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Impact of Summer Thermal Stratification on Depth Profile of Phytoplankton Productivity, Biomass, Density and Photosynthetic Capacity in Lake Nasser (Egypt)

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Abstract

Lake Nasser is a headwater of Nile River in Egyptian territory. In wintertime, there is a complete upwelling in the water body whereas it is clearly thermally stratified in summer. Depth profile of summer stratification at the upper 15 m was investigated in four different sites. Temperature amplitude reached about 10 °C whereas oxygen concentration was about 7.491 $mgO_2\ l^{-1}$. Epilimnion layer was extended to 10 m depth whereas metalimnion underwnt from about 10 to 15 m and hypolimnion was initiated down. Bands of stratification were affected with the inflow of River Nile at the south. Peak maximum of chlorophyll *a*, phaeophytin, and standing crop was recorded at 10 m. Net primary productivity was irregular along the depth profile. Superficial water had climax photosynthetic capacity and declined downward. Integrated column productivity was correlated with that equivalent concentration of chlorophyll *a*. Khore Korosko exhibited the highest integrated productivity rate (315.9 $mgC\ m^{-2}\ h^{-1}$) and photosynthetic capacity (24.4 $mgC\ mgChl^{-1}\ h^{-1}$) among the studied sites. Layering width of water stratification and its temporal occurrence were affected with currant and physics of flooded water. So epilimnion is usually shallow in the north section while it becomes deeper toward the inflow of Nile floodwater at the south.

الملخص

بحيرة ناصر هي خزان لمياه نهر النيل في مصر.عامة تمتزج مياه البحيرة كليا خلال موسم الشتاء، بينما تتسم بظاهرة التدرج الحراري خلال الصيف. تم دراسة القطاع الرأسي لمياه البحيرة بعمق 15 متر خلال هذه الظاهرة من خلال أربعة مواقع والتي أسفرت عن: تراوح تذبذب درجة حرارة المياه فى حدود 10 درجات مئوية، في حين كان نطاق التدرج فى الأوكسجين الذائب فى حدود $7.491\ mgO_2\ l^{-1}$. امتدت الطبقة السطحية إلى عمق حوالي 10 أمتار، في حين أن الطبقة الوسطي تراوحت ما بين 10 إلى 15 متر، ثم تتدرج بعد ذلك العمق الطبقة السفلى (الأكثر كثافة). يتأثر سمك هذه الطبقات بمعدل فيضان نهلا النيل. سجلت أعلى تركيزات لصبغ الكلوروفيل و الفيوفيتين وكذلك كثافة العوالق النباتية عند عمق 10 متر.بينما كانت قيم حصيلة الإنتاجية الأولية غير منتظم في مختلف الأعماق. لكن سجلت الطبقة السطحية من مياه البحيرة أعلى معدل لعملية البناء الضوئي ثم تضاءلت في الطبقات السفلى. وقد تناسب التقدير التراكمي لإنتاجية وحدة المساحات للأعماق المختلفة فى القطاع الرأسي للمياه مع تركيزات الكلورفيل أ، و التي سجلت أعلى قيمة لها ($315.9\ mgC\ m^{-2}\ h^{-1}$) فى مياه خور كوروسكو، وكذلك أعلى معدل للبناء الضوئي ($24.4\ mgC\ mgChl^{-1}\ h^{-1}$) مقارنة بالمواقع الأخرى.وقد تبين من المسح الأفقي و الرأسي لهذه الظاهرة أن سمك هذه الطبقات و توزيعاته الجغرافية تتوقف على طبيعة مياه الفيضان و سرعة معدلاتها. ولذلك يلاحظ ضآلة عمق الطبقة السطحية لمياه البحيرة في الشمال، بينما يزداد عمقا كلما اتجهنا إلى الجنوب باتجاه مياه فيضان نهر النيل.

Key wards: Lake Nasser; Stratification; Phytoplankton Biomass; Photosynthetic Capacity

1. Introduction

After construction of the High Dam, in 1968 for flood protection at Aswan city (Egypt), the High Dam Lake was formed as a newly created headwater of Nile River. It is one of the largest man-mad lakes in the world and among four largest African man-made reservoirs. A reservoir that has been used for many purposes including water supply, hydro-electric generation, and fish production. Even the smallest of these reservoirs exhibited a measurable thermal stratification during summer. Surface water quality standards of dissolved oxygen concentration for reservoirs only apply to the surface mixed layer. Lack of oxygen in the deeper water limits aquatic life uses and may produce other undesirable water quality conditions.

Primary productivity, a division of biological productivity dealing with transformation of solar energy to

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the potential energy of organic protoplasm, is the best studied aspect of biological productivity (Saunders et al., 1962). Importance of primary productivity measurements in aquatic environment is well established. It would be obvious that fish production in natural and tended waters should be related to primary production of water bodies concerned. In African lakes, it has been found that fish yield is well correlated with corresponding primary production (Melack, 1976).

