ISSN 1110-0354

Bull. Nat. Inst. of Oceanogr. & Fish., A.R.E., Vol. (27) 2001: 241 - 260

ECOLOGICAL AND FISHERY INVESTIGATIONS OF THE NOZHA HYDRODROME NEAR ALEXANDRIA, EGYPT. 2000-2001.

2. *PHYTOPLANKTON ABUNDANCE AND STRUCTURE UNDER THE INFLUENCE OF FERTILIZER APPLICATION IN THE NOZHA HYDRODROME, FISH FARM.*

By

SAMIHA M. GHARIB*

National Institute of Oceanography and Fisheries, Alexandria, Egypt.

Key words: Nozha Hydrodrome, Fish farm, Phytoplankton, species diversity index .

ABSTRACT

Phytoplankton abundance and structure were studied monthly from August 2000 to September 2001 in the Nozha Hydrodrome (a model of fish farm) and in the adjacing Mahmoudia feeding canal.

Compared with the previous work, changes were observed in both the structure and magnitude of phytoplankton standing crop in the hydrodrome due to the application of fertilizers. A total of 116 species were recorded from the hydrodrome, comprising 39 Chlorophyceae, 37 Bacillariophyceae, 27 Cyanophyceae, 11 Euglenophyceae, one species belonging to each of Dinophyceae and Cryptophyceae were recorded. The hydrodrome had a chlorophycean character. The green algae formed about 92% of the total counts with an obvious bloom of ***Crucigenia rectangularis*** *extending during winter.*

The species diversity as well as species richness were low during winter and high in autumn and summer. No nuisance blue-green algal bloom was observed during the course of present study.

INTRODUCTION

The need for increasing fish production is necessary as a relatively cheap source of animal protein. During the last 20 years, aquaculture began to play a significant role in total fish yields in Egypt. Additions of fertilizers or supplemental feeds to fish ponds are beneficial for increasing fish production. However, in some ponds, the nutrients contained in feeds and fertilizers may cause excessive phytoplankton production. Unmanaged phytoplankton growth may cause major constraints to profitability of aquaculture. One of these fish farms is the Nozha Hydrodrome which serves as a good aquaculture in Egypt and is managed by the Northern Fishing Company.

The Nozha Hydrodrome lies at 31° 10′ E and 30°N and it has a total area of about 504 hectars (1200 feddans) and an average depth of about 2.7m. The hydrodrome is supplied with fresh Nile water from the Mahmoudia Canal. The surplus water is constantly discharged into El-Qalaa Drain (Fig. 1). Inorganic fertilizers were applied in the form of superphosphates and ammonium nitrates in equal monthly increments at the quantity of 12 and 96 tons for each, respectively (Shakweer in press). The intense use of fertilizers undoubtedly contributed to an enhanced productivity of the hydrodrome.

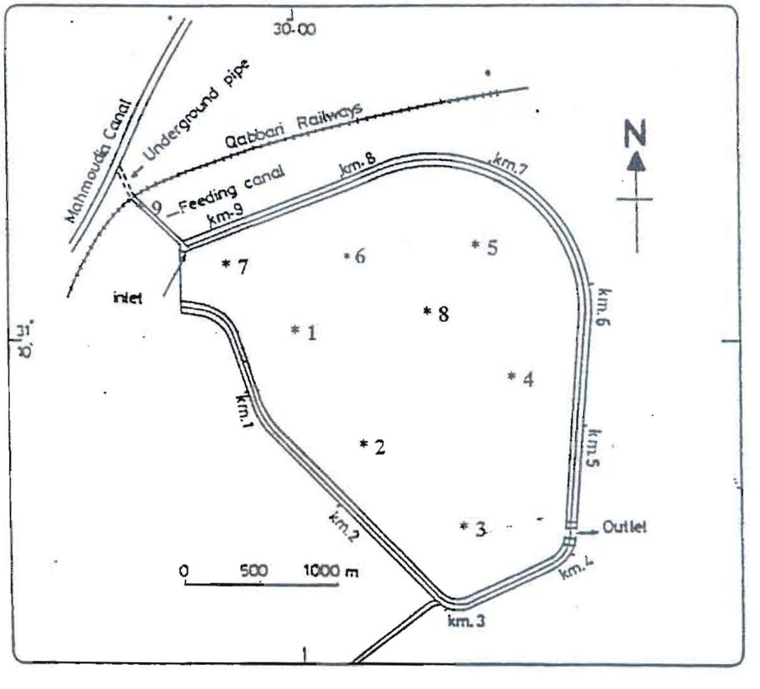

Fig. (1): Nozha Hydrodrome and position of stations.

The detailed morphometric features of the hydrodrome was previously given by Elster and Jensen (1960). Quantitative estimation of the phytoplankton community was carried out by Salah (1959). The distribution of the hydrophytes was given by Zaki (1960 a & b). Further contributions on the chemistry and hydrography were carried out by Banoub and Wahby (1961) and Saad (1973). The periphyton community was also investigated by Samaan and Abdallah (1982). The community structure of phytoplankton was studied by Gharib (1991), chlorophyll-*a* and biomass by El-Sherif (1989) and Gharib (1998), and nutrient salts by Samaan *et al* (1994 a). The dynamics of nutrient salts between bottom sediments and adjacent water was discussed by Samaan *et al* (1994 b).

The principle objective of this paper was to follow up the changes of the population density and species composition of phytoplankton community in the Nozha Hydrodrome under the continuous application of fertilizers.

The present environmental study is a part of the 2[ed] phase of research plan of the Fisheries Division of the National Institute of Oceanography and Fisheries. This work was carried out with the aim of increasing the annual fish production and ecological management of the Nozha Hydrodrome.

