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Relative Abundance, Species Composition and Spatial Distribution of the Phytoplankton During a Significant Flood Period in Lake Nasser, Egypt

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Abstract: The phytoplankton community structure in Lake Nasser was qualitatively and quantitatively studied in a significant flood season. The most common planktonic algae were the cyanoprokaryotic species *Anabaenopsis cunningtonii* and *Phormidium* sp. in addition to the centric diatoms *Aulacoseira granulata, Cyclotella meneghiniana* and the green alga *Ankistrodesmus falcatus*. Quantitatively, eight species, *Anabaenopsis cunningtonii, Lyngbya* sp., *Oscillatoria* sp., *Phormidium* sp., *Aulacoseira distans, Aulacoseira granulata, Cyclotella meneghiniana* and *Cyclotella ocellata* were recorded as the major species. The data were analyzed by clustering and ordination multi variate techniques using the programmes TWINSPAN and DECORANA. Data analyses showed that water turbidity was the most important factor determining the distribution of phytoplankton in Lake Nasser during the flood. Among the other estimated water variables pH, oxygen contents, nitrate, silicate, phosphate, sodium and potassium seemed to be important in characterizing the phytoplankton community structure and its spatial distribution along the main water body of Lake Nasser during the flood period.

Key words: Cyanoprokaryotes, diatoms, dinoflagellates, flood, green algae, Lake Nasser, phytoplankton, water level

Introduction

Man-made lake ecosystems are often characterized by their own phytoplankton assemblages, referred to as plankton formations (Teiling, 1916). These phytoplankton assemblages can reflect the ecological status of lakes and respond both qualitatively and quantitatively to changes therein. The dynamics and species diversity of the phytoplankton are greatly influenced by water physico-chemistry and biological factors (Harris, 1986; Reynolds, 1986; Sommer, 1989) as well as the external physical disturbances (i.e. accidental water mixing, storms, floods). Thus, they must be taken into account when considering the reasons for fluctuations in phytoplankton (Jacobsen and Simonsen, 1993). The importance of such factors in controlling the biotic structure including phytoplankton assemblages of man-made lakes was discussed by Uhlmann (1998) and subsequently confirmed by Wilk-Wozniak and Kosinski (2001). However, due to the complex interactions, rapid changes and great variability of these factors no absolute standards for biological quality can be set (Commission of the European Communities, 1999).

Lake Nasser in south Egypt (Fig. 1) constitutes about 84% of the surface area of the total High Dam reservoir basin. There is a regular annual rhythmic fluctuation in water level caused by the famous Nile flood. The effect of flood is manifested in the arrival of turbid water in July-August (Entz, 1997) starting from the southernmost part of the reservoir. Then extended northwards and reaches only the southern sector of Lake Nasser (180-200 km south of the High Dam) in October-November. The water level in Lake Nasser is subjected to dramatic changes from one year to another due to the fluctuations in amount of flood water flowing into it. During the flood season of 1999 the water level increased remarkably to 181.6 m a.s.l. (above sea level), which is considered the highest record since the construction of the High Dam (Fig. 2A and B). The irregular hydrological events due to the strong water level fluctuations may influence the life conditions and produce an irregular pattern of variability in phytoplankton assemblages in the lake (Harris and Baxter, 1996).

Investigations of phytoplankton assemblages in Lake Nasser were initiated in the early 1970s by some sporadic works during the limnological studies supported by UNDP and FAO as well as the Egyptian government. In the late 1970s and the early 1980s some other fragmentary works were devoted to the lake phytoplankton and summarized by Bishai *et al.* (2000). Otherwise, the phytoplankton development was systematically and comprehensively investigated by Zaghloul (1985), Mohammed *et al.* (1989); El-Otify (1991), Abd El-Monem (1995) to follow the dynamics of seasonal succession and spatial variability of phytoplankton. During most of these systematic surveys, the planktonic cyanoprokaryote, *Microcystis aeruginosa* was one of the infrequent species. However, intermittent occurrence of water blooms caused mainly by this species were reported by Entz (1976), Mohamed (1993), Abd El-Monem (1995) in a limited area in the southern part of the lake and monitored using remote sensing by Hamed (2000).

The main task of this work was to investigate the species composition and relative abundance of phytoplankton during the highest water level reached in a significant flood period of 1999 in order to evaluate the main features of the phytoplankton assemblages in Lake Nasser during the flood.

Materials and Methods

The area of Lake Nasser where the present work was carried has been repeatedly described in previous studies (Ahmed *et al.*, 1989; El-Otify, 1991; Entz, 1997; Bishai *et al.*, 2000). It is necessary to emphasize that the large surface area (mean value: 3917 km^2), elongated shape (length: > 300 km; average width: 13.5 km) and deepness (maximum depth: 100 m and mean depth: 23.4 m) represent the main features of the lake.

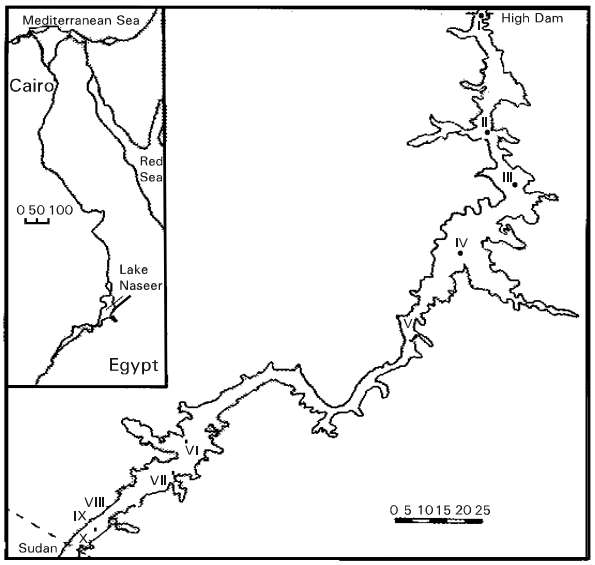

Fig. 1: Map showing he location of investigated sites along the main water body of Lake Nasser. The inset shows the location of Lake Nasser in Egypt.

