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PHYTOPLANKTON PRODUCTION, DIVERSITY AND CHLOROPHYLL-A IN THE SUEZ CANAL, EGYPT.

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ABSTRACT

Qualitative and quantitative estimations of phytoplankton and its diversity, beside determination of chlorophyll-a , phytoplankton biomass, gross primary production and dissolved oxygen of the Suez Canal were carried out during the four seasons of 1991. The samples were taken from 15 stations along the Canal and they were further grouped into three regions, namely; Port-Said, Ismailia and El-Suez.

A total of 139 species and varieties were identified from the different samples, of them, 94 species and varieties representing 40 genera belong to diatoms and 36 species within 11 genera belong to dinoflagellates. The highest number of species (100) were recorded from El-Suez region, followed by Port-Said and Ismailia respectively (97 & 90 species). Most species and varieties were wide spread through the canal except of 13, 8 and 15 species which were confined to Port-Said, Ismilia and El-Suez respectively, where these species were recorded in Mediterranean, Red Sea and Lake Manzalah. It was found that at least 13 species of Red Sea origin have crossed the canal northward to Port-Said, while many species have immigrated south to El-Suez.

Quantitatively, the standing crop was numerically much higher at Ismailia region (average 25,380 units L^{-1}) than Port-Said and El-Suez regions (18,883 and 4,767 units L^{-1} respectively).The highest counts of phytoplankton were recorded at St.6 (39 x 10^3 Units L^{-1}) and it decreased towards both the south and north except of a remarkable increase noticed at St.1. The minimal value was recorded at St 13 (2.8 x 10^3 units L^{-1}). The annual average of the total phytoplankton counts amounted to 16,342 units L^{-1}. Also, the standing crop attained its highest density during winter (average 41,658 units L^{-1}) in all regions, with its maximum at Ismailia (59,584 units L^{-1}) and Port-Said

(50,372 units L^{-1}) while its minimum was recorded at El-Suez (15,034 units L^{-1}). In all regions, diatoms constituted more than 97% by number of the standing crop.

The concentration of chlorophyll-a, phytoplankton biomass, gross primary production and dissolved oxygen amounted with averages 1.95 mg m^{-3}, 0.146 mgC L^{-1}, 2.936 ml O_2 L^{-1} 8 hr^{-1} and 4.1 ml O_2 L^{-1} respectively in the Suez Canal and they showed the same regional and seasonal trend of the phytoplankton standing crop.

The relatively low numbers of species and low standing crop of phytoplankton numerically and its biomass after reopening the Suez Canal for navigation is attributed to the fact that the water is always turbid and slightly polluted as supported by the results of diversity (average 1.8) in the present investigation.

INTRODUCTION

The Suez Canal lies between longitudes 32° 20' and 32° 35' E, and between latitudes 29° 55' and 31° 15' N. It is a passage between the Mediterranean Sea at Port-Said and Red Sea at Port-Taufiq. The Canal was opened in 1869 with 162 Km length, recently increased to 195 Km including Lake Timsah, the Great Better Lake and Little Bitter Lake through which the canal passes. Also, the canal is connected at Port-Said with Lake Manzalah .

Little work has been done on the phytoplankton of the Suez Canal, and this was confined to the preliminary reports of Macdonald (1933) and Ghazzawi (1939), while Dowidar (1976) studied the phytoplankton community in the Canal during July, 1969 and February, 1970 when the canal was closed against navigation.

For the lack of any particular study on the Suez Canal plankton during the last 20 years and after its promotion and reopening in 1985 for navigation, the present investigation was necessary to deal with the phytoplankton community, chlorophyll-a Biomass, gross primary production and population diversity.

MATERIAL AND METHODS

Through the period from June to December, 1991 four trips were carried out in the Suez Canal, representing four seasons, namely; spring (June), summer (August), autumn (October) and winter (December).

The samples were taken from 15 stations along the Canal. These stations were further grouped into three main regions as follows: I Port-Said region (stations 1-5) and it comprises stations (1) Deleceps, (2) 22- Hectometer, (3) Ras El-Esh, (4) El-Cap and (5) El-Ballah. II- Ismailia region (stations 6-10) which comprises stations (6) Lake Timsah, (7) East-Defersoir, (8) West-Defersoir, (9) East-Fayed, (10) West-Fayed. III- El-Suez region (Stations 11-15) and it includes stations (11) 1-Kabret, (12) 2-Kabret, (13) Genefa, (14) 2-Port Taufiq and (15) 1-Port Taufiq. (Fig. 1).

Samples used for determination of dissolved oxygen were fixed immediately after collection and analysed in the laboratory; according to the classical Winkler technique (Strickland and Parsons, 1965) and the results were given in ml O_2 L^{-1}. Gross primary production was determined as oxygen production according to the light and dark bottle method (Strickland and Parsons, 1968). In situ measurements were carried out by exposing the glass bottles containing the water samples just below the surface water in the canal for 8 hours (from 8 a.m to 4 p.m.). The data were expressed as ml O_2 L^{-1} and ml O_2 L^{-1} 8 hr^{-1}. Chlorophyll-a was determined spectrophotometrically after extraction of the studied samples with 90% acetone solution and expressed in mg m-3 according to the method described by Strickland and Parsons (1972). The phytoplankton biomass was tentatively calculated in ug C L^{-1} by multiplying chlorophyll-a content by factor 75 as given by Holm-Hansen (1973). Estimation of the phytoplankton standing crop was carried out by using the sedimentation method and the different species were calculated as their total number per liter (units L^{-1}). Diversity index of the phytoplankton community was calculated on computer according to the equation of Shannon-Wiener (Shannon & Weaver, 1963), using primer program.

