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Water quality and potamoplankton evaluation of the Nile River in Upper Egypt

Qualidade da água e avaliação do potamoplâncton do rio Nilo no Alto Egito

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Abstract: Aim: The composition, abundance, community structure of potamoplankton and major physical and chemical variables of the Nile water in Upper Egypt were investigated to assess its status in different seasons during 2007. **Methods:** Water samples were collected seasonally during 2007 from six investigated sites from variable depths at levels of 0, 2.5 and 5 m. The area of this investigation is defined as the southern 120 Km of the main stream of the Nile in Upper Egypt (24° 04' – 25° 00' latitudes and 32° 51' – 32° 54' longitudes), downstream of Aswan Old Dam. **Results:** Altogether, 121 potamoplankton species, of which 85 related to phytoplankton and 36 appertaining to zooplankton were recorded. Most numerous phytoplankton were Chlorophyceae (42 species) followed by Bacillariophyceae (30 species). Cyanobacteria and Dinophyceae were less numerous with only 11 and 2 species, respectively. Zooplankton species were mainly belonging to three systematic groups namely; Rotifera (24 species), Copepoda (3 species) and Cladocera (9 species). Besides, other rare zooplankton including Platyhelminthes, Nemata and Ciliophora were sparsely encountered. The main hydrological conditions characterizing the investigated area include water level fluctuations (<82 - >85 m above sea level), relatively high current velocity (0.8 - 1.3 m sec^{-1}) and disposal of wastewater. Plankton populations were variably but rather weakly dependent on the major nutrients due to their excessive availability in accessible form for uptake by the producers. For phytoplankton, the community structure was categorized in relation to temperature, pH, SO_4^{2-} and Mg^{2+}. For zooplankton, the community structure was categorized in relation to conductivity as well as Mg^{2+}. Sampling intervals were inadequate to demonstrate the existing successional pattern of the Nile potamoplankton community. Alterations in the phytoplankton community structure accompanied changes in water temperature represented by the alternate dominance between diatoms and cyanobacteria, while zooplankton community was always dominated by rotifers. Phytoplankton populations were numerically more abundant in autumn and zooplankton peaked in spring. **Conclusions:** Wastewater disposal restricted the abundance of the Nile zooplankton assemblages mainly due to the numerical decline of Rotifera and Cladocera. Otherwise, wastewater did not exert major limits for phytoplankton. The data obtained in this investigation will be crucial to understand potamoplankton regulation and contribute to the knowledge regarding the Limnology of the Nile basin.

Keywords: potamoplankton; phytoplankton; zooplankton; water quality; River Nile.

Resumo: Objetivo: A composição, abundância, estrutura da comunidade do potamoplâncton e as principais variáveis físicas e químicas da água do Nilo, no Alto Egito foram investigadas para avaliar o seu estado em diferentes estações do ano em 2007. **Métodos:** Amostras de água foram coletadas zonalmente em 2007 em seis locais nas profundidades 0; 2,5 e 5 m, no canal principal do rio Nilo. A área estudada se estende por 120 Km a jusante da Barragem Velha de Aswan, no Alto Egito (24° 04' – 25° 00' latitude e 32° 51' – 32° 54' longitude). **Resultados:** Ao todo, foram observadas 121 espécies de plâncton, dos quais 85 pertencentes ao fitoplâncton e 36 pertencentes ao zooplâncton. Durante o período de estudo o fitoplâncton foi dominado por algas verdes (40 espécies) e diatomáceas (36 espécies). As cianobactérias e os dinoflagelados são menos representados, com apenas com 11 espécies. No zooplâncton foram identificadas 24 espécies de Rotífera 3 espécies de Copepoda e 9 espécies de Cladocera. Também foram encontradas outros organismos zooplactônicos pouco abundantes, incluindo Platyhelminthes, Nematoda e

Ciliophora. As condições hidrológicas da área de estudo caracterizam-se por acentuadas flutuações no nível da água (<82 - >85 m acima do nível do mar), e por uma elevada velocidade de corrente (0.8 - 1.3 m sec^{-1}). Outro factor a se salientar é o input de águas residuais, com elevadas concentrações de nutrientes disponíveis para o fitoplâncton. Para o fitoplâncton, a estrutura da comunidade foi relacionada com a temperatura, pH, $SO4^{2-}$ e Mg^{2+}. Para zooplâncton, a estrutura da comunidade foi relacionada com a condutividade, bem como Mg^{2+}. Os Intervalos de amostragem foram insuficientes para demonstrar a existência de padrões sucessionais na comunidade de potamoplancton no Rio Nilo. As alterações observadas na estrutura da comunidade fitoplanctônica acompanharam as variações na temperatura da água, verificando-se a alternância entre as diatomácias e cianobactérias. A comunidade zooplanctónica foi dominada por rotíferos. As densidades de fitoplancton atingiram o pico no outono enquanto que as densidades do zooplâncton atingiram o pico na primavera. **Conclusões:** Os inputs de águas residuais contribuíram para a redução na abundância do zooplâncton não tendo influenciado o fitoplâncton. Os dados obtidos nesta investigação serão cruciais para aumentar os conhecimentos limnológicos na bacia do Nilo.

Palavras-chave: potamoplâncton; fitoplâncton; zooplâncton; qualidade da água; Rio Nilo.

1. Introduction

In river ecosystems, ecological structure and processes are represented by autotrophic and heterotrophic potamoplankton organisms. Autotrophic potamoplankton consists of phytoplankton, whereas heterotrophic plankton components are mainly represented by zooplankton. Phytoplankton plays a central role in the structure and function of river ecosystems and determines their primary productivity. Zooplankton assemblages form an integral part of the lotic community and contribute significantly to the biological productivity. These assemblages have a decisive role in mediating and determining the strength of energy transfer from lower to higher trophic levels of freshwater streams (Lampert & Sommer, 1997). Changes in potamoplankton abundance, species diversity or community composition constitute a potential bio-indicator of water quality and changes in response to local pollution or disturbance (Wetzel, 2001; Kalff, 2002). Consequently, potamoplankton is regarded as one of biological elements in the assessment of the ecological status in inland freshwater streams.

Several factors could simultaneously influence the development and population dynamics of potamoplankton in lotic ecosystems (Karrasch et al., 2001; Fetahi et al., 2011). In this respect, seasonal changes of physical and chemical variables (Lack, 1971; Swanson & Bachmann, 1976; Grobbelaar, 1985; Harris, 1986; Descy, 1987, 1993; Ruyter Van Steveninck et al., 1990; Reynolds, 1992, 1995; Reynolds et al., 1994; Billen et al., 1994; Stoyneva, 1994; Bos et al., 1996; Ayodele & Adeniyi, 2006; Okogwu & Ugwumba, 2006; Ibrahim, 2009) have been discussed as major controlling conditions. In addition, the biotic factors such as competition, grazing and predation pressure (Brooks & Dodson, 1965; Gallegos, 1989; Armendáriz et al., 2012; Dokulil, 2013) appeared to be important in determining the potamoplankton assemblages.

Investigations of potamoplankton along the main stream of the Nile in Egypt started in early twentieth century (Kneucker, 1904). Since then, many uncoordinated studies, rather diverse in duration, approach; sampling frequencies have been carried out dealing with phytoplankton (Abdin, 1948a, b; Fayed & Shehata, 1979; El-Ayouty & Ibrahim, 1980; Shehata & Bader, 1985; Ahmed et al., 1986; Mohammed et al., 1986; Kobbia et al., 1990, 1993, 1995; Shabana et al., 1993). Similarly, the Nile zooplankton community was repeatedly investigated dealing with taxonomy and quantitative composition (Elster & Vollenweider, 1961; Klimowicz, 1961a, b; Obuid-Allah, 1990a, b; Mostafa et al., 1998; Hussein et al., 1999; Iskaros et al., 2008; Dumont, 2009). Accordingly, zooplankton community of the Nile in Egypt is mainly composed of 112 species of rotifers, in addition to 14 copepods and 10 cladocerans.

Since Upper Egypt underwent rapid urbanization and industrialization in the last few decades, the Nile water have been increasingly exposed to nutrients and organic pollutants generated by untreated industrial and domestic wastewaters. The Nile water serves as a drinking water supply in Upper Egypt and is also a recipient of both industrial and municipal wastes discharged at certain sites along its main stream. Pollution in the drinking water supplies calls for special attention due to the ability of the pollutants to cause considerable hazards to animal and human health. The Nile potamoplankton was found to be sensitive to water quality (Shehata & Bader, 1985) and disturbance caused mainly by input of industrial wastes. Thus, it is of great importance to understand the Nile potamoplankton dynamics and the factors influencing their development and distribution.

This study aimed at investigating potamoplankton assemblages and the major water physical and chemical features along the main stream of the Nile in Upper Egypt in order to depict the dynamics of potamoplankton community in an attempt to evaluate the influence of wastewater discharge on the Nile water potamoplankton populations.

