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PHYTOPLANKTON DIVERSITY IN THE OLIGOTROPHIC WATERS WEST OF ALEXANDRIA (EGYPT)

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ABSTRACT

The annual diversity cycle west of Alexandria (Egypt) is described using the Shannon-Weaver diversity index. A simple mathematical regression equation describing the dependence of diversity on species frequency variations for this area is given. The correlations between diversity and some physico-chemical parameters are also given. Diversity index and species composition confirm the presence of a longshore westward surface current in the area.

INTRODUCTION

Diversity is a property of communities, including both the number of species and the distribution of individuals between them, Ideally, an index of diversity will vary from a minimum, when all the individuals present in a community along to a single species, to a maximum when each belividual belongs to a different species. The work of indAington (1984) is a full review of diversity and Washarity indices in aquatic ecosystems. It is assumed by simil authors that ecological diversity increases from the many to the tropics, (Fisher, 1960, Sanders, 1968). poles ef (1958) explained this latitudinal gradient by this Margalation of temperate and polar communities as immature concept of succession arrested by suboptimal climate. stages y in the opinion of many workers, should increase Diversituccession. However, Margalef (1958 and 1978) with sed that diversity may both increase during succession suggest rease during parts of succession. and dec

It has often been suggested that diversity could be correlated with particular environmental factors, such as water depth, temperature, dissolved phosphate and nitrate and dissolved pollutants in sea water, (Basson et al, 1976, Godfrey, 1978 and Cosser, 1988). Extensive field tests of various diversity indices have been carried out by Margalef, (1965) and Travers (1967), in the Mediterranean. The present study is concerned with the annual cycle of phytoplankton species diversity and its correlation with some physico-chemical environmental factors along the Egyptian Mediterranean coast west of Alexandria from El-Mex to Mersa Matrouh.

MATERIAL AND METHODS

The investigated area extends along the Egyptian Mediterranean coast west of Alexandria for about 230 km., between El-Mex Bay (Lat. 29° 50' E) and Mersa Matrouh (Lat. 27° 10' E) (Fig. 1). This area receives no runoff water except for El-Mex Bay. In this Bay a hydraulic pumping station pumps out about six million cubic meters per day of

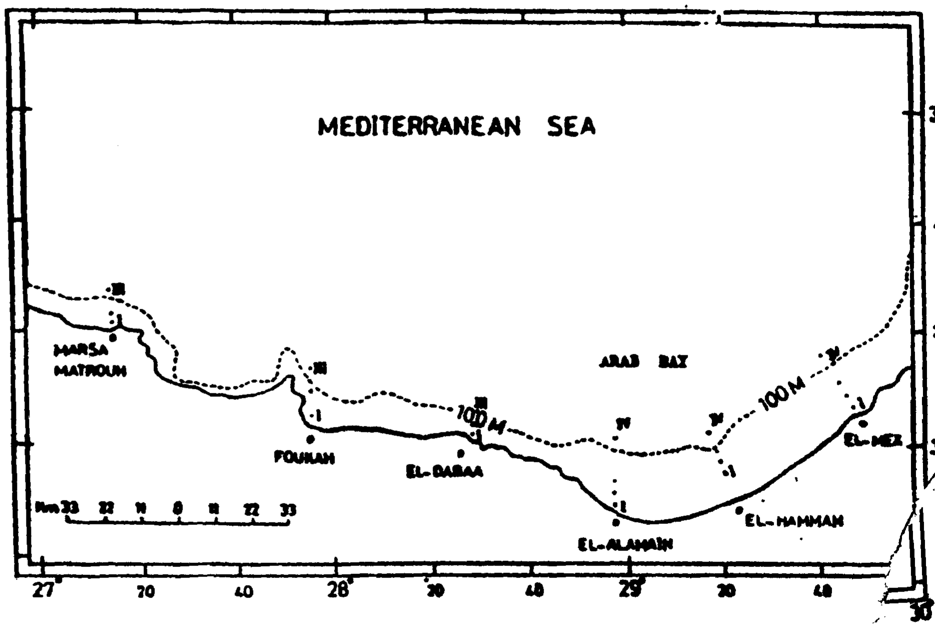


Fig. (1)

Chart showing the investigated area and position of stations.