MATERIAL AND METHODS

The physical and chemical conditions of the investigated area were discussed by Shakweer (in press). Surface phytoplankton samples were collected monthly from August 2000 to September 2001 at selected eight stations in the hydrodrome (1-8 stations) and one station in the Mahmoudia feeding canal (station 9)by dipping a litre glass bottle 10 cm below the water surface. Lugol's iodine solution was added immediately to preserve the phytoplankton for quantitative analysis .The water samples were allowed to sediment for 24 hours .Algae .were counted as units per litre with an inverted microscope using Utermohl's(1936) sedimentation method . Identification of species follow: El-Nayal (1935 & 1936), Heurck (1896), Huber-Pestalozzi (1938), Dodge (1982), Smith (1933) and Khunnah (1967). The diversity indices were as follows:

The species richness (Margalef 1968) given by the equation:

$$D = (s-1)/ \ln N$$

Shannon and Weaver (1963) diversity index (H) given by the equation

$$H = -\sum_{N=1}^{N} \left\langle \frac{nl}{N} \right\rangle \log \left\langle \frac{ni}{N} \right\rangle$$

Where n = Number of individuals.
S = Number of species in a population.
N = Total number of individuals in S species.
ni = Number of individuals in i th species.

Species equitability or evenness (Heip 1974) based on the Shannon-Weaver information function H:

$$E = (e^{H}-1)/(S-1)2$$

Where: E = equitability
e = 2.1783 (base of natural logarithm).

RESULTS

Community structure and distribution

A total of 128 species, comprising 43 Chlorophyceae, 42 Bacillariophyceae, 28 Cyanophyceae, 12 Euglenophyceae, 2 Dinophyceae and one Cryptophyceae, were identified in Nozha Hydrodrome and Mahmoudia Canal during the present study. Out of these 30 and 11 species were confined to the Nozha Hydrodrome and Mahmoudia Canal, respectively, while 86 species (35 Chlorophyceae, 24 diatoms, 18 Cyanophyceae, 7 Euglenophyceae, one Cryptophyceae and one Dinophyceae) were common to both Nozha Hydrodrome and Mahmoudia Canal. Few of them were perennial and the majority were seasonal.

Chlorophyceae was represented by 39 species in both Nozha Hydrodrome and Mahmoudia Canal ,diatoms 37 and 29 species,Cyanophyceae 27and18 species, Euglenophyceae 11 and 8 species, Dinophyceae one and 2 species , respectively , while Cryptophyceae was represented by one species in both basins, to a total species content of 116 in the Nozha Hydrodrome and 97 in Mahmoudia Canal.

Chlorophyta was the most abundant algal group in the whole study area, constituting 92.34% of the total phytoplankton count in the Nozha Hydrodrome and 59.11% in Mahmoudia Canal (Table 1). The dominant species in Mahmoudia Canal were: *Scenedesmus quadricauda, Pediastrum boryanum* and *Actinastrum hantzschii*. The first mentioned 2 species beside *Crucigenia rectangularis, Cosmarium polygonum, Oocystis borgei, Sphaerocystis schroeteri, Gloeocystis gigas ,Tetraedron minimum* and *T. muticum* were the dominant in the Nozha Hydrodrome.

Cyanophyceae took the second place in the Nozha Hydrodrome with 27 species forming 7.10% of the total abundance (Table 1) , but were represented by 18 species in Mahmoudia Canal (4.05 % of the total abundance) . The species *Chroococcus minutus, Oscillatoria limnetica* and *Merismopedia punctata* were numerously in Mahmoudia Canal while *Anabaena circinalis, Anabaenopsis* sp., *Microcystis aeruginosa* and *Chroococcus minutus* frequency of occurrence and considerable numbers in the Nozha Hydrodrome.

Bacillariophyceae held the third place in the Nozha Hydrodrome and the second in Mahmoudia Canal reaching, respectively; 31.9% and 29.9% of all the determined taxa and 0.5% and 24.8% to the total abundance. The species *Cyclotella meneghiniana, Synedra ulna, Melosira granulata* and *Cocconeis*

Table (1): The annual average numbers of the different groups of phytoplankton, their percentage frequencies , and number of species and percentage frequencies in the Nozha Hydrodrome and Mahmoudia canal.

	Nozha Hydrodrome				*Mahmoudia Canal*			
	No.of sp.	%	Units.l X10^3	%	No.of sp.	%	Units.l X10^3	%
Chlorophyceae	39	33.6	8,987	92.34	39	40.2	398	59.11
Cyanophyceae	27	23.3	680	6.99	18	18.6	27	4.05
Bacillariophyceae	37	31.9	49	0.50	29	29.9	167	24.80
Euglenophyceae	11	9.6	12	0.12	8	8.2	5	0.76
Dinophyceae	1	0.8	4	0.04	2	2.1	16	11.26
Cryptophyceae	1	0.8	1	0.01	1	1.0	1	0.02
Total	116	**100**	**9,733**	**100**	97	**100**	674	**100**

placentula were numerously represented in Mahmoudia Canal, while *C. meneghiniana* , *Epithemia sorex*, *Nitzschia palea*, and *Navicula cryptocephala* in the Nozha Hydrodrome.

Euglenophyceae was represented in both Mahmoudia Canal and Nozha Hydrodrome by 8 and 11 species , respectively , belonging to only two genera; *Euglena* and *Phacus*. Dinophyceae took the third place in Mahmoudia Canal with 2 species , mainly; *Gymnodinium* which formed 11.26% of the total counts. The share of Dinophyceae and Cryptophyceae in the Nozha Hydrodrome was small (0.06%), *Gymnodinium* and *Cryptomonas* were occasionally found in insignificant counts. Among all the determined taxa, only 11.0% occurred during the whole period of the investigation, others appeared sporadically, in spring and autumn,while 16.4%were recorded once .