Chemical and physical measurements tend to measure only the cause of change in water quality while biological tests deal primarily with effects of the change. Phytoplankton composition and density can be considered as an indicator of trophic status of the lakes. Seasonal changes in environmental condition greatly affect fluctuations in phytoplankton flora of the water. While regional variations of phytoplankton reflect its response to varying environmental conditions and this is affected by advection, turbulence, and grazing (Chang and Bradford, 1985). Other wise, Chlorophyll a (Chl a) is one of the most effective variables on eutrophication of aquatic ecosystem. Its measurement is much easier, which serves as an integrative measure of phytoplankton biomass and of photosynthetic potential. And thus a number of trophic-state prediction models which are based on phosphorus-chlorophyll relations (Horne and Goldman, 1994).

Temperature measurements occupy a central position in limnology, as its changes may affect many physiological processes, the density of water, and fundamental stratification of a water body. Water temperature has extremely important ecological consequences. It has influence on water chemistry. It is a regulator of gases and minerals solubility in water body. Solubility of important gases like oxygen and carbon dioxide increases as temperature decreases. Inversely, solubility of most minerals increases with increasing temperature. It exerts a major influence on aquatic organisms with respect to selection/occurrence and level of activity of the organisms. All aquatic organisms prefer temperature in which they can survive and reproduce optimally (Lund and Talling, 1957).

While thermal stratification is a process that occurs in natural lakes, a case which is made for managing undesirable aspects of this process Water thermal stratification, or layering, have been occurred in some Egyptian lakes, particularly in the warm months. It was recorded in Lake Nasser (Abd El-Monem, 1995), Wadi El-Rayan (Taha and Abd El-Monem, 1999) and Abo-Zabal Aquatic Depressions (Abd El-Monem et al. 2006). Lake stratification depends on a number of factors like shape and depth of the lake, the amount of wind, and orientation of the lake (Entz and Latif, 1974). It is often paralleled by stratification of other water quality measurements (chemical and biological).

Primary productivity was discussed using 14C technique along the main channel and was discussed with phytoplankton biomass, density, and some physico-chemical variables during 1993 (Abd El-Monem, 1995). He reported that water column was well thermally stratified during hot months with maximum amplitude during summer. In addition, he stated that water temperature was the most important factor that regulates ecology of aquatic ecosystem in the lake, especially phytoplankton density and activity in the water column during thermal stratification.

Primary productivity of the Egyptian lakes, which has a wide range of trophic status, has been inadequately covered. It was highly temperature dependence (Abd El-Monem, 2001). The present study on Lake Nasser was designed to investigate some ecological variables that control water fertility and fish production, especially in Khores. The temperature profile depicts this layering for a hypothetical summer profile and its role on water variables. To estimate temperature amplitude in the water column, and thermocline impact on depth profile of dissolved oxygen, phytoplankton productivity, biomass, density and photosynthetic capacity. Integration for the water column production, per surface area, at the different khors and evaluate which is the most productive one.

2. Material and Methods

2.1. Lake Morphometry and Site Discretion

To study the primary productivity of the aquatic ecosystem in Lake Nasser, topography and ecology of the lake must be introduced to indicate its ecological status. The High Dam Lake is a newly created headwater of Nile River formed after construction of the High Dam (1968) at Aswan city (Egypt). It is one of the largest man-mad lakes in the world and among four largest African man-made reservoirs (extended about 496 km and occupied about 6275 km^2). Lake Nasser is the largest part of the High Dam Lake in Egyptian territory (292 km long) while the other is Lake Nobia in Sudan (204 km long). It lies in subtropical arid region and extends between latitude 22° 00′ – 23° 58′ N and longitude 31° 19′ – 33° 19′ E. It has an area about 5248 km^2, mean depth about 21.5-25.5 m and width about 8.9-18.0 km, at 160 and 180 m above the main sea level, respectively. The Lake morphometry is shown in Table (1). According to its topography, it has great variations in its ecological nature. It has many employments locally called Khors as shown in Figure (1). There are 85 important Khors (48 on the eastern side and 37 on the western). Those Khors covered about 4900 km^2, constituting about 79 % of the total lake surface area outside the main valley and contained only 86.4 km^3 water, forming about 55% of the total lake volume. Kalabsha, Tushka, and Allaqi are the widest Khors with slope gently while El-Sabakha and Korosko are steep with relatively narrow (Bishai et al., 2000).

Lake Nasser is one of the main sources of fish yield in Egypt. Its amount peaked to 34,206 ton of fresh fishes cached during 1981 as recorded in Bishai et al. (2000). Ecological natures of water body in Khors are different than those characterize the main channel. Khors are highly productive, and most of fish landing and catches from it. In the main channel, water column is deep, with a maximum depth (about 130 m) in the north at the High Dam; and decreased gradually downward while it was shallow in khors.