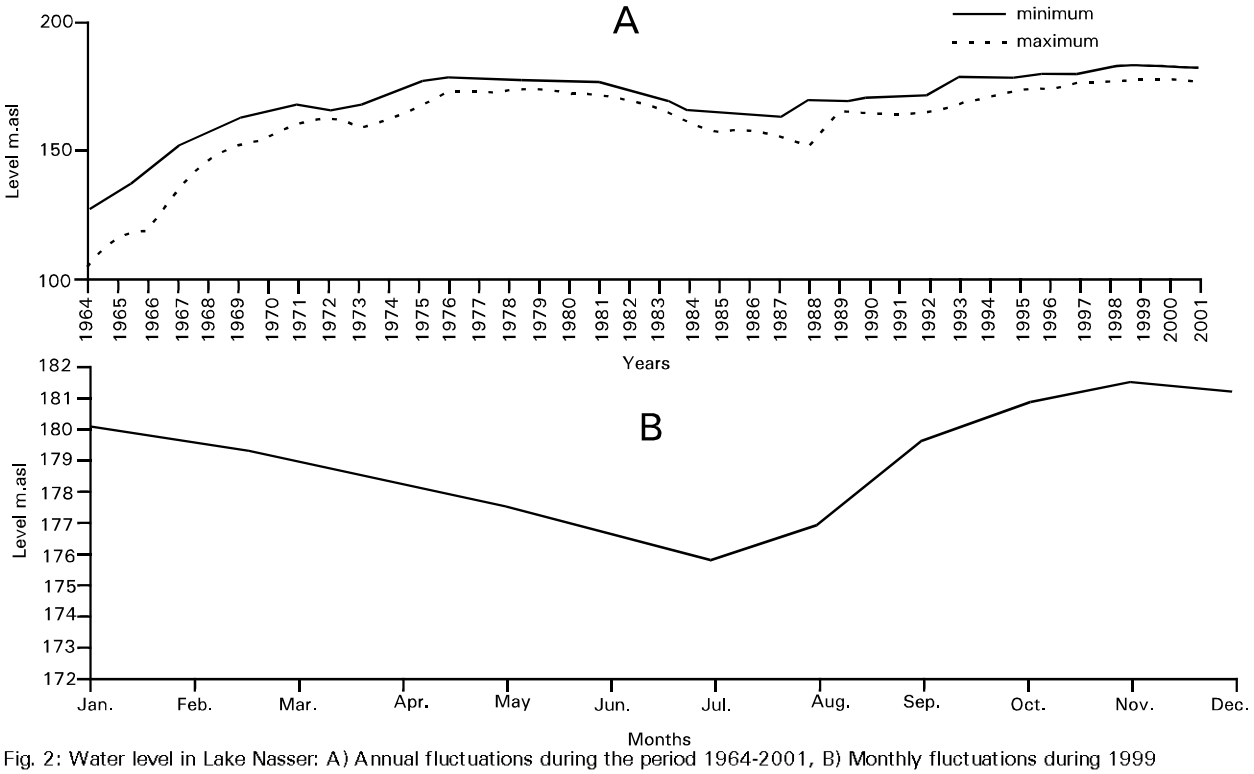

Fig. 2: Water level in Lake Nasser: A) Annual fluctuations during the period 1964-2001, B) Monthly fluctuations during 1999

The materials (water samples) for this study were collected once during October-November 1999 from 10 successive sites (I-X) along the main water body of the lake situated at variable distances: 3, 45, 85, 110, 190, 250, 270, 300, 320, 333 Km south of the High Dam, respectively (Fig. 1). Sites IX, 320 and X, 333 km were in the confluence of Lake Nubia. Samples were collected from the water surface in clean polyethylene bottles, each of one litre capacity and has a wide mouth. In addition, water samples were gathered from different depths by the water sampler, Nansen bottle (Goodwin and Goddard, 1974). The different depths include the subsurface water layer (1 m deep) and the other depths starting from 2.5 to 20 m in the intervals of 2.5 m. Water physico-chemistry was analyzed according to APHA (1992). Samples for chlorophyll-*a* determination were filtered onto SM 13400 Sartorius glass fibre filter buffered with magnesium carbonate. Phytoplankton chlorophyll-*a* concentrations were estimated according to the method of Parsons and Strickland (1965) after 12 h extraction in 90% acetone in a dark freezer. For phytoplankton qualitative and quantitative analyses, the samples were preserved with 4% formaline and concentrated by sedimentation (Stein, 1973) to aliquot volumes. Quantification of phytoplankton was performed microscopically using a counting chamber of 10^{-1} cm^3. The cyanoprokaryotic and eukaryotic phytoplankton were identified according to the following references: Smith (1950), Prescott (1954), Kimor and Pollingher (1965), Weber (1971), Krienitz (1990), Guarrera and Echenique (1992). Then, the phytoplanktons were enumerated and their counts were expressed in terms of number of individuals (cells, colonies, coenobia and filaments) per litre.

Two-Way Indicator Species Analysis (TWINSPAN) as a classification technique and Detrended Correspondence Analysis (DCA) as an ordination technique were applied to the recorded 81 phytoplankton species from 100 collected water samples using the programmes TWINSPAN and DECORANA, respectively (Hill, 1979a,b). Species richness (alpha-diversity) of each phytoplankton cluster was calculated as the average number of species per sample and species turnover (beta-diversity) as the ratio between the total species recorded in a certain phytoplankton cluster and its alpha diversity (Pielou, 1975). The statistical computer programme MINITAB was used to study the correlation of the water variables with the first two axes of DCA.

