A COMPARATIVE STUDY OF PHYTOPLANKTON COMMUNITY STRUCTURE AND THEIR ENVIRONMENTAL VARIABLES AT THREE DIFFERENT WATER BODIES IN ISMAILIA, PROVINCE

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Abstract

Three different locations in, Ismailia, Egypt was chosen for this study during the period from autumn 2005 to summer 2006. Blue-green algal bloom occurred during winter in Ismailia freshwater canal. Physico-chemical parameters varied among the selected freshwater, marine and brackish water bodies, chlorophyll a at all water bodies were more or less correlated with the total phytoplankton counts through the study period. Phytoplankton samples yielded a diverse array of algae including a total of 116 taxa have been identified. Most of them belong to Chlorophyceae (31); Bacillariophyceae (51); Cyanophyceae (19); Dinophyceae (12); one species of Cryptophyceae and two species belong to Euglenophyceae. The result indicated that the most important environmental variables affecting the differences and distribution of phytoplankton among the selected three different water bodies are nitrogen in the form of nitrate and ammonium which was highly correlated with the leading species of phytoplankton while PO_4, salinity and water temperature are highly negatively correlated with it while lead is not affecting the phytoplankton. Other variables showed no significance correlations with the exception of chlorophyll a which had a highly negative correlation.

Introduction

The use of biological assessments and habitat surveys, in conjunction with analyses of environmental variables of water, is becoming the standard for assessing the status of aquatic ecosystems (Barbour *et al*., 1999). Ancient Egypt grew up along the Nile (CIAE, 1996). Many investigators in several areas of the Nile delta studied the seasonal distribution of phytoplankton, the physico-chemical characteristics, and the quality of its water Kobbia *et al*. (1990) and Touliabah (1996). Goldman and Horn (1983) study the freshwater habitat, El-Ayouty and Ayyad (1976 and 1980) Ayyad (1980) and Brower and Zar (1984). The qualitative analysis differences of phytoplankton at different investigated areas showed significant variations (Amin, 1994 and Abd El-Hamid, 1997).

The composition and distribution of species in the Red and the Mediterranean Seas and in the Suez Canal could be a strong indicator of the current regime in the Suez Canal (Madkour, 2000). The first record on

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phytoplankton distribution throughout the Canal was made by MacDonald (1933), followed by Ghazzawi (1939) and Dorgham (1990). El-Sherief and Ibrahim (1993). Gab-Allah (1985) and El-Shoubaky and Rained (2006).

Brackish water (the place where the river meets the sea) structure is modified by the shape, the tide, and the amount of inflowing fresh water through it. The density difference provided by the salt and fresh water results in a salt wedge which provides a structure to the water mass unlike that caused by thermal stratification in lakes (Goldman and Horne,1983). The area covered by the salt wedge as it moves up and down the estuary is often the zone of greatest phytoplankton abundance (Goldman and Horne, 1983).

One of the plankton ecologist's main goals is to identify what factors influence the distribution, abundance and species composition of plankton. This goal is made difficult by the complexity of natural water environments. A useful approach is to examine habitats that differ in as few respects as possible; the differences seen in the plankton can be attributed to these differences in habitat, and used as a basis for experiments designed to attach cause to effect (Kimmerer and Mckinnon, 1985). These were the basis of the present investigation which paid special attention to phytoplankton. The objective of this study is to evaluate the biological integrity of three different water bodies using biological assessments of phytoplankton, habitat, and environmental variables in order to make a comparative study.

Materials and Methods

Study area

This work was confined to three different sites, an Ismailia freshwater canal (site I), El-Timsah lake (site II), and one site represented a brackish water in the north of the El-Timsah lake (site III) (Figure1). Ismailia canal is the main source of water for drinking, irrigation and industry in Ismailia (Ali and Mehana, 1995). Lake Timsah is a saline shallow-water basin with an average depth of about 6 m. and a surface area of about 15 $km^{2.}$ It is located nearly half way along Suez Canal between 30° 13' 00" to 32° 35' 18" North and 32° 16' 30" to 32° 18' 30" East. The lake was a swamp which, long ago, used to be flooded by Nile waters at very high floods through the Tumilat valley. This site receives sewage water from the sewage canal passing behind Chevalier Island. The lake receives fresh water through the Ismailia Canal, in addition to fresh water drains from neighboring cultivated land which open into some of the western lagoons communicating with the lake. This fresh water has been reported to reduce the surface salinity to about 35 ppt (El-Sabh, 1969).

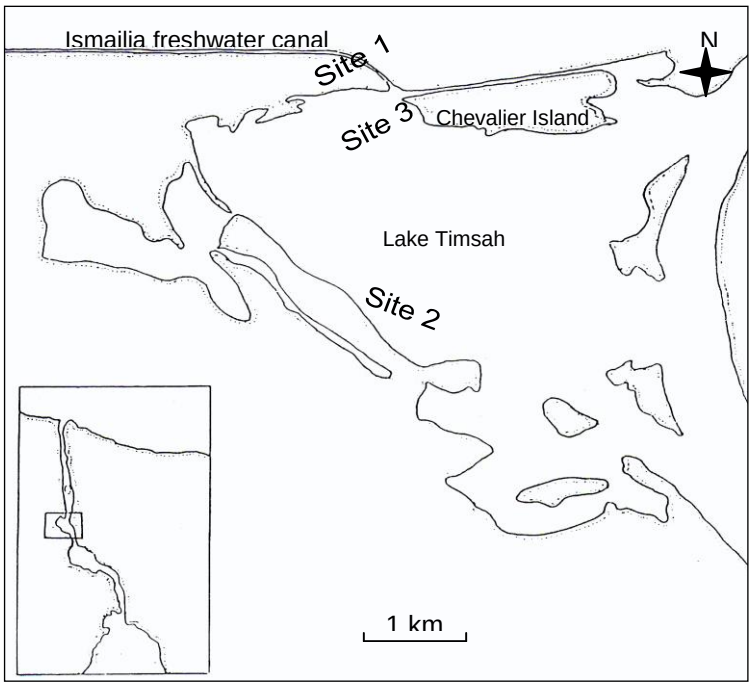


Figure (1): The position of the selected three sites; site 1 (Ismailia freshwater canal); site II (lake Timsah, the marine water and; site III (brackish water)

Water sampling

Regular seasonally collections were carried out to the studied sites from autumn 2005 to summer 2006. Subsurface water samples were taken at all sites. Four replicates were collected from different sites surrounding each sampling site at different distances. These replicates were mixed together and again divided into 4 or more portions. Water temperature, pH, and fixation of O_2 for subsequent analysis were recorded in the field at the sites of collections. Water samples for physico-chemical studies were collected in polyethylene bottles of one liter capacity, and laboratory analysis started within few hours from the time of collection.