The present study was designed to represent water body and depth profile in the main channel and Khors during summer thermocline during July (2005). Samples were collected from the upper 15 m depth (the approximate mean depth of the photic zone) at different depths: 0, 3, 5, 10 and 15m from four sites. One represented the main channel and located in El-Madiq. The other three represented the khors (kalabsha, Korosko and Tushka) and located in the deepest position. The sampling sites are shown in Figure (1).

Results were expressed at the given depths per unit volume (m^3); and were integrated to calculate it per unit area (m^2) for that layer. The main morphometric variables of the selected locations are illustrated in Table (1) as reported in Bishai et al. (2000).

Site name	Distance from High Dam (km)	Length (km) at 160 and 180 m		Surface area (km^2) at 160 and 180 m		Perimeter (km) at 160 and 180 m		Maximum depth (m)
Kalabsha	46	22.0	47.2	54.0	620.0	85	517	40
El-Madiq	127	Main channel						54
Korosko	177	10.7	22.56	23.4	83.6	34	253	30
Tushka	245	24.1	33.35	49.1	366.8	89	127	20

Table 1. General morphometry of the studied sites in Lake Nasser at 160 and 180 m (above sea level) water levels. (cf. Bishai *et al*, 2000).

2.2. Field Measurements

Water depths were measured using Portable Echosounder (Lowrance x25). Water temperature and pH were measured in situ using Environmental Monitoring System (YSI-3800). A black and white standard Secchi-disc (25cm diameter) was used in measuring water transparency.

2.3. Collection and Preparation of Samples

Water samples were collected with water sampler (Ruttner, 1.5 liter) equipped with mercury thermometer. BOD bottles were filled carefully with the collected water samples, dissolved oxygen (DO) was fixed, and two others were prepared for primary productivity measurements as will be discussed below. For pigments analyses, a definite volume of water sample was filtered on glass microfiber filter (GF/F), using filtration unit (Sartorius). The filters with the remnants were foiled and preserved (refrigerated) for pigments analysis in the laboratory. One litter of sample was fixed in 4% neutral formalin and Lugol's iodine solution for quantitative analysis of phytoplankton, as described by Margalef (1974).

2.4. Methods of Analysis

DO in the lake was measured using Winkler method. It was analyzed and calculated as maintained by Thompson and Robinson (1939). Oxygen content is used as the initial concentration in calculating productivity.

Net primary productivity was measured as amount of DO increased in specific water volume during a period of time. Light and dark bottles technique was applied as described by Vollenweider (1969). Two sealed white bottles were immersed in the water body and incubated for 4 hours (mid day hours) at the same level of the water where sample is taken. After the incubation period, DO of the incubated bottles was fixed and measured. Net primary productivity was calculated as the difference in DO between light and initial bottles. Rate of oxygen released can be converted to rate of carbon uptake by calculation from the summary equation of photosynthesis

$$6CO2 + 6H2O \rightarrow 6O2 + (COH2)6 \quad (1)$$

So the values in $mgO_2\ l^{-1}$ are converted to $mgC\ l^{-1}$ by multiplying by the factor 0.735, the ratio of the weight of carbon to oxygen (Moss, 1980).

Phytoplankton biomass was represented as Chl *a* content. The preserved samples of the remnants residue on filters (G/F) were extracted in 90% acetone overnight at 4 ºC as described by Parsons et al. (1984). To estimate Chl *a* concentration, the extract was centrifuged and measured with spectrophotometer (Double beam, Kontron 930, UV&Vis) at the different wave lengths required for applying trichromatic equation as reported in SCOR/UNESCO (1991). The extract was acidified with dilute HCl and re-measured to calculate phaeophytin.

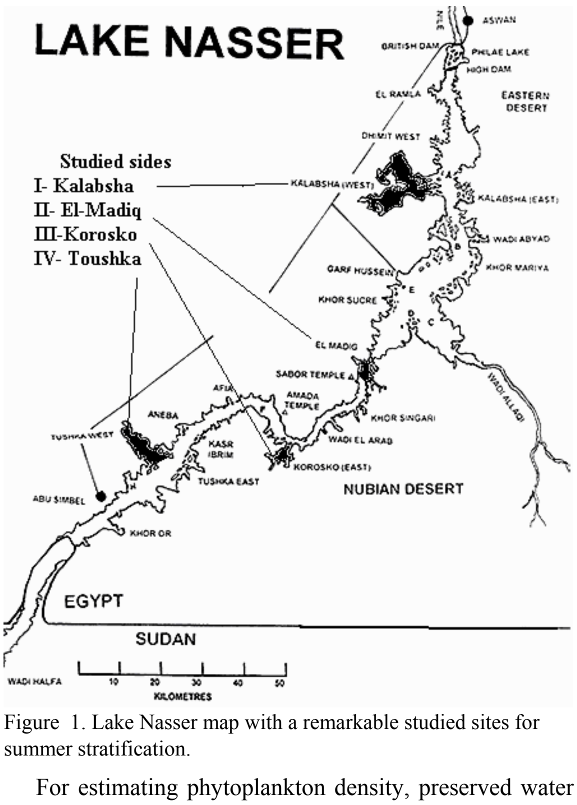

Figure 1. Lake Nasser map with a remarkable studied sites for summer stratification.