Results and Discussion

A total of 81 phytoplankton species were recorded from Lake Nasser in this investigation and were listed with their authorities (Table 1). Here, the relative frequencies of the species are indicated by the number of occasions in which they were recorded out of the 100 investigated water samples. The most common species were; *Anabaenopsis cunningtonii, Phormidium* sp. (cyanoprokaryotes) and *Aulacoseira granulata* (diatom) that were present in all samples (100%), while two others, the diatom *Cyclotella meneghiniana* and the green alga *Ankistrodesmus falcatus* were present in more than 90% of the samples. Six species were recorded in ≥ 75% of the samples, *Lyngbya* sp., *Merismopedia tenuissima* (cyanoprokaryotes), *Nitzschia holsatica, Synedra acus* (diatoms), *Chodatella ciliata* and *Oocystis* sp. (green algae). Nine species were recorded in over 50% of the samples, *Chodatella citriformis, Closterium venus, Crucigenia rectangularis, Dictyosphaerium pulchellum, Golenkinia radiata, Scenedesmus* sp., *Staurastrum paradoxum* (green algae), *Aulacoseira distans* and *Cyclotella ocellata* (diatoms). Fourteen species appeared in over 25% of the samples: *Anabaena* sp., *Anabaenopsis* sp., *Chroococcus* sp., *Oscillatoria* sp. (Cyanoprokaryotes), *Navicula exigua* (diatom), *Coelastrum reticulatum, Elakatothrix genevensis, Gloeocystis ample, Micraactinum* sp., *Pediastrum simplex, Pediastrum* sp., *Scenedesmus ecornis, Schroederia setigera* and *Staurastrum uniseriatum* (green algae). A further 19 species were recorded in ≥ one-tenth of the samples. At the other extreme, the remaining 28 species, which appeared in less than one-tenth of the samples, especially the 16 that were recorded only once or twice, were regarded as the rare species. Majority of the recorded species were quantitatively of low contributions (< 5%) to the total phytoplankton counts. Only eight of the species individually

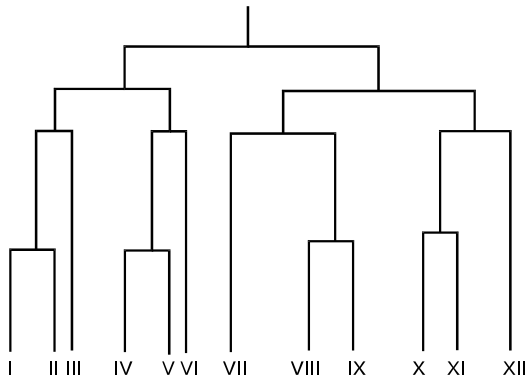

Fig. 3: Cluster diagram for the phytoplankton species distribution derived from TWINSPAN analysis. The 12 phytoplankton clusters are: I. *Oscillatoria* sp.-*Scenedesmus acuminatus,* II. *Oocystis* sp., III. *Crucigenia rectangularis-Merismopedia tenuissima-Chodatella citriformis,* IV. *Elakatothrix genevensis-Closterium venus,* V. *Golenkinia radiata-Oscillatoria* sp.-*Pediasrum simplex,* VI. *Cymbella ventricosa-Elakatothrix genevensis,* VII. *Elakatothrix genevensis-Cosmarium depressum- Synedra ulna,* VII. *Aulacoseira distans,* IX. *Pediastrum simplex- Ankistrodesmus spiralis,* X. *Navicula exigua- Nitzschia holsatica-Cosmarium depressum-Oscillatoria* sp., XI. *Coelastrum reticlatum-Cyclotella ocellata- Peridinium* sp., XII. *Scenedesmus quadricauda-Scenedesmus ecornis.*

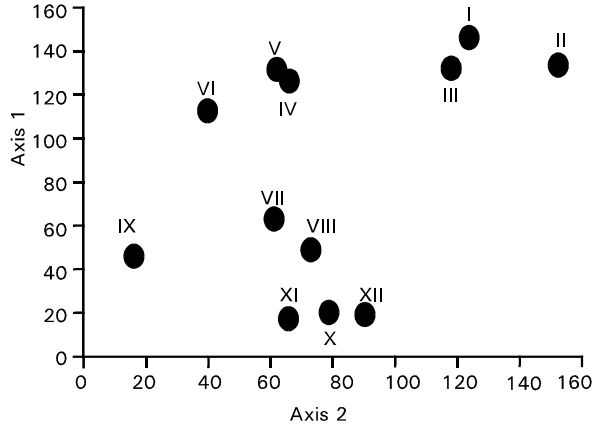

Fig. 4: Relationship between 12 phytoplankton clusters identified according to TWINSPAN analysis and the ordination of the first to axes derived from DCA analysis of the phytoplankton species distribution.

contributed > 5% of the phytoplankton population in at least one sample and were designated as the "major" species. Similar community structures and species combinations have been reported from Lake Nasser during the last three decades (Bishai *et al.*, 2000), from the headwater lakes of the Nile (Talling, 1976; 1986; Hecky, 1993) and from other different African lakes (Hecky and Kling, 1987; Patterson and Kachinjika, 1993; Zohary *et al.*, 1996). *Microcystis aeruginosa* was recorded in 22% of the collected water samples and its quantitative contribution was always less than 1% of the total phytoplankton counts. Due to the ability of buoyancy of this cyanoprokaryote it can move to the euphotic zone (Carr and Whitton, 1982; Van der Veer *et al.*, 1995) and create blooms closer to the water surface in a limited area in Lake Nasser (Entz, 1976; Mohamed, 1993; Abd El-Monem, 1995;

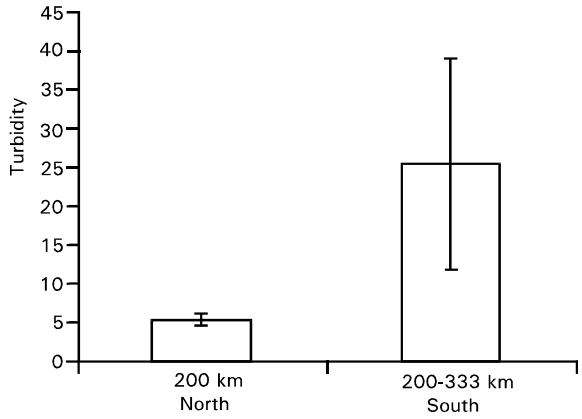

Fig. 5: Mean values (± SD) of water turbidity (N.T.U., Nephelometric turbidity unit) along the main water body of Lake Nasser during the flood period of 1999.