Physico-chemical analysis (Environmental Variables)

Portable field meters were used to record the subsurface water temperature (glass mercuric thermometer (110°C with 0.5 °C graduation), oxygen (Oxygen-meter, Cole Parmer model 5946-70), pH (Digital pH-meter, Cole-Parmer, model 5938-50), turbidity (Turbidity-meter, Chemtrix, Type 12 FSc) and conductivity (Conductivity-meter, Chemtrix Type 700). Analysis of water included alkalinity, chemical oxygen demand (COD), silicate, nitrate, nitrite, ammonia, phosphorus, lead and nickel. Analysis is based on the methods recommended by the American Public Health Association (1985).

Dissolved oxygen (DO), biological oxygen demand (BOD) and ammonium (NH_4-N) samples were collected first from Nisken's bottle then fixation was carried out for each of DO and NH_4-N samples just after collection. DO was determined (to calibrate that of the probe) at the same day of collection using the classical Winkler method (APHA, 1985). DO samples were measured initially and after incubation for 5 days at 20°C. The BOD values were calculated from the differences between the initial and final DO concentrations. Chlorophyll "a" was measured using the method given by the APHA (1995).

Qualitative and quantitative analysis of phytoplankton

Phytoplankton samples were preserved in 500 ml glass bottles with lugol's solution (Utermohl, 1958). The standing crop was calculated as the number of cells per liter. Qualitative analysis was carried out using the preserved as well as fresh samples. These were examined microscopically for the identification of the present genera and species. The algal taxa were identified according to the following references: Hustedt (1930-1937), Desikashary (1959), Hendey (1964), Vinyard (1975), Taylor (1976), Humm and Wicks (1980), Bourrely (1968), Prescott (1978), Sykes (1981), Van-Heurck (1986), Hindak (1984, 1988, 1990) and Tomas (1997).

Statistical analysis

Two trends of multivariate analysis namely; classification and ordination were applied. Two-Way Indicator Species Analysis (TWINSPAN-a FORTRAN Program) was used for classification (Hill, 1979, and Gauch, 1982). While the ordination techniques applied was the Canonical Correspondence Analysis (CCA) using CANOCO-a FORTRAN program (Ter Break, 1988).

Results and Discussion

Physico-chemical analysis (Environmental Variables)

The minimum and maximum values of physicochemical parameters are presented in Table (1). The general climate of the study area is that of warm temperate zones. The absolute surface water temperature ranged from 19 to 37 °C. It showed similar temporal patterns at all sites. It appeared that these temperatures are suitable for algal growth as well as the fluctuation of phytoplankton standing crop. This trend agrees with that found by (Kebede *et al.*, (1996); Deyab *et al*., 2000 and Shaaban-Dessouki *et al*., 2004; El-Manawy and Amin (2004). pH values recorded fall in the alkaline range and it fluctuates between 7 at site III and 8.2 at site II which is beyond the extreme range of sea water pH (7.6-8.3), (Reynold, 1984). This general tendency towards alkaline side could be mainly due to activation of photosynthetic process of dense phytoplankton populations. In marine systems pH has a very minor ecological role because sea water is highly buffered and the pH remains relatively constant (Shapiro, 1990). Seasonal variations of salinity at all sites indicated that site I was homogeneous for salinity and ranged from 0.36 and

0.58ppt. Salinity increased from 14.2 to 17.1 in site III and ranged from 28.74 to 32.88 at site II. Miller and Munns (1974) stated that salinity will be always high and often complete dissolution of the salt bed, due to the high evaporation rate. Alkalinity varied between 120 at Site I and 220mg.L^{-1} at site III. Its highest values recorded in summer and the lowest in spring. The highest alkalinity may be attributed to lower DO content, these results agree with the finding of Siliem (1984) who reported that the alkalinity is quite related to DO.

Table (1): Range of change, minimum, maximum and mean of some physicochemical parameters, chlorophyll a and some heavy metals at three different sites during the period of the study.

Parameters	Sites											
	Site I				Site II				Site III			
	Min	Max	Mean	Range	Min	Max	Mean	Range	Min	Max	Mean	Range
Temp°C	19	37	27.5	18	19	36	26.2	17	20	37	26.5	17
pH	7.1	8.1	7.6	1	7.3	8.2	7.7	0.9	7	7.9	7.55	0.9
Salinity ppt	0.36	0.58	0.5	0.22	28.7	32.9	30.6	4.14	14.2	17.1	15.5	2.9
Alk. mg.L^{-1}	120	170	145	50	190	210	200	20	165	220	201	55
DO mg.L^{-1}	6.4	8.3	7.15	1.9	5.16	12.8	8.7	7.64	4.25	6.6	5.83	2.35
COD mg.L^{-1}	0.8	4.8	2.7	4	1.1	3.2	2.2	2.1	0.9	2.4	1.6	1.5
BOD mg.L^{-1}	1.15	1.33	1.23	0.18	0.1	0.8	0.3	0.7	0.41	0.9	0.6	0.49
Nitrate µg.L^{-1}	11.1	34.4	25.6	23.3	114	122	117	8.4	112	118	116	5.9
Nitrite µg.L^{-1}	1.04	4.95	2.25	3.91	1.9	4.9	3.7	3	3.3	5.1	4.06	1.8
Amm µg.L^{-1}	267	330	302	63	333	819	648	486	391	631	490	240
P µg.L^{-1}	12.7	24.8	20.8	12.1	20.9	39.1	33.1	18.2	12.9	23.2	19.4	10.3
S mg.L^{-1}	3100	8500	5525	5400	4200	7400	6150	3200	3800	5200	4750	1400
Chl a µg.L^{-1}	1.3	12.6	7.75	11.3	4.2	10.9	8.3	6.7	1.2	8.6	4.35	7.4
Lead ppm	0.62	0.72	0.65	0.10	0.63	0.74	0.7	0.11	0.73	0.94	0.7	0.21
Nickel ppm	0.13	0.26	0.19	0.12	0.32	0.55	0.4	0.24	0.46	0.58	0.51	0.13
N:P ratio	0.47	2.7	1.39	2.23	2.99	5.8	3.8	2.81	5.1	8.9	6.25	3.8

Temp=Temperature; Alk= Alkalinity; DO= Dissolved Oxygen; Amm= Ammonium; P= Phosphate; S=Silicate; Chl a= Chlorophyll a.