For estimating phytoplankton density, preserved water samples were allowed to settle in glass cylinder for 5 days with faint tea color Lugol's Iodine solution. To concentrate the samples, 90% of the supernatant fluid was slowly siphoned off with narrow plastic tube covered with 10µ plankton net. Adjusted volume (10%) was transferred to a plastic vial for microscopic examination. Drop method was applied for phytoplankton counting (APHA, 1992). Inverted microscope (ZEISS 1M4738) with magnification power 40 and 100x was used.

3. Results

Table 2. Temperature and dissolved oxygen amplitudes, and integrated values of some biological variables for water columns at the studying sites in Lake Nasser during summer stratification.

Site	Amplitude		Integrated value for depths per unit area (m^2)				
	Temperature (°C)	Dissolved oxygen (mgO_2 l^{-1})	Chlorophyll *a* (mg m^{-2})	Phaeophytin (mg m^{-2})	Primary productivity (mgC m^{-2} h^{-1})	Assimilation rate (mgC $mgChl^{-1}$ h^{-1})	Standing crop (x10^6 unit m^{-2})
Kalabsha	8.2	7.491	238.9	677.0	257.1	22.0	1713.7
El-Madyiq	10.0	6.744	206.2	535.7	238.0	23.8	2683.4
Korosko	9.9	6.878	247.0	667.9	315.9	24.4	2886.0
Tushka	6.4	5.278	231.1	571.5	253.4	18.5	2568.6

Secchi depth readings at the selected sites in Lake Nasser were taken the northern side of the lake water was more transparent than in the south. The highest Secch depth reading in the water column was about 3.15 m at Kalabsha. While it was about 76.19 % in the southern site reaching to about 2.4 m in Toshka. Trend of water visibility in the lake was decreased southward as shown in figure (2), which represents Secch depth readings in water of the different sites.

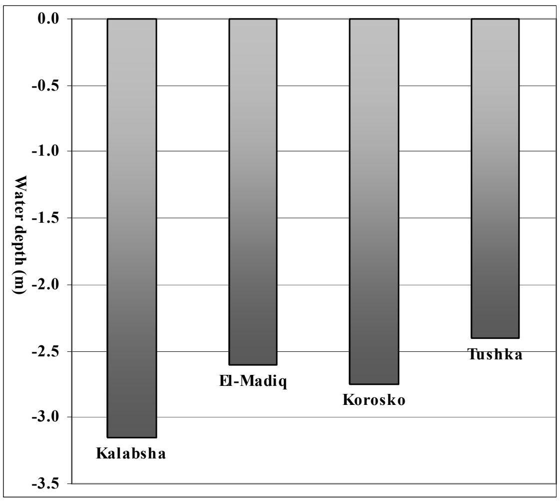

Figure 2. Water visibility (Secchi-depth readings) at the studied sites in Lake Nasser.

In contrast, water temperature of the lake was slightly increased southward. Local distribution of water temperature revealed that water was warmer upstream than in downstream. The highest water temperature was recorded at uppermost layer in Toshka of 31.8 °C. Whereas the minimum water temperature was 26.7 °C; and was recorded at the deepest studied layer (15 m depth) in El-Madiq. Depth profiles of water temperatures during summer are shown in Figure (3). It shows that water column was thermally stratified. Its amplitude, a difference between surface and bottom water temperatures, had the widest range of about 10.0 °C at El-Madiq when water temperature decreased gradually downward from 30.4 to 20.4 °C. While, amplitude was limited to 6.4 °C at Toshka when water temperature declined from 31.6 to 25.2 °C (see Table 2). It was indicated that water in the main channel, as represented by El-Madiq, has wide rang of temperature difference compared with that recorded in the Khors. Amplitude of water temperature in Khors decreased to about 64 % from that found in the main channel.