2. Material and Methods

2.1. Investigational area and monitoring sites

The Nile is one of the largest rivers in Africa with a basin area of 2.9 million Km^2 extending from 4° south to 31° north latitudes. It is the longest river in the world which flows in a tropical environment over a distance of 6670 Km from its remotest source in Tanzania northwards into the outlet of Mediterranean Sea in north Egypt.

The area of this investigation is defined as the southern 120 Km of the main stream of the Nile in Upper Egypt. This study area extends between 24° 04’ – 25° 00’ latitudes and 32° 51’ – 32° 54’ longitudes, downstream of Aswan Old Dam. The investigated part of the Nile is subjected to disposal of untreated domestic sewage and industrial wastewater through drainage canals caused point source pollution. The industrial effluents are mainly produced by Fertilizers Factory (Aswan), the Sugar Cane Factory (Kom Ombo) and the Ferrosilicon Factory (Edfu) at distances of 7, 45 and 100 km north of Aswan Old Dam, respectively. Three sectors comprising six sites (1 – 6) were selected; at each sector two sites (one upstream and the other downstream of the wastewater discharge points) were investigated (Figure 1).

2.2. Sampling regime and laboratory procedures

Water samples were collected seasonally during 2007 from six investigated sites (Figure 1). These samples were collected from variable depths at levels of 0, 2.5 and 5 m using the water sampler Van-Dorn Bottle. The following variables were measured *in situ*: water temperature with an ordinary glass mercury thermometer calibrated to tens of a degree centigrade, water transparency by a Secchi disc of 0.3 m diameter, pH value with a glass electrode pH meter (Orion model 601/ digital ionalyzer, Orion, USA), conductivity and salinity using an Amber Science Inc. San Diego, CA, USA conductivity meter model 1062, dissolved oxygen by an oxygen electrode (Jenway Oxygen meter, model 1070; Jenway, UK). Chemical variables: nitrate-nitrogen, phosphate-phosphorus, soluble reactive silica, sulphate ion concentrations, the divalent cations (Ca^{2+} and Mg^{2+}) were determined in the laboratory according to standard methods (APHA, 1985). For chlorophyll-*a* concentration, water was filtered through Whatman GF/C glass-fibber filter and subsequently extracted with acetone. Absorbance was measured spectrophotometrically at three different wavelengths (630, 645 and 663 nm). Chlorophyll-*a* concentrations were calculated according to Marker et al. (1980). For phytoplankton determinations, aliquots of water samples were immediately fixed with standard Lugol’s solution. Subsequently phytoplankton was concentrated by sedimentation and preserved with 5% neutral formalin. From each concentrated sample a 0.1 mL quantitative sub-sample was examined microscopically in a counting cell under magnification (400×). The counting unit was the individual (cell, filament or colony). The abundance of each species was presented as the number of individuals per liter (ind. L^{-1}). Zooplankton

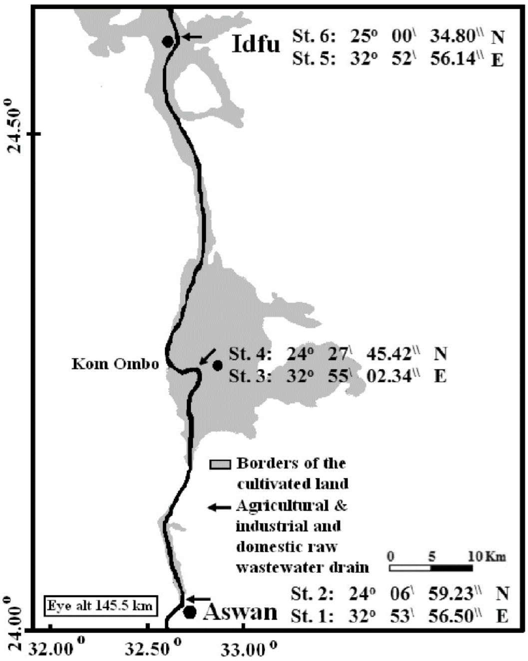

Figure 1. Map of the study area showing location of the sampling sites.

samples were collected with 50 µm mesh tow net. To determine numerical abundance, samples were vertically hauled (Wetzel & Liknes, 2001) from 5 m to the surface at each sampling site. The volume of water filtered (v) was calculated from the following formula: $v = \pi r^2 d$, where r = radius of net ring (0.15 m) and d = the distance towed (5 m). The samples were immediately preserved with formalin to a final concentration of approximately 5%. In the laboratory, each concentrated original sample of 250 mL was mixed homogeneously and three sub-samples were investigated. A one mL sub-sample was taken with a wide mouth pipette, and then poured into a counting cell where the different zooplankton individuals were identified and counted as number of individuals per cubic meter (ind. m^{-3}). Most abundant potamoplankton species were estimated from percentage contribution of individual species to total abundance. Only those potamoplankton species, which had a minimum of 5% contribution to total abundance, were considered to be the most abundant.

2.3. Data analysis

Cluster analysis was used to analyse the variability in potamoplankton composition over seasons and among sites. Detrended correspondence analysis (DCA) as an ordination technique was applied to the data set of potamoplankton species. Relationships between the potamoplankton assemblages and water variables were tested by simple linear correlation coefficient (*r*) using MINITAB statistical software, INC, USA.

3. Results

During the study period the investigated area was characterized by extreme arid conditions with no precipitation and hot summer with a mean value of maximum temperatures of 45.6 °C. The current speed in this part is relatively fast ranging from 0.8 (in winter) to 1.3 m sec^{-1} (in summer) and the water level fluctuated around 82 m above sea level during autumn-winter and increased gradually afterwards to reach its maximum of more than 85 m above sea level in summer (Aswan Water Resources and Irrigation Authority, personal communications).

3.1. Water quality

Mean annual values (Table 1) and seasonal fluctuations (Figure 2) of the main physical and chemical variables with their standard deviations are reported. During winter and autumn, the Nile water temperature was lower than spring and summer. There was a marked increase in water temperature in the summer season. Secchi Disc visibilities were recorded to be of relatively high values during the period of this investigation and reached its highest level in winter. Values of pH were always above 7, indicated slight alkaline water conditions of the Nile water. In addition, slight seasonal fluctuations in pH were observed. Relatively low values of dissolved oxygen were recorded with the elevation of water temperature in summer. Under saturation of dissolved oxygen was the main pattern throughout the investigation period. Relatively high oxygen saturation conditions were observed in winter. Conductivity was generally of moderate values with a tendency to be of somewhat higher values in the north sites than those in the south. In winter, slightly high conductivity values were recorded as compared to the other seasons. Levels of salinity and total hardness were however, relatively more stable with noticeable low values of total hardness in winter. The mean annual values of these levels fluctuated from 0.09 to 0.11% and from 34.09 to 37.62 mgl^{-1} for salinity and total hardness, respectively. Mean annual values of NO_3-N concentrations increased gradually from the south to the north sites. There was no clear trend in differences between the upstream and downstream sites of wastewater discharge points. The only dramatic elevation of NO_3-N concentrations during the four investigated seasons was in spring. In the northern investigated sites, a notable increase of PO_4-P was recorded in the downstream sites of wastewater discharge points. A progressive decline in PO_4-P was observed during the spring and summer seasons followed by a pronounced increase in autumn. Levels of the soluble reactive silica concentrations did not show substantial differences between upstream and downstream sites of the wastewater discharge points. A relatively high concentration of silica was recorded in winter followed by a steady decrease that was maintained to the end of this investigation. Water contents of sulphate ions were of relatively lower mean annual values in upstream sites as compared to the downstream ones and did not exhibit wide range of variations among the investigated sites. In winter and spring, levels of sulphate were somewhat lower than those in summer and autumn.

3.2. Phytoplankton

Chlorophyll-*a* concentrations and total counts of phytoplankton (Figure 3) fluctuated over the downstream and upstream sites of the wastewater

Table 1. Mean annual values and standard deviations (SD) of water quality parameters along the main stream of the Nile in Upper Egypt during 2007.