agricultural drainage water, contaminated with agroc hemical and industrial wastes. The coastal area from El-Hammam to Marsa Matrouh is a desert; the only fresh water source to this area is either the rain water fall, specially during autumn and winter, or underground fresh water seepage. Six traverses perpendicular to the coast were selected to cover the area, namely, El-Mex, El-Hammam, El-Alamain, El-Dabaa, Fouka, and Marsa Matrouh (Fig. 1). Each traverse included 3 or 4 sampling stations depending upon the width of the continental shelf. Six cruises were carried out during January. February, April, May, July and October 1977. One litre of sea water was collected from the standard depths (surface, 10, 20, 30, 50 and 100 m.) and vertical hauls were also made using a phytoplankton fine net (50 u). Samples were preserved in 4 % neutral formalin. After complete sedimentation, the volumetric samples were reduced to 25 ml by slow siphonation and 2 ml of the sample transferred to a counting cell. The phytoplankton species were identified and counted separately using a research microscope and the results expressed as number of cells per liter. The Shannon and Weaver (1963) diversity index was used to compute the species diversity according to the following equation:

$$D = -\sum_{i=1}^{n} Pi \quad \log Pi$$

Where Pi = n/N is the proportion of i, the (ni) species to the total number of phytoplankton cells (N).

RESULTS AND DISCUSSION

I. The flora:

During this study 204 taxa were identified. In table 1, the number of taxa (m), the standing crop (S) cell/l and diversity (D) for the whole column at the different stations are given. The dominant species and their relative frequency are given in table 2. The diatoms were represented by 127 species and contributed 94 % to the numerical standing crop. Their dominance was higher at El-Mex (99 %) and less pronounced at El-Hammam (90 %). Dinoflagellates comprised 69 species and varieties and contributed 5 % by number to the standing crop. The genera Ceratium and Protoperidinium were the most common. Silicoflagellata, Chlorophyta and Cyanophyta were very rare, together contributing not more than 1 % to the standing crop.

II. Annual diversity cycle:

A reversa relationship between diversity and relative (percent) frequency appears clearly in January. The population was generally richer in species offshore, fluctuating between 26 and 33 species, and poorer inshore particularly at El-Alamain (19-20), Diversity at El-Mex and El-Alamain was higher inshore than offshore. At both Fouka and Marsa-Matrouh, higher diversity is obtained at St. II decreasing inshore and offshore. Although the number of species was nearly unchanged inshore and offshore at El-Max, a relatively higher diversity is encountered at St. I. resulting from a lower degree of dominance of the dominant species Cyclotella kutzingiana (71 %). The large number of species and high standing crop observed offshore west of El-Mex are associated with lower diversity, since Cyclotella kutzingiana was the only significant species (table 2).

A higher diversity is observed in February along the whole area, except for St. I at El-Mex and St. II at Marsa

Table (1)

Diversity (D), standing crop, cell/l (S) and number of species (m) in the column at the respective stations.