RESULTS

Community Composition of Phytoplankton:

The phytoplankton community in the Suez Canal was rich in the numbers of species but showed moderate density. Altogether, about 139 species and varieties were recorded, included 94 diatom species and varieties representing 40 genera, 36 dinoflagellates including 11 genera, one species of silicoflagellates, 3 species of chlorophytes belonging to 3 genera and 5 species within 4 genera of cyanophytes.

As shown in Table (1), the community composition appeared more or less similar in the three regions except of 13, 8 and 15 species which were confined to Port-Said, Ismaillia and El-Suez regions respectively.

The phytoplankton population of Port-Said region comprised 97 species and varieties forming 69.8 % to the total number of species recorded in the Canal. The diatoms constituted 73.2 % of the total number of species. Most of them

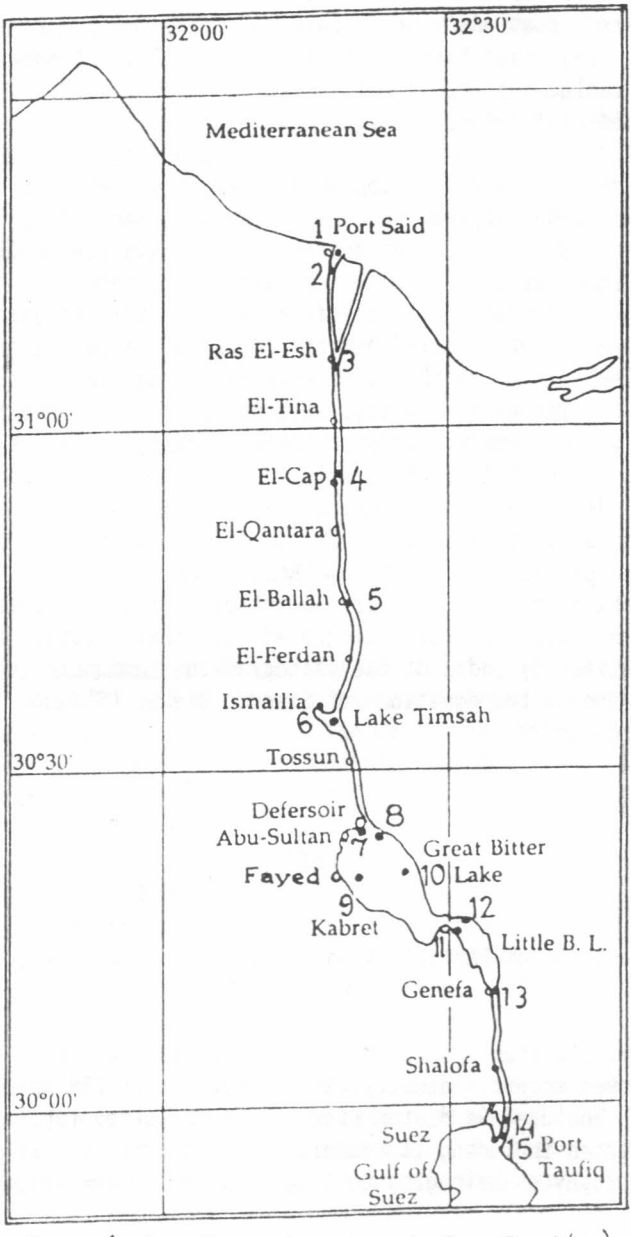

Figure 1 : Sampling stations along the Suez Canal.(•)

Table (1): Distribution of phytoplnakton species recorded from the Suez Canal during 1991.

A: Species recorded along the Suez Canal.
B: Species recorded from each region .
C: Species only recorded at each region.

PS, SI, IP : Species recorded as share between two regions.

Phytoplankton	A	P			I			S		
		B	C	PI	B	C	IS	B	C	SP
Diatoms	94	71	9	47	60	2	48	70	9	54
Dinoflagellates	36	21	3	16	27	4	18	25	4	13
Silicoflagellates	1	1	--	--	--	--	--	1	--	1
Green Algae	3	2	1	--	--	--	--	2	1	1
Blue Green algae	5	2	--	1	3	2	--	2	1	1
Total No. of species	139	97	13	64	90	8	66	100	15	70

P: Port-Said I: Ismailia S: El-Suez.

belong to the Mediterranean flora, which have been previously recorded by Dowidar (1976) in the same area beside the two Indopacific species Coscinodiscus gigas and Ceratium egyptiacum which have been previously reported in Port-Said and/or off Alexandria (Dowider, 1965; 1971 & Halim, 1970) and in the same region (Dowidar, 1976). These 2 species are immigrants into the Mediterranean through the Suez Canal.