Parameters	Aswan		Kom Ombo		Edfu	
	Mean	SD	Mean	SD	Mean	SD
Water temperature °C						
Upstream	19.52	1.91	19.80	3.04	20.55	2.69
Downstream	20.61	2.42	19.83	2.33	21.19	2.21
Secchi Disc depth m						
Upstream	4.38	1.09	4.37	1.8	3.75	0.74
Downstream	5.56	0.72	3.75	1.02	4.00	1.14
pH value						
Upstream	7.56	0.04	7.62	0.13	7.58	0.06
Downstream	7.54	0.05	7.65	0.17	7.58	0.08
Dissolved oxygen mg L^{-1}						
Upstream	5.19	1.93	5.80	1.71	6.04	1.57
Downstream	5.08	1.73	5.81	1.73	6.00	1.48
Oxygen saturation %						
Upstream	57.54	19.96	64.58	17.86	68.50	16.68
Downstream	60.13	17.27	64.95	18.28	68.80	15.35
Salinity %						
Upstream	0.09	0.01	0.11	0.01	0.11	0.01
Downstream	0.09	0.01	0.10	0.02	0.11	0.01
Electrical conductivity µS cm^{-1}						
Upstream	230.83	36.93	239.25	30.68	269.33	37.54
Downstream	253.33	80.41	238.08	31.74	266.67	39.10
No_3-N µg L^{-1}						
Upstream	533.74	188.27	674.89	363.17	858.18	418.18
Downstream	628.91	288.89	680.80	300.36	756.09	383.32
PO_4-P µg L^{-1}						
Upstream	49.90	35.12	41.66	27.94	29.60	14.41
Downstream	40.68	26.27	52.99	32.98	33.0.5	15.61
Soluble reactive silica mg L^{-1}						
Upstream	2.69	1.16	3.70	1.35	3.54	1.21
Downstream	2.89	0.62	3.53	1.35	3.54	1.07
Sulphate mg L^{-1}						
Upstream	10.03	3.93	10.88	2.27	14.06	4.03
Downstream	8.56	4.20	10.47	3.15	12.84	2.66
Ca^{2+} mg L^{-1}						
Upstream	29.58	3.61	28.71	3.58	31.18	3.29
Downstream	28.96	4.84	29.35	4.16	32.76	3.46
Mg^{2+} mg L^{-1}						
Upstream	5.47	1.39	6.52	1.64	5.80	0.94
Downstream	5.13	1.35	5.80	2.27	4.86	156
Total hardness mg L^{-1}						
Upstream	34.97	2.65	35.32	3.91	36.98	3.27
Downstream	34.09	4.25	35.20	2.64	37.62	2.34

discharge points with no distinct spatial pattern. The annual cycle observations (Figure 4) indicated somewhat temporal periodicity; low values were recorded in spring and summer whereas high values were observed in autumn and winter.

Mean annual values of the phytoplankton population density in the different investigated sites varied from 132.54 × 10^4 to 164.43 × 10^4 ind.L^{-1}, while the seasonal changes of phytoplankton abundance were in the range of 122.11 × 10^4 – 215.45 × 10^4 ind.L^{-1}. Phytoplankton community was dominated by Bacillariophyceae in winter, spring, and autumn (Figure 5). In summer, there was an increasing proportion of Cyanobacteria in the phytoplankton such that this group dominated the total phytoplankton counts by 46.59%. Chlorophyceae had intermediate densities, whereas Dinophyceae contributed only marginally to total phytoplankton densities.

Eighty-five phytoplankton species related to four groups; Cyanobacteria, Bacillariophyceae, Dinophyceae and Chlorophyceae were distinguished

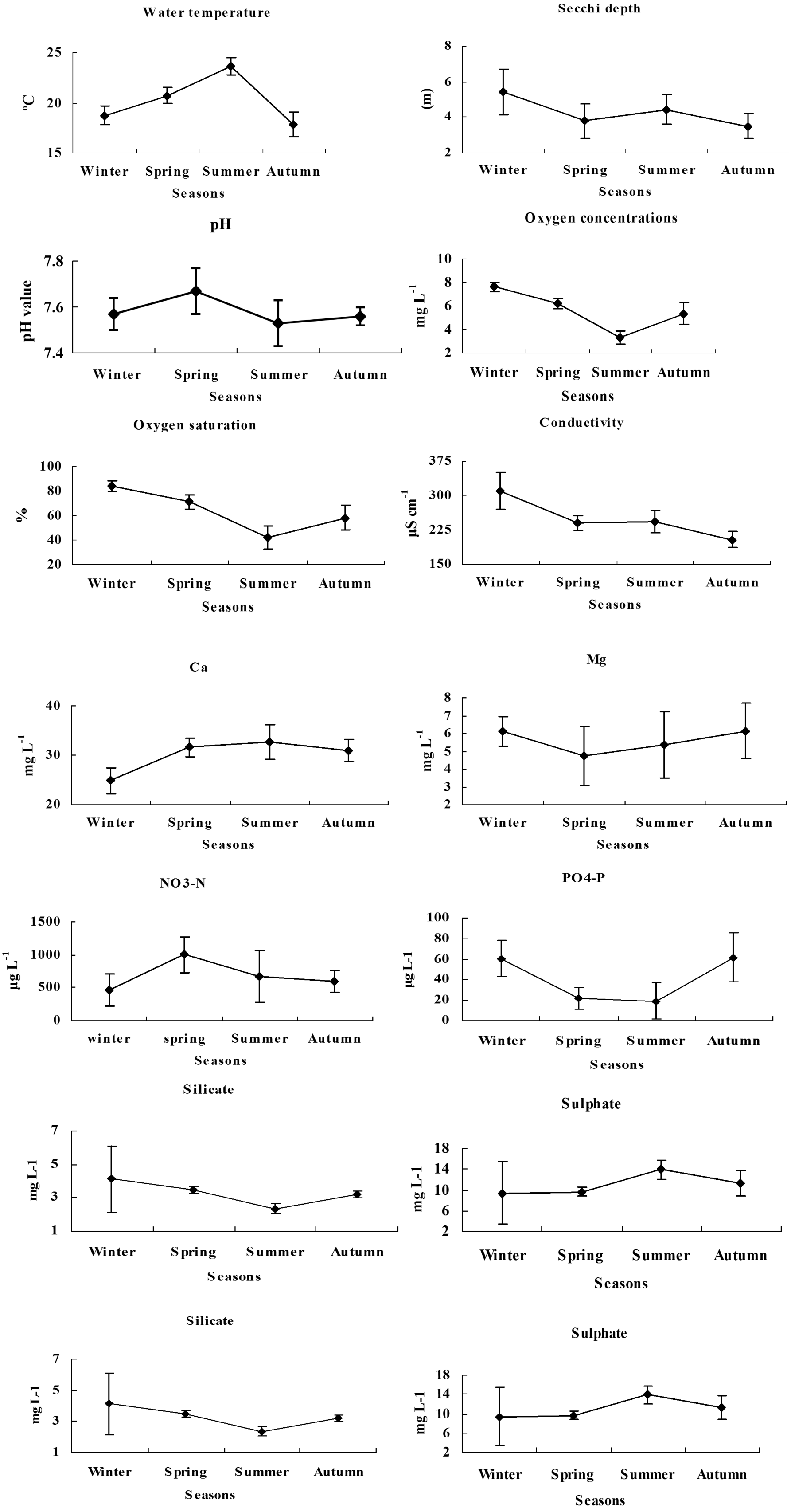

Figure 2. Seasonal variations in the major physico-chemical parameters along the main stream of the Nile in Upper Egypt during 2007.

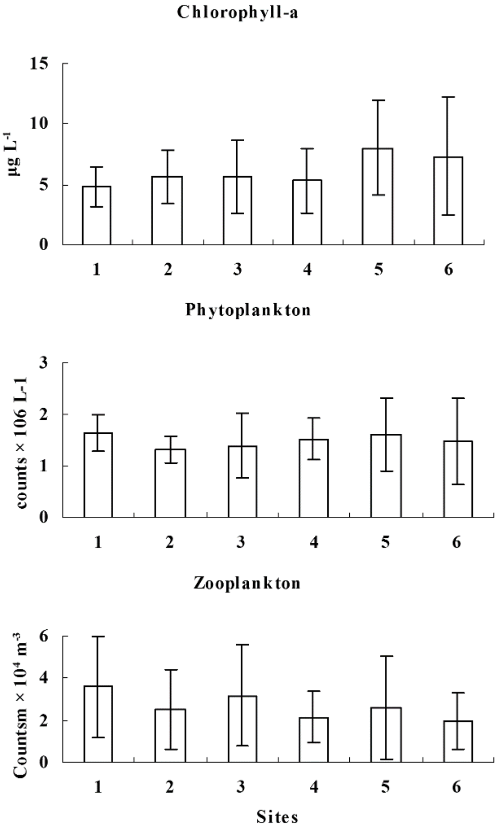

Figure 3. Spatial distribution of plankton (mean annual values ±SD) along the main stream of the Nile in Upper Egypt during 2007.

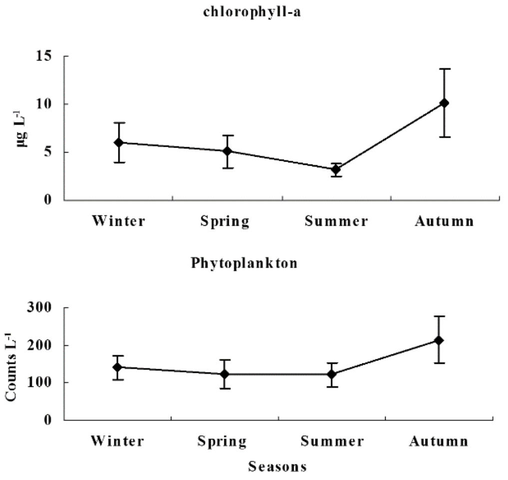

Figure 4. Seasonal periodicity of phytoplankton (mean values ±SD) along the main stream of the Nile in Upper Egypt during 2007.