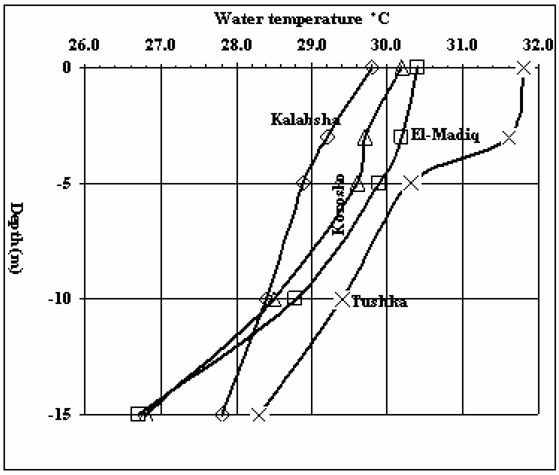

Figure 3. Depth profile of water temperature (°C) during summer stratification.

Oxygen contents of the studied water layers in Lake Nasser indicate that water column was oxycline, and epilimnion water was well oxygenated during summer. The highest values of DO were recorded in the subsurface layer at 5 m depth for most sites. Depth profiles of DO concentrations in water of the investigated sites, as represented in Figure (4), show that maximum concentration was 8.94 mgO_2 l^{-1} at 5 m depth in Kalabsha. Oxygen depletion was developed downward until it was deoxygenated in the hypolimnion layer with a concentration of 0.81 mgO_2 l^{-1} at 15 m depth in Korsko. Local and vertical distributions of DO in the water column with slight variations in oxygen contents through the upper 10 m depth were recorded whereas remarkable depressions were recorded downward in all sites. Oxygen depression in water column was maximized in Korsko getting to about 10.5 % from the one measured at 5 m depth. The differences were in oxygen contents between the maximum and minimum values in each water column, which can be defined as oxycline amplitude varied among the studied sites as illustrated in Table (2). The widest range of oxycline amplitude was about 7.491 mgO_2 l^{-1} at Kalabsha, whereas it was limited to about 5.28 mgO_2 l^{-1} at Toshka.

Spatial distribution of phytoplankton biomass, as represented by Chl a, is affected by the other environmental variables. Variations of Chl *a* in the similar depths were clear among investigated sites while its vertical distribution showed remarkable difference between the depths in the water column as illustrated in

Figure 5. Generally, surface water contained the lowest concentration of Chl *a*, comparied with other investigated depths whereas the highest value was established at 10 m depths in all sites. Phytoplankton biomass in the lake water ranged from the least Chl *a* value of 4.67 mg m^{-3} at the surface water in El-Madiq to about 5.7 times at 10 m depth in Korsko, recording its highest absolute value that reached 27.01 mg m^{-3} (see Figure 5).

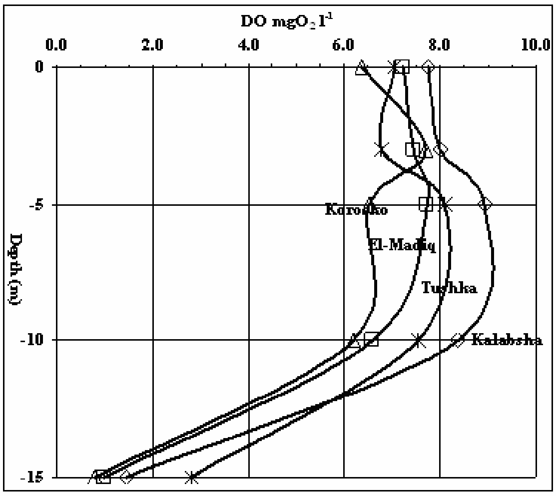

Figure 4 . Depth profile of dissolved oxygen (mgO_2 l^{-1}) during summer stratification.

Geographical distribution of phaeophytin pigment in the water columns, as represented in Figure (6), showed that It has the same trend of Chl *a* distribution; and is closely associated with its corresponding value in the studied layers. Phaeophytin concentrations were fluctuated from the minimum value of 12.334 mg m^{-3} to the maximum of 75.283 mg m^{-3} at its equivalent points of Chl *a*, respectively.

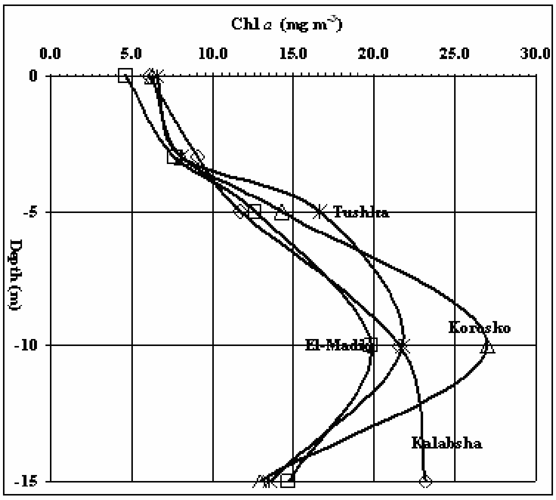

Figure 5. Depth profile of Chlorophyll *a* (mg Chl *a* m^{-3}).