The phytoplankton standing crop in the Nozha Hydrodrome varied widely during the study period between 938 x 10^3 and 51, 740 x 10^3 units.l^{-1} with an average of 9, 733 x10^3 units.l^{-1}, while in the Mahmoudia canal decreased to an average of 674 x 10^3 units.$l^{-1}$and fluctuated between 251 x 10^3 units.l^{-1} and 1, 256 x 10^3 units.l^{-1}.

The abundance distribution of the phytoplankton groups indicated that, Chlorophyceae sustained high density in the central part of the hydrodrome (St. 8) and decreased towards the southeastern part (St. 4), while Cyanophyceae attained high densities in the southern part (St. 3) and decreased towards the center of the hydrodrome. Bacillariophyceae occurred in large numbers in the western part of the hydrodrome near the inlet of Mahmoudia Canal (St. 7) and decreased to the lowest count in the north eastern part of the hydrodrome. Similarly , Euglenophyceae were relatively more abundant at station 7 and decreased towards the south (St. 3). Dinophyceae were recorded in small numbers in front of the Mahmoudia Canal and decreased toward the eastern part of the hydrodrome.

Seasonal variations

The temporal changes of the total phytoplankton in the Mahmoudia Canal and Nozha Hydrodrome are shown in figure (2) as variations in the absolute and relative abundance of the major phytoplankton groups.

In the Mahmoudia Canal, each of the three common groups; Chlorophyceae, Bacillariophyceae and Dinophyceae dominated for a period of the year. By November 2000, Bacillariophyceae was the dominant group forming 70% of total count, with the leadership of *Cyclotella meneghiniana* (539×10^3 cells.l^{-1}). A water-blooms were observed in April and June 2001 due to the increased numbers of *Pediastrum simplex.* and *Scenedesmus quadricauda.* respectively . In May ,the Dinophycean *Gymnodinium* was abundant (685×10^3 cells.l^{-1}). In July and August, the maximum was made up of green algae, mainly, *Scenedesmus quadricauda.*

In the Nozha Hydrodrome, striking features were the overwhelming dominance of Chlorophyceae with an irregular peaks over the year , except the period December-March, it showed a narrow range of increase and decrease.

Fig. (2) presents the seasonal patterns of phytoplankton standing crop, at each station.

During August-September 2000, Chlorophyceae formed about 78.6-88.0% of the total density. Several genera were shared as: *Cosmarium. Pediastrum. Sphaerocystis* and *Gloeocystis.* Cyanophyceae were recorded in considerable numbers forming about 11.0-16.2% of the total counts with the dominance of *Chroococcus dispersus* Diatoms showed their highest occurrence in August (4.8%). *Cyclotella menghiniana* was the leading.

By October, Chlorophyceae were still dominant (57.2%), but Cyanophyceae showed intermittently pronounced contributions (up to 40.0%) and were mainly represented by *Anabaenopsis circularis.* In November, Chlorophyceae again flourish and forming 70% of the total density, while the numbers of Cyanophyceae decreased to about 24.0%. A considerable numbers of Euglenophyceae were also observed.

High peak extended from December to March with absolute dominance of *Crucigenia rectangularis* (> 90%). From April onwards, the *Crucigenia* maximum was superseded by *Oocystis borgei. Gloeocystis gigas* and *Scenedesmus quadricaude.* From July to September, Chlorophyceae were still the dominant ,but decreased to 61.3-78.9% and Cyanophyceae increased in numbers to form about 37.8% of the total density (July). *Anabaenopsis* sp. was the leading.

