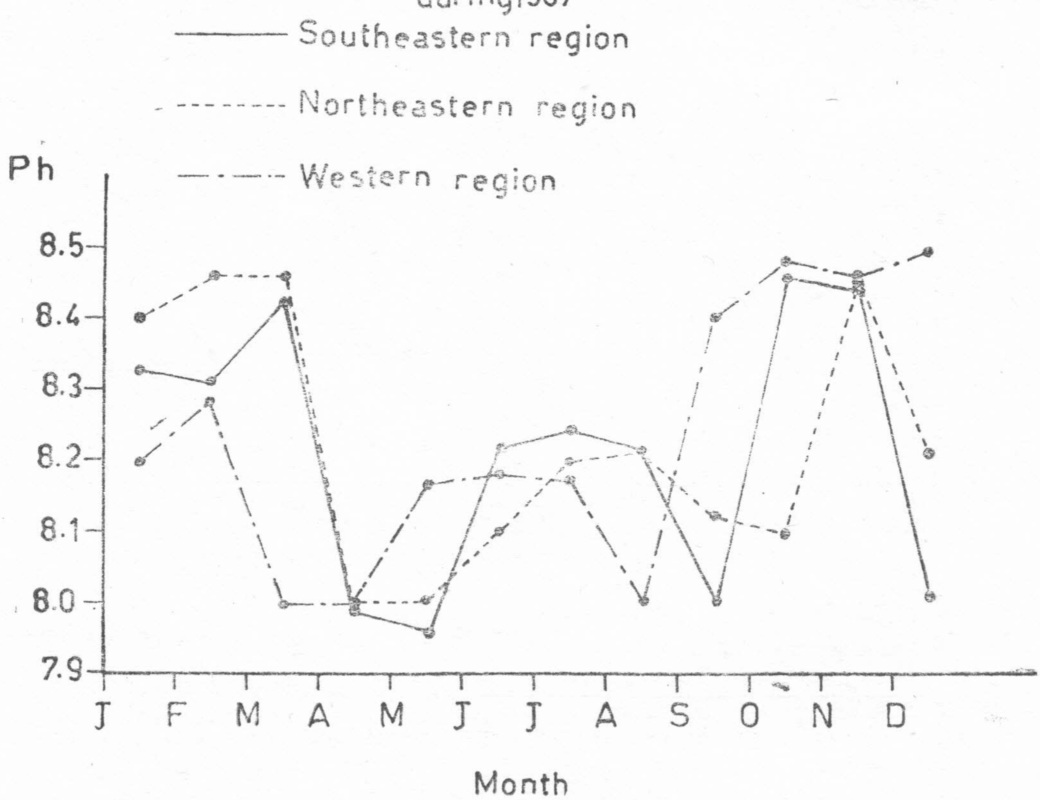


Fig 2-chlorosity variations during 1967
Cl‰
1967
1963
67
Western region
J F M A M J J A S O N D
1967
Northeastern region
J F M A M J J A S O N D
1967
63
Southeastern region
J F M A M J J A S O N D
Month

stations also seasonal variations are recorded and illustrated on Fig. (3). Such changes are the resultant of many factors including chemical and biological ones. The average pH values of Lake Manzalah during 1967 are similar to those in 1963 (El-Wakeel & Wahby, 1970). They are also similar to those given by Salah (1947) for Lake Edku, Egypt, varying from 8.0 to 8.8. For Lake Quarun, Naguib (1958) found a pH range from 7.95 to 8.25. In the tropical lakes studied by Beadle (1966), a pH range from 7.4 to 8.5 was measured in Lake Nkuguto, Uganda. In Lake Bunyoni the pH of the water was 8.0 and in Lake Edward a pH of 9.0 was recorded. In the Sudan, at Bahr El Ghazal a pH of 8.5 was recorded, at Bahr El-Zaraf a pH of 8.0, at lake No a pH of 8.5 was recorded (Bishai, 1962).

The increase in pH values in Lake Manzalah during winter and autumn may be correlated with photosynthetic activity (Juday et al. 1924). (Philip, 1927), (Juday et al. 1943), with increased carbonate concentration (Smith, 1940). The decrease in pH values from May to September may follow the decay in the bottom (Juday, 1924), decrease in oxygen content (Wattenberg, 1933; Smith, 1952) and sulphide accumulation (Strom, 1936).

Fig 3_pH variations during1967



Oxygen variations :

The amount of dissolved oxygen in natural waters is always changeable and its concentration at any time represents a momental balance between the rates of supply and depletion of such gas. Such equilibrium is affected by the physical and biological processes in the water.