Integrated concentrations of Chl *a* for the studied layers were fluctuateing from 206.2 to 247.0 mg m^{-2} at El-Madiq and Korsko, and Phaeophytin from 535.7 to 677.0 at El-Madiq and Kalabsha, respectively (Table 2).

Notable irregular variations in net primary productivity were observed along water column of the different sits. It was increased in the upper water layers (3 and 5 m) at two sites (Kalabsha and El-Madiq) and decreased downward. Whereas, a regular decrease in its value was recorded in the other two sites. Net primary productivity values fluctuated from the minimum of 10.6 mgC m^{-3} h^{-1}, at 15 m depth in El-Madiq, while the maximum was 24.8 mgC m^{-3} h^{-1}, at 3 m in Kalabsha (see Figure 7). Integrated values of net primary productivity for those depths at the studied sites were minimized to 238.0 mgC m^{-3} h^{-1} at El-Madiq and maximized to 315.9 mgC m^{-3} h^{-1} at Korsko as shown in Table (2).

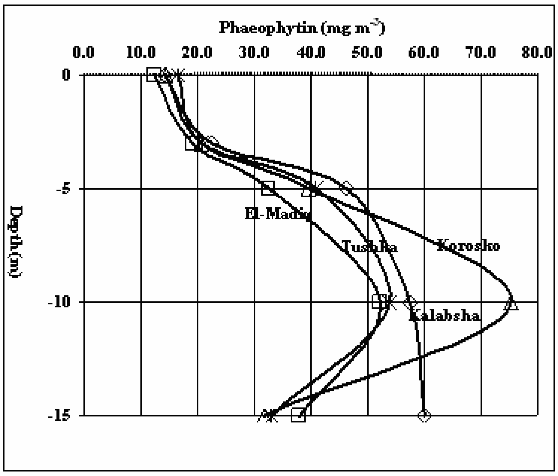

Figure 6. Depth profile of Phaeophytin (mg m^{-3}).

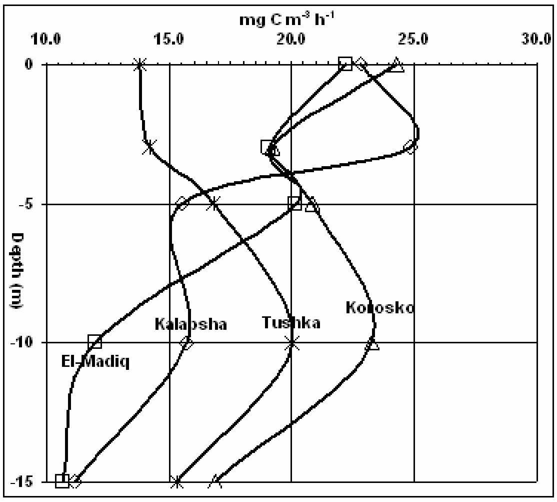

Figure 7. Depth profile of net primary productivity (mg C m^{-3} h^{-1}).

Photosynthetic capacity (assimilation rate) of the given sites in Lake Nasser is illustrated in Figure (8). In the studied sites, vertical and horizontal distributions of the assimilation rate values showed greet variations. Vertically, the highest assimilation rate was recorded at the upper water layer in all sites. Horizontally, limits of the assimilation rate varied from site to another. In general, assimilation rate in the studied sites varied from the maximum value of 4.753 mgC $mgChl^{-1}$ h^{-1}, which was recorded in El-Madiq to the lowest value of 0.479 mgC $mgChl^{-1}.h^{-1}$ recorded at 15 m depth at Kalabsha. Integration for its depth profile (Table 2) showed that, Korsko had the highest assimilation rate (24.4 mgC $mgChl^{-1}$ h^{-1}), and the lowest (18.5 mgC $mgChl^{-1}$ h^{-1}) was at Toshka.

Distribution of phytoplankton standing crop along water column (Figure 9) indicated that it was condensed at a depth of 10 m in most sites. Its highest density was about 278.8 x 10^6 unit m^{-3} which was observed at 10 m depth in Toshka. whereas it declined to the minimal density of about 28.7 x 10^6 unit m^{-3} at the deep water layer in Kalabsha. Integration of phytoplankton density in the water depth profile, at different locations, indicated that water column in Toshka contained the maximum density of phytoplankton, which was about 2886.0 x 10^6 unit m^{-2}, compared to with other sites. While the minimum density found in Kalabsha (1713.7 x 106 unit m^{-2}).