The dissolved oxygen content of the water is one of the most important factors in any aquatic system. Whether the variations in oxygen level were recorded during the present investigation is due to the atmosphere or the photosynthetic activity showed that dissolved oxygen fluctuated between 4.25 mg O_2 L^{-1} at site III and 12.8 mg O_2 L^{-1} at site II might be attributed to photosynthetic activity in addition, variations due to wind action and turbulence caused by ship movement. Lowest values were recorded in summer and spring whereas the highest was observed during winter.

Agricultural and domestic sewage pollution could be the reason for the low oxygen value recorded at site III which is contaminated with mixed pollution from fresh and marine water, which would reduce the diffusion of oxygen across the air/water interface. COD fluctuated between 0.8 and 4.8mg.l^{-1}. Its lowest value recorded in spring and the highest during autumn. BOD varied between 0.1 at site II and 1.33 at site I.

Nutrients and heavy metals

The minimum and maximum values of nutrients and heavy metals are present in Table (1). At site I, nitrate, nitrite and ammonium were lower than its concentration at site II and III. NO_3-N concentrations were ranged between 11.1 µg.L^{-1}, mean (25.6) at site I and 122 µg.L^{-1}, mean (117.4) at site II. It exhibited high values during summer, while the lowest one during autumn. The source of high concentration is due to organic matter supply carried with fresh water from domestic sewage from the tourism villages on the lake. Nitrate is variable in all sites because they are involved in biological processes and can be incorporated into organic or structural compounds within living organisms (Payne, 1986). NO_2–N concentrations was remained below 5.1 µg.L^{-1} and ranged between 1.8 and 3.91 in all seasons along the selected sites. Riley and Chester (1971) stated that nitrite concentrations in aquatic environment were affected by the bacterial activity, phytoplankton uptake, oxidation reduction reactions and the inputs of domestic water which affected concentration markedly in water. In this respect the concentration of nitrite is considered very low in the selected sites.

NH_4-H values in all sampling sites varied between 267 µg L^{-1} at site I and 819 µg L^{-1}at site II. This high concentration may be attributed to high pollution mainly due to domestic and agricultural wastes which in turn decomposed by the bacterial effect and produced a high amount of NH_4. In this connection Abd El-Star (1998), pointed that, ammonia in excess of 1mgL^{-1} is considered as indicator of organic pollution. The seasonal variations of phosphate was relatively homogeneous with the exception of site II which represent the marine water bodies had a higher content of phosphate ranged from 20.9 to 39.1 µg.L^{-1}. PO_4-P which forms about 5% of the total phosphorus in a lake (Wetzel, 1983), and is the most available form for phytoplankton, and it was considered the most frequently limiting element because its concentrations in surface water are often low compared to other nutrients affecting on the succession of phytoplankton (Falkner *et al*., 1995).

The N:P ratio in the water is an important variable since it can denote which of these nutrients appears to be in excess for phytoplankton growth (Redfield, 1958). In the present study, the ratio ranged between 0.5 and 8.9. The lowest value occurred at sites I and site II. This could be attributed to agricultural pollution at fresh water canal and eutrophication caused by wastewater and domestic input into the lake. In this connection Knuuttila *et al*. (1994), stated that this ratio is lower in eutrophic than oligotrophic lakes. Lake

Timsah, according to the lake classification proposed by (Komarovsky, 1959), has characteristics of the eutrophic class. SiO_3-Si values fluctuated between 3100 and 8500 µg.L^{-1}. Its highest values occurred in autumn and the lowest in spring. The importance of the element lies in its significance for the construction of the cell wall of diatoms. This element is not a limiting factor for diatoms in this study. Willem (1991) reported dissolved silica content between 0.03 mg.L^{-1} and 0.20 mg.L^{-1}as limiting level for diatom growth, in addition to Fathi and Kobbia (2000) reported that silica is essential for Bacillariophyta. Lead concentrations ranged from 0.6 to 0.7 ppm at site I and II (Table 1), and increased to 0.942 ppm at site III during the study period. Most sites showed nickel concentrations that not exceeded 0.584 ppm. Its lower values were recorded at fresh water while its higher value was observed at brackish water.

Chlorophyll a

Chlorophyll a content changed at all sites during the study periods. The results demonstrated in Table (1) revealed that chlorophyll a at all sites was more or less correlated with the total phytoplankton counts through the study period. Its content ranged from 1.2 to 8.6µg.L^{-1} at brackish water, while its content gradually increased from 1.3 to 12.6 µgL^{-1} at fresh water. This may be attributed to increase the population density of phytoplankton and algal blooms occurrence. Site II which represent the marine water bodies had a chlorophyll a ranged from 4.2 to 10.9 µgL^{-1}, may be due to increase the Bacillariophyceae and Pyrrhophyceae.

Figure (2) presents the graphic representation of the Canonical Correspondence Analysis for axis 1 and 2. Environmental variables and chlorophyll a concentration along the selected sites are clear.

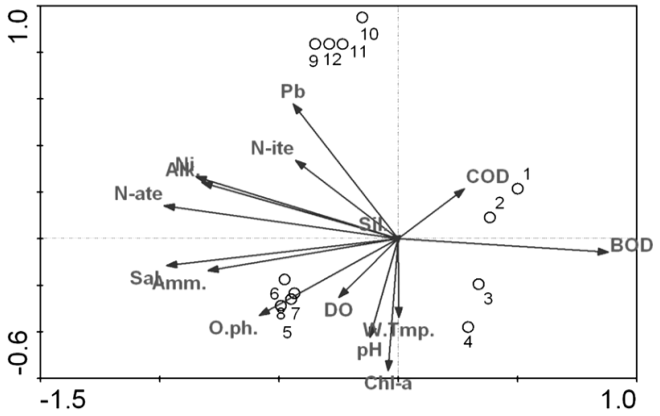


Figure (2): CCA ordination of some environmental variables represented by arrows and the sites represented by number and circle legend during the period: (1-4) freshwater sites; (5-8) Marine site; and (9-12) brackish site

The results indicated that the selected sites are completely different from each other based on the physicochemical parameters. Site (III) which represents the brackish water was highly positively correlated with lead, NO_2, NO_3 and heavy metals, while site (II) which represents the marine water are highly positively correlated with Salinity, Silicate, PO_4, DO and pH. Fresh water site was correlated with COD during autumn and winter while during spring and summer was correlated with BOD, temperature and chlorophyll a. Axis 1 of Canonical Correspondence Analysis (CCA) was highly correlated with salinity, nitrate and ammonium and was only significantly correlated with BOD, and nickel, but showed no significance in its correlation with other parameters. Axis 2 was only highly correlated with nitrate and chlorophyll a. But it showed no significance in its correlation with other parameters. More or less most of correlation values are extremely low (less than 0.5) (Table 2).