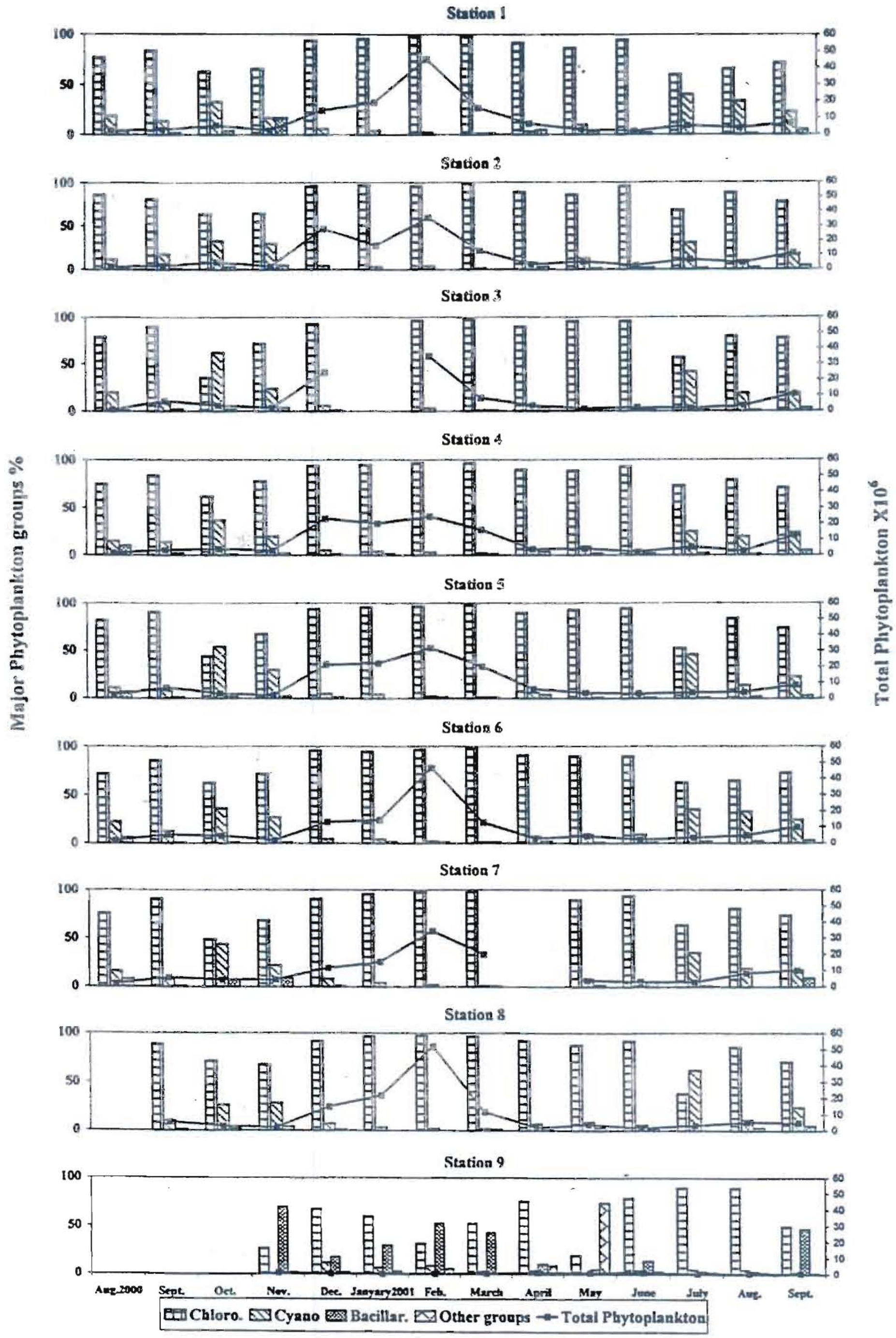

Fig (2): Monthly variations of relative abundance of major phytoplankton groups in the Nozha Hydrodrome and Mahmoudia Canal at the different stations *during the study period.*

Species diversity

In Mahmoudia Canal, relatively high diversity of species was recorded most time. Such increased diversity reflects the absence of distinct dominance of any particular species most of the year. It ranged between 1.26 (May) and 3.17 (December & June) with a mean of 2.58. The low diversity recorded in May was due to the dominance of *Gymnodinium* (73.8% of the total count). Phytoplankton equitability (or evenness) showed more or less similar seasonal pattern. The species richness of phytoplankton community was characterized by more or less high values during most of the present study, varying between a minimum of 2.44 (July) and a maximum of 3.39 (March).

In the Nozha Hydrodrome, diversity indices had a wider range of variations throughout the study period. Both species richness (d) and Shannon and Weaver Index (H) decreased towards the eastern part of the hydrodrome (Fig. 3). From August to November, diversity index ranged between 1.56 and 3.08. Pronounced decrease was observed from December to March at all stations (0.18-1.03), a pattern possibly related to dominance by only one species, *Crucigenia rectangularis*. Equitability was also very low in this period. The relationship between the total number of individuals and eveness (E) was inverse (Fig. 4). High diversity indices were observed from April to September with small monthly changes. Numbers of species and equitability increased parallel to diversity. Generally, low values of the diversity index indicate dominance of one or two species and high values indicate the species numbers are more evenly dispersed.

The species richness of phytoplankton community in the hydrodrome varied between 0.83 and 2.74. In addition to clear spatial changes, monthly variations in species richness were also observed (Fig. 3).