Thirteen species were confined to Port-Said region, namely; Coscinodiscus radiatus, Surirella striatula, Gomphonema gracile, Mastogloia elliptica, Cosinodiscus gigas, Surirella gemma, Chaetoceros densum, Thalassiothrix longissima, Streptotheca thamensis, Ceratium pulchellum var euplchellum, C. pulchellum var. tripodioides, Dinophysis caudata and Coelastrum microporum. The first 4 species and the latter one were recorded in Lake Manzalah (El-Sherif et al, 1993) and the other species were recorded in the Mediterranean (Dowidar, 1974) except Streptotheca thamenis which appeared in Red Sea (Halim, 1969).

Other species of brackish affinities were also recorded in Port-Said region as Crucigenia tetrapedia, Spirulina laxissima, S. platensis, Cocconcis placentula, Pleurosigma elongatum, Chaetoceros affinis, Synedra ulna, Melosira granulata, Cyclotella meneghiniania, Amphiprora paludosa, Hyalodiscus laevis, Nitzschia spp and Navicula cryptocephala all of them were recorded in the adjacent brackish water Lake Manzalah (El-Sherif et al., 1993) and were transported to Port-Said region. A total of 66% of the species estimated in this region was also recorded in Ismailia sector (Table 1).

The community composition of phytoplankton at Ismailia region was relatively lower than that of the other two regions. A total of 90 species and varieties were enumerated forming 64.7 % of the total number of species recorded in the Canal. Of these, the diatoms were represented by 60 species [forming about 66.7 % of the total population]. A total of 73.3% of the species present in this region was also recorded in El-Suez (Table 1). Eight species were confined to this region, namely; Biddulphia alternans, Rhizosolenia styliformis, Ceratium karsteni, Noctiluca milaris, Peridinium leosis, P. portus-crientalis, Oscillatoria limnetica and Gomphosphaeria aponiana, all of them were previously recorded in the Mediterranean (Dowidar, 1974) except the latter two species which are considered as fresh forms. While, the species from the second to the fifth were also recorded in the Red Sea (Halim, 1969).

At El-Suez region, 100 species and varieties were recorded, representing about 72% of the total species estimated in the Canal. Diatoms were represented by 70 species and varieties.
About 15 species were confined to this region, being absent from Port-Said and Ismailia regions (Table 1), namely; Bacillaria paradoxa, Cosinodiscus oculus-irdis, Nitzschia panduriforms, Biddulphia laevis, B. mobiliensis, B. aurita, Synedra undulata, Epithemia zebra, Rhopalodia gibba, Pediastrum tetras, Oscillatoria tenuis, Exuviella opora, Ceratium longirostrum, C. extensum and

Goniaulax spinifera. The first species and the latter two ones were recorded in both the Red Sea (Halim, 1969) and the Mediterranean (Dowidar, 1974). The rest of the recorded species were also observed in the Mediterranean Sea except

Pediastrum tetras and Oscillatoria tenuis which are considered as brackish water forms and were previously recorded in Lake Manzalah (El- Sherif et al., 1993). A total of 70 % of the species present in this area was also recorded in Port-Said region (Table 1).

Seasonally, the total number of species recorded in the Suez Canal as a whole were 82, 80, 68, and 61 species in spring, summer, autumn and winter respectively, where the number of diatom species amounted to 60, 52, 52 and 49 in the four seasons respectively, while that of dinoflagellates species were 20, 23, 13 and 11 respectively.

Distribution and Seasonal Variations of phytoplankton:

The phytoplankton of the Suez Canal consisted mainly of Bacillariophyceae, which contributed numerically 97.3 % of the total community with annual average of 15,895 cells L^{-1}. Dinophyceae appeared infrequently and it averaged 401 cells L^{-1} (2.4 %), whereas Cyanophyceae, Chlorophyceae and Silicoflagellates remained as rare forms and they constituted collectively 0.3 % of the total phytoplankton (average 46 units L^{-1}). The annual average standing crop for the whole canal amounted to 16, 342 units L-1. (Table 2).

The highest density of phytoplankton appeared in Ismailia region (25,380 units L^{-1}), it was more productive than Port-Said region (18,883 units L^{-1}), while it showed a sharp drop in their numbers at El-Suez region (4,767 units L^{-1}). Regarding the spatial variation between the different stations, the highest counts of phytoplankton appeared at St.6 (average 39 x 10^3 units L^{-1}) and it decreased towards both the south and north, except of a remarkable increase noticed at St.1 (average 31 x 10^3 units L^{-1}). The minimal value was recorded at St. 13 (2.8 x 10^3 units L^{-1}) as shown in table (3).

Diatoms formed numerically 96.5 %, 98.3 % and 97 % of the total phytoplankton at Ismaillia, Port-Said and El-Seuz regions respectively (averages 24,497; 18,562 & 4,626 cells L^{-1}), while the dinoflagellates comprised 3.45%. 1.2 % and 2.2 % at the same regions (averages 876, 222 & 106 cells L^{-1} respectively).

The distribution of phytoplankton in the Suez Canal showed a relatively low density in spring, followed by a pronounced increase during summer (Table 2). The standing crop decreased again in autumn and this was succeeded by an outstanding peak in winter as shown in the following pages.