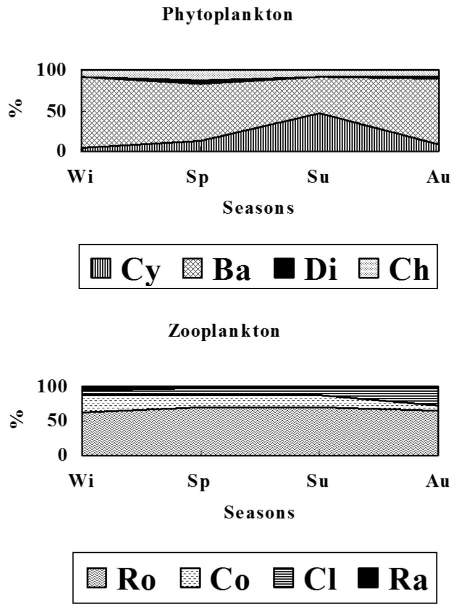

Figure 5. Seasonal fluctuations in percentage contribution of the different plankton groups along the main stream of the Nile in Upper Egypt during 2007. Wi: Winter; Sp: Spring; Su: Summer; Au: Autumn; Cy: Cyanobacteria; Ba: Bacillariophyceae; Di: Dinophyceae; Ch: Chlorophyceae; Ro: Rotifera; Co: Copepoda; Cl: Cladocera; Ra: Rare forms.

over the entire period of this investigation (Table 2). Eleven species were detected during counting as the most abundant species. The largest community in terms of number of species was Chlorophyceae with 42 species constituting 49.4% of overall recorded species. Bacillariophyceae was the second most common with 30 species accounting for 35.3% of the total community number of species. Other 13 species; 11 Cyanobacteria and 2 Dinophyceae contributed 12.9 and 2.4% of the total species number, respectively.

Compositional data set of phytoplankton was subjected to cluster analysis which resulted in separation of some distinct patterns (Figure 6). Group-I and the closest related Group-II clusters correspond to those summer occasions when cyanobacteria dominated the phytoplankton community. The most characteristic feature is the co-dominance of *Planktolyngbya* sp. and *Anabaenopsis cunningtonii*. Group-I comprises a cluster (1) emanates from the northern investigated sites. Group-II embraces four clusters (2 – 5) that combine the intermediate and southern sites. Clusters 6 and 7 (Group-III) combine winter – spring phytoplankton assemblages. Next to them clusters 8 - 9 from the same group and clusters 10 - 11 from the fourth (Group-IV) contain data exclusively related to spring season. Then, another small cluster (12) which is loosely connected to this group contains the autumn phytoplankton assemblages of the southern investigated site. At this point, the primary bifurcation of the diagram is reached and the second part of the diagram

Table 2. Phytoplankton species recorded along the main stream of the Nile in Upper Egypt and their presence contributions (%) of the eight phytoplankton clusters distinguished after the application of Twinspan classification.

Phytoplankton species	I (1)	II (2 – 5)	III (6 – 9)	IV (10 -12)	V (13 – 15)	VI (16)	VII (17 – 18)	VIII (19)	Total presence (%)
Cyanobacteria:									
Anabaena sp. Bory de Saint Vincent ex Bornet & Flahault *	-	●	R	●	-	-	●	●●●	R
*Anabaenopsis cunningtonii*Taylor	●●●●●	●●●●●	●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Chroococcus sp. Nägeli	-	R	●●●	●●	●	●●	●●●	●●●	●●
Gomphosphaeria sp. Kützing	-	-	R	●	-	-	-	-	R
Merismopedia warmingiana Lagerheim	●●●●●	●●●●●	●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Microcystis aeruginosa Kützing	●●	-	R	●●●	●●●	-	●●●	●●●●●	●●
Oscillatoria sp. Vaucher	●●●●	●●●●	●●	●●●●●	●●●●●	●●●●●	●●●	●●●●●	●●●
Phormidium sp. Kützing *	-	●●●	R	●●●	●	●●●	●	-	●●
Planktolyngbya sp. Anagnostidis & Komárek *	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Planktothrix agardhii (Gomont) Anagnostidis & Komárek	●●	●	R	●●●	●●	●●●	-	-	●
Spirulina sp. Turpin	●●●●●	●●●●●	●	●●	●●	●●●●	●●	-	●●
Bacillariophyceae:									
Amphora ovalis Kützing	●●●●	R	●	-	●●●●●	●●●●	●●●	●●●	●●
Aulacoseira granulate (Ehrenberg) Simonsen *	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Caloneis silicula (Ehrenberg) Cleve	●●	-	R	-	-	-	-	-	R
Cocconeis placentula Ehrenberg *	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●	●●●●●
Cyclotella meneghiniana Kützing Ehrenberg *	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Cymatopleura elliptica (Brébisson) W. Smith	-	-	-	●	-	-	-	-	R
C. solea (Brébisson) W. Smith	-	-	R	-	●●●	●●	●●●	●●●	●
Cymbella ventricosa Kützing	●●●●●	●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Epithemia sorex Kützing	-	R	R	●	-	-	-	-	R
Fragilaria ulna (Nitzsch) Lange-Bertalot *	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●

●●●●●: ≥ 90%, ●●●●: ≥ 75%, ●●●: ≥ 50%, ●●: ≥ 25%, ●: ≥ 10%, R (Rare): ≤ 10%, -: absent. The eleven important species are designated by asterisks.

Table 2. Continued...

Phytoplankton species	I (1)	II (2 – 5)	III (6 – 9)	IV (10 -12)	V (13 – 15)	VI (16)	VII (17 – 18)	VIII (19)	Total presence (%)
Gomphonema acuminatum Ehrenberg	-	-	-	-	-	●●	-	-	R
G. olivaceum (Hornemann) Brébisson	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
Gyrosigma acuminatum Kützing	●●	-	R	●	-	-	-	-	R
G. scalproides (Rabenh) Cleve	●●	-	-	-	●●	-	-	-	R
Melosira varians J. G. Agardh *	-	-	R	●●	-	-	●●●	●●●	●
Navicula bacillum Ehrenberg	-	-	R	-	-	●●	-	-	R
N. cryptocephala Kützing	●●●●●	●●●	●●●	●●●	●●●	●●	●●●	●●●	●●●
N. exigua Gregory	●●●●	●	●●●●●	●●●	●●●●●	●●●●●	●●●	●●●	●●●●
N. gastrum Ehrenberg	●●●●	●●	●●●	●●●●	●●●●●	●●●●●	●●●●	-	●●●
N. pupula Kützing	-	-	R	-	●●●●	●●●●	●	-	●
N. rhynchocephala Kützing	●●	R	●	●	-	-	●●	-	●
Nitzschia holsatica Hustedt	●●●●●	●●●●●	●●●	●●●	●●●●	●●●●●	●●●●●	-	●●●
N. parvula W. Smith non Lewi	●●●	-	-	-	-	●●●	●	-	R
N. sigmoidea (Nitzsch)	-	-	●	-	-	-	●	-	●
N. sp. Hassall	●●●●●	●	●●	●	●	●●●●	●●	●●●●●	●●
Pinnularia sp. Ehrenberg	●●	-	-	-	-	-	-	-	R
Rhoicosphenia curvata (Kützing) Grun.	●●●	-	-	-	-	●●●	-	-	R
Rhopalodia gibba (Ehrenberg) O. Müller	●●●●	●	R	●	●●	●●	-	-	●
Surirella ovata Kützing	●●	●●	R	-	●●	●●●●●	●●●	●●●	●●
S. robusta Ehrenberg	-	-	-	●	-	●●	-	-	R
Dinophyceae:									
Ceratium hirundinella (O. F. Müller) Dujardin *	-	●	●●	●●●●●	●●●	●●	●●●	●●●	●●
Peridinium sp. Ehrenberg *	●●●●●	●●●●	●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●
Chlorophyceae:									
Ankistrodesmus bibraianus Korshikov	●●	-	R	-	●●	●●	-	-	R
A. falcatus (Corda) Ralfs *	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
A. spiralis (Turpin) Lemmermann	-	R	●	●●	●●●	●●●	●●●●●	●●●●●	●●

●●●●●: ≥ 90%, ●●●●: ≥ 75%, ●●●: ≥ 50%, ●●: ≥ 25%, ●: ≥ 10%, R (Rare): ≤ 10%, -: absent. The eleven important species are designated by asterisks.

Table 2. Continued...