Hamed, 2000). Mass appearance of *Microcystis aeruginosa* was used for estimation of the degree of water eutrophication, signaling deterioration of water quality (Bucka, 2000) due to the production of toxins. Blooms were developed in a limited area of the south region of Lake Nasser only during exceptionally warm and calm conditions. Since these conditions are disturbed by the flood, it could be regarded as a factor involved in explanation for the irregularity of *Microcystis aeruginosa* blooms. This irregularity is a positive feature in the aspect of eventual eutrophication water and the toxic effect on the water of Lake Nasser.

Classification of the sampling sites and depths resulted in 12 clusters at level four of the hierarchy (Fig. 3). The clusters were named after the dominant species as follows: *Oscillatoria* sp.-*Scenedesmus acuminatus* (I), *Oocystis* sp. (II), *Crucigenia rectangularis-Merismopedia tenuissima-Chodatella citriformis* (III), *Elakatothrix genevensis-closterium venus* (IV) *Golenkinia radiata-Oscillatoria* sp.-*Pediastrum simplex* (V) and *Cymbella ventricosa-Elakatothrix genevensis* (VI). This group of clusters contains the south sites (250-333 Km. south of the High Dam) and at this point, the primary bifurcation of the diagram is reached. Then, the second part of the diagram contains all of the sampling sites in the north 250 Km. of the lake. The clusters of this part are named as follows: *Elakatothrix genevensis-Cosmarium depressum-Synedra ulna* (VII), *Aulacoseira distans* (VIII), *Pediastrum simplex-Ankistrodesmus spiralis* (IX), *Navicula exigua-Nitzschia holsatica-Cosmarium depressum-Oscillatoria* sp. (X), *Coelastrum reticulatum-Cyclotella ocellata-Peridinum* sp. (XI) and *Scenedesmus quadricauda-Scenedesmus ecornis* (XII). These results provide evidence that the phytoplankton community structure was subjected to spatial differentiation along the main water body of the lake depending on hydrological conditions. Since, the distribution of phytoplankton species in different clusters may reflect the influence of habitat disturbance in the south part of the lake due to the decisive effect of the strong water level fluctuation (Harris and Baxter, 1996). In contrast, the cluster analysis of the phytoplankton spatial distribution during the last three decades separated the main water body of the lake into three parts. No remarkable regular differences in depth distribution of phytoplankton could be recognized in this investigation. This could be related to the destruction of summer stratification conditions (Entz, 1997). In this respect, it was reported that the vertical variation of phytoplankton appeared concomitantly with the thermal stratification in Lake Nasser (Mohammed *et al.*, 1989).

The most frequent phytoplankton group (Table 2) was the green algae (50%) followed by diatoms (28.39%), cyanoprokaryotes (18.52%) and dinoflagellates (2.47%). The highest value of species

Table 1: Mean values of the frequency of occurrence (%) of the different species belonging to the 12 phytoplankton clusters identified after the application of TWINSPAN analysis