1- Distribution of phytoplankton during spring :

The spring was characterized by low counts of phytoplankton where their average numbers in the canal reached 3,419 units L^{-1}. The highest density appeared in Ismailia region attaining 7,999 units L^{-1}, showing its maximum distribution at stations 8 and 7 (Table 3). It decreased to 1,327 cells L^{-1} in Port-Said region and reached lowest density in El-Suez region (932 cells L^{-1}).

Table (2): Seasonal variations of the different classes of phytoplankton and their frequency in the Suez Canal during 1991.

Phytoplnakton classes	Spring		Summer		Autumn		Winter		Average	
	No.L-1	%	No.L-1	%	No.L-1	%	No.L-1	%	No.L-1	%
Diatoms	3.160	92.4	13,094	92.2	5,831	95.9	41,494	99.6	15,895	97.3
Dinophyceae	248	7.3	999	7	207	3.4	150	0.36	401	2.45
Other forms	11	0.3	115	0.8	44	0.7	14	0.034	46	0.3
Total No L-1	3,416	100%	14,208	100%	6,082	100%	41,658	100%	16,342	100%

Table (3): Standing crop of phytoplankton (units-L^{-1}), Chlorophyll-a (mg m^{-3}), dissolved oxygen (ml O_2 L^{-1}) and gross primary production (ml O_2 L-1 8 hr^{-1}) at the different stations of the Suez Canal during the four seasons of 1991.

Season		Spring	Summer				Autumn				Winter			
Region	Station	Phytopl. No. L^{-1}	phytopl. No. L^{-1}	Chl.a mg m^{-3}	Diss Oxygen ml O_2 L^{-1}	Gross lry production ml O_2 L^{-1} 8 hr^{-1}	Phytopl. No. L^{-1}	Chl.a mg m-3	Diss Oxygen	Gross lry production ml O_2 L^{-1} 8 hr^{-1}	phyt. No L-1	Phytopl. No. L^{-1}	Diss Oxygen ml O_2 L^{-1}	Gross lry production ml O_2 L^{-1} 8 hr^{-1}
	1	1,218	38,766	0.232	3.29	5.712	2,784	0.632	3.36	0.42	80,454	4.009	5.38	10.16
	2	2,028	30,525	—	4.11	4.58	867	1.014	3.19	0.20	52,922	3.066	5.88	6.96
	3	1,080	3,597	2.265	3.50	0.80	2,550	0.200	3.19	0.34	28,208	3.037	5.21	4.50
	4	1,300	10,197	0.815	2.47	2.17	5,952	1.011	3.19	0.89	25,546	2.197	4.96	3.36
	5	1,008	5,544	—	3.50	0.825	18,444	1.221	3.36	2.77	64,660	8.163	5.04	8.52
	Avg.	1,327	17,726	1.104	3.37	2.817	6,119	0.816	3.26	0.924	50,372	4.094	5.29	6.7
	6	6,460	29,684	1.224	4.32	4.44	45,540	2.442	3.86	6.83	73,752	8.760	5.21	9.1
	7	10,699	35,145	0.786	4.73	5.26	1,938	0.206	3.69	0.29	—	—	—	—
	8	13,754	18,150	0.380	4.11	2.73	2,850	0.203	3.53	0.36	—	—	—	—
	9	7,596	26,059	0.290	4.11	3.915	540	0.325	3.19	0.18	61,692	6.590	5.63	7.84
	10	1.488	8,294	1.012	3.50	1.245	1,485	0.380	3.36	0.224	43,308	3.064	5.29	6,20
	Avg.	7,999	23,466	0.738	4.15	3.518	10,471	0.711	3.53	1.58	59,584	6.138	5.38	7.71
	11	1.472	2,494	1.012	2.67	0.245	4,050	1.768	3.19	0.61	9,588	1.139	5.29	1.42
	12	2,109	2,158	0.812	3.50	0.217	931	0.757	3.19	0.14	13,303	1.844	5.12	2.10
	13	400	1,575	1.247	4.11	0.298	1,372	0.174	3.19	0.21	7,802	0.542	5.54	1.68
	14	90	609	0.598	3.50	0.134	—	—	—	—	24,708	2.441	5.46	3.34
	15	588	341	4.408	3.29	0.081	318	0.206	3.19	0.11	19,769	1.953	4.70	2.84
	Avg.	932	1,435	1.615	3.41	0.64	1,668	0.726	3.19	0.27	15,034	1.584	5.22	2.28
Total average No L-1		3,419	14,209	1.153	3.645	2.325	6,081	0.751	3.327	0.924	41,663	3.939	5.30	5.36

Diatoms constituted about 92.4 % of the total phytoplankton (3,160 cells L^{-1}), being dominated by Rhizosolenia spp. with average 2,433 cells L^{-1} (71 % to the total phytoplankton) and it comprised R. alata, R. alata var. gracillima , R. calcaravis, R. shrubsolei, R. stolterfothii, R. styliformis. Besides Guinardia flaccida and Nitzschia spp appeared frequently and contributed collectively about 4.8 % of the total phytoplankton (164 cells L^{-1}). All the previous species were recorded in the three regions, while Chaetoceros curvisetum, C. decipiens, C. densum, C. affinis were confined to Port-Said region, and Melosira granulata was only observed at St.6 of Ismailia region.