In Lake Manzalah, the South eastern region showed maximum oxygen saturation in April 104.3 % saturation. Another smaller maximum extended from September to November. The rise in oxygen saturation values is evidently due to photosynthesis. In the North eastern region oxygen values are higher with two marked maxima, one in April (113.2 % saturation), the other in September (106.5 % saturation). In the Western region the first maximum occurs in May (100 % saturation), the second in September (104 % saturation). (Fig. 4).

The oxygen saturation values during 1967 are of the same magnitude as during 1963 but with a more pronounced maxima.

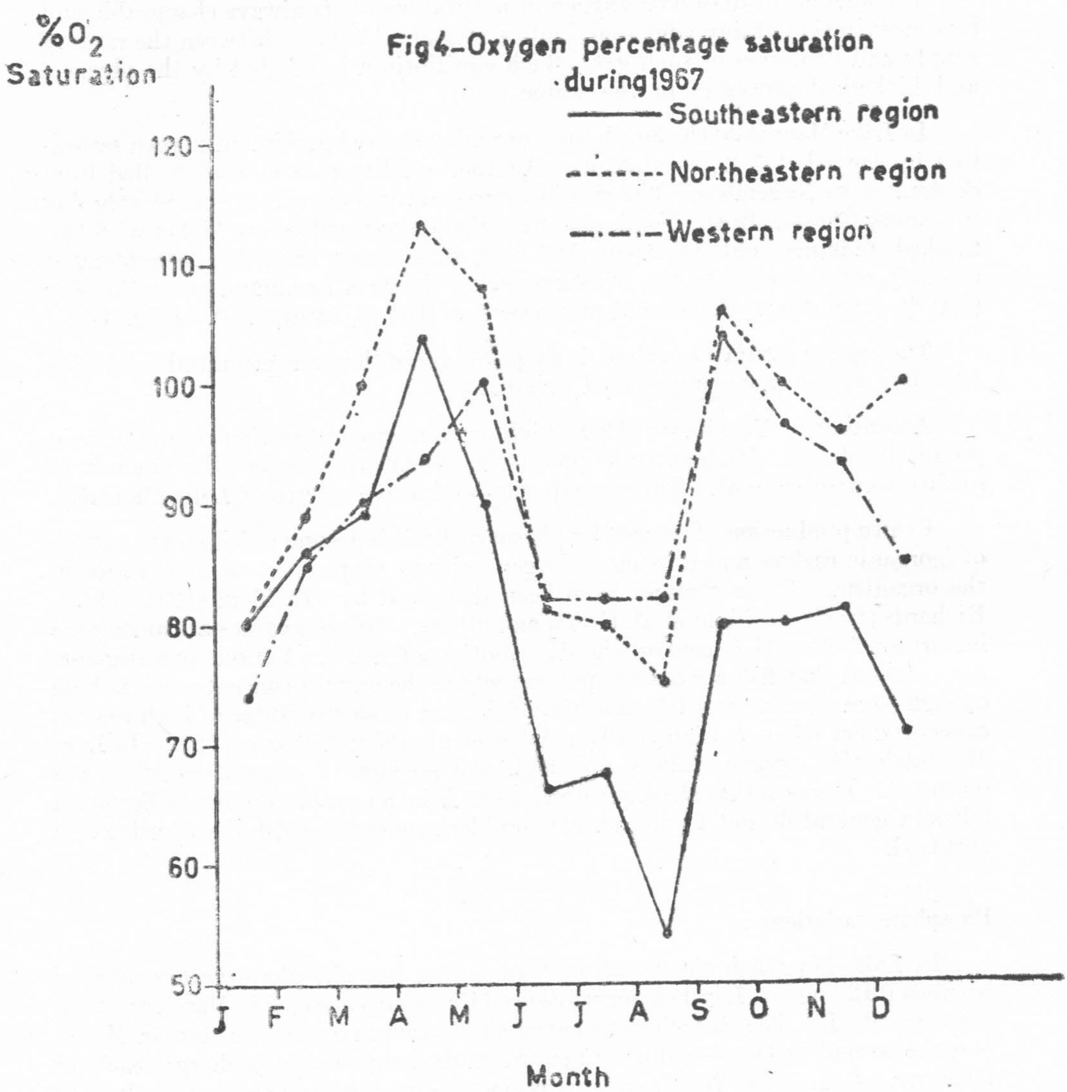
According to Yoshimura (1938) high oxygen supersaturation occurs only in productive lakes. High organic production seems to increase the amount of surface oxygen content. This reveals the productive nature of Lake Manzalah.