Phytoplankton species	I (1)	II (2 – 5)	III (6 – 9)	IV (10 -12)	V (13 – 15)	VI (16)	VII (17 – 18)	VIII (19)	Total presence (%)
A. stipitatus (Chodat) Komárková-Legnerová	-	-	-	-	-	-	●	-	R
Closterium aciculare T. West	-	-	●	●	-	-	-	-	R
C. acutum Brébisson	-	-	R	●	-	-	-	-	R
C. venus Kützing	●●●●●	●●●	●●●●	●●	●●●●●	●●●	●●●●●	●●●	●●●
Coelastrum cambricum Archer	-	-	●●	●●●	●●●	●●●	●●●●	-	●●
C. microporum Nägeli	-	-	●	●	-	-	-	-	●
C. reticulatum (Danjeard) Senn.	●●●	●	●●	●●●	●●●●●	●●●●	●●●●	●●●	●●●
Cosmarium botrytis Meneghini	-	●	-	-	-	-	-	-	R
C. depressum Lundell	●●	●●●	R	-	-	●●	-	-	●
Crucigenia rectangularis (Nägeli) Gay	●●●●●	●●●	●●●●●	●●●●●	●●●●●	●●●●	●●●●●	●●●●●	●●●●
Dictyosphaerium pulchellum Wood	●●●	●●●	●●●●●	●●●●●	●●●●	●●●●	●●●●●	●●●●●	●●●●
Elakatothrix genevensis (Reverdin) Hindák	●●●●●	●●●●	●●●●	●●●●●	●●●●●	●●●●●	●●●●	●●●●●	●●●●●
Golenkinia radiata Chodat	●●	●	●●●●	●●●	●●	●●●	●●●	●●●	●●●
Kirchneriella lunaris (Kirchner) Moebius	-	-	R	●●	●●●	-	●●	●●●	●
K. obesa (W. West) Schmidle	-	R	●	●	-	●●	●●	●●●●●	●
Lagerheimia ciliate (Lagerheim) Chodat	●●●	●●●●	●●●●●	●●●	●●●●	●●	●●	●●●●●	●●●●
L. quadriseta Lemmermann	●●	●	●●	●●●	-	-	-	-	●●
Micractinium sp. Fresenius	-	-	-	●	●●	●●●●	●●●●	-	●
Oocystis solitaria Wittrock	●●	-	R	-	-	-	-	-	R
O. sp. A. Braun	-	-	-	●●	-	-	●	●●●●●	R
Pediastrum biradiatum Meyen	-	-	-	-	-	-	●	-	R
P. boryanum (Turpin) Meneghini	-	-	-	●	●	●●●●●	●●	-	●
P. duplex Meyen	-	-	-	-	●	-	●	-	R
P. simplex Meyen	●●●●	●●	●●	●●●●	●●●●	●●●●●	●●●●	-	●●●
P. tetras (Ehrenberg) Ralfs	-	-	R	-	●●	-	-	-	R
Scenedesmus acuminatus (Lagerheim) Chodat	●●●	●	R	●	●●●●	●●●●●	●●	-	●●
S. acutus Meyen	-	-	R	-	-	-	-	-	R
S. arcuatus Lemmermann	-	-	R	-	-	-	-	-	R
S. bijuga (Turpin) Lagerheim	-	-	R	-	-	-	-	-	R

●●●●●: ≥ 90%, ●●●●: ≥ 75%, ●●●: ≥ 50%, ●●: ≥ 25%, ●: ≥ 10%, R (Rare): ≤ 10%, -: absent. The eleven important species are designated by asterisks.

Table 2. Continued...

Phytoplankton species	I (1)	II (2 – 5)	III (6 – 9)	IV (10 -12)	V (13 – 15)	VI (16)	VII (17 – 18)	VIII (19)	Total presence (%)
S. ecornis (Ehrenberg) Chodat	●●●●	●●	●●	●	●●	●●●	●	-	●●
S. obtusus Meyen	-	-	-	-	-	-	-	●●●	R
S.quadricauda (Turpin) Brébisson	●●●●	●●	●●	●●	●●●●	●●●●	●●●	-	●●
S. sp. Meyen	●●●●	●●●	●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●
Schroederia setigera (Schröder) Lemmermann	●●	●●	●●	-	-	●●	-	-	●
Staurastrum leptoclodum Nordst	-	-	-	-	-	●●	●	-	R
S. paradoxum Meyen	●●●●●	●●●●●	●●●●	●●●●●	●●●●●	●●●●	●●●●●	●●●●●	●●●●●
Tetraedron caudatum (Corda) Hansgirg	-	-	R	-	-	●●	-	-	R
T. minimum (A. Braun) Hansgirg	●●	●●●	●●●●	●●	●●●	●●	●●●	●●●	●●●
T. trigonum Hansgirg	-	●●	-	-	-	-	-	-	R
Total species	49	49	68	57	51	56	56	38	85

●●●●●: ≥ 90%, ●●●●: ≥ 75%, ●●●: ≥ 50%, ●●: ≥ 25%, ●: ≥ 10%, R (Rare): ≤ 10%, -: absent. The eleven important species are designated by asterisks.

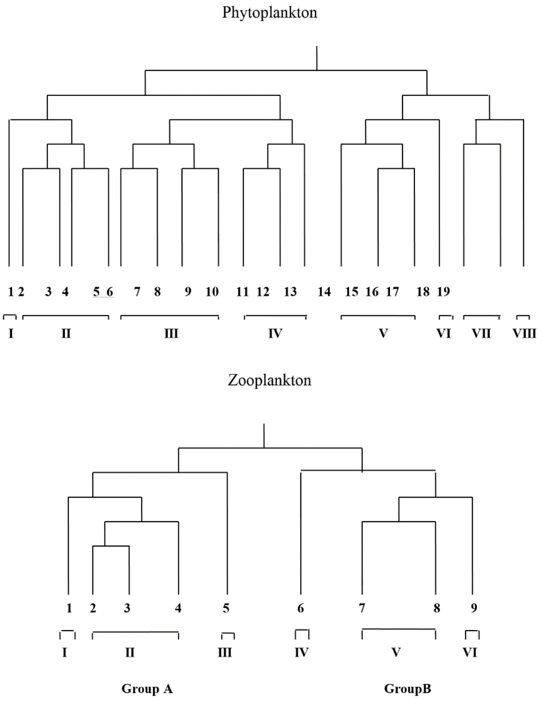

Figure 6. Diagrams of the different Nile plankton groups generated after the application of cluster analysis.

(Groups V - VIII) encompasses, with few exceptions clusters that combine the autumn phytoplankton assemblages. Those assemblages were characterized by the co-dominance of *Cyclotella meneghiniana* and *Aulacoseira granulate*; besides *Melosira varians* was subdominant.

In the Decorana analysis, the phytoplankton clusters showed a remarkable spread along axis 1 of the ordination diagram (Figure 7). The vast majority of the clusters that correspond to winter - spring assemblages occupied the left side of the diagram and those related to summer – autumn assemblages occupied the right side. DCA axis 1 scores showed a negative correlation with pH value (r = -0.593, p = 0.033) and a positive correlation with $SO4^{2-}$ (r = 0.586, p = 0.035). DCA axis 2 scores correlated positively with water temperature (r = 0.604, p = 0.029) and negatively with Mg^{2+} (r = -0.61, p = 0.014).

3.3. Zooplankton

High levels of the Nile zooplankton standing crop were recorded at the sampling sites that located upstream of the wastewater discharge points with mean values varied between 26092 and 33849 ind. m^{-3} (Figure 3). In contrary, relatively lower values (19557 - 24180 ind. m^{-3}) were recorded in the downstream sites. The highest zooplankton population density (avg. 29015 ind. m^{-3}) in the southern sites at Aswan was followed by slight gradual decrease towards the north sites. Zooplankton population density sustained

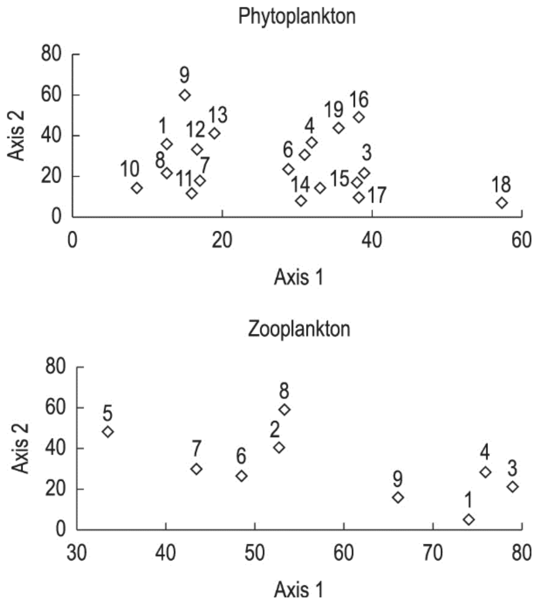

Figure 7. Ordination of the Nile plankton clusters along the first two axes of DCA.

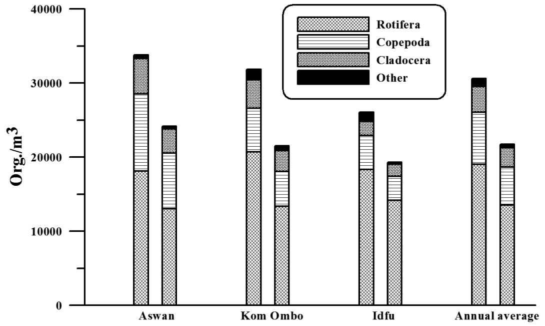

Figure 8. Spatial distribution of the Nile zooplankton groups in Upper Egypt. Left bar (upstream) and right bar (Downstream).