Phytoplankton species	Phytoplankton clusters I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total presence (%)
Green algae:													
1. *Ankistrodesmus falcatus* (Corda) Ralfs	100.00	50.00	71.43	100	100.00	100	100	100.00	100.00	100.00	100.00	100.00	91
2 *Ankistrodesmus spiralis* (Turpin) Lemm.	0	0	0	0	0	0	0	0	57.14	66.67	66.67	100.00	21
3 *Ankistrodesmus* sp.	33.33	0	14.29	25	47.06	0	0	28.57	14.29	0	0	0	14
4 *Chodatella ciliata* Lagerh. Lemm.	0	35.71	42.86	100	82.35	75	100	93.33	100.00	75.00	88.89	100.00	75
5 *Chodatella citriformis* Snow	66.76	14.29	85.71	100	94.12	75	80	86.67	100.00	66.67	66.67	66.67	73
6 *Chodatella quadriseta* Lemm.	0	0	0	0	0	0	0	6.67	28.57	41.67	0	66.67	10
7 *Closterium acutum* Breb.	0	0	0	0	0	0	0	0	14.29	0	0	0	1
8 *Closterium moniliferum* Ehrb.	0	21.43	0	25	0	0	0	0	0	0	0	0	4
9 *Closterium venus* Kutz.	100.00	78.57	71.43	100	47.06	25	60	46.67	28.57	75.00	77.78	66.67	62
10 *Coelastrum cambricum* Archer	0	0	0	75	64.71	50	20	0	0	8.33	0	33.33	18
11 *Coelastrum microporum* Nag.	0	0	14.29	0	35.29	50	40	0	0	0	0	0	11
12 *Coelastrum reticulatum* (Danjerard) Senn.	0	0	14.29	25	17.65	25	40	73.33	100.00	91.67	100.00	66.67	49
13 *Cosmarium botrytis* Menegh.	0	0	0	50	11.76	25	0	6.67	28.57	0	22.22	0	10
14 *Cosmarium depressum* Lundell	0	7.14	0	25	11.76	0	80	40.00	28.57	50.00	0	0	22
15 *Crucigenia rectangularis* (A. Braun) Gay	0	0	85.71	100	94.12	100	100	93.33	100.00	66.67	66.67	33.33	71
16 *Dictyosphaerium pulchellum* Wood	0	7.14	0	100	100.00	100	100	86.87	42.86	25.00	22.22	33.33	53
17 *Elakatothrix genevensis* (Revedin) Hindak	0	0	14.29	75	5.88	100	80	6.67	14.29	83.33	100.00	66.67	36
18 *Euastrum* sp.	0	0	0	0	0	25	0	0	0	0	0	0	1
19 *Golenkinia radiata* Chodat	0	0	14.29	0	88.24	75	60	86.67	100.00	41.67	33.33	33.33	51
20 *Gloecystis ample* (Kutz) Log.	0	7.14	0	0	11.76	75	60	53.33	85.71	58.33	55.56	0	35
21 *Gloecystis* sp.	0	0	0	25	29.41	25	40	40.00	0	16.67	11.11	33.33	19
22 *Kirchneriella microscopica* Nyg.	0	0	0	25	0	25	0	0	0	0	11.11	0	3
23 *Micraatinum* sp.	0	7.14	42.86	100	100.00	100	0	6.67	0	0	0	0	30
24 *Oocystis* sp.	0	94.29	71.43	100	100.00	100	100	86.67	85.71	66.67	55.56	100.00	79
25 *Pediastrum boryanum* (Turp.) Menegh.	0	0	0	0	0	0	40	6.67	0	0	11.11	0	4
26 *Pediastrum ovatum* (Ehr.) A. Braun	0	0	14.29	75	23.53	0	40	0	0	0	0	0	10
27 *Pediastrum simplex* Meyen	33.33	7.14	28.57	25	82.35	75	0	0	71.43	0	0	33.33	28
28 *Pediastrum* sp.	66.67	21.43	14.29	100	70.59	75	20	6.67	28.57	16.67	33.33	0	34
29 *Scenedesmus acuminatus* (Lagerh.) Chod.	66.67	0	14.29	0	23.53	50	0	0	0	0	0	0	9
30 *Scenedesmus actus* Meyen	0	0	0	25	5.88	25	20	0	0	8.33	0	0	6
31 *Scenedesmus arcuatus* (Lemm.)Lemm.	0	0	0	25	0	25	0	0	0	0	0	0	2
32 *Scenedesmus ecornis* (Ehr.) Chod.	0	0	14.29	50	5.88	50	40	46.67	71.43	33.33	11.11	100.00	28
33 *Scenedesmus obtusus* Meyen	0	0	0	0	5.88	0	0	0	0	0	0	0	1
34 *Scenedesmus quadricauda* (Turp.) Breb.	0	42.86	14.29	0	23.53	50	20	13.33	14.29	0	11.11	100.00	21
35 *Scenedesmus* sp.	0	21.43	0	25	58.82	75	100	66.67	85.71	83.33	66.67	100.00	57
36 *Schroederia setigera* (Schroed.) Lemm.	66.67	78.57	100.00	100	94.12	100	0	13.33	0	0	0	0	46
37 *Staurastrum paradoxum* Meyen	0	14.29	42.86	50	58.82	75	60	80.00	57.14	91.67	88.89	100.00	61
38 *Staurastrum uniseriatum* Nyg.	0	0	14.29	50	17.65	25	20	33.33	14.29	16.67	11.11	33.33	18
39 *Tetraedron minimum* (A. Br.) Hansg.	0	0	0	25	5.88	0	80	66.67	71.43	25.00	22.22	100.00	29
40 *Tetraedron trigonum* Hansg.	0	0	0	0	0	25	20	26.67	0	8.33	11.11	0	8
41 *Volvox* sp.	0	0	14.29	0	0	0	40	6.67	0	0	0	0	4
Diatoms:													
42 *Aulacoseira distans* (Ehr.) Simonsen*	33.33	71.43	100.00	100	100.00	100	80	73.33	100.00	25.00	11.11	0	69
43 *Aulacoseira granulata* Her. Simonsen*	100.00	100.00	100.00	100	100.00	100	100	100.00	100.00	100.00	100.00	100.00	100
44 *Aulacoseira islandica* (O. Mull.) Simonsen	0	0	0	0	58.8	0	0	0	14.29	0	0	0	2
45 *Cocconeis placentula* Ehr.	0	0	0	0	17.65	50	40	0	28.57	16.67	0	0	11
46 *Cocconeis scutellum* Ehr.	0	0	14.29	0	0	0	0	0	0	0	0	0	1
47 *Cyclotella meneghiniana* Kutz.*	100.00	92.86	100.00	100	100.00	100	100	100.00	100.00	100.00	100.00	100.00	99
48 *Cyclotella ocellata* Pantocsek*	0	0	14.29	25	29.41	50	40	93.33	85.71	83.33	100.00	100.00	53
49 *Cymbella ventricosa* Kutz.	0	0	14.29	0	5.88	100	0	0	14.29	8.33	11.11	33.33	10
50 *Diploneis* sp.	0	0	0	0	0	25	0	0	0	0	0	0	1
51 *Epithemia sorex* Kutz.	0	7.14	0	0	0	0	0	0	0	0	0	0	1
52 *Gomphonema olivaceum* (Lyngybe) Kutz.	0	0	14.29	0	5.88	25	0	0	14.29	0	0	0	4
53 *Gyrosigma* sp.	0	7.14	0	25	0	0	0	0	0	0	0	33.33	3
54 *Navicula confervaceae* Kutz.	0	0	0	0	0	0	0	6.67	14.29	0	0	0	2
55 *Navicula exigua* (Gregory) Grun.	0	7.14	14.29	0	0	0	100	53.33	71.43	100.00	11.11	100.00	36
56 *Navicula gastrum* Ehr.	33.33	14.29	0	25	0	0	20	0	0	0	0	33.33	5
57 *Navicula pupula* Kutz.	0	0	14.29	0	0	0	0	0	0	0	0	0	1
58 *Nitzschia holsatica* Hust.	100.00	71.43	85.71	100	94.12	100	100	93.33	85.71	83.33	0	33.33	79
59 *Nitzschia lacunarum* Hust.	0	0	0	0	0	0	0	0	14.29	0	0	0	1
60 *Nitzschia* sp.	0	0	0	25	0	0	0	0	0	0	11.11	0	2
61 *Pinularia* sp.	0	0	0	0	0	0	0	0	0	8.33	0	0	1
62 *Rhopalodia gibba* (Ehr.) O. Mull.	0	21.43	14.29	0	29.41	0	0	0	28.57	25.00	11.11	33.33	16
63 *Synedra acus* Kutz.	100.00	78.57	71.43	100	100.00	100	100	93.33	100.00	83.33	66.67	66.67	88
64 *Synedra ulna* Her.	0	0	28.57	25	5.88	25	60	6.67	14.29	0	11.11	0	11
Cyanoprokaryotes:													
65 *Anabaena* sp.	66.67	71.43	100.00	75	94.12	100	20	0	0	8.33	0	0	45
66 *Anabaenopsis cunningtonii* Taylor*	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100
67 *Anabaenopsis* sp.	0	28.57	14.29	100	76.47	75	80	26.67	57.14	0	0	0	37
68 *Aphanocapsa* sp.	0	0	0	0	5.88	25	0	0	0	0	22.22	0	4
69 *Chroococcus limneticus* Lemm.	0	0	0	0	0	0	0	0	0	0	0	33.33	1
70 *Chroococcus turgidus* (Kutz.) Nag.	0	0	0	0	5.88	0	20	6.67	0	0	0	0	3
71 *Chroococcus* sp.	33.33	0	0	0	41.18	100	40	53.33	71.43	66.67	77.78	0	42
72 *Gomphosphaeria* sp.	0	7.14	0	25	11.76	0	0	13.33	0	0	22.22	66.67	10
73 *Lyngbya* sp.*	66.67	78.57	85.71	100	82.35	100	100	93.33	100.00	100.00	77.78	100.00	89
74 *Merismopedia glauca* (Ehr.)Naeg.	0	0	14.29	25	29.41	0	80	53.33	28.57	0	11.11	0	22
75 *Merismopedia tenuissima* Lemm.	0	21.43	71.43	75	100.00	75	100	86.67	100.00	91.67	100.00	100.00	80