Dinophyceae appeared infrequently with average 248 cell L^{-1} (7.3%) and was mainly represented by Ceratium (216 cells L^{-1}, 6.3 %). The chlorophytes, Crucigenia tetrapedia was rarely recorded at stations 3 and 12 (72 and 76 cells L^{-1}, respectively), while Cyanophytes Oscillatoria tenuis was only recorded at St. 14 as very rare form (9 cells L^{-1}).

2- Distribution of phytoplankton during summer:

The magnitude of the standing crop during the summer was higher than the spring records and it amounted to 14,209 units L^{-1}. The maximum frequency occurred also in Ismailia region which reached 23,466 units L^{-1} and it decreased gradually to 17,726 and 1,435 units L^{-1} in Port-Said and El-Suez regions respectively. Its highest density was recorded at stations 1,2,7,6,9 (Table 3).

The diatoms remained dominant in the three regions with average 13,094 cells L^{-1} (92.9 %) . Thalassionema nitzschoides appeared as the most dominant diatom in the canal during this season, with an average of 5,797 cells L^{-1} (40.8%), followed by Asterionella japonica, with an average of 3,703 cells L^{-1} (26.1%) and it appeared mainly at Port-Said region, while Cyclotella meneghiniana (554 cells L^{-1}), Thalassiothrix frauenfeldii (360 cells L^{-1}), Chaetceros spp. (897 cells L^{-1}) and Nitzschia spp (248 cells L^{-1}) were frequently recorded. Ceratium spp and Peridinium spp. (437 & 164 cells L^{-1}, respectively) were the most frequent forms of Dinophyceae. Besides, Goniaulax, Gessnerium and Noctiluca (averages 106;203 & 48 cells L^{-1}, respectively) persisted with low counts where the latter species was only recorded in Ismailia region. All the previous species of Dinophyceae represented collectively 6.7 % of the total phytoplankton. The species Dictyocha fibula (Silicoflgagellates) and Coelastrum microporum (green algae) were once recorded at stations 4 and 5 respectively (33 & 896 cells L^{-1}). The blue green algae appeared scarcely at scattered stations. Thus, Spirulina laxissima was observed at St. 4, 13 & 14, Oscillatoria lemnitica at St. 6 and Gmphosphaeria aponiana at St.5.

3- Distribution of phytoplankton during autumn:

The average numbers of the phytoplankton for the whole Canal decreased again during autumn to 6,081 units L^{-1}, due to their decreased densities in Ismailia and Port-Said regions which sustained respectively 10,471 and 6,119 units L^{-1}. Its maximum density was recorded at ST.6 (Table 3). The community was

dominated by diatoms with an average of 5,831 cells L^{-1} (95.9%) particularly Nitzschia spp. (41.8 % to the total phytoplankton) which flourishing with N. delicatissima (36.6 %) while Melosira spp (12.9%) and Leptocylindrus danicus (13.16 %) were recorded at stations 4,5, and 6. Skeletonema costatum (10.1%) at Port-Said region and St. 6 of Ismailia region. The other species of Rhizosolenia (3.7 %), Cyclotella (1.8 %) and Asterionella (3.7%) were less frequent, the latter species was only recorded at St 4,5 and 6.

Dinophyceae remained infrequent (average 207 cells L^{-1} = 3.4%) and mainly represented by Peridinium spp, Ceratium spp. and Goniaulax spp. in the different stations.

Other species like Dictyocha fibula, Spirulina platensis, and Pediastrium tetras were also recorded as rare forms at scattered stations.

4- Distribution of phytoplankton during winter:

An outstanding peak of phytoplankton was recorded at the Suez Canal in this season which reached an average of 41,663 units L^{-1}. The highest density occurred in Ismailia region (59,584 units L^{-1}) and it decreased successively to 50,372 units L^{-1} in Port- Said region and 15,034 units L^{-1} in EL-Suez region. The highest density of phytoplankton in this season was recorded at stations 1 and 6, and the lowest appeared at St. 13 (Table 1).

The diatoms attained 41,494 cells L^{-1} (93.3 % to the total counts) and they persisted as the more dominant plankters. This was attributed to the flourishing of Rhizosolenia alata (22%), R. alata var gracillima (16%), Melosira granulata (12.9 %) and to a less extent Nitzschia delcatissima (6.1 %), Chaetoceros affinis (1.7 %), C. curvisetum (1.3%) at the three regions. Besides, Skeletonema costatum (5.4 %) was recorded in Port-Said and El- Suez regions, and Asterionella japonica at stations 1,2, and 3 of the former region.

Dinophyceae appeared rarely (0.03%) in some stations and comprised Goniaulax catenata, Ceratium spp., Peridinium spp. Pyrophacus horlogium, Oxytoxum sceptrum and Exuviella marina. While the Cyanophyte Spirulina laxissima was only recorded at St. 3 (215 fil.L^{-1}).

A Complete list of the phytoplankton community recorded in the different regions of the Suez Canal at the different seasons are represented in Appendix (I).