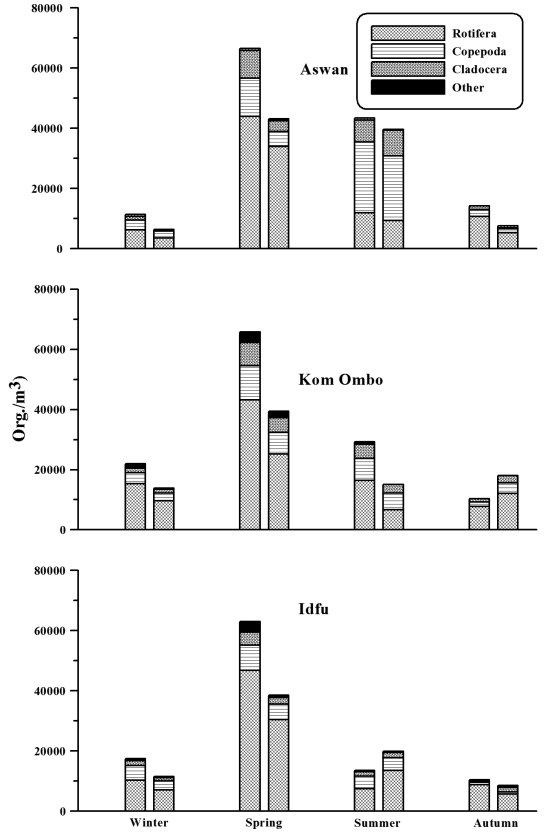

Figure 9. Seasonal variations of the Nile zooplankton Upper Egypt. Left bar (upstream) and right bar (Downstream).

an annual average of; 26697 ± 18835 ind. m^{-3} (Figure 8). Seasonal variations in zooplankton population densities (Figure 9) revealed that, relatively high values of 63012 and 66552 ind. m^{-3} were reached during spring due to the increased number of rotifers. In contrast, zooplankton were less abundant during the other seasons, apart from the result recorded at site 1 (Aswan) in summer, being 43357 ind. m^{-3} produced by the increased individual numbers of copepods.

Thirty-six species of zooplankton (Table 3) belonging to Rotifera (24 species), Copepoda (3 species) and Cladocera (9 species) were recorded during the study period contributing 66.7, 8.3 and 25% of the total number of species, respectively. Besides, other rare zooplankton including the Platyhelminthes; *Microdalyellia* sp. in addition to Nemata and Ciliophora were sparsely encountered. Sixteen zooplankton species were encountered as important species. The abundance of zooplankton groups followed the order of Rotifera, Copepoda and Cladocera (Figure 5) contributing; 62.2, 23.2, and 11.6% of the total zooplankton populations, respectively. Besides the other rare zooplankton individuals, that collectively accounted for 3% of the total zooplankton population density. Rotifera was recorded to be the major group with an annual average of 16284 ind. m^{-3}. Site 3 (Figure 8) maintained the richest counts of rotifer populations with a mean value of 20694 ind. m^{-3}. The spring peak of rotifers (Figures 9 and 10) was mainly represented by high counts of the genus *Keratella* where its highest density was recorded at site 5, being 29736 ind. m^{-3}. Its annual average number amounted to 9150 ind. m^{-3}, contributing 35 and 56.2% of zooplankton and rotifers, respectively. The genus *Keratella* reached its maximum mean annual values at site 1 and site 5 being 11240 ind. m^{-3} at each. This genus was represented by three species, of which *K. cochlearis* was found to be dominant over the other species. Copepoda ranked second in numerical importance with an annual average of 6078 ind. m^{-3}. Site 1 (Figure 8) had the highest mean value (10494 ind. m^{-3}) of copepods. During spring and summer, copepods (Figure 9) were numerous with peaks at sites 1 and 2. Nuplii and copepodite stages (Figures 11 and 12) were always more abundant than other copepods

Table 3. Zooplankton species recorded along the main stream of the Nile in Upper Egypt and their presence contributions(%)of the nine zooplankton clusters distinguished after the application of Twinspan classification.

Zooplankton species	**I (1)**	**II (2 – 4)**	**III (5)**	**IV (6)**	**V (7 – 8)**	**VI (9)**	**Total presence (%)**
Rotifera:							
Keratella cochlearis Gosse*	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
K. tropica Apstein*	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●
K. procurva Thorpe	-	-	-	-	●	-	R
Conochilus hippocrepis Schrank*	●●●●●	●●●●●	●●●●●	●●●●●	●	●●●	●●●●
C. hippocrepis Schrank(colonies)	●●●●●	●●●	●●●	-	-	-	●●
Trichocerca longiseta Schrank*	●●●●●	●●●●●	●●●●●	●●●●	●●●●	●●●	●●●●
T. similis Wierzejski	-	●●	●●●●●	●●	-	-	●●
T. chattoni Beauchamp	-	-	●●●	●●●	-	-	●
Proales sp. *	-	-	-	●●●●●	●●●●●	●●	●●
Anuraeopsis fissa Gosse*	●●●●●	-	●●●●	●●●●●	●●●●	●●●●●	●●●
Lecane bulla Gosse*	●●●●●	●●●	●●●●●	●●●●●	●●●●●	●●	●●●●
L. lunaris Ehrenberg*	-	-	●●●●●	●●●●●	●●	●●	●●
L. luna Müller*	●●●●●	●●●●	●●●	●●●	●	●●	●●●
L. depressa Bryce	-	-	-	●●	-	-	R
Brachionus calyciflorus Pallas*	-	-	●●●	●●●●	●●●	●●●	●●
B. patulus Müller	-	-	-	●●●●●	●●●●	-	●●
B. caudatus Müller	-	-	-	●●	-	-	R
B. rachionus angularis Gosse	-	-	-	-	●	-	R
Asplanchna priodonta Gosse	●●●●●	●●●	●●●●●	-	-	-	●●
Cephalodella catellina Müller	-	-	●●●●●	●●●	-	-	●●
Lepadella ovalis Müller	-	-	●●●	●●●●●	-	-	●●
L. patella Müller	-	-	●●	●●●●	-	●●●	●●
Polyarthra vulgaris Carlin*	-	-	●●	●●●●	●●●	●●●	●●
Hexarthera mira Hudson	-	-	-	-	●	-	R
Euchlanis dilatata Ehrenberg	-	-	-	●●●	-	-	R
Copepoda:							
Nauplius larvae	●●●●●	●●●●●	●●●●●	●●●●●	●●●●●	●●●	●●●●●
Copepodite stages	●●●●●	●●●●●	●●●●●	●●●●●	●●●	●●●●●	●●●●●
Thermodiaptomus galebi Barrois*	●●●●●	●●●●●	●●●●●	●●●	●●●●●	●●●	●●●●
Thermocyclops hyalinus Sars	●●●●●	●●●	●●●●	●●●●●	●●●●	-	●●●
Mesocyclops leuckarti Claus	-	-	●●●●	●●	●	●●	●●
Cladocera:							
Bosmina longirostris Müller*	●●●●●	●●●●●	●●●●●	●●●●●	●●●●	●●●	●●●●●
Daphnia barbata Weltner*	●●●●●	●●●●●	●●●●●	●●●●●	-	-	●●●
Ceriodaphnia cornuta Sars*	-	●●●	●●	●●●●●	●●●●●	●●●●●	●●●
Ceriodaphnia sp.	-	-	-	-	●	-	R
*Diaphanosoma excis*um Sars	-	-	●●●	●●●●	-	-	●
Alona quadrangularis Müller	-	-	-	●●●●	-	●●●●●	●●
A. intermedia	-	-	-	●●	-	-	R
Alona sp.	-	-	-	●●	-	●●	R
Chydorus sphaericus Müller	●●●●●	●●	●●●●	●●●	-	-	●●
Embryonic stages of Cladocera	●●●●●	-	●●●●	-	-	-	●
Other forms							
Platyhelminithes*	●●●●●	●●●●	●●●●	●●	●	-	●●●
Nemata	-	-	●●	●●●●	●●	●●●●●	●●
Ciliophora	●●●●●	-	●●	-	-	●●	●
Total species	19	18	31	35	25	22	43

●●●●●: ≥ 90%, ●●●●: ≥ 75%, ●●●: ≥ 50%, ●●: ≥ 25%, ●: ≥ 10%, R (Rare): ≤ 10%, -: absent. The sixteen important species are designated by asterisks.