In situ production of oxygen by photosynthesis is accompanied by the uptake of inorganic carbon and nutrient ions generally in proportions to their ratios in the organism. These changes have been discussed by Redfield (1934–1942), Richards (1957), Redfield et al. (1963) and others. Oxygen values are among the important factors that control the distribution of fishes. Various investigators have showed that fish are always present where the oxygen concentration is high enough to maintain their life, and that fish tend to choose water of high oxygen concentration (Hile & Juday, 1941; Allen et al. 1958; Alabaster, 1959). In Lake Manzalah the oxygen values are high and no sign of oxygen depletion was observed. It seems that the oxygen values in Lake Manzalah and in the Egyptian lakes in general do not form a special problem concerning fish distribution and survival.

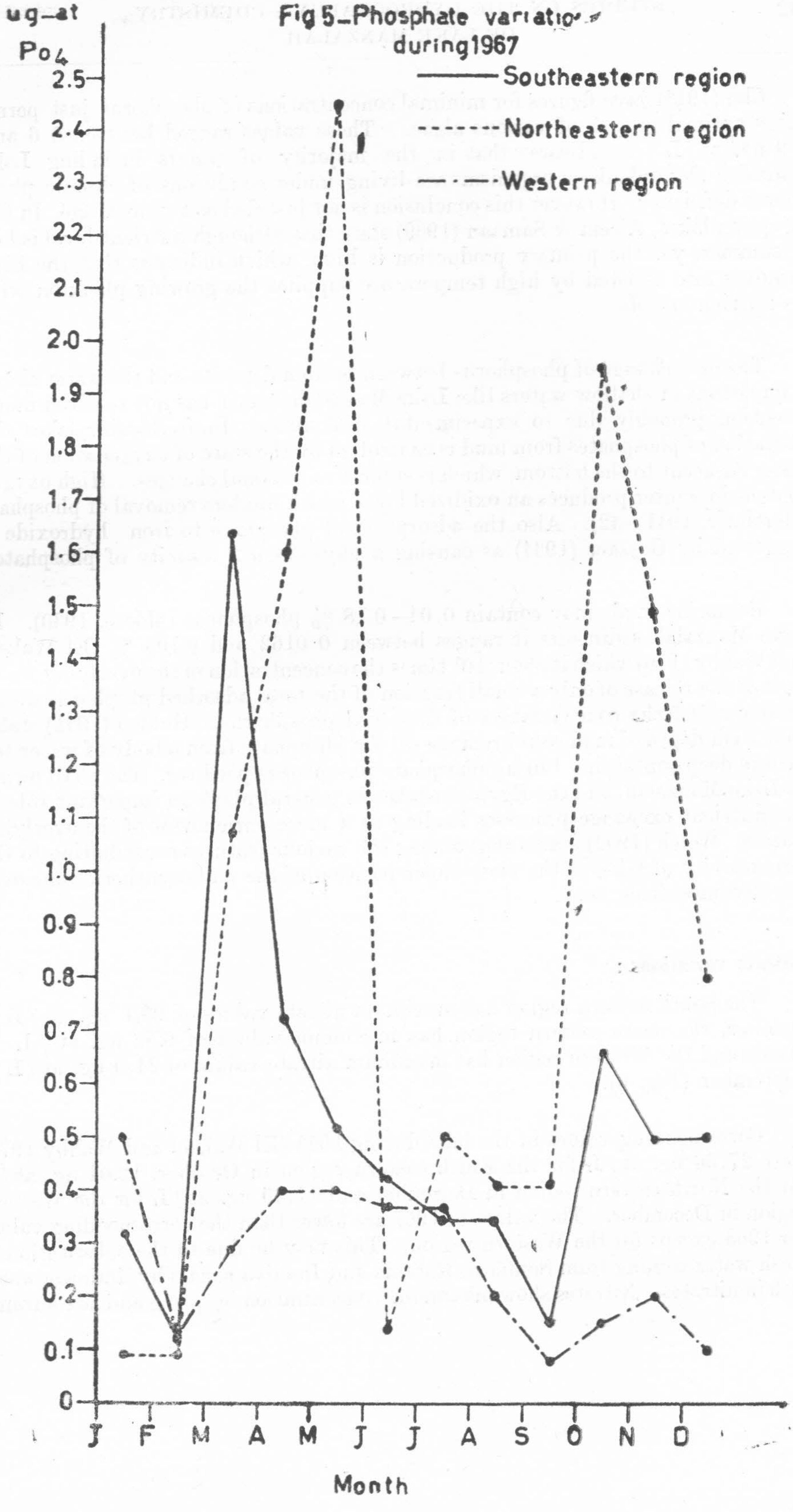
Phosphate variations :

In Lake Manzalah the South eastern region has phosphate values ranging between 0.122 ug. at/L in February followed by a sharp increase in March reaching 1.64 ug. at / L. The distribution curve shows two maxima, the first in March and the second in October during maximum drainage water discharge reaching 0.666 ug. at / L. The North eastern region has maximum phosphate values of 2.44 ug. at / L in May and the Western region has maximum phosphate values of 0.5 ug. at / L in January. Minimum phosphate concentration occurs in summer (Fig. 5).