Station and Month	St. I			St. II			St. III			St. IV		
	m	D	s	m	D	s	m	D	s	m	D	s
A. January												
El-Mex	31	0.60	7500	34	0.49	8430	32	0.41	5120	33	0.48	4570
El-Alamain	20	0.59	4740	19	0.28	3780	29	0.30	5100	26	0.26	5030
Foukah	25	0.37	6680	32	0.45	4700	32	0.30	6950			
M. Matrouh	25	0.54	7600	29	0.58	4020	31	0.39	7520			
B. February												
El-Mex	32	0.42	322530	34	0.59	165610	40	0.88	35640	40	0.76	11920
El-Hammam	21	0.78	2840	26	0.76	2810	27	0.81	5500	21	0.70	1720
El-Alamain	32	0.94	3320	17	0.81	1360	49	1.42	6420	46	1.37	5830
Foukah	14	0.49	3180	19	0.63	2345	23	0.70	2185			
M. Matrouh	23	0.75	3815	16	0.43	3465	28	0.56	5944			
C. April												
El-Mex	29	0.69	198600	19	0.80	1390	35	0.79	1500	26	0.82	1150
El-Hammam	14	1.03	780	19	0.64	1485	15	0.53	1075	21	0.57	1230
El-Alamain	22	0.55	2700	20	0.63	1850	19	0.38	2570	19	0.57	2825
El-Dabaa	16	0.72	1365	19	0.88	610	15	0.65	540			
Foukah	28	0.62	3400	39	0.96	5665	25	0.51	1940			
M. Matrouh	13	0.80	815	17	0.74	850	23	0.77	1765			
D. May												
El-Mex	34	0.87	101540	18	1.09	1020	18	1.00	870	26	1.00	1460
El-Hammam	19	0.99	7300	20	0.95	4610	17	0.89	2175	23	0.76	1020
El-Alamain	8	0.66	550	11	0.64	680	15	0.79	510	16	0.57	325
El-Dabaa	21	0.70	2220	34	0.84	4455	15	0.94	355			
Foukah	17	0.83	1015	17	0.79	965	21	0.89	545			
M. Matrouh	10	0.86	375	12	0.90	355	15	0.84	375			
E. July												
El-Mex	34	0.17	31780	36	1.15	1010	13	0.84	325	20	1.14	135
El-Hammam	17	0.90	445	54	1.51	2570	24	1.11	340	26	1.21	220
El-Alamain	18	1.05	385	20	0.97	370	20	1.06	360	19	0.92	180
El-Dabaa	25	1.25	425	29	1.17	260	24	1.13	160			
Foukah	25	1.29	245	20	1.07	230	32	1.37	200			
M. Matrouh	25	1.06	440	22	1.02	405	24	0.79	400			
F. October												
El-Mex	42	0.90	23470	34	1.09	6435	54	1.00	14305	53	1.07	6046
El-Hammam	40	0.59	121960	47	0.50	120160	42	0.71	6475	39	0.51	33937
El-Alamain	22	1.26	335	20	1.13	380	40	1.34	575	35	1.28	433
El-Dabaa	25	1.30	290	27	1.19	290	26	1.26	290			
Foukah	23	1.26	300	23	1.17	180	36	1.37	280			
M. Matrouh	17	0.96	200	22	0.91	285	28	1.28	175			

Matrouh. In the case of El-Mex a sharp increase in the standing crop compared with that of January was associated with the dominance of **Skeletonema costatum** (77 %), while in Marsa Matrouh the standing crop was less than in January with the dominance of **C. kutzingiana** (77 %).

The relatively higher diversity at St. III of El-Hammam indicates that dominance was not restricted to a limited number of species. The diversity has markedly increased at El-Alamain, particularly offshore, dominance being shared by several species (**Navicula abrupta, Synedra affinis** and **Striatella interrupta**). The number of species and the standing crop have decreased at Fouka below those of January, yet diversity is increased as a result of the lower degree of dominance of **C. kutzingiana** At Marsa Matrouh, this species contributed 77 % at St. II and hence the diversity is lower than at the other stations (tables 1 & 2).

In April, the standing crop is contributed by several species at St. I of El-Mex, resulting in a lower diversity. The degree of dominance was minimal at El-Hammam St.I and so diversity reaches a maximum (1.03)., El-Alamain was marked by a general diversity decrease. This low diversity is associated with dominance by one spoecies, again **C. kutzingiana**. The relatively higher diversity obtained at St. II of both El-Dabaa and Fouka and St. I of Marsa Matrouh indicates that several species share the dominance with **C. kutzingiana (Melosira crucipunctata** and **Navicula** spp.).

By May, a general rise in diversity associated with the increased importance of several species is recorded. Such an increase is clear at El-Mex and El-Hammam. The relatively lower diversity at El-Alamain indicates that dominance was restricted to a smaller number of species, (**Melosira crucipunctata, Leptocylindrus danicus** and **Chaetoceros didymus**). **Skeletonema costatum** was dominant at St. I and II of El-Dabaa, associated with relatively lower diversities than in April. The relatively higher diversity at St. II, Marsa Matrouh, reflects the absence of dominance (table 2).

In July, diversity drops to its minimum at St. I, El-Mex, where **Skeletonema costatum** became much more important (93 %) than the other species. An abrupt increase in diversity is observed both inshore and offshore and towards the west along the whole area. Such increased diversity reflects the absence of a distinct dominance for any particular species. The maximum diversity is obtained at St. II El-Hammam (1.51), where the corresponding number of species increased and the standing crop was highest. At Marsa Matrouh a relatively lower diversity is encountered offshore where **Melosira crucipunctata** and **Lauderia danicus** were dominant (table 2).

Table (2)

Dominant species and their relative frequency for the whole coulmn at the respective stations.