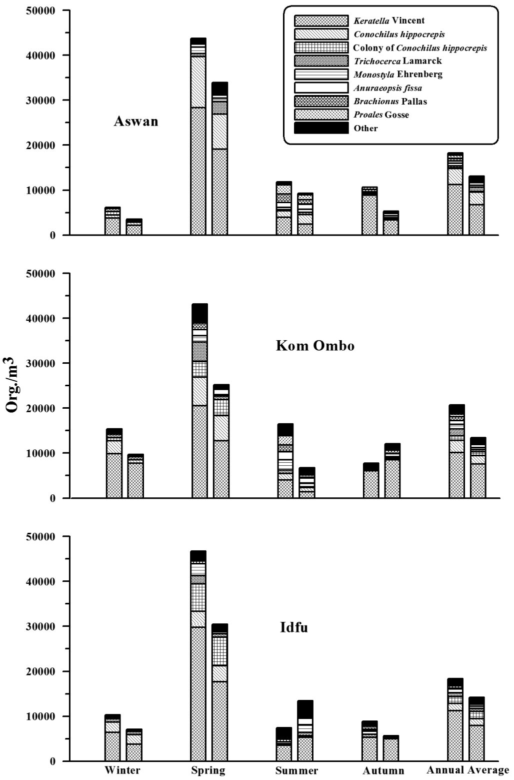

Figure 10. Distribution and seasonal variations of Rotifera in the River Nile. Left bar (upstream) and right bar (Downstream).

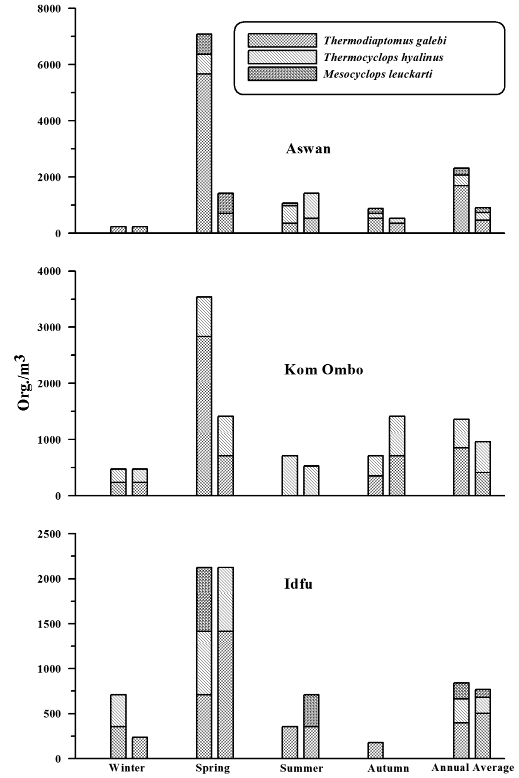

Figure 12. Distribution and seasonal variations of adult copepods in the River Nile. Left bar (upstream) and right bar (Downstream).

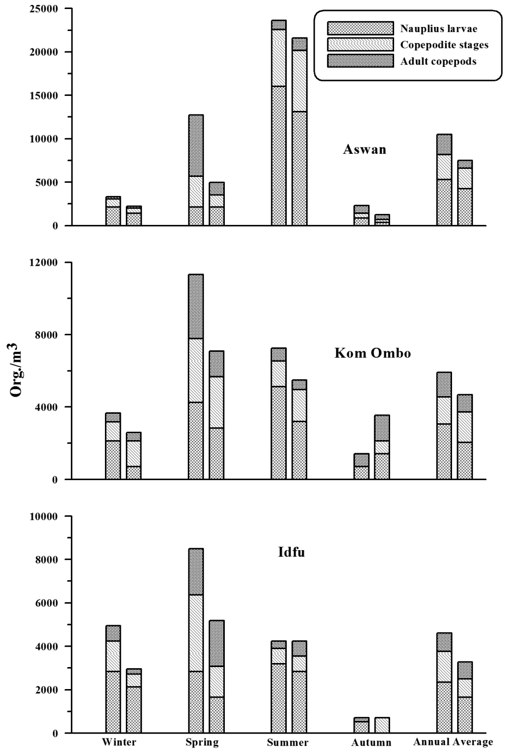

Figure 11. Distribution and seasonal variations of Copepoda in the River Nile. Left bar (upstream) and right bar (Downstream).

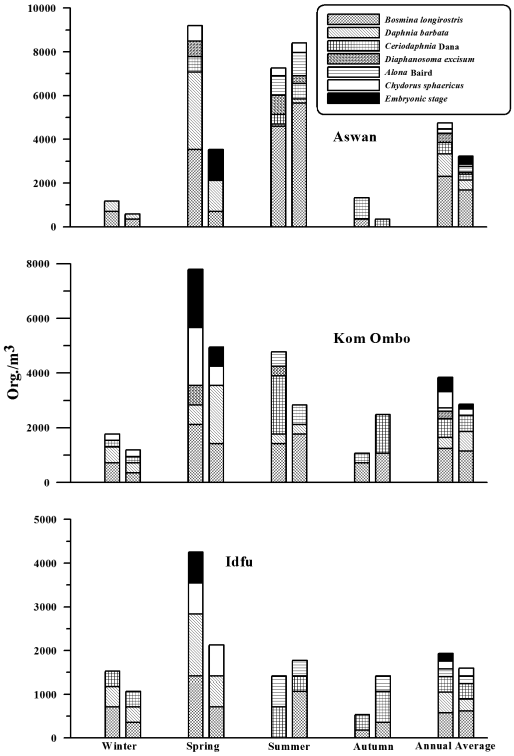

Figure 13. Distribution and seasonal variations of Cladocera in the River Nile. Left bar (upstream) and right bar (Downstream).

and contributed 51 and 29.4% of this group, respectively. Cladocera was the third important group with an annual average of 3033 ind. m^{-3}. The high mean values of cladocerans (Figure 8) were recorded at site 1 followed by site 3. Their peaks (Figures 9 and 13) were confined to spring and summer, particularly at sites 1 and 2.

To determine groups of similar seasons, hierarchical classification for zooplankton samples was performed. The resulting dendrogram (Figure 6) shows that the first separation produced two main groups of seasons. Group-A combines clusters correspond to winter – spring zooplankton assemblages and Group-B comprises those of summer – autumn assemblages. Nine (1 - 9) clusters were recognized at the fifth level of the hierarchy and connected to six subgroups (I - VI) at the fourth level. The subgroup: I and III correspond to the spring zooplankton that numerically dominated by *Keratella cochlearis*, *Conochilus hipocerpis* and its colony as well as *Thermodiaptomus galebi*. The subgroup-II comprises with one exception, the winter assemblages. The subgroups: IV and VI emanate, with one exception from summer when nauplius larvae and copepodite stages together with *Bosmina longirostris* dominated zooplankton assemblages. The subgroup-V embraces data exclusively related to autumn zooplankton assemblages.

Application of the detrended correspondence analysis to zooplankton data set indicated that, axis 1 represented variations in seasonal distribution (Figure 7). The clusters of summer and autumn zooplankton assemblages showed a remarkable spread along axis 1. However, the winter – spring assemblages occupied the most left and right parts of the diagram. Positive correlations appeared between DCA axis 1 and conductivity ($r = 0.722$, $p = 0.043$) as well as between DCA axis 2 and Mg^{2+} ($r = 0.727$, $p = 0.041$).

4. Discussion

4.1. Water quality

Mean annual Secchi Disc readings indicated good light penetration and clarity conditions of the Nile water. Secchi depth was reduced during spring and autumn peaks of plankton. This may explain the contribution of plankton assemblages to low Secchi Disc depth through light absorption and scattering. Furthermore, the highest Secchi Disc depth readings appeared concomitantly with the decrease of water level and current velocity in winter. This may reflect that the Nile water transparency in the investigated region is greatly influenced by the river hydrology.

Concerning the major nutrients, enhancement of nitrate and phosphate concentrations occurred in part simultaneously due to the external nutrient loading exerted by discharge of the wastewater. The notable increases of phosphate concentrations in the downstream sites of wastewater discharge points could also reflect that inputs from runoff are very likely to bring about some of the changes in nutrient loads. Temporal and spatial fluctuations of the soluble reactive silica concentrations did not indicate that the wastewater discharge has a primary role in determining the levels of silica contents. In this respect, it was found that the actual concentrations of the river silica contents depend on the mobility of surrounding soils and weathering of silicate rocks (Kotut et al., 1999). However, the data of this investigation did not indicate the possibilities of silicate limitation (at least periodically) in phytoplankton growth despite diatoms were recorded as dominant phytoplankton components. The irregularity in differences in nutrient concentrations between the upstream and downstream sites of wastewater discharge points could be related to dilution effects on wastewater caused by the Nile water or some impacts of the trophic cascades. The relatively high current velocity (0.8 - 1.3 m sec^{-1}) provided evidence of dilution on wastewater from up- to downstream sites of the wastewater disposal points. Such effects on dilution of nutrients in the river ecosystem were demonstrated by Mihaljević et al. (2010).