The corresponding values in 1963 (El Wakeel & Wahby, 1970) were 4.79 ug. at. / L for the South eastern region in February, 1.40 ug. at. / L for the North eastern region in December and 0.80 ug. at. / L for the Western region in October. The values in 1967 are lower in the South eastern and western regions but higher in the North eastern region.



In lakes, phosphorus is affected by both the utilization by phytoplankton, and the interchange between mud and the overlying water. Phosphate concentration may limit the rate of photosynthesis (Goldman, 1961). The waters of oligotrophic lakes often contain less than one thousandth of a milligram (1 ug) of inorganic phosphate per liter. Phytoplankton are able to utilize this trace of phsphorus (Ruttner, 1968). They not only utilize phosphorus in the proportions necessary for their growth and reproduction but they also store phosphorus in their tissues in big quantities if the supply of phosphorus in the water allows it. This fact was established by Einsele (1941) and further confirmed by Rodhe (1948), Coffin et al. (1949), McCarter et al. (1952) and Macereth (1953).


ug-at
Po4
Fig 5_Phosphate variation during 1967
Southeastern region
Northeastern region
Western region
2.5
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
J F M A M J J A S O N D
Month

Chu (1943) gave figures for minimal concentrations of phosphorus just permitting optimal growth of various algae. These values ranged between 0.6 and 2.9 ug. at / L. It indicates that in the majority of waters including Lake Manzalah phytoplankton organisms are living under conditions of chronic phosphorus deficiency. However this conclusion is not justified as a general one. In the Egyptian lakes, Aleem & Samaan (1969) state that although nutrient level is low in summer, yet the primary production is high, which indicates that the high turnover rate assisted by high temperature supplies the growing plankton with its nutrient needs.

The interchange of phosphorus between bottom deposits and the water above is important in shallow waters like Lake Manzalah, but it has not received much attention probably due to experimental difficulties. In freshwater lakes the liberation of phosphates from mud is controlled by the state of oxygenation of the water adjacent to the bottom, which is subject to seasonal changes. High oxygen content in winter produces an oxidized layer which hinders removal of phosphate (Mortimer, 1941 – 42). Also the adsorption of phosphate to iron hydroxide is suggested by Gessner (1934) as causing a physiological scarcity of phosphates.