Diversity:

Through the investigation period, the diversity values were relatively high during autumn, ranging from 1.35 to 2.56 and with an average of 2.04. While the lower diversity was recorded during winter with values ranging from 0.69 to 2.06 and with an average of 1.51.

The diversity during spring and summer was more or less equal with averages 1.84 and 1.91 respectively. The average diversity value was relatively high at El-Seuz region (2.05) and it decreased to 1.62 and 1.82 at Ismailia and Port-Said regions respectively. Generally, the diversity of the Suez Canal fluctuated between 0.47 at St. 9 in spring and 2.72 at St. 13 in summer, with an average of 1.824.

Dissolved Oxygen:

The dissolved oxygen in the Suez Canal is controlled by the physical conditions such as water temperature and wind action as well as the photosynthetic activities of phytoplankton.

The distribution of dissolved oxygen in the Suez Canal shows a pronounced seasonal variations. The highest values occurred in winter with an average of 5.3 ml O_2 L^{-1} i.e. when the water temperature attained its minimum values (13.1-17.1 °C) and agitation of water by strong wind action which increased the solubility of oxygen, beside the highest standing crop of phytoplankton (Table 3). On the other hand, the lowest concentration of dissolved oxygen was recorded in autumn (average 3.3 ml O_2 L^{-1}), and this coincided with lower standing crop of phytoplankton.

A noticeable increase in the oxygen content was recorded during summer (average 3.65 ml O_2 L^{-1}) and is attributed to the increased standing crop of phytoplankton. As shown in table (3), Ismailia region sustained the highest oxygen concentration which was accompanied by the highest density of phytoplankton, reaching a maximum average of 5.38 ml O_2 L^{-1} in winter and decreased gradually to 4.15 and 3.53 ml O_2 L^{-1} in summer and autumn.

Generally, the water of the Suez Canal is mostly well oxygenated. The dissolved oxygen in the Canal fluctuated between 2.47 and 5.88 ml O_2 L^{-1}, with annual average of 4.1 ml O_2 L^{-1}.

Gross primary production: (Oxygen production method):-

The gross primary production was roughly estimated by measuring the amount of oxygen evolved through the process of photosynthesis and the samples were incubated in situ for 8 hours during day time.

The gross primary production of the Suez Canal varied between 0.08 and 10.15 ml O_2 L^{-1}. 8 hr^{-1} at stations 14 (summer) and 5 (winter) respectively and with annual average 2.94 ml O_2 L^{-1} 8 hr^{-1}.

According to the monthly averages, the winter represented the highest value (average 5.56 ml O_2 L^{-1}. 8 hr^{-1}) while it attained 2.33 ml O_2 L^{-1}. 8 hr^{-1} in summer and decreased to 0.924 ml O_2 L^{-1}. 8 hr^{-1} in autumn, showing the same seasonal trend of both dissolved oxygen and phytoplankton standing crop (Table 3).

Regionally, Ismaillia region sustained relatively higher gross primary production than Port-Said region in the three seasons (averages 4.27 & 3.48 ml O_2 L^{-1}. 8 hr^{-1} for the 2 regions respectively) while the minimum value was recorded at El-Suez region (average 1.06 ml O_2 L^{-1}. 8 hr^{-1}). These, coincided with the same results of chlorophyll-a and standing crop of phytoplankton.

Chlorophyll-a :

Chlorophyll-a is considered as the main pigment used for the determination of phytoplankton biomass.

The average chlorophyll-a biomass amounted to 1.153 and 0.751 mg m^{-3} during summer and autumn respectively. It is obvious that the variations in chlorophyll-a during these two seasons, generally followed the corresponding variations in the standing crop of phytoplankton, but they were differed in their values within the different stations due to the variation in the size of the dominant species occurring at these stations (Table 3).

During winter, the maximum values of Chl-a were recorded in the Canal (3.94 mg m-3), where the standing crop of phytoplankton attained its highest value. The average value of chlorophyll-a for the whole canal amounted to 1.95 mg m^{-3}.

According to the phytoplankton equivalents given by Holm-Hansen (1973), the phytoplankton biomass in the Canal fluctuated between 0.013 and 0.657 mg C L^{-1} at stations 13 and 6 during autumn and winter respectively, with annual average 0.146 mg C L^{-1}. Its maximum annual average appeared in Ismailia region (0.190 mg C L^{-1}) and it decreased in both Port-Said and El-Suez regions to 0.15 and 0.098 mg C L^{-1} respectively. Generally, the highest average biomass of phytoplankton was recorded in winter (0.295 mg C L^{-1}) and it decreased during both summer and spring to 0.087 and 0.056 mg C L^{-1} respectively.

DISCUSSION

The present study deals with qualitative and quantitative estimation of phytoplankton after promotion and reopening of Seuz Canal for navigation in 1985. A total of 139 species of phytoplankton was recorded, including 94 diatoms, 36 dinoflagellates, one silicoflagellates, 3 chlorophytes and 5 cyanophytes.