Table 1: Continued

Phytoplankton clusters	Phytoplankton species I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total presence (%)
76 *Microcystis aeruginosa* Kutz.	33.33	7.14	14.29	25	70.59	75	40	6.67	0	0	0	0	22
77 *Oscillatoria* sp.*	66.67	7.14	42.86	0	58.82	50	60	66.67	57.14	50	0	100	44
78 *Phormidium mucicola* Naum. & Huber.	0	0	0	0	5.88	0	0	0	0	0	0	0	1
79 *Phormidium* sp.*	100.00	100.00	100.00	100.00	100.00	100	100	100.00	100.00	100	100	100	100
Dinoflagellates:													
80 *Ceratium hirundinella*(O. F. Mull.) Bergh.	0	0	14.29	0	0	0	0	6.67	0	0	0	0	2
81 *Peridinium* sp.	0	0	0	0	0	0	0	6.67	0	66.67	100	100	21

*: Major species comprising > 5% of the total phytoplankton counts in at least one sample

Table 2: Presence contributions of the different phytoplankton groups, total species richness (species/sample) and species turnover belonging to 12 clusters identified after the application of TWINSPAN analysis

Groups	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Total (%)
Green algae	38.10	45.71	48.89	59.57	54.39	58.82	56.25	56.00	52.08	55.81	55.81	53.85	50.62
Diatoms	28.57	31.43	28.89	21.28	21.05	21.57	20.83	18.00	31.25	25.58	23.26	25.64	28.39
Cyanoprokaryotes	33.33	22.86	20.00	19.15	24.56	19.61	22.92	22.00	16.67	16.28	18.60	17.95	18.52
Dinoflagellates	0.00	0.00	2.22	0.00	0.00	0.00	0.00	4.00	0.00	2.33	2.33	2.56	2.47
Total species	21.00	35.00	45.00	47.00	57.00	51.00	48.00	50.00	48.00	43.00	43.00	39.00	81.00
Species richness	14.67	13.71	19.29	29.50	28.94	34.25	30.40	25.33	28.43	24.33	21.89	28.00	24.22
Species turnover	1.43	2.55	2.33	1.59	1.97	1.49	1.58	1.97	1.69	1.79	1.96	1.39	3.34

Table 3: Correlation coefficient between water variables and the first two axes of DCA

Water variables	Axis 1	Axis 2
Water temperature °C	-0.223	-0.404
pH	0.866***	0.454
Total alkalinity mg l^{-1}	-0.420	-0.123
Oxygen content mg l^{-1}	0.719**	0.013
EC μmohs/cm	-0.243	-0.692*
Turbidity N.T.U.	0.792**	0.817**
TDS mg l^{-1}	0.454	-0.086
PO_4-P µg l^{-1}	0.820**	0.702*
NH_4 mg l^{-1}	-0.533	-0.308
NO_3-N µg l^{-1}	0.728**	0.527
SiO_2 mg l^{-1}	0.898***	0.433
Na^+ mg l^{-1}	-0.984***	-0.426
K^+ mg l^{-1}	-0.960***	-0.503
Ca^{2+} mg l^{-1}	-0.523	-0.103
Mg^{2+} mg l^{-1}	-0.100	0.167
SO_4 mg l^{-1}	0.817**	0.059
Chlorophyll-*a* µg l^{-1}	0.262	-0.641*
Total phytoplankton counts l^{-}	-0.281	-0.913***

*: P< 0.05, **:P< 0.01, ***: P< 0.001

richness was that of cluster VI (34.25 species/sample), followed by cluster VII (30.4 species/sample). Otherwise, cluster II had the lowest value of species richness (13.71 species/sample).