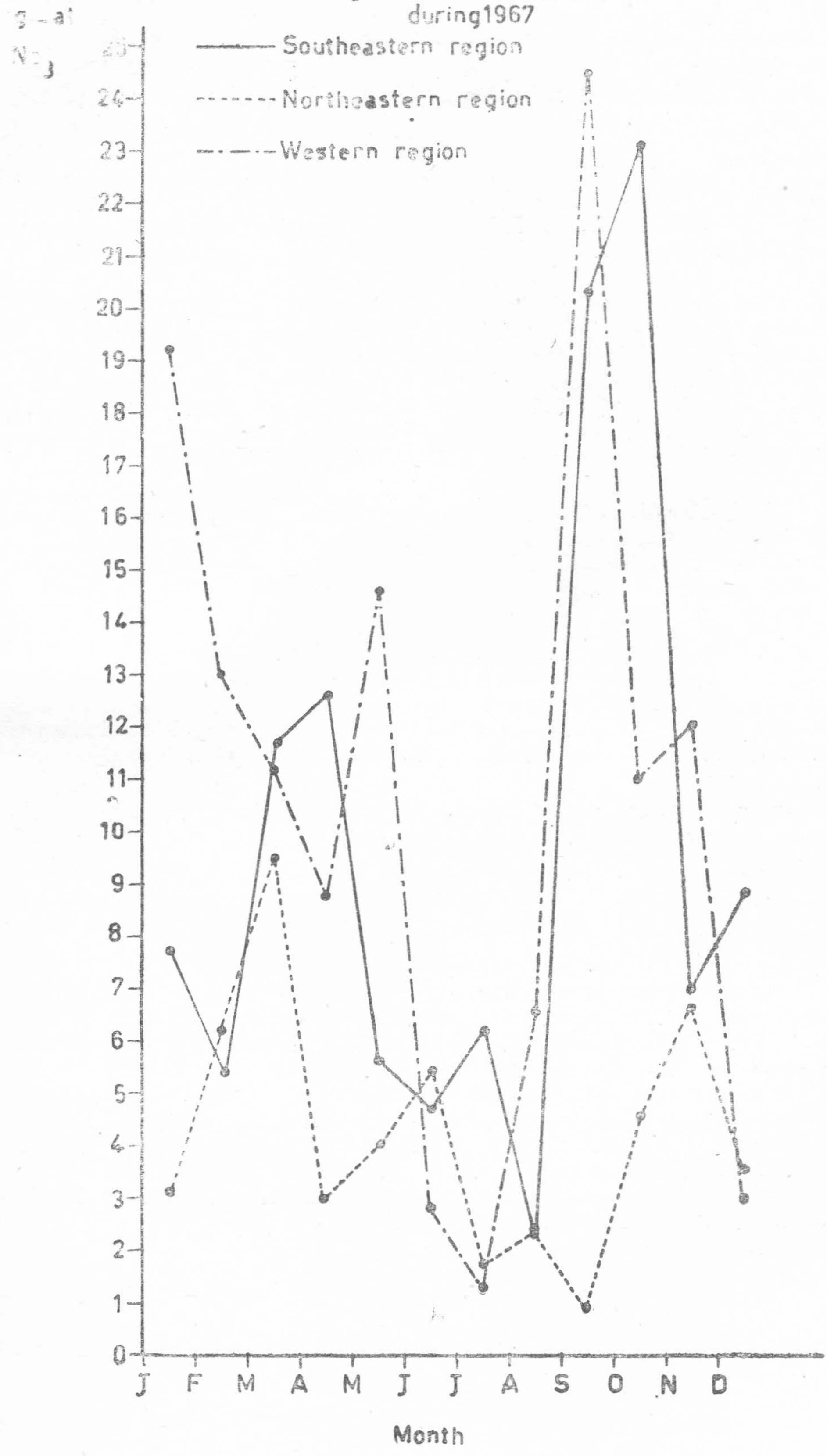
Estuarine muds may contain 0.04 – 0.18 % phosphorus (Moore, 1930). In Lake Manzalah sediments it ranges between 0.0162 and 0.103 % (El Wakeel and Wahby 1970) which is about 10^5 times the concentration in the overlying water so that the release of only a small fraction of the total adsorbed phsphorus would greatly affect the concentration of dissolved phosphorus. Holden (1961) states that 1 cm depth of mud could remove all the phsophate from a body of water ten meters deep containing 140 ug phosphate phosphorus per liter. The shall ownes of Lake Manzalah, and the Egyptian lakes in general plays an important rôle in the nutrient exchange processes leading to a more enrichment of the overlying waters. Welch (1952) states that among the various features contributing to the productivity of lakes is the close super position of the photosynthetic zone over the decomposition zone.

Nitrate variations :

The South eastern region has maximum nitrate values of 23.1 ug. at / L in October, the north eastern region has maximum values of 9.52 ug. at / L in March and the Western region has maximum nitrate values of 24.5 ug. at / L in September (Fig. 6).

Corresponding values in the lake during 1963 (El Wakeel and Wahby 1970) were 27.36 ug. at / L for the South eastern region in October, 12.04 ug. at / L for the North eastern region in December and 17.45 ug. at / L for the Western region in December. The values of 1967 are lower than the corresponding values for 1963 except for the Western region. This may be due to the substitution of fresh water coming from Souffara, Ratama and Inaniya canals by drainage water rich in nitrates. Nitrates show maximum concentration in spring and late autumn

Fig 6 – Nitrate variations during 1967



and minimum concentration in summer. A similar seasonal variation was observed in Lake Manzalah (El Wakeel & Wahby, 1970), Lake Maryût (Wahby. 1961), Samaan (1966), and for Lake Quarun (Naguib, 1958), also in the sea (Vaccaro, 1965).

In the oceans, nitrate concentration varies from 0.1 to 43.0 ug. at / L (Sverdrup et al. 1955). In Lake Quarun nitrates range between 36.8 and 55.9 ug. at / L (Naguib, 1958). For Lake Maryût it ranges between 0.00 and 18.0 ug. at / L (Wahby, 1961).

For any species of plankton there is doubtless a concentration of available nitrogen which if continually maintained would only just be sufficient to support a maximum rate of photosynthesis at I max. (Saturation light intensity). In nature such a constant concentration of nutrients is rarely mantained except perhaps in the tropics and we have only a rough indication of the limiting concentration of nitrate. It is probably safe to assume that this is less than 50 and probably less than 10 ug. $N0_3$ – N / L (Strickland, 1965).