Regarding to conductivity, pH and major ions, measurements of the Nile water conductivity were mostly of moderate values with slight elevations in the north investigated sites. This may suggest that the intermittent supply with wastewater could have contributed to such elevations. The irregularity in seasonal and spatial variations of conductivity during this investigation could be due to differences exerted by contributions of different ions to conductivity. The pH values of the Nile water varied little over the study period, indicating well-buffered water conditions. Concentrations of Ca^{2+} were always higher than those of Mg^{2+} during the entire period of study depending on the difference in their precipitation rates and ability to remain in solution. Fluctuations in sulphate ion concentrations could be due to biological activities and changes in redox potential (Zinabu, 2002).

4.2. Phytoplankton

The magnitude of temporal variability in the Nile phytoplankton was estimated by chlorophyll-*a* concentration and total counts of phytoplankton individuals which were in remarkably good agreement with each other. Chlorophyll-*a* concentrations and total counts of phytoplankton tended to increase in autumn and winter, remain high in spring and then decrease in summer. Relatively low water temperature during winter and autumn probably favoured the growth of diatoms which dominated the phytoplankton community in this period and this increase was reflected in the increase of phytoplankton densities. It is tempting to attribute low phytoplankton population densities in summer to the high zooplankton abundance observed in this period. However, zooplankton numbers peaked in spring, which coincided with relatively high values for phytoplankton, undermining speculation that zooplankton grazing was the primary control of the Nile phytoplankton development in the investigated region. Another loss factor leading to decrease the phytoplankton density could be grazing by phytoplanktivorous fish. The phytoplanktivorous Nile tilapia (*Oreochromis niloticus*) which is a commercially an important fish in the region may be regarded as an important grazer of phytoplankton population. In this respect, Semyalo et al. (2011) showed that phytoplankton account for a significant part of the diet of *O. niloticus*. Phytoplankton development did not strongly affected by the discharge of wastewater to the Nile in Upper Egypt. This may indicate a minor effect of wastewater or include some adaptive responses of phytoplankton to ambient pollutants. Therefore, the phytoplankton population appeared to be most likely influenced by a range of other environmental conditions.

The alternation between cyanobacteria during summer (a short period) and diatoms during autumn until spring characterized the pattern of seasonal periodicity of the Nile phytoplankton throughout the investigation period. The relatively high proportion of diatoms appeared during autumn – spring period when water temperature conditions were most likely constituted a good environment for their growth and ability to compete for nutrients (Lung'Ayia et al., 2000). The dominance of centric diatoms for most part of the year was also recorded in different other parts of the Nile in Egypt (El-Ayouty & Ibrahim, 1980; Shehata & Bader, 1985; Ahmed et al., 1986; Mohammed et al., 1986; Shabana et al., 1993). The community of Cyanobacteria was developed concomitantly with the elevation of water temperature and suitable current velocity that may favor the abundance of this group in summer. The temperature optima for the growth of Cyanobacteria were found to be of relatively higher values than those for other phytoplankton groups (Haande et al., 2011). Hence, the Nile water temperature conditions in summer were favorable for the abundance of Cyanobacteria. In addition, the summer dominance of the Nile water by filamentous Cyanobacteria could be in part attributable to the relative unpalatability of those filamentous forms that may favor the selection of other phytoplankton individuals by zooplankton (Gragnani et al., 1999).

The vast majority of the identified species in the Nile water were true phytoplankton except for limited number were originally benthic. A relative importance of the typically benthic pennate diatoms; *Cocconeis placentula* and *Fragilaria ulna* was recorded in the Nile phytoplankton during the present investigation. These results indicated partial contribution of benthic algae as a part of the Nile phytoplankton populations. Similarly, Al-Saadi et al. (2000) pointed out the importance of various benthic or periphytic species among the riverine phytoplankton communities.

Further, from the standpoint of community structure, the general pattern of similarity among the phytoplankton clusters was revealed by DCA analysis along the two-dimensional plane of the first two axes. On the first DCA axis, phytoplankton assemblages were driven by pH value and SO_4^{2-}concentrations. On the second DCA axis phytoplankton assemblages were significantly correlative with water temperature and Mg^{2+}contents. These results suggested that the alterations that may take place in the Nile phytoplankton community could be related to the combined effects of those water variables. The observed slightly strong negative correlation with pH values could suggest that photosynthetic activity is an important pH controlling factor of the Nile water. Fluctuations of pH levels could be the result of the phytoplankton photosynthetic status since; pH value is strongly regulated by the rate of CO_2 consumption through the phytoplankton photosynthetic activities. The observed dependence of the categorized phytoplankton clusters along DCA axis 2 on water temperature postulated the importance of this abiotic variable as a main factor determining the phytoplankton community structure. Fluctuations in seasonal abundance of freshwater phytoplankton were found to be explicable by changes of water temperature (Karrasch et al., 2001; Mihaljević et al., 2010; Chen et al., 2013). The observed dependence of the Nile phytoplankton on SO_4^{2-} and Mg^{2+} could be in part attributable to the variability in the requirement of different phytoplankton species for these ions. The requirement of different species for such ions varied according to individual physical and ecological features (Reynolds, 2006). Thereby, the Nile phytoplankton development in Upper Egypt could be liable to the concentrations of those ions. No significant or strong correlation was observed between the phytoplankton community and the major nutrients particularly phosphorus, nitrogen or silica suggested that there was an excessive occurrence of these factors in the environment.

4.3. Zooplankton

The seasonal distribution of the Nile zooplankton in Upper Egypt appeared to be susceptible to water temperature. The observed temporal trend showed the maximum abundance in spring. These results go in agreement with the previously observations (Iskaros et al., 2008) in the Nile. On the other hand, the low abundance of zooplankton during the summer - autumn period was accompanied by reduction of light penetration and relatively high flow rate which may be regarded as abiotic factors influencing the development of zooplankton. The influence of these abiotic factors on the freshwater zooplankton was reported by Gliwicz (1986); Schmid-Araya & Zungiga (1992) and Dumont (2009). Those authors advocated that the pressure exerted by the combination of such factors may indirectly enemies the plankton development.

The disposal of wastewater into the main stream of the Nile changes the water quality and may have an adverse effect on potamoplankton as a natural food resource that is required for fish growth and development. In the present study, the spatial trend exhibited by the zooplankton community showed a steady state of low population densities in the sites that located in the downstream of the wastewater discharge points. These observations indicated that the wastewater discharged from factories located on the eastern side of the Nile restricted the abundance of the Nile zooplankton assemblages. This indicated that wastewater creates unfavorable conditions due to alterations in water physical and chemical characteristics which in turn affect zooplankton population density and community structure. In this context, some species were more abundant in the downstream sites throughout the investigation period. These species were mainly represented by: *Thermodiaptomus galebi*, *Mesocyclops leuckarti* and *Thermocyclops hyalinus* (Copepoda); *Bosmina longirostris* and *Alona quadrangularis* (cladocera); *Trichocerca longiseta* (Rotifera) in addition to one species belonging to Ciliophora. Therefore, such conditions could be regarded as limiting factors affecting the feeding rates of herbivores, its population dynamics and production process which ultimately cause population decrease in the Nile system. In addition, wastewater may contain substances that have toxic effects on aquatic flora and fauna exerting an imbalanced food chain in the aquatic ecosystem. In this respect, Ibrahim (2009) concluded that the zooplankton diversity in African rivers was a clear indication of the presence of pollution in a localized state due to the industrial effluents discharge.

In the case of the main stream of the Nile in Upper Egypt, the observed dependence on conductivity and Mg^{2+} showed a significant effect of these factors in the construction and shape of zooplankton assemblages throughout the seasons of the year. Ibrahim (2009) observed some significant correlations of the river zooplankton with conductivity and ionic composition of water. Besides, Morales-Baquero et al. (1989) advocated low conductivity yielded greater density of typical planktonic species and as the conductivity increases the diversity of the invertebrate species decreases and contained predominantly benthic and periphytic species. This also agrees with the present investigation and other results of the Nile Basin where the predominant zooplankton were typically planktonic species (Ridder, 1984; Dumont, 2009). Based on those observations it can be suggested that conductivity and Mg^{2+} were considered as the most significant factors responsible for the dynamics of the Nile zooplankton assemblages.

The variability of factors controlling the biotic structure was confirmed by the behavior of Nile plankton assemblages in Upper Egypt during this investigation. Thus, this study provided information on the combination of hydrological mechanisms with biotic and abiotic conditions as the main regulatory factors for potamoplankton populations of the subtropical vast river ecosystems.

The need to integrate the Nile potamoplankton species according to their ability to cope with specific river environments still exists and further investigations, focused on the changes of potamoplankton along the main stream of the Nile, would undoubtedly improve the understanding of the Nile potamoplankton community' structure and function, as well as dynamics and the mechanisms of succession. Besides, studies concerning the influence of industrial wastewater discharges on the Nile potamoplanktonton are still needed for better substantiation. Future research should be directed including an enhanced number of sites along the main stream of the Nile and thereby potentiallty providing novel approaches for evaluating the progress in understanding the influence of industrial pollution on the Nile potamoplankton. The results of such investigations will provide a useful clue for tracking the impact of wastewater effluents on the Nile ecology and limnology.

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