Inshore

Section and Month	St. I D. Sp.	%	St. II D. Sp.	%
A. January				
El-Mex	Cyclotella kutzingiana	71	Cyclotella kutzingiana	78
El-Alamein	Cyclotella kutzingiana	67	Cyclotella kutzingiana	85
Foukah	Cyclotella kutzingiana	80	Cyclotella kutzingiana	77
M. Matrouh	Cyclotella kutzingiana	62	Cyclotella kutzingiana	73
B. February				
El-Mex	Skeletonema costatum	77	Skeletonema costatum	68
El-Hammam	Cyclotella kutzingiana	55	Cyclotella kutzingiana	53
El-Alamain	Bellarochea malleus	46	Cyclotella kutzingiana	40
Foukah	Cyclotella kutzingiana	61	Cyclotella kutzingiana	59
M. Matrouh	Cyclotella kutzingiana	72	Cyclotella kutzingiana	77
C. April				
El-Mex	Lauderia borealis	52	Cyclotella kutzingiana	60
El-Hammam	Cyclotella kutzingiana	19	Cyclotella kutzingiana	67
El-Alamain	Cyclotella kutzingiana	74	Cyclotella kutzingiana	70
El-Dabaa	Cyclotella kutzingiana	58	Cyclotella kutzingiana	44
Foukah	Cyclotella kutzingiana	72	Cyclotella kutzingiana	44
M. Matrouh	Cyclotella kutzingiana	48	Cyclotella kutzingiana	50
D. May				
El-Mex	Chaetoceros affinis	29	Chaetoceros affinis	15
El-Hammam	Chaetoceros affinis	24	Chaetoceros didymus	25
El-Alamain	Melosira crucipunctata	43	Leptocylindrus danicus	51
El-Dabaa	Skeletonema costatum	64	Skeletonema costatum	40
Foukah	Melosira crucipunctata	46	Leptocylindrus danicus	48
M. Matrouh	Melosira crucipunctata	38	Cyclotella kutzingiana	12
E. July				
El-Mex	Skeletonema costatum	93	Skeletonema costatum	34
El-Hammam	Melosira crucipunctata	44	Ceratium longirostrum	16
El-Alamain	Cyclotella meneghiniana	33	Melosira crucipunctata	37
El-Dabaa	Leptocylindrus danicus	22	Leptocylindrus danicus	30
Foukah	Leptocylindrus danicus	19	Leptocylindrus danicus	29
M. Matrouh	Leptocylindrus danicus	36	Leptocylindrus danicus	50
F. October				
El-Mex	Asterionella japonica	50	Asterionella japonica	33
El-Hammam	Asterionella japonica	75	Asterionella japonica	71
El-Alamain	Leptocylindrus danicus	12	Melosira crucipunctata	20
El-Dabaa	Asterionella japonica	13	Asterionella japonica	22
Foukah	Rhizosolenia calcar-avi	13	Leptocylindrus danicus	18
M. Matrouh	Bacteriastrum elongatum	38	Chaetoceros affinis	45

Table 2 (cont.)

Offshore

St. III		St. IV	
D. Sp.	%	D. Sp.	%
Cyclotella kutzingiana	81	Cyclotella kutzingiana	79
Cyclotella kutzingiana	85	Cyclotella kutzingiana	89
Cyclotella kutzingiana	85		
Cyclotella kutzingiana	82		
Skeletonema costatum	32	Cyclotella kutzingiana	57
Chaetoceros affinis	35	Chaetoceros affinis	47
Navicula abrupta	16	Chaetoceros affinis	14
Cyclotella kutzingiana	44	Pinnularia trevelyana	9
Cyclotella kutzingiana	66		
Cyclotella kutzingiana	60	Cyclotella kutzingiana	51
Cyclotella kutzingiana	72	Cyclotella kutzingiana	72
Cyclotella kutzingiana	82	Cyclotella kutzingiana	77
Cyclotella kutzingiana	62		
Cyclotella kutzingiana	76		
Cyclotella kutzingiana	55		
Cyclotella kutzingiana	22	Chaetoceros affinis	22
Leptocylindrus danicus	37	Leptocylindrus danicus	57
Chaetoceros didymus	25	Melosira crucipunctata	45
Leptocylindrus danicus	37		
Leptocylindrus danicus	50		
Melosira crucipunctata	48		
Melosira crucipunctata	34	Melosira crucipunctata	16
Melosira crucipunctata	24	Melosira crucipunctata	17
Melosira crucipunctata	24	Melosira crucipunctata	34
Leptocylindrus danicus	31		
Melosira crucipunctata	32		
Melosira crucipunctata	52		
Asterionella japonica	30	Asterionella japonica	35
Asterionella japonica	64	Asterionella japonica	75
Chaetoceros affinis	12	Skeletonema costatum	21
Asterionella japonica	16		
Chaetoceros affinis	15		
Leptocylindrus danicus	9		