In the Egyptian lakes nitrate concentration falls below the values given by Strickland, but we assume that the rapid regeneration of nutrients assisted both by high temperature and shallowness of the lakes supply the growing plankton with its nutrient demands.

The $N0_3$ / $P0_4$ ratio in Lake Manzalah varies from 1.63 due to nitrate depletion to 306.2. The corresponding values in 1963 (El Wakeel and Wahby, 1970) were zero and 37.9. The increase in 1967 with respect to 1963 is due to the high nitrate level of 1967 than the phosphorus level. The increased introduction of drainage water rich in nitrates than phosphates is perhaps the cause.

In Lake Maryût, Egypt, Wahby (1961) found the $N0_3$ / $P0_4$ ratio to vary between 0.25 and 4.0 due to the high phosphorus content induced by sewage pollution.

Nitrite variations :

In the South eastern region nitrites vary between 0.006 ug. at/L in September and 2.0 ug. at / L in December. In the North eastern region it varied between 0.187 ug. at/L in October and 1.6 ug. at/L in December. In the Western region it varied between 0.00 ug. at / L in August and September and 1.6 ug. at / L in November (Fig. 7). Corresponding values during 1963 in the South eastern region, nitrites varied between 0.1 ug. at/L in June and 10.03 ug. at/L in October. The North eastern region had values ranging between 0.03 ug. at / L in August and 3.45 ug. at/L in April. The Western region had nitrite values between 0.005 ug. at / L in July and 2.09 ug. at / L in November. Nitrite values in 1963 are higher than those in 1967.