Table (2) Correlation coefficients between different environmental variables and the first and second axes of CCA.

Environmental variabilis	Axis 1	Axis 2
Temperature °C	0.0006	-0.0805
pH	-0.0056	-0.0200
Salinity ppt	**-1.0335**	-0.1233
Alkalinity $mg.L^{-1}$	-01570	0.0459
Dissolved Oxygen $mg.L^{-1}$	-00669	-0.0677
COD $mg.L^{-1}$	0.1643	0.1263
BOD $mg.L^{-1}$	0.4455	-0.0295
Nitrate $\mu g.L^{-1}$	**-0.6442**	**0.928**
Nitrite $\mu g.l^{-1}$	-0.2258	0.1762
Ammonium $\mu g.L^{-1}$	**-0.4514**	-0.0606
Phosphate $\mu g.L^{-1}$	-0.1976	-0.1118
Silicate $mg.L^{-1}$	-0.0108	0.0024
Chlorophyll a $\mu g.L^{-1}$	-0.0214	**-0.4835**
Lead ppm	-0.0455	0.0597
Nickel ppm	**-0.4015**	0.1258

Phytoplankton samples yielded a diverse array of algae. The total number of algal taxa in the different sites was composed of 116 taxa (Table 4). Most of them belong to Chlorophyceae (31); Bacillariophyceae (51); Cyanophyceae (19); Dinophyceae (12); one species of Cryptophyceae and two species belong to Euglenophyceae. The population density of algal groups and their percentage abundance to total cell numbers of phytoplankton throughout the study period at various sites presented in (Figures 3, A-F). The maximum occurrence of the total phytoplankton density was recorded in summer.

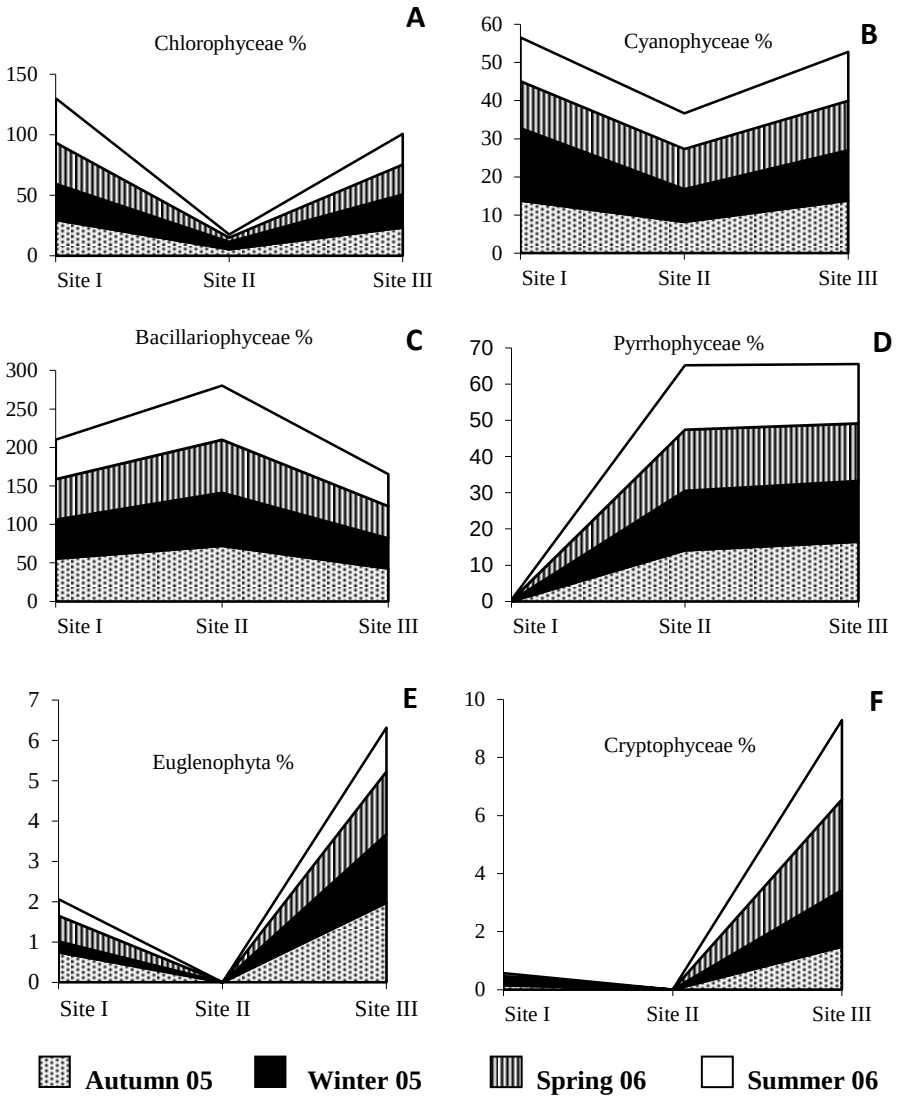


Figure (3, A-F): The population density of algal groups and their percentage abundance to total cell numbers of phytoplankton throughout the period (2005-2006) at the study sites

This can be attributed to concurrent increase of Bacillariophyceae (51.32 %) and Chlorophyceae (36.6%) at site I and increase of Bacillariophyceae (70.29%); Cyanophyceae (9.35%) and Pyrrhophyceae (17.8%) at site II (Table 3). This may be attributed to concentrations of NH_4-N, PO_4-P, NO_3-N and NO_2-N and at site II showed relatively higher values of salinity (29.99 ppt). In marine habitats, it is generally recognized that the water temperature and salinity are the chief factors regulating the distribution of

phytoplankton as well as most of the other organisms inhabiting the water column (Goldman and Horne, 1983). Greenwald and Hurburt (1993) stated that the phytoplankton abundance increases as salinity ranges from (17-42‰). This statement seems to be in agreement with our results. Pyrrhophyceae were flourished only in marine and brackish water and more or less completely absent from fresh water canal with the exception of *Ceratium hirundinella* are presented only in fresh water canal. While Cryptophyceae and Euglenophyceae were completely absent from marine water but present at other sites.

Table (3): The population density of algal groups and their percentage abundance to total cell numbers of phytoplankton throughout the study period at various sites.