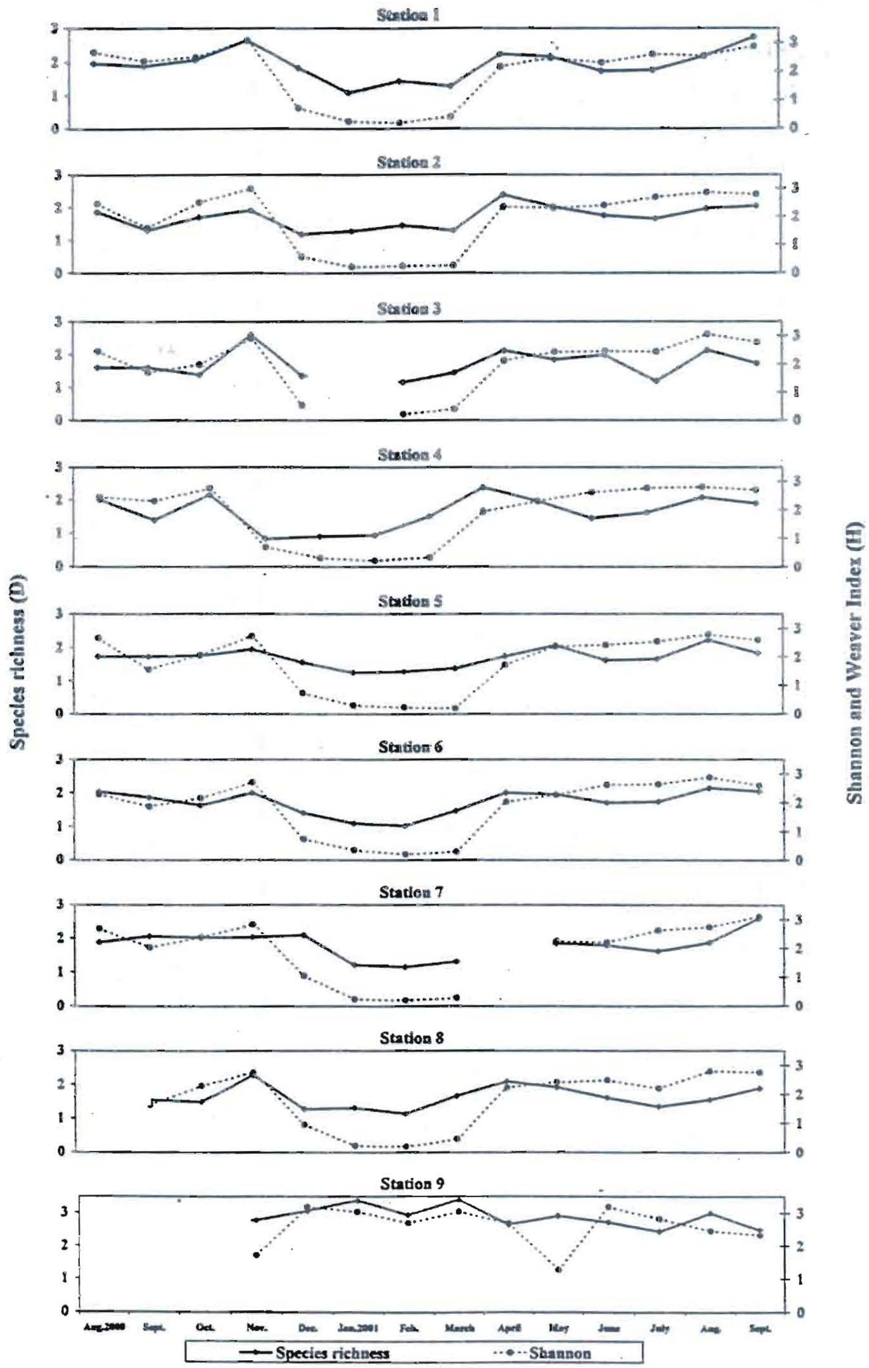

Fig (3) Monthly variations in species richness (D) and Shannon and Weaver Index (H) at the different stations.

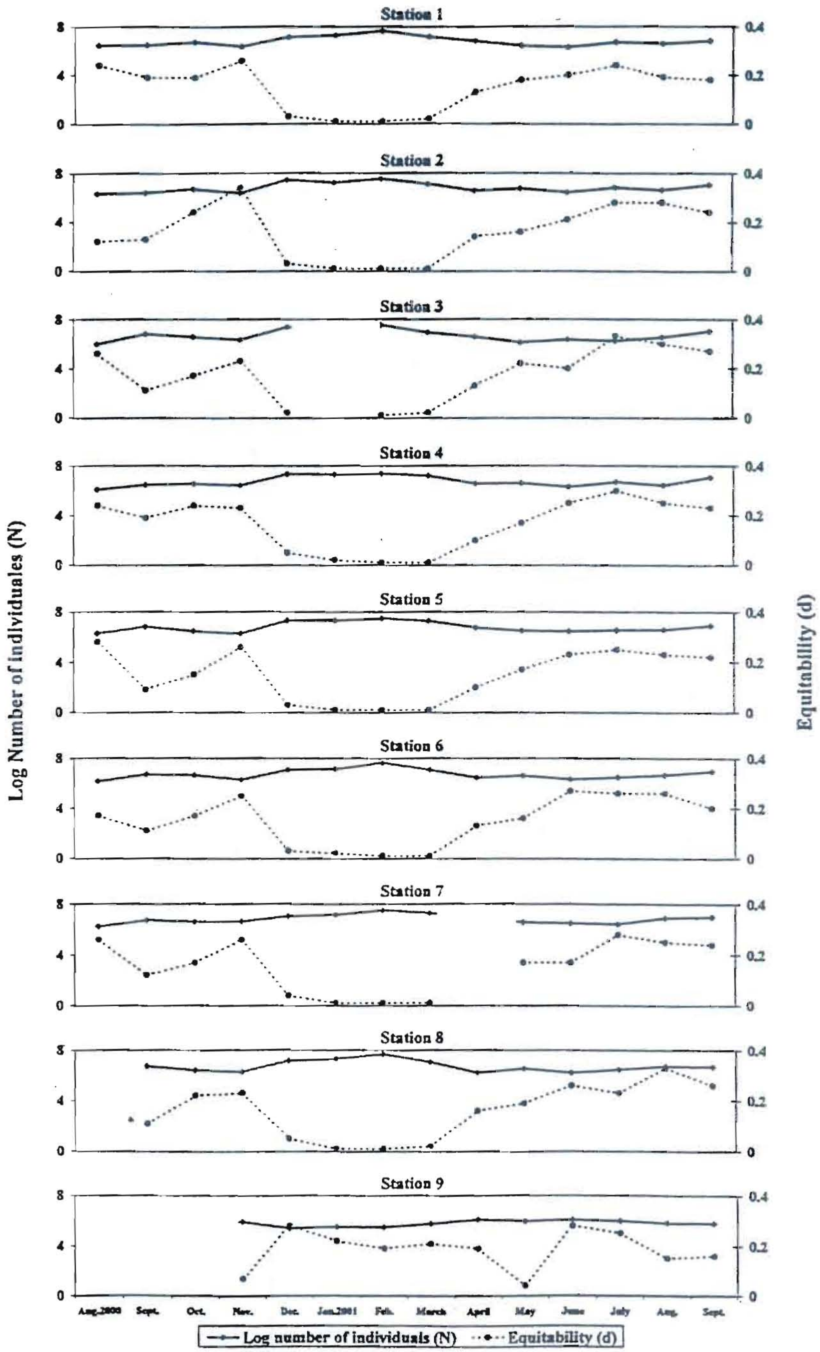

Fig (4) Monthly variations between Log number of individuals (N) and equitability (d) at the different stations.