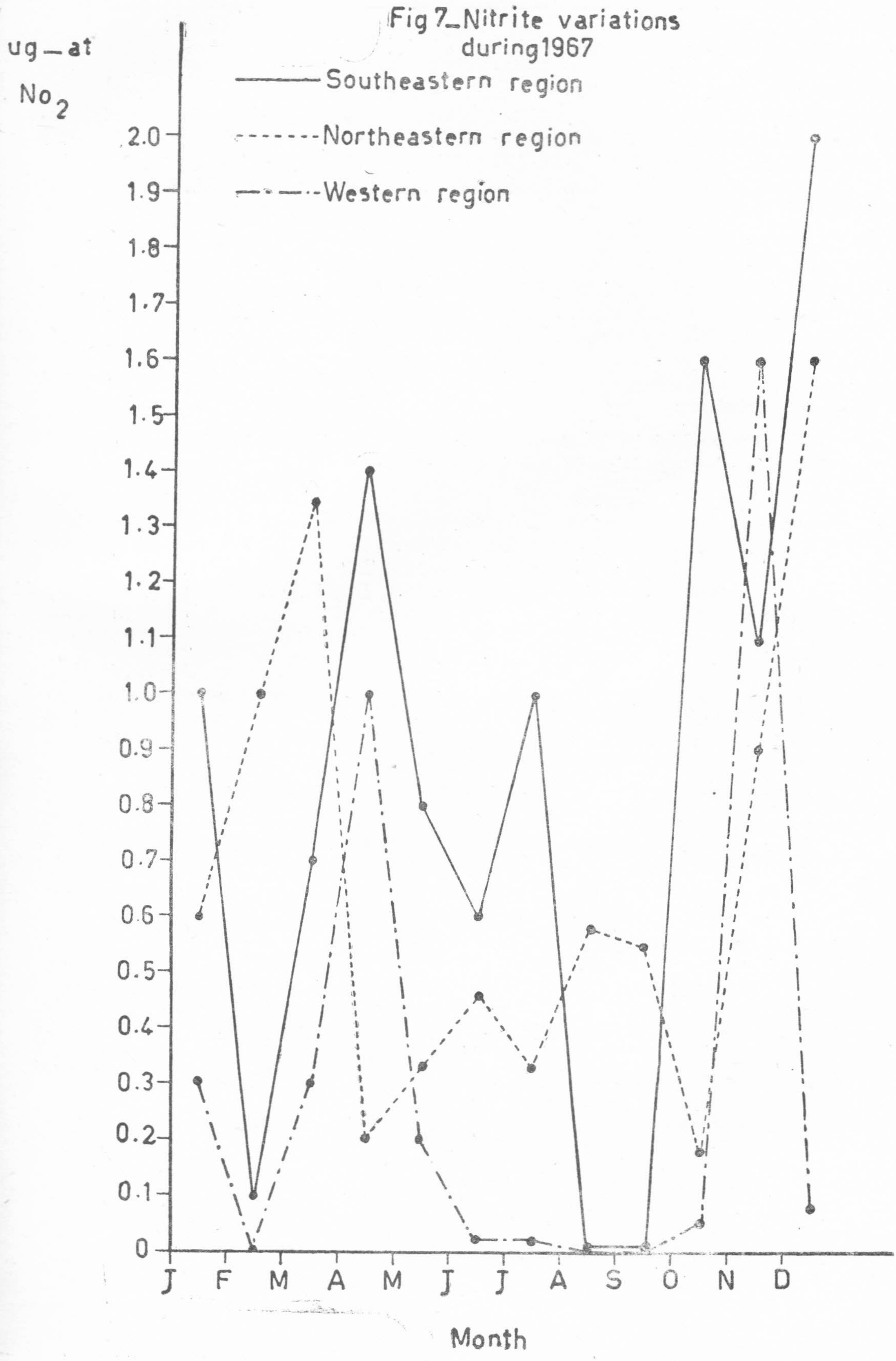


Fig 7_Nitrite variations during 1967
ug_at
No2
Southeastern region
Northeastern region
Western region
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
J F M A M J J A S O N D
Month

Fig. (7) showing the trend of nitrite variations is similar to that of nitrates in Fig. (6). Nitrites are detected only in those months which have high nitrate content which makes it possible to conclude that nitrites are produced as a result of nitrate reduction (Einsele & Vetter, 1938). It seems likely that the nitrite present in summer which tends to vary with the nitrate is produced through the reduction of nitrate (Hutchinson, 1957). Einsele and Vetter (1938) attributed the presence of nitrites to nitrate reduction rather than ammonia oxidation and believed that the seasonal variation reflected variations in nitrate content.

The excretion of extracellular nitrite by physoplankton as observed by Orr (1926), Zobell (1935) and Kessler (1957-1959) may also influence the distribution of nitrite within the surface layers of natural waters (Rakestraw 1936; Hutchinson 1957), Vaccaro & Ryther (1960).

Silicate variations :

Silicates are high in the Egyptian lakes due to the influx of drainage water rich in silica into the lakes (Elster & Gorgy, 1959).

In the South eastern region of Lake Manzalah silicates (SiO_2-Si) range between 144 ug. at/L in June and 474 ug. at/L in October. In the North eastern region it varies between 102 ug. at./L in July and 244 ug.at/L in November. In the Western region silicates vary between 200 ug. / at / L in July and 383 ug.at/L in Sptember and October (Fig. 8).

Corresponding values in 1963 (El Wakeel & Wahby 1970) were 245-616 ug. at/L for the South eastern region, 208-546 ug.at/L for the North eastern region and 282-523 ug./at/L for the Western region. Minimum values are observed in summer and maximum in winter. Values of 1967 are lower than those of 1963 in all the three regions, due to the big reduction in the quantities of clay introduced into the lake as a result of the construction of Aswan High Dam.

In Lake Maryût, Egypt, silicate values range between 30 and 400 ug. t/L (Wahby, 1961).

In the Sudan the following quantities for silicates in the River /Niler we given by Bishai (1960) :

Sobat River	14 p.p.m.
Gazal	12 p.p.m.
Zaraf	8 p.p.m.
Lake No.	14 p.p.m.