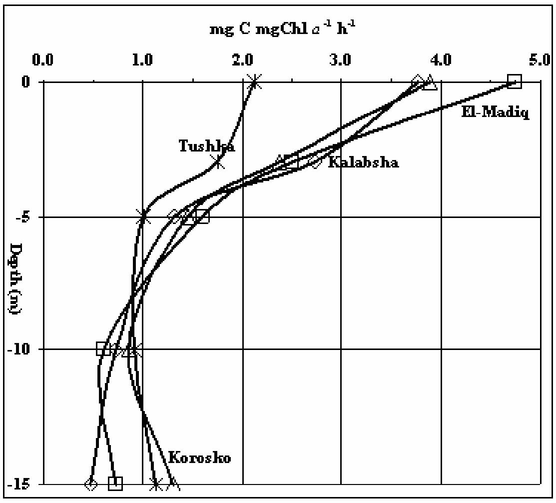

Figure 8. Depth profile of assimilation rate (mg C mgChl^{-1} h^{-1}).

Qualitative investigation of phytoplankton showed that it was dominated by Cyanophyceae, where *Lyngbya limnetica*, *Oscillatoria limnetica*, *Oscillatoria planctonica* and *Microcystis aeruginosa* were the most common species. Chlorophyceae had more diversity than the others did, and dominated by *Chlorella vulgaris* and *Ankistrodesmus falcatus*. Bacillariophyceae were low in both diversity and density, whereas *Cyclotella ocellata* was the most frequent species. Dinophyceae was scarce and could not be observed in some locations.

4. Discussion

Lake Nasser is a newly created headwater of Nile River after construction of the High Dam (1968) at Aswan City (Egypt). It had not yet reached the steady state. About 79 % of the total lake surface area (4900 km^2) is employments, outside the main valley, and locally named Khors. It contained only 86.4 km^3 of water, forming about 55% of the total lake volume (Entz and Latif, 1974). Ecological status of water body in Khors is different than those characterize the main channel. Each one has specific environmental conditions. Therefore, its local variations in the limnological characteristics are expected to be of considerable importance.

Secchi disc readings have been occasionally used to deduce vertical extinction coefficient and euphotic zone depth, but in general such calculations are uncertain, particularly when clear and turbid waters are compared (Lund and Talling, 1957). That is manly controlled by suspended organic or/and inorganic maters. In the present study, water visibility in khors were mainly biologically controlled because it was reversely associated with integrated phytoplankton density in that water column (r = 0.75). It increased downstream with a maximum of 3.15 m in Kalabsha. In comparison with the previous investigations, Abd El-Monem (1995) found that water turbidity at the northern region of the main channel (down stream) are biologically controlled, while in the southern side it was affected with the suspended inorganic matters carried with the flooded water.

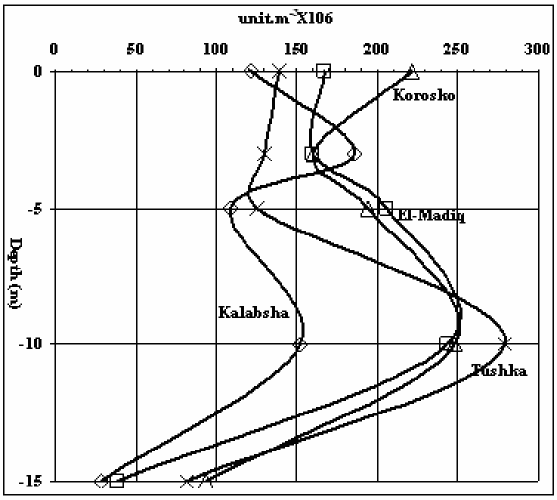

Figure 9. Depth profile of phytoplankton density (unit m^{-3} x 10^6).

In wintertime, there is a complete upwelling in the water body, and the lake lies under unstratified conditions. But during summer, water column was thermoclined and temperature of water body was increased upstream. In the upper layer, water temperature was rising up to 31.8 °C. Difference in water temperature (amplitude) in 15 m layer varied from 1.4 °C in Kalabsha to 5.3 °C in Toshka. Its amplitude was increased upstream, but it can extend more down to 15 m (studied zone) in the northern khors. This agrees with Abdel Rahman and Goma (1993). On this concept, Entz and Latif (1974) who surveyed the lake during the filling phase (1972-1973), reported that the time of total circulation is ending in March or April when the stratification started to develop. The depth of metalimnion is usually initiated in 12-17 m depth with a peculiar decline to the south. So the epilimnion is usually shallow in the north section and becomes deeper towards the inflow of Nile River water at the south. Under stratified conditions, temperature of the epilimnion is rising up to 25-29 °C. Higher temperatures are unusual, except on very calm days when within the upper 1 or 1.5 m the temperature can rise up to 30 °C. This may be caused by the decrease of thermal stability of the lake towards the south and the inflowing flood water. Stratification is usually dissolved from the south, starting in September and completed gradually towards Aswan in November.