Seasons	Sites					
	Site I		Site II		Site III	
	Total no.	%	Total no.	%	Total no.	%
Chlorophyceae						
Autumn 05	400	29.63	53	5.4	95	23.4
Winter 05	434	29.6	64	6.09	112	27.3
Spring 06	645	34.36	40	3.65	95	24.74
Summer 06	709	36.6	32	2.56	93	25.41
Bacillariophyceae						
Autumn 05	751	55.6	706	72.26	174	42.86
Winter 05	744	50.75	724	68.89	161	39.17
Spring 06	985	52.48	756	68.92	160	41.67
Summer 06	994	51.32	880	70.29	152	41.53
Cyanophyceae						
Autumn 05	186	13.78	80	8.19	56	13.8
Winter 05	278	18.96	90	8.56	54	13.14
Spring 06	232	12.36	116	10.57	50	13.02
Summer 06	222	11.46	117	9.35	47	12.84
Pyrrhophyceae						
Autumn 05	1	0.07	138	14.12	67	16.5
Winter 05	2	0.14	173	16.46	69	16.79
Spring 06	2	0.11	185	16.86	61	15.89
Summer 06	2	0.1	223	17.8	60	16.4
Cryptophyceae						
Autumn 05	2	0.15	0	0	6	1.48
Winter 05	4	0.27	0	0	8	1.95
Spring 06	1	0.05	0	0	12	3.13
Summer 06	2	0.1	0	0	10	2.73
Euglenophyceae						
Autumn 05	10	0.74	0	0	8	1.97
Winter 05	4	0.27	0	0	7	1.7
Spring 06	12	0.64	0	0	6	1.56
Summer 06	8	0.41	0	0	4	1.09

The percentage contribution of chlorophyceae to the total phytoplankton density (Table 3) fluctuated between 2.56 % at site II during summer (Figure 3A) when salinity and water temperature were high and 36.6 %, 34.6 % respectively at site I during summer and spring when PO_4-P, NH_4-N were relatively high where they receive organically polluted water from fertilizers pollution. *Cosmarium panamense and Kirchnerilla obesa* were the most dominant species among all sites. *Scenedesmus quadricauda* and *Coelastrum microporum* were the most dominant species in summer in fresh water canal and the former species are considered as less organic pollution tolerant (Palmer,1969).

Table (4): Species composition of phytoplankton of the different sites (I-III) and their frequency (FR) from autumn 2005 to summer 2006.

No	Species	I	II	III	FR	No. of cases of isolation			Rank of occurrence		
						I	II	III	I	II	III
Chlorophyceae											
1	*Actinastrum hantzschii* Lagerheim	1	0	1	2	4		4	H		H
2	*Ankistrodesmus convolutus* Corda	0	0	0	0	1			R		
3	*A. falcatus** (Corda) Ralf	1	0	1	2	4	2	4	H	F	H
4	*A. angustus* Bernard	0	0	0	0		2			F	
5	*Closterium moniliferum* (Bory) Ehrenberg	0	0	0	0	1			R		
6	*Coelastrum microporum* Naegeli	1	0	0	1	4			H		
7	*C. reticulatum* (Dangeard) Senn.	0	0	0	0	3			M		
8	*Cosmarium panamense* Prescott	1	1	1	3	4	4	4	H	H	H
9	*Crucigenia rectangularis* (A.Br.) Gay	0	0	0	0	3			M		
10	*C. tetrapedia* (Kirch.)W.&G.S. Wes.	0	0	0	0	1			R		
11	*Golinkinia radiata* (Chodat) Wille	1	0	1	2	4		4	H		H
12	*Kirchneriella obesa* (W.West) Schmidle	0	1	1	2	3	4	4	M	H	H
13	*Oocystis nephrocytioides* Naegeli	0	0	0	0	2		1	F		R
14	*Pandorina morum* (O.Muller) Bory	0	0	1	1	3		4	M		H
15	*Pediastrum boryanum* (Turp.) Menegh.	0	0	0	0	2			F		
16	*P. clathratum* (Chroter) Lemmermann	1	0	1	2	4		4	H		H
17	*P. duplex* Meyen	1	0	0	1	4			H		
18	*P. graclium* (Meyen) Lemm.	1	0	0	1	4			H		
19	*P. simplex* (Meyen) Lemm.	1	0	0	1	4			H		
20	*P. tetras* (Ehr.)	0	0	0	0	2			F		
21	*Scenedesmus acuminatus* (Log.) Chodat	1	0	0	1	4			H		
22	*S. bijugua* (Turp.) Long.	1	0	0	1	4			H		
23	*S. dimorphus* (Turpin) Kützing	1	1	1	3	4	4	4	H	H	H
24	*S. intermedius* Chodat	1	0	0	1	4			H		
25	*S. nagalii* Brebisson	0	0	0	0	2			F		
26	*S. obliquus* (Turpin) Kützing	1	0	1	2	4		4	H		H
27	*S. quadricauda** (Turp.) de Brebisson	1	0	1	2	4		4	H		H
28	*Selenastrum bibraianum* Reinsch	0	0	0	0	3			M		
29	*Staurastrum gracile* Ralfs	1	0	1	2	4		4	H		H
30	*Tetraedron minimum* (A.Br.) Hansgrig	0	0	0	0	2	3		F	M	
31	*T. Trigonium* (Naeg.) Han.	1	1	0	2	4	4		H	H	
Bacillariophyceae											
32	*Achnanthes lanceollata* (Breb.) Höst.	1	1	1	3	4	4	4	H	H	H