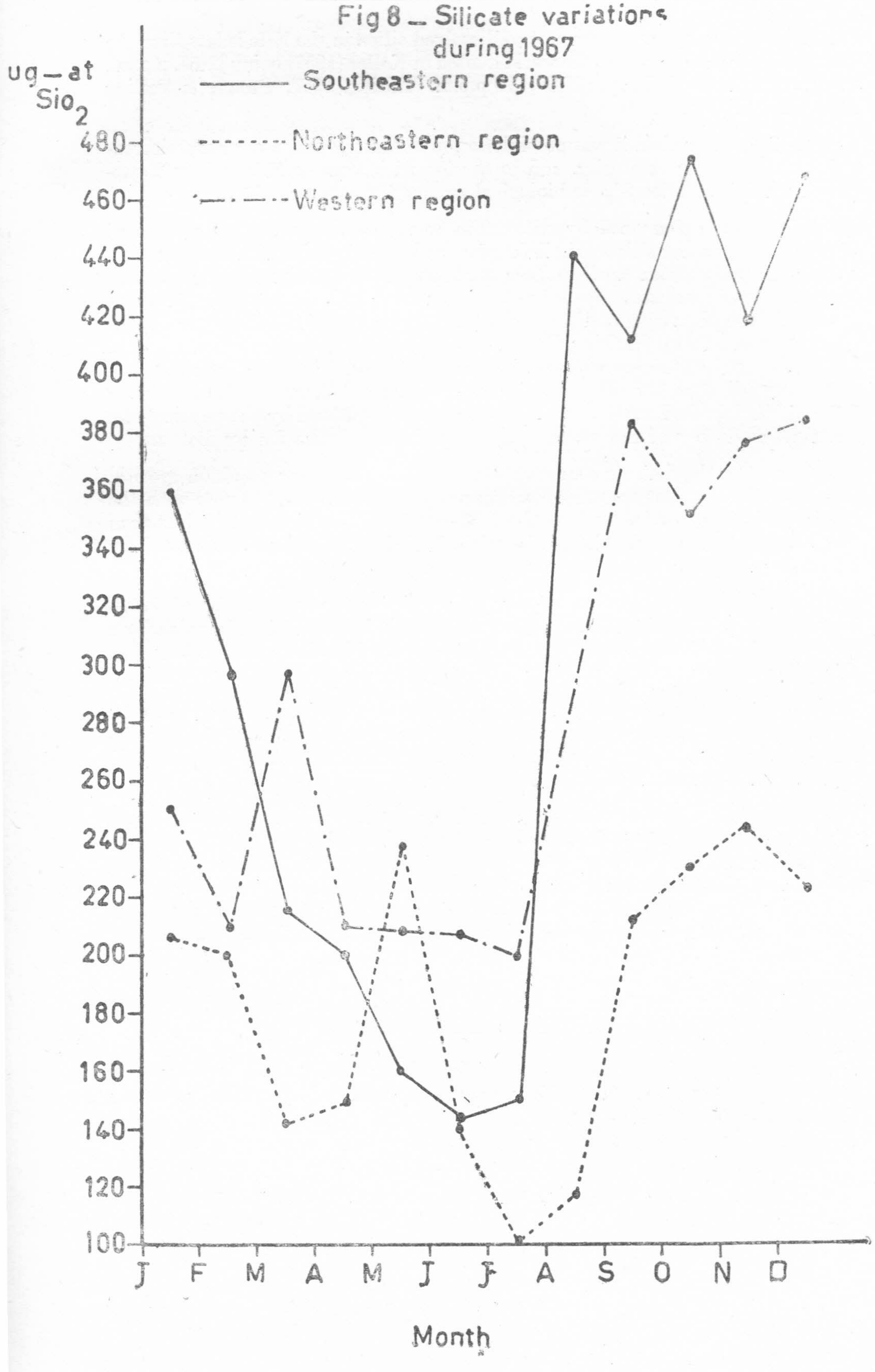


Fig 8 _ Silicate variations during 1967
Southeastern region
Northeastern region
Western region
ug — at Sio2
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
J F M A M J J A S O N D
Month

He also states that the amount of dissolved silica in the Nile is less than the average in the other rivers of the world quoted in Keller (1957) being 11.87 p.p.m., the maximum recorded in the Nile is 10 p.p.m. (Talling, 1957; Prouse & Talling 1958, and Bishai, 1961).

For Lake Manzalah, it was possible to prove that the silicate content decreased with increasing chlorosity, and to ascribe with some confidence any departure from this relationship to biological agents (Armstrong, 1965).

Silicates are consumed by diatoms in spring and summer. The seasonal distribution curve for silicates in Lake Manzalah shows a minimum concentration during the period from April to July, perhaps due to consumption by diatoms. The variation in silicate content has been compared with the amount of diatoms produced both in marine and fresh waters. Atkins (1926) found no proof that silica is even a factor limiting diatom production in the oceans. Meloche et al (1938) observed certain correlations between silica and diatoms in Lake Mendota but concluded that several factors were involved. Samaan (1966), studying Lake Mariût, pointed out that the silicate content is affected by the physical and chemical conditions of the water rather than due to utilization by diatoms.

Concerning the limiting concentration of silicates affecting plankton growth, Strickland (1965) states that this limiting concentration appears to vary with the species of diatoms but is less than about 50-100 ug.Si/L, which is much less than the concentrations found in Lake Manzalah, indicating that silicates do not form a limiting factor for plankton growth.

From the above discussion we may point out that the construction of Faraskour barrage and the High Dam at Aswan, although deprived lake Manzalah from the fresh Nile water previously poured through the Nile-Lake connections, yet this Nile water was compensated by drainage water in nearly the same quatinty.

This drainage water changed the nutrient level in the lake in many respects especially the nitrate-phosphate ratio, and the nutrient distribution in the different regions of the lake. This change may continue for a number of years until equilibrium is maintained.

As a result of the construction of the High Dam at Aswan, the clay content of the water which was estimated in 1963 to be more than 500,000 tons will be enormously reduced. Consequently the concentration of the dissolved silicates will be less. Besides we may expect that the silting at the lake bottom will be slowered and erosion at the shore line especially near the sea will take place with a faster rate. As a consequence of this process the natural aging of the lake will be more slow.

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