This is relatively higher than the number of phytoplankton species encountered in the Canal during earlier periods up to 1936, where only 60 phytoplankton species were recorded and comprised 43 diatoms and 18 dinoflagellates (Ghazzawi, 1939), but it appeared lower than that recorded in July, 1969 and February, 1970 when the Canal was closed against navigation. Thus it was highly diversified and comprised 273 species (182 diatoms, 88 dinoflagellates, one silcioflagellates and 2 Ibriidae) (Dowidar, 1976). The decreased of phytoplankton species nowadays is most probably due to the turbulance caused by ships traversing the Canal and various other processes of Canal maintenance. Such disturbances caused the canal water to be almost always turbid and unfavourable for many phytoplankton species.

Of the 139 species recorded in the present study investigation, 50 species were reported in the three regions of the canal (36 % of the total species), 53 species shared between two regions (38.1 %) and 36 species were recorded as being confined to one region or the other (25.9 %).i.e. about 74.1 % of the total species were recorded in the different regions of the canal. Most of them belong to the Mediterranean or Red Sea flora beside some brackish water forms. The homogenety of phytoplankton in the Suez Canal is attributed to their immigration in the Canal due to the current pattern prevailing the area. Thus over 71 % of the total species were recorded in both El-Suez and Port-Said regions.

Generally, the Suez Canal, as an interoceanic link, connects Mediterranean-Atlantic and Red Sea-Indopacific and more than 70 % of the phytoplankton population of EL-Suez region are common to the Mediterranean. Besides, the two Indopacific species Coscinodiscus gigas and Ceratium egyptiacum have been recorded in Port-Said. Also, several species of the Suez Bay and/or Red Sea were also recorded at Port-Said such as Peridinium leonis, P. divergens, Streptotheca thamensis , Rhizosolenia spp. and Hemiaulus heibergii.

Generally, of the total phytoplankton recorded in the Suez Canal during the present study; 13 species are confined to the Red Sea; 109 species are already known in the Mediterranean and 8 species of green and blue green algae are common in Lake Manzalah, one of them was also recorded in Red Sea (Oscillatoria sp). These 8 brackish water species were absent from the pervious records in the Canal, namely; Crucigenia tetrapedia, Pediastrum tetras, Coelastrum microporum, Oscillatoria limnetica, O. tenuis, Spirulina laxissima, S. platensis and Gomphosphaeria aponina. Besides, the species Streptotheca thamemsis and Peridinium leonis of the Red Sea and Gessnerium mochimaensis, Noctiluca miliaris and Dissodinium lunula of the Mediterranean sea were also recorded in the canal for the first time.

The standing crop of phytoplankton in Ismailia and Port-Said regions was much higher than that of El-Suez region (averages 25.4, 19 & 4.8 x 10^3 units L^{-1} respectively), and showing the same trend of its biomass and dissolved oxygen. Its maximum density was recorded at stations 1 (Deleceps) and 6 (Lake Timsah) (31 & 39 x 10^3 units L^{-1} respectively) due to the fact that the salinity is always within the normal range as tolerated by many species (about 37.28 ‰), and nutrient salt are also probably abundant as they receive variable amounts

of brackish water rich in nutrients from the adjacent Lake Manzalah and Ismailia canal respectively. The species that were able to build up relatively large population in the Canal comprised Rhizosolenia alata, R. alata var. gracillima, Melosira granulata and Thalassionema nitzschoides, beside Asterionella japonica at the north side.

The blooming season of phytoplankton in the different regions of the canal was in winter (average 41,663 units L^{-1}) coinciding with the highest values of dissolved oxygen (5.3 ml O_2 L^{-1}) and Chl.-a (3.9 mg m-3). This is similar to the seasonal distribution of phytoplankton in the central part of the Red Sea (McGill & Lawson, 1966), northern part of the Gulf of Aqaba-Red Sea (Levanonspanier et al., 1979). While in the previous work on the Canal by Dowidar (1976), the winter phytoplankton population was lower than the summer records (averages 27,103 & 43,100 cells L^{-1}, respectively).

The abundance of R. alata in Port Said during winter may be regarded to be of allochtonous origin, being transported from Ismailia by the strong north-word current. This species never occurred in large numbers in the Mediterranean waters off the Nile Delta. Its abundance in Port-Said during winter may indicate enrichment from the south part of the canal.

Results of diversity revealed that the Canal sustained a moderate number of species as indicated by its moderate diversity (1.82). The highest diversity of 2.72 was recorded in summer at St. 13, due to the increased number of species while the phytoplankton standing crop remained low there. On the other hand, the lower diversity appeared at stations 8 and 9 in spring (0.61 & 0.47 respectively) where Rhizosoleina alata var. gracilliam formed about 89 % & 91.6 % of the total phytoplankton at these two stations respectively (12,090 and 6,957 cells L^{-1}). The same case was met with at station 2 in summer (0.66), and statoions 1 and 2 in winter (0.81 % & 0.7 respectively) where Asterionella japonica formed about 85.6 % , 84 % and 81 % of the total phytoplankton (26,136; 67,522 & 42,720 cells L^{-1} respectively) and these were accompanied with an increase in the standing crop of phytoplankton.

Results revealed regional and seasonal inverse correlation between diversity and the standing crop of phytoplankton in the Suez canal and it is regarded as a slightly polluted habitat.