In DECORANA analysis, the Eigenvalues of the axes were as follows: axis 1, 0.2; axis 2, 0.11; axis 3, 0.09; and axis 4, 0.07 (Fig. 4). Because the first two axes represented by far the largest portion of the variation, the other axes were not plotted. The sites of clusters I-VI (north sites) occupied the upper part of axis 1 and the sites of clusters VII-XII (south sites) occupied the lower part of the same axis. It is clear that axis 1 represents variation in distribution based on the site locations along the main water body of the lake. The southern sites were affected by the flood water and the northern ones were not. To emphasize this, the mean values of water turbidity in both of the north and south parts were determined (Fig. 5). Axis 2 showed more variations, as judged by the scores that ranged between-378 and 629, as compared with-281 and 468 for axis 1. The distribution of species along axis 2 indicated that the sites of clusters I-III occupied the right side of axis 2 and the sites of clusters IV-XII occupied the left side of the same axis.

The data concerning the correlation between the water variables and both of axis 1 and 2 (Table 3) revealed some significant correlation. The monovalent cations (Na^+ and K^+) correlated negatively with axis 1. The pH value, oxygen content, nitrate, silicate and sulphate correlated positively with axis 1. Turbidity and phosphate correlated positively with both of axis 1 and 2. The electrical conductivity, total phytoplankton counts and phytoplankton chlorophyll-*a* correlated negatively with axis 2. These results may indicate the importance of the aforementioned parameters in determining the structure and general pattern of the spatial distribution of phytoplankton communities in lake during the flood period. In this context, the turbulence caused by water turbidity could be regarded as a factor influencing water colour and light conditions that consequently affect the phytoplankton assemblages (Lepisto, 1999). Phytoplankton species composition and their relative abundance were shown to be consistently related with variables including physical disturbances (Padisak and Reynolds, 1998), pH values and nutrients (Wilk-Wozniak and Kosinski, 2001) particularly nitrate-nitrogen and phosphate-phosphorus (Pociecha and Wilk-Wozniak, 2000). It is worth mentioning here that in Lake Nasser, the main source of nutrient supply is the Nile river inflow which is controlled by the flood. Chlorophyll-*a* contents were estimated as the best descriptive parameter to indicate phytoplankton quantity in freshwater lakes (Voros and Padisak, 1991). Phytoplankton density and chlorophyll-*a* values in man-made lakes showed relatively good correlation (Bucka, 1998; Lepisto, 1999).

The results obtained from phytoplankton analyses, although based on once-collected samples, provided important information, stressing out the usefulness of investigations of its communities during the significant flood periods to evaluate the possible influences of the strong water level fluctuations on the development of phytoplankton in Lake Nasser.

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References

Abd El-Monem, A.M., 1995. Spatial distribution of phytoplankton and primary productivity in Lake Nasser. Ph. D. Thesis, University College of Girls, Ain Shams University, Egypt, pp: 161.

Ahmed, A.M., A.A. Mohammed, I. Springuel and A.M. El-Otify, 1989. Field and laboratory studies on Nile phytoplankton in Egypt-III, Some physical and chemical characteristics of Aswan High Dam Lake (Lake Nasser). Int. Revue ges. Hydrobiol., 74: 329-348.

APHA., 1992. Standard Methods for the Examination of Water and Wastewater. 18th Edn., American Public Health Association, Washington, DC., USA., ISBN-13: 978-0875532073, Pages: 1100.

Bishai, H.A., S.A. Abdel-Malek and M.T. Khalil, 2000. Lake Nasser. Publications of National Biodiversity Unit, Egypt. No. pp:11-577.

Bucka, H., 1998. Phytoplankton communities in the Wisla-Czarne dam reservoir in 1993-1994. In: Environmental Degradation in the Czarna Wiselka and Biala Wiselka Catchments, Western Carpathians Studia. S. Wrobel (Ed.), Nature, 44: 195-213.

Bucka, H., 2000. Diversity of flora and fauna in running waters of the Province of Cracow (Southern Poland) in relation to water quality-6. Characteristics of rivers on the basis of phytoseston communities. Acta Hydrobiol., 42: 95-122.

Carr, N.G. and B.A. Whitton, 1982. The Biology of Cyanobacteria. Bot. Monographs 19, Blackwell Sci. Publ., Oxford, Melbourne, pp: 688.

Commission of the European Communities, 1999. On line-Annex V of the Water Framework Proposal 1999. Water quality in the European Union (cited in 23 August). Available at http://europa. Eu. Int/water/water-framework/index-en. html.

El-Otify, A.M., 1991. Studies on phycoperiphyton of the Nile system at Aswan (Egypt). Ph. D. Thesis, Faculty of Science, Aswan, Assiut University, Egypt, pp: 373.

Entz, B., 1976. Lake Nasser and Lake Nubia. In: The Nile, Biology of an Ancient River, J. Rzoska (Ed.). Dr. W Junk B.V. Publishers. The Hague, Netherlands, pp: 271-298.

Entz, B., 1997. Natural history of Lake Nasser-Nubia with special reference to environmental and economic questions-In: Guidelines of Lake Management. S.E. Jogensen and S. Matsui (Eds.), Vol. 8, pp: 79-119.

Goodwin, M.H. and C.I. Goddard, 1974. An inexpensive multiple level water sampler. J. Fish. Res. Bd. Can., 31: 1667-1668.

Guarrera, S.A. and R.O. Echenique, 1992. Las algas der sistema del rio limay)R. Argentina) II. Chlorophyta: 3. Chlorococcales. Cryptogamie, Algol, 13: 257-272.

Hamed, A.F., 2000. Early warning on the blooming of phytoplankton inhabiting Lake Nasser Tushka area monitoring by remote sensing imagery. Egypt. J. Phycol., 1: 121-132.