In October, a sharp decline in diversity is obtained at El-Hammam, associated with the dominance of **Asterionella japonica** (64-75 %). Diversity rises again both in east and west indicating that several species maintain some degree of importance (table 2). The low diversity at Al-Hammam during autumn, confirms the suggestion of Gergis (1979), (based on temperature and salinity data), that at this time of the year this area was affected by continental runoff, either as a result of westward transport of El-Mex fresh water or possibly from underground water. Comparing species relative frequency for El-Mex and El-Hammam (table 2), it is clear that the neritic estuarine diatom **Asterionella japonica** became dominant in both areas. Eastward from El-Mex, at Abu-Qir Bay and Rosetta estuary, (Anon, 1979), the species was also recorded but in very small numbers at this time. In the mean time, the species was absent from El-Alamain to Marsa Matrouh. This may confirm the idea that the continental runoff which affected El-Hammam, derives from El-Mex. The diatom **A. japonica** florished in El-Mex at first and water mass was moved by a westward wind drift current to El-Hammam where it attained its maximum growth.

III- Diversity-frequency relationship:

It appears from the present study that the Shannon Weaver diversity index reflects a inverse relationship to the degree of dominance or relative frequency (%) rather than to the number of species contributing to the standing crop. This conclusion holds for the whole area throughout the year. Figure 2 represents the relationship between diversity (D) and the degree of dominance (F %). The simple regression equation describing this dependence is as follows:

$$D = 1.398 - 0.012 F$$

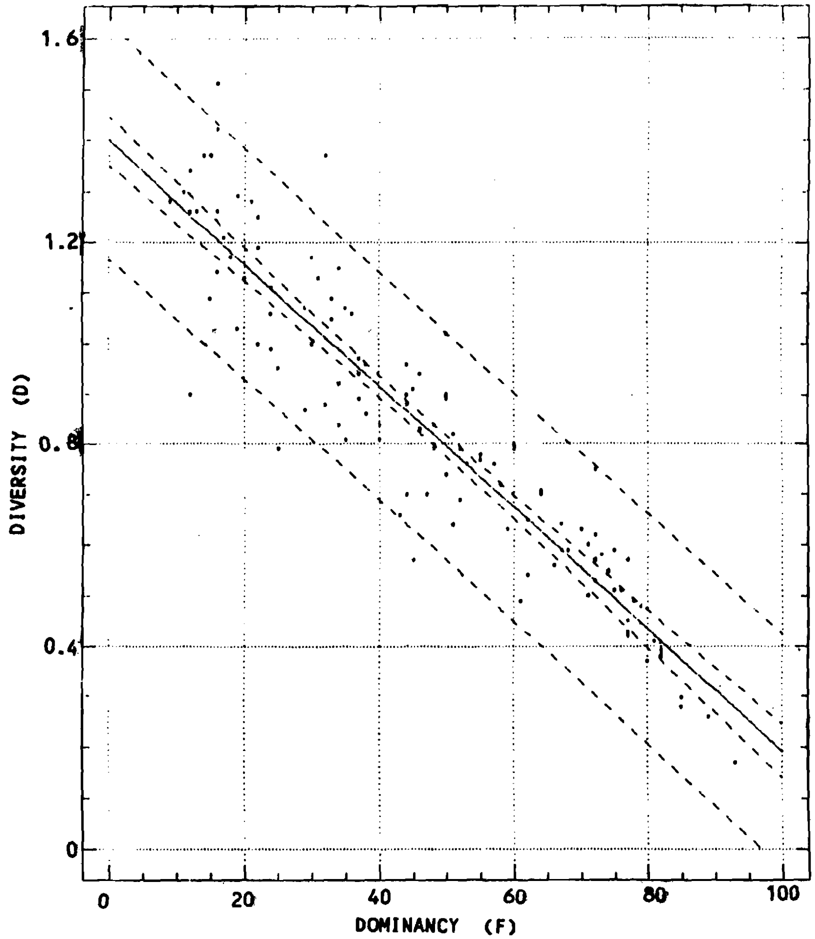
For example at El-Hammam, inshore St. I, the maximum cell density (122.000 cell/l) and the greatest number of species (40) recorded in October were accompanied by a low diversity (0.59), while in July diversity rose to a maximum (0.9) although the cell density (445 cell/l) and number of species (17) were low. In the first case **Asterionella japonica** was dominant (75 %), whereas dominance was shared by several species in the second case.