DISCUSSION

The structure of the phytoplankton community under the continuous application of fertilizers is a focus of study in any aquaculture fish farm. The Nozha Hydrodrome has recently undergone significant changes due to an excessive influx of fertilizers into the system as a result of projects on the improvement of fish yield. This had also brought many changes in the phytoplankton community.

Although the concentrations of nutrient salts in Mahmoudia Canal were usually higher than that of the hydrodrome (Shakweer, inpress) , the latter appeared to be exclusively more productive as it harboured more than 14 folds of phytoplankton numbers.

Frome the present results the hydrodrome could be regarded as eutrophic basin . Biological estimation of the degree of eutrophication are probably more informative than chemical determinations (Round 1981). The temporal fluctuations of nutrients in the hydrodrome are considered to reflect phytoplankton consumption. Dissolved inorganic nitrogen decreased gradually to reach minimum concentrations in February (1.74µg at. l^{-1}) concomitant with a great bloom of phytoplankton. Nitrate and ammonia were quickly exhausted with the bloom formation and the exhaustion of ammonia preceded that of nitrate during the winter. During non-bloom period, the nitrogenous nutrients seemed to be supplied sufficiently (4.0-29.37µg at. l^{-1}).

The maximum concentrations of dissolved oxygen in winter (9.06mlO_2.l^{-1}) coincided with low temperature (18°C) and high concentrations of phytoplankton (28 x 10^6 unit.l^{-1}) showing the active dissolved oxygen generation by the phytoplankton. The effect of temperature variations on phytoplanktpon is mostly manifested on the periodicity of the different groups of the algal communities and algal succession (Behrendt 1990 & Tilman *et al* 1986), but the application of fertilizers in the hydrodrome affected phytoplankton community rather than temperature variations. Murphy & Haugen (1985) and Odate *et al* (1990) mentioned that Cyanophyceae are abundant under warm water condition and Blomquist *et al* (1993) estimated that Cyanophyceae have higher temperature optima than other phytoplankton but in the hydrodrome Cyanophyceae dominated the phytoplankton at temperature below 13°C during 1986 (Gharib 1991).

Planktonic abundance does not seem to affect transparency (Ravichandran and Ramanibai , 1988), this was observed during the winter when Secchi disc transparency values were high and the phytoplankton numbers exceed 28×10^6 units.l^{-1}. Winter clear water phase, low temperature, low nutrient availiability, small coccoid green algae usually become briefly dominant (Blomquist *et al* 1993). This was occurred in the hydrodrome when the inedible colonial *Crucigenia rectangularis* showed an interesting distribution during the winter reaching more than 98% of the total counts. Several studies have shown that coccoid greens (Chloro), due to thick cellulose cell walls and in certain species to a gelatinous envolope, are difficult for zooplankton to digest (e.g. Nauwerck 1963) and may even benefit from passage through the nutrient-rich intestine (Porter 1973, 1977). This may be satisfactory explanation for the extend of these algae blooms. After the winter peak, phytoplankton counts dropped to the initial level, indicating a senescence of the winter bloom due to the diminution of nutrient salts concentrations. Generally, green algae predominated the hydrodrome with a mean of 92% of the total counts , and thus ,it may be concluded that, the phytoplankton of the Nozha Hydrodrome had a chlorophycean character.

Cyanophytes showed considerable occurrence in October 2000 and July 2001. In October, the high persistence of *Chroococcus dispersus* coincided with high concentrations of dissolved inorganic nitrogen . In July, the sharp decline of dissolved inorganic nitrogen with the availability of phosphorus led to the development of N_2-fixing algae (*Anabaena* sp.). It is apparent that these species compensate for a nitrogen deficiency in a phosphorus-rich environment (Healey 1985; Suttle and Harrison 1988). Denitrification is considered one of the most important mechanisms for nitrate loss in fertile lakes (Lathrop 1988) .

The phytoplankton abundance and species composition in the study area were compared with those reported during the years 1986-1987 by Gharib (1991). The present study identified 116 phytoplankton species belonging to 6 classes, while Gharib(1991) found only 65 species . This increase could be related mainly to the changes in both the amount of fertilizers used and the total N: P ratio. These observation will provide a reference set to evaluate long-term changes that could occur in the phytoplankton community in relation with to those of chemical ones.

In contrast , the phytoplankton abundance decreased from a mean of 16 x 10^6 unit.l^{-1} during 1986-1987 (Gharib 1991) to a mean of 10 x 10^6 unit.l^{-1} in the present study (Table 2). The dominance of species was also different, Gharib (1991) recorded *Anabaenopsis circularis, A. tanganyikae, Spirulina platensis. Nitzschia acicularis* and *Pediastrum tetras* as dominant species in the hydrodrome, while they were minor constituents or absent during the present study ,although there was no changes in the sampling techniques or time intervals and water temperature experienced no serious variation . Gharib (1991) measured higher concentrations of dissolved inorganic nitrogen and phosphate (18.79 and 27.8µg at.l^{-1}, respectively), than the present study (13.25 and 1.58µg at.l^{-1}). This situation caused increase of N/P ratio from a mean of 0.67: 1 (Gharib 1991) to 8.4: 1 (the present study) and may suggest a large year-to-year variation in phytoplankton abundance and dominant species.