Harris, G.P., 1986. Phytoplankton ecology; structure, function and fluctuation. Cambridge University Press, pp: 384.

Harris, G.P. and G. Baxter, 1996. Interannual variability in phytoplankton biomass and species composition in a subtropical reservoir. Freshwat. Biol., 35: 545-560.

Hecky, R.E., 1993. The eutrophication of Lake Victoria. Verh. Int. Verein. Limnol., 25: 39-48.

Hecky, R.E. and H.J. Kling, 1987. Phytoplankton of the great lakes of the rift valleys of central Africa. Arch. Hydrobiol., Ergebn. Limnol., 25: 197-228.

Hill, M.O., 1979a. DECORANA: A FORTRAN Program for Detrended Correspondence Analysis and Reciprocal Averaging. Cornell Univ. Ithaca, New York.

Hill, M.O., 1979b. TWINSPAN: A FORTRAN Program for Arranging Multi variate Data in an Order Two-Way Table by Classification of the Individuals and Attributes. Cornell Univ. Ithaca, New York.

Jacobsen, B.A. and P. Simonsen, 1993. Disturbance events affecting phytoplankton biomass, composition and species diversity in a shallow, eutrophic temperate lake. Hydrobiologia, 249: 9-14.

Kimor, B. and U. Pollingher, 1965. The plankton algae of Lake Tiberias. Ministry of Agriculture, Department of Fisheries, Sea Fisheries Research Station, Haifa, pp: 76.

Krienitz, L., 1990. Coccal green algae of the middle area of the river Elbe. Limnologica, (Berlin) 21: 165-231.

Lepisto, L., 1999. Phytoplankton assemblages reflecting the ecological status of lakes in Finland. Monographs of the Boreal Environmental research No. 16 Finish Environment Institute, Finland, pp: 43.

Mohamed, I.O., 1993. Some observations on water blooms of the High Dam Lake in 1987-1992. Working Report Fish Manag. Cent. High Dam Lake Develop. Auth., Aswan, Egypt. 3: 281-284.

Mohammed, A.A., A.M. Ahmed and A.M. El-Otify, 1989. Field and laboratory studies on Nile phytoplankton in Egypt. IV-Phytoplankton of Aswan High Dam Lake (Lake Nasser). Int. Revue ges. Hydrobiol., 74: 329-348.

Padisak, J. and C.S. Reynolds, 1998. Selection of phytoplankton associations in Lake Balaton, Hungary, in response to eutrophication and restoration measures, with special reference to the cyanoprokaryotes. Hydrobiologia, 384: 41-53.

Parsons, T.R. and J.D.H. Strickland, 1965. Particulate organic matter. III. I. Pigment analysis. III. I. I. Determination of phytoplankton pigments. J. Fish Res. Bd. Can., 8: 117-127.

Patterson, A.J.H. and O. Kachinjika, 1993. Effect of wind-induced mixing on the vertical distribution of nutrients and phytoplankton in Lake Malawi. Verh. Int. Verein. Limnol, 25: 872-876.

Pielou, E.C., 1975. Ecological Diversity. New York.

Pociecha, A. and E. Wilk-Wozniak, 2000. Effect of the flood upon the biological conditions in Dobczyce Reservoir. Acta Hydrobiol., 42: 59-67.

Prescott, G.W., 1954. How to know the freshwater algae. Brown Com., Dubuque Iowa, pp: 272.

Reynolds, C.S., 1986. The Ecology of Freshwater Phytoplankton. Cambridge University Press, pp: 348.

Smith, G.M., 1950. The Freshwater Algae of the United States, 2nd ed., New York McGraw-Hill Book Co., pp: 719.

Sommer, U., 1989. The role of competition for resources in phytoplankton succession. In: Plankton Ecology. Sommer, U. (Ed.). Springer Verlag, New York, pp: 57-106.

Stein, J.R., 1973. Hand Book of Phycological Methods, Culture Methods and Growth Measurements. Cambridge University Press, pp:448.

Talling, J.F., 1976. Water characteristics. In: The Nile, Biology of an Ancient River. J. Rzoska (Ed.). Dr. W. Junk B.V. Publishers. The Hague, Netherlands, pp: 357-384.

Talling, J.F., 1986. The seasonality of phytoplankton in African Lakes. Hydrobiologia, 138: 139-160.

Teiling, E., 1916. En kaledonisk fytoplanktonformation. (Caledonian phytoplankton formation). Svensk. Bot. Tidskr. 10: 506-519. (In Swedish).

Uhlmann, D., 1998. Reservoirs as ecosystems. Int. Rev. Hydrobiol., 83: 13-20.

Van der Veer, B., J. Koedood and P.M. Visser, 1995. Artificial mixing: A therapy measure combating cyanobacteria in lake Nieuwe Meer. Wat. Sci. Tech., 31: 245-248.

Voros, L. and J. Padisak, 1991. Phytoplankton biomass and chlorophyll-*a* in some shallow lakes in central Europe. Hydrobiologia, 215: 111-119.

Weber, C.I., 1971. A Guide to the Common Diatoms at Water Pollution Surveillance System Stations. U. S. Environmental Protection Agency, Ohio, pp: 98.

Wilk-Wozniak, E. and M. Kosinski, 2001. Effect of allochthonous and autochthonous factors on phytoplankton biomass in a submontane dam reservoir (S. Poland). Biologia, Bratislava, 56: 345-354.

Zaghloul, F.A., 1985. Seasonal variations of plankton in Lake Nasser. Ph. D. thesis, Faculty of Science, Suez Canal University, Egypt, pp: 364.

Zohary, T., A.M. Pais-Madeira, R. Robarts and K.D. Hambright, 1996. Interannual phytoplankton dynamics of a hyper trophic African lake. Arch. Hydrobiol., 136: 105-126.