Spatial distribution of DO along the water column showed that Oxygen distribution has a similar trend as that of the temperature. So, water depth up to 10 m was well oxygenated and represented the epilimnion layer while metalimnion can be extended to 15 m depth and hypolimnion layers initiated down. The value of hypolimnion was the widest near the High Dam; and is diminishing to the south. Concerning yearly cycling of DO, Entz and Latif (1974) found that water is saturated till the bottom during winter circulation. From March, when the enormous development of the phytoplankton starts, there is a strong increase in DO content within the surface layer up to 14-18 $mgO_2\ l^{-1}$. But, because of the increased thermal stability, the metalimnion is formed, and the hypolimnion becomes poorer and poorer in oxygen. The gradient of DO in metalimnion layer, which occurs when the hypolimnion becomes severely deoxygenated, creates a chemically diverse layer. The main loss of oxygen in that layer is probably due to decomposing sinking plankton organisms forming the so called plankton rain. The bacterial activity might be the most vivid just below the metalimnion.

In warm tropical water, small temperature differences have disproportionately large effects on the density of consumers and hence on the stability of stratification (Talling, 1957). This study reveals that the upper 10 m layer represents the critical zone in physical, chemical, and biological activities along the water column during summer. In spite of a limited decrease in water temperature, that depth included a noticeable variation in phytoplankton activity among the water column. It included the peak of phytoplankton density, biomass (Chl *a*) and phaeopigments. As well as it is still well oxygenated. Those parameters sharply declined downward.

In aquatic ecosystem, phytoplankton density, biomass, and its photosynthetic capacity may indicate eutrophic status of the lake. This study showed that depth profiles of phytoplankton standing crops are associated with water thermal stratification. Phytoplankton density is much greater in epilimnion than hypolimnion. Epilimnion was turbulent, and phytoplankters are maintained in suspension in it. Reynolds (1984) established that many cellular processes of phytoplankton are temperature-dependent, especially between 25 and 40 ^{0}C. Other physical and chemical factors, as well as biological (heterotrophic organisms), can affect the temporal distribution of phytoplankton in the lakes' water. Grazer and predator populations may control phytoplankton population directly and indirectly by large zooplankton, which can transport significant quantity of nutrients from the epilimnion layer (Longhurst and Harrison, 1988). So Regional variation of phytoplankton reflects its response to varying environmental conditions; and is affected by advection, turbulence, and grazing (Chang and Bradford, 1985).

Spatial and vertical distributions of net primary productivity in the lake water are varied and reflected the response of phytoplankton to ecological variables. Its values were limited between 31.9 and 74.4 $mgC\ m^{-3}\ h^{-1}$. Trend of its fluctuations in water column was irregular. Maximum production value was detected in surface water at El-Madiq and Korosko while it was at 3 and 10 m at kalabsha and toshka, respectively. Integrated column productivity for the studies depths revealed that korosko was the highest productive area (947.8 $mgC\ m^{-2}\ h^{-1}$), while El-Madiq was the lowest one (713.9 $mgC\ m^{-2}\ h^{-1}$). It was correlated with that equivalent concentration of Chl *a*. Tilzer (1983) reported that light fractions absorbed by algae increase with biomass but decreases with rising inorganic turbidity.

Generally, variability of primary productivity in the given results cannot be related to specific factor/s. There may be a variety of factors controlling primary productivity, mostly abiotic in nature such as light climate, turbulence, and nutrients (Tilzer, 1989). It was mainly limited by light penetration (Secchi depth) and turbidity when nutrients are in excess of growth demands. Nevertheless, primary productivity control by the food web has been shown to be sometimes as influential as the aforementioned abiotic factors (Carpenter et al., 1987). Water movement can result in marked variations in interception of light by phytoplankton (Grobbelaar and Stegmann, 1976). One therefore has to pay attention to other biotic components of the lacustrine ecosystem if a clear picture of the primary productivity is to be achieved. This is especially true for hypertrophic ecosystem where physical features are suspected to control primary productivity in view of nutrient excess (Robarts, 1984). Extensive human land use results in various levels of impact on actual net primary production. In a few regions, such as the Nile valley, irrigation has resulted in a considerable increase in primary production (Haberl, 2007).

Lake Nasser is one of the main sources of fishing in Egypt. Variability of the entire studied parameters, in the water budget during summer stratification, are greatly affected on the seasonal distribution of fishes, and can be controlled on fisheries and fishing activities during the whole year. In addition, the expected fish yield and its sustainability can be expected from the primary productivity of the lake. Because Entz and Latif (1974) mentioned that usually fish avoid water layer containing less than 2 or 3 $mgO_2\ l^{-1}$ and the same is true for fish food organisms. So fish searching for food usually avoid hypolimnion, and choose the epilimnion for a habitat. But they even don't like that, if the water temperature increases very quickly. So, most of them avoid the upper 1-2 m, and thus most of the fish may be located in summer time (during the stagnation period). Of course, there are typical littoral fish species which come likely to the very shallow water near the shore and find their best conditions for feeding. There in wintertime, the fish spread all over the lake water.

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