Table (2): The annual average numbers of the different groups of phytoplankton, the percentage frequencies and numbers of species during 1986- 1987 (Gharib 1991) and 2000 - 2001 in the Nozha Hydrodrome

Year Groups	*1986-1987*			*2000- 2001*		
	Number of species	**Units. l⁻¹X 10^3**	%	**Number of species**	**Units. l⁻¹X 10^3**	%
Chlorophyceae	28	10,569	67.0	39	8,987	92.34
Cyanophyceae	14	2,859	18.1	27	680	6.99
Bacillariophyceae	18	2,253	14.3	37	49	.5
Euglenophyceae	4	82	0.5	11	12	0.12
Dinophyceae	1	1	0.1	1	4	0.04
Cryptophyceae	-	-	-	1	1	0.01
Total	**65**	**15,774**	**100**	**116**	**9,733**	**100**

A number of studies suggest that blue-green algal blooms are associated with low mean TN: TP ratios (Schindler 1977; Flett 1977; Niemi 1979; Björk 1979; Flett *et al* 1980). This was observed in January 1987 (Gharib 1991) when a decrease in nitrate concentration was associated with the increase of phosphorus , causing intensive growth of the blue-green algae *Anabaenopsis circularis*. Smith (1983) mentioned that the relative abundance of blue-green algae is primarily determined by ratios of nitrogen to phosphorus in the water. This may explain the absence of excessive bloom of blue-green algae in the present study. The high levels of silicate throughout the year, probably owing to the absence of increased uptake by the diatom flora which was reduced considerably.

Diversity in a community is principally a mechanism that generates community stability, while dominance is principally a mechanism that generates community production. A mature community ecosystem represents a large number of species (high diversity) and needs less energy to maintain community stability (Atlas 1983). In the present study , the stability in the algal community was disturbed owing to the bloom of chlorophycean algae in winter. The trend was then shifted to lower species diversity, in the phytoplanktonic ecosystem which was overwhelmingly dominated by *Crucigenia rectangularis*.

The high values of both species richness and diversity at positions nearer to Mahmoudia Canal could be due to the mixture of fresh and brackish water species at different times of the year. High diversity values coincided with high numbers of diatoms which were usually higher in the western part of the hydrodrome. Generally, high values of Shannon and Weaver Index (H) were recorded in autumn and summer, this could be a reflection of greater equitability of species due to the presence of many fresh water species from Mahmoudia Canal. According to Karentz and Mclntire (1977), the number of species in an assemblage and the degree of evenness are closely related to the species diversity and low values of the diversity index indicate dominance by one or two species and high values indicate the species numbers are more evenly dispersed. This probably explains the low (E) values in the winter.

Results of the present investigation indicate that the Nozha Hydrodrome is a highly productive fish farm. The application of inorganic fertilizers should proceed in calculated small doses at short intervals and N: P ratio must be taken n consideration to avoid undesirable algal blooms. .,

ACKNOWLEDGEMENT

I am greatly indobted to Prof. A.A. Alsayes, Head of Fisheries Division, who ıelped in collecting samples. Thanks are also to Dr. L. Shakweer, Associate Professor of Marine Chemistry, National Institute of Oceanography and Fisheries for providing hydrographic data included in the present investigation.

REFERENCES

Atlas R.M., 1983. Diversity in microbial communities. In: Marshall K. C. (Ed.): Advances in microbial ecology. New York, London, Plenum Press, 1-47.

Banoub, M.W., and S.D. Wahby, 1961. Further contribution to the chemistry and Hydrography of the Nozha Hydrodrome near Alexandria, 1957-1958. Notes and Mem., 61. Alexandria Institute of Hydrobiology, U.A.R., 42 p.

Behrendt, H., 1990. The chemical composition of phytoplankton and zooplankton in an eutrophic shallow lake. Arch. Hydrobiol. 118 (2): 129-145.

Björk, S., 1979. Lake management studies and the results at the Institute of Limnology in Lund. Arch. Hydrobiol. Beih. Ergebn. Limn. 13: 31-55.

Blomquist, P., R.T. Bell, H. Olofsson, U. Stensdotter and K. Vrede, 1993. Pelagic ecosystem responses to nutrient additions in acidified and limed lakes in Sweden. – Ambio 22: 283-289.

Dodge, J.D., 1982. Marine Dinoflagellates of the British Isles. Her Majesty's Stationery Office, London, 303 p.

El-Nayal, A.A., 1935. Egyptian fresh water algae. Bull. Sci. Cairo, (4): 106 p.

El-Nayal, A.A., 1936. Contribution to our knowledge to the fresh water algae of Egypt. Bull. Fac. Sci., Cairo, Part I, No. 9, 31 p.

El-Sherif, Z.M., 1989. Chlorophyll-a Biomass of Nozha Hydrodrome, Near Alexandria, Egypt. Bull. Inst. Public Health . Vol. XIX. 4 (4): 983-991.

Elster, H.J., and W.K. Jensen, 1960. Limnological andd Fishery Investigations of the Nozha Hydrodrome near Alexandria, Egypt. 1954-1956-Notes and Memories, 43. Alex. Inst. Hydro. U.A.R. 99 p.

Flett, R.J., 1977. Nitrogen fixation in Canadian precambrian shield lakes. Ph. D. thesis, University of Manitoba, Winnipeg, Man. 197 p.

Flett, R.J., D.W. Schindler, R.D. Hamilton, and N.E.R. Campbell., 1980. Nitrogen fixation in Canadian precambrian lakes Can. J. Fish. Aquat. Sci. 37: 494-505.

Gharib, S.M., 1991. Study of the biological productivity of the Nozha Hydrodrome as a model of artificially fertilized fish farm Ph.D. Thesis, El Mansoura University, Faculty of Science Botany Dep. 453 p.

Gharib, S.M., 1998. Phytoplankton biomass and environmental factors in the Nozha Hydrodrome, Alexandria, Egypt. Egypt. J. Aquat. Biol. & Fish., vol 2 (3): 65-80.