33	*Amphiprora alata* Kötz.	1	1	1	3	4	4	4	H	H	H
34	*Amphora ovalis* var. *ovalis* Kützing	1	1	1	3	4	4	4	H	H	H
35	*Astrionella formosa* Hass.	1	1	1	3	4	4	4	H	H	H
36	*Bacillaria paradoxa* Gmelin	1	1	1	3	4	4	4	H	H	H
37	*Cocconeis pediculus* Ehrenberg	1	0	0	1	4			H		
38	*C. placentula* Ehrenberg	1	0	0	1	4			H		
39	*Coscinodiscus lineatus* Ehrenberg	0	1	0	1		4			H	
40	*Cyclotella bodanica* Eulenst	1	0	1	2	1		4	R		H
41	*C. glomerata** Bachmann.	1	1	0	2	4	4	1	H	H	R
42	*C. meneghiniana** kötz.	1	1	1	3	4	4	4	H	H	H
43	*C. ocellata** Pant.	1	1	1	3	4	4	4	H	H	H
44	*C. operculata* Kützing	1	1	1	3	4	4	4	H	H	H
45	*Cymatopleura solea* Breb.	1	1	1	3	4	4	4	H	H	H
46	*Cymbella enhrenbergii* Kutzing	0	0	0	0	3			M		
47	*Diploneis ovalis* (Hilse) Cl	0	1	0	1		4			H	
48	*Fragilaria capucina* Lyngbye	0	1	0	1	2	4		F	H	
49	*F. crotonensis* Kitton	0	1	0	1		4			H	
50	*Gomphonema lansulata* Kutzing	0	1	0	1		4	2		H	F
51	*G. ventricosum** Gregory.	1	1	1	3	4	4	4	H	H	H
52	*G. parvulum** (Kützing) Grunow	1	0	0	1	4		3	H		M
53	*Gyrosigma attenuatum (Kz.) Rabh.*	0	1	1	2		4	4		H	H
54	*G. scalproides* (Rabh.) Cleve.	1	1	0	2	4	4	2	H	H	F
55	*Melsira granulata** var. *granulata* (Ehr.) Ralfs	1	1	1	3	4	4	4	H	H	H
56	*Navicula cryptocephala** Kutzing	1	1	1	3	4	4	4	H	H	H
57	*N. cardinalis** Ehrenberg	0	0	0	0	1	3		R	M	
58	*N. dicephala** (Ehr.) W.Sm.	0	1	0	1		4	2		H	F
59	*N. pygmaea* Kutzing	0	1	0	1		4	1		H	R
60	*N. Salinarum** Grun.	0	1	1	2		4	4		H	H
61	*N. viridula** var. *viridula* Kötz.	0	1	1	2	2	4	4	F	H	H
62	*Neidium iridis* (Ehrenberg) Cleve	0	0	0	0	2			F		
63	*Nitzschia acicularis* W. Smith.	1	1	0	2	4	4	3	H	H	M
64	*N. closterium* (Ehr.) W. Sm.	0	0	0	0	2		1	F		R
65	*N. palea** var. *palea* (Kötz.) W.Smith	0	1	1	2		4	4		H	H
66	*N. Panduriformis** Ehr.	0	1	1	2		4	4		H	H
67	*N. Pseudo-delicatissima** Hasle.	0	1	1	2		4	4		H	H
68	*N. punctata** (W.Sm.) Grun.	0	1	1	2		4	4		H	H
69	*N. gracilis** Ehrenberg	1	0	0	1	4	3		H	M	
70	*N. obtusa** W. Smith	1	1	1	3	4	4	4	H	H	H
71	*N. sigmoidea** (Ehr.) W.Smith	1	1	1	3	4	4	4	H	H	H
72	*Rhizosolenia hebatate* Gran.	0	0	0	0	3			M		
73	*Rhopalodia gibba* (Ehrenberg) O.Müller	0	1	1	2	2	4	4	F	H	H
74	*Stephanodiscus hantzschii* (Grim.)	0	1	1	2		4	4		H	H
75	*Stauroneis anceps* Ehrenberg	1	1	1	3	4	4	4	H	H	H
76	*Surirella angustata* Kützing	1	1	1	3	4	4	4	H	H	H
77	*S.* ovalis var. ovata Kötz.	1	1	1	3	4	4	4	H	H	H
78	*S. robusta* Ehr.	1	1	1	3	4	4	4	H	H	H
79	*Synedra acus** var. *radians* Ehr.	1	1	1	3	4	4	4	H	H	H
80	*S. ulna** var. *ulna* (Nitzsch.) Ehr.	1	1	1	3	4	4	4	H	H	H
81	*Tabellaria fenestrata* (Lyngb.)	0	1	1	2		4	4		H	H
82	*Thalassionema nitzschoides* Grun.	0	1	1	2		4	4		H	H
Cyanophyceae											
83	*Anabaena bergii* (Kissel.) Ka.	1	1	1	3	4	4	4	H	H	H
84	*A. Constricta* (Szalf) Geitler.	1	1	1	3	4	4	4	H	H	H
85	*A. variabilis* Kötzing	0	0	0	0	2	2		F	F	
86	*Arthrospira jenneri* Stizen ex. Gom.	0	1	0	1		4			H	
87	*Chroococcus limneticus* Lemm.	1	1	1	3	4	4	4	H	H	H
88	*C. turgidus* (Kutzing) Naegeli	1	0	0	1	4			H		
89	*Merismopedia tenuissima* Lemmermann	1	0	0	1	4			H		

90	*M. glauca* (Ehr.) Naeg.	1	0	0	1	4			H		
91	*Microcystis aeruginos*a Kutzing	1	0	1	2	4		4	H		H
92	*M. elegans* (Bréb.)Kütz.	1	0	0	1	4			H		
93	*Oscillatoria chalybea*** *(Mert) Gom.*	1	1	1	3	4	4	4	H	H	H
94	*O. limosa*** Ag.Ex. Gom.	1	0	0	1	4	2		H	F	
95	*O. princeps* Vaucher	0	0	1	1	2		4	F		H
96	*O. curviceps* Vaucher	0	0	1	1	2		4	F		H
97	*O. subtilissima* **Kütz.	1	0	1	2	4	3	4	H	M	H
98	*Phormidium molle** Kützing (Gomont)	0	1	0	1	1	4		R	H	
99	*Spirulina major* Kützing	0	1	0	1		4			H	
100	*S. subsalsa* Ostred.	1	1	1	3	1	4	4	R	H	H
101	*Synechocystis salina* Wisl.	0	1	1	2	3	4	4	M	H	H
Pyrrhophyceae											
102	*Amphidinium acutum* Loh.	0	1	1	2		4	**4**		H	H
103	*Ceratium extensum* (Gour.) Cl.	0	1	1	2		4	4		H	H
104	*C. furca* (Ehr.) Claparéde and Lachmann	0	1	0	1		4			H	
105	*C.hirundinella* (O.F.Muell.) Dujardin	1	0	0	1	4			H		
106	*C. tripos* (Müller) Nitzsch	0	1	1	2		4	4		H	H
107	*Dinophysis caudata* Saville-Kent	0	1	1	2		4	4		H	H
108	*Gymnodinium mitratum* Schil.	0	1	0	1		4			H	
109	*G. simplex* Loh.	0	1	1	2		4	4		H	H
110	*Prorocentrum gracile* Shutt.	0	1	1	2		4	4		H	H
111	*P. compressum* (Baily)ABFP&DoDge	0	1	1	2		4	4		H	H
112	*P. minimum* (Pavillard) Schil.	0	1	1	2		4	4		H	H
113	*Protoperidinium oceanicum* Van Hoffen	0	1	0	1		4	2		H	F
Cryptophyceae											
114	*Rhodomonas minuta* var. *nanoplanktonica Lemmermann*	1	0	1	2	4		4	H		H
Euglenophyceae											
115	*Euglena acus* Ehrenberg	1	0	0	1	4		3	H		M
116	*Euglena oxyhrius* Schm.	0	0	1	1	3		4	M		H