In the Suez Canal, the annual averages of Chlorophyll-a, phytoplankton biomass, gross primary production and the dissolved oxygen amounted to 1.95 mg m^{3}, 0.146 mg C L^{1}, 2.936 ml O_2 L^{-1} 8 hr^{-1} and 4.1 ml O_2 L^{-1} respectively. The highest values for all them were recorded in winter, while their lowest values were noticed during autumn, similar to the seasonal variations of phytoplankton standing crop.

A positive correlation was also found between the four previous parameters and the standing crop of phytoplankton both in the different seasons and regions. Contrarily, the concentration of chlorophyll-a at Ismailia region during summer and autumn was slightly lower than the other two regions and this

is attributed to the dominance of species with large size in the latter two regions such as Pleursigma, Surirella, Skeletonema, Synedra, Melosira, Pediastrum and Spirulina.

In general, the standing crop of phytoplankton (16,342 units L^{-1}) recorded in the present investigation is lower than the pervious records from 20 years ago. Also, rather low chlorophyll-a concentration and primary production was estimated in the canal when compared to those of the coastal waters of south eastern part of the Mediterranean (4.0-7.0 mg m^{-3}) (Dowidar & Mostafa, 1983), or to the western part of the Black Sea (new Danoub) (3.0-35.0 mg m^{-3}) (Bologa et al., 1983). But it is higher than that recorded in the central part of the Red Sea (McGill & Lawson, 1966), and Gulf Aquaba (Levanon-Spauter et al., 1979).

In conclusion the relatively low standing crop of phytoplankton, numerically and its biomass in the Suez Canal compared with the previous records may be attributed to the prevailing ecological conditions such as the paucity of nutrient salts. The canal water is almost always turbid due to the continuous passage of ships and oil tankers which cause more or less homogenety in species distribution. The water is also slightly polluted as indicated by diversity values which attained an average of 1.8.

REFERENCES

Dowidar, N.M., 1965. Distribution and ecology of marine plankton in the region of Alexandria, Egypt. Ph.D. Thesis, Alexandria University.

Dowidar, N.M. 1971. Distribution and Ecology of Ceratium egyptiacum and its validity as indicator of the regime in the Suez Canal. Int. Revue ges. Hydrobiol., 56(6), pp. 957-966.

Dowidar, N.M. 1974. The phytoplankton of the Mediterranean waters of Egypt. I- A check list of the species recorded Bull. Inst. Ocean. & Fish., ARE. vol. 4., 1974:319-344.

Dowidar, N.M., 1976. The phytoplankton of the Suez Canal. Symp. East. Med. Sea. IBP/PM Unesco. Acta Adriatica, 18(14): 241-255.

Dowidar N.M. and H.M Mostafa, 1983. Phytoplankton biomass and primary production in the South Eastern Mediterranean off the Egyptian coast. Rapp.Comm.int.Mer.Medit.,28(9):85- 88.

El-Sherif, Z.M.; S.M. Aboul-Ezz and M.M. El-Komi, 1993. Effect of pollution on the productivity in Lake Manzalah (Egypt). NIOF & USPD, International conference on future of Aquatic Resources in Arab region. (in press).

Ghazzawi, F.M. 1939. A study of the Suez Canal plankton. The phytoplankton. Fish. Res., Direct Notes Memories No. 24, p.83.

Halim, Y. 1969. Plankton of the Red Sea. Oceanogr. Mar. Biol., Ann. Rev., 7, pp. 231-275.

Halim, Y. 1970. Microplancton des eaux egyptiennes III. -Especes indopacifiques ou erythreennes a l'extreme nord du Canal de Suez. Journees Etudes Planctonol., Rapp. Comm. Int. Mer Medit., pp. 57-59.

Holm-Hansen, O., 1973. Determination of total microbial biomass by measurement of adenosine triphosphate. In Esturaine Microbial Ecology, H.L. Stevenseon and R.R. Colwell (Eds.). University of south Carolina Press, Columbia, S.C. PP. 73-89.

Levanon-Spanier I., E. Pandan and Z. Reiss, 1979. Primary production of a desert-enclosed sea-the Gulf of Elat (Aqaba), Red Sea . Deep sea Res., 26(6):673-685.

Macdonald, R. 1933. An examination of plankton hauls made in the Suez Canal during 1928. Fish. Res., Direct., Notes Memories No. 3.

McGill, D.A. and T.J. Lawson, 1966. The distribution of Chlorophyll in the western Indian Ocean during the Northeast monsoon period. Woods Hole Oceanographic Institution, Ref., 66-12, 69 p (unpublished manuscript).

Strickland, J.D.H. and T.R., Parsons, 1965. A manual of sea-water analysis 2nd. Ed. Bull. Fish. Res. Bd., Canada, No. 125, 311 pp.

Strickland , J.D.H. and T.R. Parsons, 1968. A practical Handbook of sea-water analysis. Bult. Fish. Res. Bd. Canada, Ottowa No. 167, 311. PP.

Strickland , J.D.H. and T.R. Parsons, 1972. A practical Handbook of sea-water analysis ,2 nd, Ed. Bult. Fish. Res. Bd. Canada, No. 167, 310. PP.

Shannon, G.E., and W. Weaver, 1963. The mathematical theory of communication . Univ. of Illinois. Press, Urbana, 125 pp.