IV- Diversity and habitat structure relationship:

The number of species occurring in a particular phytoplankton community depends on the interaction between ecological, biogeographic and evolutionary processes (Margalef, 1978 and Hallegraeff and Reid 1986). The availability of resources is one of the most important ecological factors affecting species diversity. This effect was emphasized by numerous workers who have reported

Fig. (2)

Regression analysis of diversity (D) on dominancy (F).



Regression Analysis - Linear model: Y = a+bX

Dependent variable: DIVERSITY . Independent variable: DOMINANCY

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	1.39815	0.0243905	57.3234	.00000
Slope	-0.0120475	4.6846E-4	-25.7173	.00000

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	8.50303	1	8.50303	661.3811	.00000
Error	1.46564	114	:01286		
Total (Corr.)	9.96867	115			

Correlation Coefficient = -0.923567 R-squared = 85.30 percent
Stnd. Error of Est. = 0.113386

correlations between species diversity and some aspects of habitat structure, (Mac-Arthur, 1964, Borowitzka, 1972, Basson, et al 1976, Fogg 1978, Margalef, 1978 and Cosser, 1988). In the present case, according to the data of Anon (1979), Assad (1981), and Emara, et al (1984), the area west of Alexandria, except for El-Mex Bay, is characterized by a very low nutrient concentration. The average phosphate content did not exceed 0.05 ug at/l, nitrite 0.03 ug at/l and nitrate 0.15 ug at/l. Silicate concentration showed wide variations (0.0-6.42 ug at/l). These concentrations are low compared with other areas along the Egyptian Mediterranean coast. El-Mex area represents a special case, as it receives a huge amount of waste water rich in nitrogen, phosphorus, silicon and other microelements, that creates eutrophication at times particularly in summer. The correlation coefficient of diversity versus some physico-chemical parameters are given in table 3. Looking at the whole area except for El-Mex Bay, one can conclude that temperature as it is generally supposed, has a positive effect on phytoplankton diversity. Salinity is also supposed to have a positive correlation, but its effect was significant only at El-Alamain and El-Dabaa. The insignificant correlation coefficients for Fouka, Marsa Matrouh and El-Hammam sections can be attributed to the fact that the first two sections receive more or less moderate quantities of rain water specially during autumn and winter seasons, while El-Hammam section is affected by the westward low salinity surface current originating from El-Mex Bay. Concerning diversity nutrients relationships, nitrate

Table (3)

Correlation coefficients between diversity and some physico-chemical variables.

Variables	Section					
	El- Mex	El- Hammam	El- Alamain	El- Dabaa	Foukah	M. Matrouh
Temp.	0.174	0.455**	0.356**	0.462**	0.614**	0.351**
Salinity	-0.027	0.123	0.298**	0.422**	0.014	0.025
PO_4	-0.228*	-0.116	0.040	0.019	-0.109	0.109
NO_3	0.066	0.234*	0.045	0.232**	0.238*	-0.058
$Si\ O_4$	0.257*	0.129	0.028		0.171	0.182
Fe	0.345**					
Cu	-0.233*					

** Significant at 1 % level

* Significant at 5 % level

concentration showed a positive correlation at El-Hammam, El-Dabaa and Fouka, indicating a limiting effect on both phytoplankton standing crop and niche width at these areas. Phosphorus and silicon showed insignificant effect on phytoplankton species diversity. From table 3 one can characterize El-Mex area by a negative correlation of diversity versus phosphrous and copper. The effect of phosphorus is related to its role in the eutrophication phenomenon in the area at times throughout the year. The copper negative effect can be referred to its toxic effect. Moreover, diversity in El-Mex Bay was positively correlated with both iron and silicon concentrations, which reflects their limiting effect on phytoplankton growth and niche width in the Bay.

On the basis of the present data, we conclude that Shannon-Weaver diversity index should be interpreted in terms of resources abundance and abiotic habitat structure in addition to ommunity structure.

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