**** High organic pollution tolerance;* Less organic pollution tolerance;Rank of occurrence, H (High occurrence); M (Moderate occurrence); F (frequent occurrence) and R (Rare occurrence)**

Bacillariophyceae constituted the dominant algal groups in terms of cell numbers and taxa at site II. This was also recorded by Gab Allah (1985) on Lake Timsah, this may be due to their tolerance to salinity. The minimum occurrence of diatom observed during winter (39.17%) at site III, while the maximum one (72.26 and 55.6 %) recorded in autumn at sites II and I respectively (Figure 3 C). When NH_4-N and NO_3-N were relatively high when compared to PO_4-P concentrations. The increase in populations of this group at high nitrogen concentrations agrees with the findings of Tilman *et al.* (1986), who stated that diatoms are good competitors for phosphorus but weak competitors for nitrogen. Among the dominant species of diatoms among sites were *Achnanthes lanceollata*, *Amphiprora alata*, *Amphora ovalis* var. *ovalis*, *Astrionella formosa*. Some species of bacillariophyceae were recorded only in fresh water canal and are completely absent from marine and brackish water. On the other side others were found only in marine water and completely absent from other sites (Table 4). *Thalassionema nitzschoides*, and *Nitzschia Pseudo-delicatissima* were absent completely from fresh water canal and considered among the dominant species of marine and brackish water. This species was recorded by Gab-Allah (1985), in Timsah Lake is known as an

indicator of high nutrient conditions and tolerate extreme variable conditions (Van Iprene *et al.*, 1987). *Nithzchia pseudo delicatissima* is geographically widely distributed genus restricted to marine plankton (Tomas, 1997). It is worth mentioning that at the time of predomination of this genus, it produces domoic acid (Martin *et al.*, 1990). Domoic acid may be a worldwide threat on temperate coasts.

Cyanophyceae constituted the third important group in terms of cell numbers. Its high regional occurrence observed at fresh water canal (site I). This may be attributed to slightly High PO_4 following winter low temperature and slowing in water flow. Being was dominant in winter (18.96 %) followed by a wintertime algal bloom has been declared in February 2006 following winter low temperature and slowing in water flow and may be attributed to nutrient concentration content at site I was higher than its concentration in site II and III., including numerous indicators of eutrophication dominated the canal. *Merismopedia tenussima. Microcystis aeruginosa*, *Oscillatoria limosa.* and *O. princeps*. The present results are in accordance with those of Hyenstrand, 1999; El-Manawy and Amin, (2004); and Amin (2001) who reported that the presence of cyanobacterial bloom-forming species in fresh water canal in winter season. The most dominant species at all sites *were Anabaena bergii*, *A. Constricta*, *Chroococcus. Limneticus*, *Oscillatoria chalybea* (high organic pollution tolerant) and *Spirulina. subsalsa*. The present results are in accordance with those of Kobbia *et al*. (1993) who reported that assemblages of cyanobacteria were presumably favored in most cases. While, *Arthrospira jenneri*, and *Spirulina major* were recorded in marine water and brackish water and completely absent from fresh water canal. On the other side *Chroococcus turgidus, Merismopedia tenuissima,* and *M. glauca* were completely absent from marine and brackish water and presented only in fresh water canal.

Figure (4) present the graphic representation of the Canonical Correspondence Analysis for axis 1 and 2. Community structure and distribution along the gradient of the selected variables are clear. The results indicated that NO_3 and HN_4 are highly correlated with the leading species of phytoplankton while PO_4, salinity and water temperature are highly negatively correlated with it while lead is not affecting the phytoplankton.

The application of TWINSPAN classification on the importance value of species composition of the most dominant and highly occurred species in the selected three sites during the period from autumn 2005-summer 2006 (Figure 5,a). The species compositions of these groups are presented in Table (4). Group A comprises 10 species highly occurred in marine and freshwater sites the indicator species identified by TWINSPAN classification in this group are *Achnanthes lanceollata, Cyclotella ocellata, C. operculata, Cymatopleura solea, Melosira granulata* var. *granulata, Surirella angustata, S. ovalis* var. *ovata, S. robusta, Synedra acus* var. *radians, Spirulina subsalsa*.

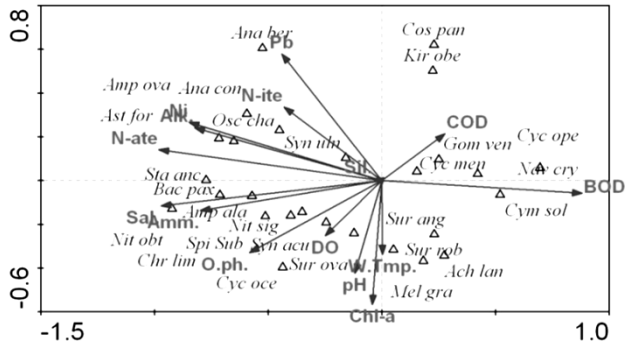
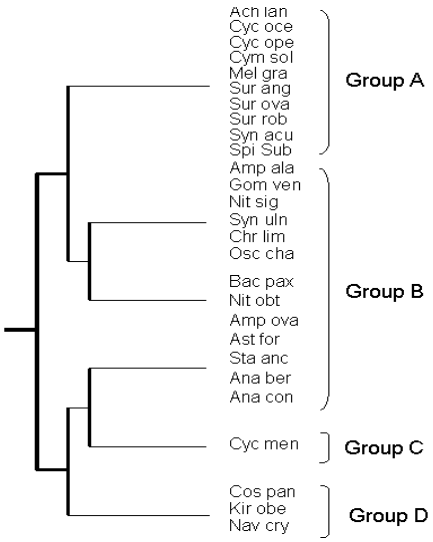


Figure (4): CCA ordination of some environmental variables represented by arrows and the most dominant and highly occurred species represented by triangular legend during the study period 2005-2006.

Group B comprises 13 species highly occurred in marine site the indicator species identified by TWINSPAN classification in this group are *Amphiprora alata*, *Gomphonema ventricosum*, *N. sigmoidea*, *Synedra. ulna* var. *ulna*, *Chroococcus. Limneticus*, *Oscillatoria chalybea*, *Bacillaria paradoxa*, *Nitzschia obtusa*, *Amphora ovalis* var. *ovalis*, *Astrionella formosa*, *Stauroneis anceps*, *Anabaena bergii*, and *A. Constricta*. Group C comprises 3 species highly occurred in freshwater the indicator species identified by TWINSPAN classification in this group are *Cosmarium panamense*, *Kirchnerilla obesa* and *Navicula cryptocephala*. Group D comprise only one species *Cyclotella. meneghiniana* and this species is highly occurred along the selected three sites.