Healey, F.P., 1985. Interacting effects of light and nutrient limitation on the growth rates of Synechococcus linearis (Cyanophyceae). J. Phycol. 21: 134-146.

Heip, C., 1974. Anew index measuring evenness. J. Mar. Biol. Assoc. U.K, 54: 555-557.

Heurck, V. H., 1896. A treatise on the Diatomaceae. William Westey and Son, 28, Essex, Strand, W.C. 559 p.

Huber-Pestalozzi, G., 1938. Das phytoplankton des Suss Wassers. I. Teule, Die Binnenge wasser –Stuttgart 342p.

Karentz, D. and C.D. McIntire, 1977. Distribution of diatoms in the plankton of Yaquing Estuary Oregon.-J. Phycol. 13: 379-388.

Khunnah, M.C., 1967. Chlorococcales, the Indian Council of Agricultural Research, New Delhi. Job Press Private Ltd., Kanpur 363 p.

Lathrop, R.C., 1988. Evaluation of whole-lake nitrogen fertilization for controlling blue-green algal blooms in a hypereutrophic lake. Can. J. Fish. Aquat. Sci. 45: 2061-2075.

Margalef, D.R., 1968. Perspectives in Ecological Theory University of Chicago, Press, Chicago, III p.

Murphy, L.S. and E.M. Haugen, 1985. The distribution and abundance of phototrophic ultraplankton in the North Atlantic Limnol. Oceaongr., 31, 47-58.

Nauwerck, A., 1963. Die Beziehungen zwischen Zooplankton and Phytoplankton im See Erken-Symbolae Botanicae Upsaliensis 17 (5): 1-163.

Niemi, A., 1979. Blue-green algal blooms and N: P ratio in the Baltic Sea. Acta Bot. Fenn. 110: 57-61.

Odate, T.; M. Yanada; L.V. Castillo and Y. Maita, 1990. Distribution of Cyanobacteria and other Picophytoplankton in the western North Pacific Ocean, summer 1989. J. of Ocean. Soci. of Japan 46: 184-189.

Porter, K.G., 1973. Selective grazing and differential digestion of algae by zooplankton.- Nature 244: 179-180.

Porter, K.G., 1977. The plant-animal interface in freshwater ecosystems.- Amer Sci. 65: 159-170.

Ravichandran, S. and P.S. Ramanibai, 1988. The physical and chemical limnology of Buckingham canal (Madras, India). Arch. Hydrobiol 114 (1): 97-115.

Round. F.E., 1984. Eutrophication. In: Round F.E. (Ed.): The ecology of algae. Cambridge, Oxford, Cambridge Univ. Press, 526-558.

Saad, M.A.H., 1973. Some limnological characteristics of the Nozha Hydrodrome, near Alexandria, Egypt, Hydrobiologia, 41 (4): 477-499.

Salah, M.M., 1959. Phytoplankton population in the Nozha Hydrodrome. Notes and Memoires, 40. Alexandria Inst. of Hydrobiology, U.A.R., 19 p.

Samaan, A.A. and R.R. Abdallah, 1982. Limnological Investigation of periphyton in the Nozha Hydrodrome. Notes and Memoires, V. 8, No. 1, Alexandria Institute of Hydrobiology, A.R.E., 107-122.

Samaan, A.A., Z.M. El-Sherif, S.A. Shaaban Dessouki and S.M. Gharib., 1994a. Nutrient salts in the Nozha Hydrodrome (Egypt) as affected by previous application of inorganic fertilizers J. Environ. Science, Mansoura Univ., Egypt. 8: 171-187.

Samaan, A.A., Z.M. El-Sherif, S.A. Shaaban Dessouki and S.M. Gharib., 1994b. Dynamics of nutrient salts between bottom sediments and adjacent water in the Nozha Hydrodrome (Egypt). Bull. Nat. Inst. Oceanogr. & Fish., A.R.E. 20 (2): 85-97.

Schindler, D.W., 1977. Evolution of phosphorus limitation in lakes. Science (Wash., DC) 195: 260-262.

Shakweer, L.,. Chemistry of the Nozha Hydrodrome water under the conditions of fertilizer applications, Bull. Nat. Inst. Oceanogr. & Fish.(in press).

Shannon, C.E., and W. Weaver., 1963. The mathematical theory of communication. Univ, of Illinois Press, Urbana, 111-125 p.

Smith, G.M., 1933. The fresh water algae of the U. S. New York, 716p.

Smith, V.H.,1983. Low nitrogen to phosphorus ratios favour dominance by blue-green algae in lake phytoplankton. Science (Wash., DC) 221. 669-671.

Suttle, C.A., and P.J. Harrison., 1988. Ammonium and phosphate uptake rates, N: P supply rates, and evidence for N and P limitation in some oligotrophic lakes. Limnol. Oceanogr. 33: 186-202.

Tilman, D.R. Kiesling, R. Sterner, S.S. Kilham and F.A. Johnson, 1986. Green, blue-green and diatom algae, Taxonomic differences in competitive ability for phosphorus, silicon and nitrogen. Arch. Hydrobiol. 106 (4): 473-485.

Utermohl, H., 1936. Quantitative methoden untersuchung des nanoplankton in adderheldens. Handbuch der Biolog Arab Methoden Abt. IX (1).

Zaki, S., 1960 a. Density distribution of rooted hydrophytes in Nozha Hydrodrome. Notes and Memoires, 48. Alexandria Institute of Hydrobiology. U.A.R., 28 p.

Zaki, S., 1960 b. The effect of wind on the distribution and density of *Potamogeton pectinatus* in Nozha Hydrodrome. Notes and Memoires, 44. Alexandria Institute of Hydrobiology, U.A.R., 33 p.