Dinophyceae increased at site II during summer due to the luxuriance growth of *Prorocentrum minimum, and Ceratium furca, Protoperidinium oceanicum and Dinophysis caudata and Ceratium extensum*, when salinity and temperature were high. This dinoflagellate are known for its euryhalinity (Smayda, 1983), and relatively high temperature tolerance (Boney, 1975). Cryptophyceae and Euglenophyceae were completely absent in marine water and they were recorded in fresh water canal. Slightly increased in brackish water was observed during spring (3.13 %) for Cryptophyceae and (1.97%) during autumn for Euglenophyceae (Table 3). In this respect Round (1981) and El-Attar (2000) emphasized that Euglenoids often occur in deoxygenated waters. The most dominant species among Euglenophyceae were *Euglena acus* and *E. oxyhrius*, while Cryptophyceae were represented by one genus: *Rhodomonas minuta* var. *nanoplanktonica*.



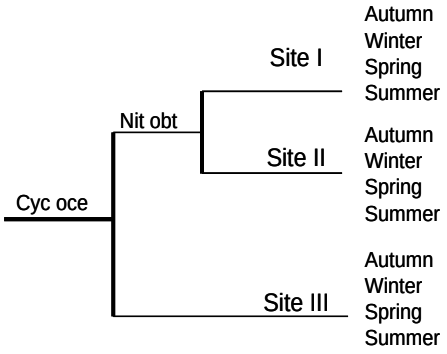


Figure (5 a) **Figure (5 b)**

Figure (5 a): TWINSPAN Dendrogram of the most dominant and highly occurred species recorded in the selected three sites representing the study period during autumn 2005-summer 2006. ***The indicator species are abbreviated to the first letter of the genus and species name.***

Figure (5 b): TWINSPAN Dendrogram of the selected three sites representing the study period during autumn 2005 -summer 2006 based on the indicator species. ***The indicator species are abbreviated to the first letter of the genus and species name.***

Floristic similarity, based on presence/absence data and Sørensen coefficient (1948) in Table (5) indicates that all sites were closely dissimilar to each other, with the exception of site II (marine water) and site III (brackish water) were closely similar to each other. The similarity indices between sites I and II were 49.6%; sites I, III 61.79; and between sites II & III were 75%, while the floristic dissimilarity between sites II and III was thus lower than 25%. The difference, however, resulted from absence of some species along the most sites throughout the study period. As regards the factors affecting the distribution of phytoplankton species in the three different water bodies, it is well known that a species range may be determined seasonally, spatially or geographically by one or more of a number of limiting factors such as competition with other species, abundance of suitable food, temperature, salinity or other hydrographic factors. It is preferable thus to seek the factors affecting the distribution of phytoplankton in the area.

Table (5) : The similarity matrix for the three sites based on Sørensen coefficients.

	I	II	III
I	**0**	50.4	38.21
II	49.6	**0**	25
III	61.79	75	**0**

Conclusion

Generally our result is essentially providing a base information concerning the population density and species composition of phytoplankton in relation to their environmental variables among three different water bodies and the result indicated that the most important environmental variables affecting the differences and distribution of phytoplankton among the selected three different sites are nitrogen in the form of nitrate and ammonium which showed highly correlated with the leading species of phytoplankton while PO_4, salinity and water temperature are highly negatively correlated with it lead is not affecting the phytoplankton while other variables showed no significance correlations with the exception of chlorophyll a which had a highly negative correlation. This result enables us to do a comparative study of the three different water bodies based on the evaluation of biological integrity, habitat, and environmental variables. Floristic similarity, based on presence/absence data indicates that all sites were closely dissimilar to each other. These results are in accordance with the application of TWINSPAN classification on the selected three sites based on the indicator species of these sites. Thus this result ensure that the selected three sites are completely different from each other based on the species composition of phytoplankton

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دراسة مقارنة لمحتوى الهائمات النباتية وتأثرها بالمتغيرات الطبيعية فى ثلاثة أجسام مائية مختلفة بمنطقة الإسماعيلية.

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إستهدفت هذه الدراسة فحص تغيرات محتوى الهائمات النباتية فى مختلف البيئات ولهذا تم اختيار ثلاثة مواقع بمنطقة الإسماعيلية , لتمثل ثلاثة مناطق بيئية مائية مختلفة على مدار عام بدأت من خريف 2005 حتى صيف 2006 وقد ازداد كم الهائمات النباتية فى صورة إزدهارات طحلبية تمثل مجموعة الطحالب الخضراء المزرقة فى المحطة التى تمثل المياه العذبة خلال فصل الشتاء. وأظهرت نتائج العوامل الفيزيائية والكيميائية للمياه اختلافات واضحة على مدار المحطات الثلاثة المختارة والتى تمثل المياه العذبة والمالحة ومنطقة إلتقاء المياه العذبة بالمالحة. وأظهرت نتائج محتوى الكلورفيل علاقة إلى حد ما واضحة بينها وبين عدد الهائمات النباتية خلال فترة الدراسة. وقد لوحظ تغير محتوى الهائمات النباتية مع المتغيرات البيئية وسجلت الهائمات النباتية حوالى 116 نوعا يضم 31 نوعا من مجموعة الطحالب الخضراء , 51 نوعا من الدياتومات , 19 نوعا من الطحالب الخضراء المزرقة و12 من الدينوفلاجيلات ونوعا واحد فقط من مجموعة الطحالب المتحركة ونوعان من السوطيات. وقد أثبتت النتائج الإحصائية أن من أهم المتغيرات البيئية المؤثرة فى توزيع الهائمات النباتية فى الثلاثة مناطق محل الدراسة هو النيتروجين فى صورة النترات والأمونيوم حيث كان معدل الإرتباط بينه وبين الأنواع السائدة عالى خلال فترة الدراسة وكان معدل الإرتباط سالب بين الفوسفات والملوحة ودرجة حرارة المياه بينما الرصاص لم يظهر تأثير واضح على الهائمات النباتية ولم تظهر باقى العوامل تأثير ملحوظ فيما عدا الكلورفيل أظهر معدل الإرتباط واضح . وهذه النتائج تمكننا من عمل دراسة مقارنة للثلاثة مناطق محل الدراسة بناء على محتوى الهائمات النباتية والتغيرات البيئية.