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MARINE FOULING IN SUEZ CANAL, EGYPT

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ABSTRACT

The marine fouling was investigated in the Bitter lakes and Lake Timsah for one year through four seasons, began during autumn 2002 till summer 2003 at different eight stations, the first five stations (I-V) represented the Bitter lakes namely, Shandora, Kabret, Fanara, Fayed, and Devresoir, while the last three stations (VI-VIII) represented Timsah Lake namely, Ismailia sweet canal, North western and North eastern of Timsah Lake. The settlement of marine fouling organisms, species composition and seasonal abundance in addition to the total biomass/100cm^2/panel achieved by immersed test panels over 2 series on an iron frame below 2 m depth to know the nature of fouling organisms on the panels and buoys. These groups are, Algae, Hydroids, Bryozoa, Polychaeta, Cirripedia, Amphipoda, Isopoda, Decapoda in addition to Mollusca and Ascidia. Different main sources of pollution flow into the study area; fishing and swimming due to the human activity, agricultural effluents and domestic drainage and land based activities of Ismailia City.

Timsah Lake lies in a half-way of the Suez Canal especially Ismailia, its water is salty but fresh water, coming from the Nile through Ismailia canal reduces its salinity and its pH value which change the nature of these organisms in the investigated area. The effect of pollution on Timsah Lake plays an essential role of the appearance of some molluscs, gastropod limpet (Patella caerulea), Bivalvia (Brachidontes variabilis and Modiolus auriculatus) which considered as biomonitor of pollution in this lake. Also, the total biomass is depending upon temperature, season of immersion, kind of substrate, color and duration of exposure. The structure of the total fouling community of the test panels was examined, using measures of statisitical analysis of species diversity, evenness and dominance. The diversity and evenness increase during winter and decrease during summer, arranged in the following sequence, winter > autumn > spring > summer of the season levels, while among main groups were arranged as follow polychaeta > Isopoda > Amphipoda > Cirripedia > Decapoda.

INTRODUCTION

The growth of sessile plants and invertebrate animals on submerged artificial surface is commonly referred to as "fouling". The fouling organisms occur (attached) on a wide range of structure, such as floating docks, pilling, underwater cables and breakwalls. Fouling organisms are the same species that grow on nearby natural hard substrates such as rocks or coral reefs.

The last investigation of benthic communities in the Suez Canal was carried out by Ghobashy *et al.*, (1980). The Suez Canal is international waterway between the Mediterranean and Red seas and all the investigations made so far on this study area have been mainly dealing with its hydrography (Morcos and Messieh, 1973 and Gerges, 1976) and with its plankton populations (Dowidar, 1971 and 1976) and (El-Sherif and Ibrahim, 1993 and Abdel Rahman, 1997). These investigations have shown that the current regime in the Canal had been northward in the majority of year and for few months, namely from July to October, a reversed current occurs. Damming

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of the river Nile made this latter current no longer taking place. Suez Canal as waterway can function as a route for the transportation of sessile animals and plants, by being attached to traversing ships, from one end of the world to the other.

Many of the foulers inhabiting the Canal may thus be imported to it from other parts of the world and during navigation traversing ships will become infected by fouling growths and carry them to seas perhaps have been previously free of it.

The fouling assemblages on exposed surfaces under this study, represents a part of an ecosystem in that they depend upon the prevailing environmental conditions for their development and survival. Thus, it is important to study the seasonal abundance, accumulated biomass and the growth rate of sessile forms.

In the Egyptian harbours, many ecological studies about the marine fouling organisms have been carried out, particularly at the Eastern Harbour of Alexandria (Ghobashy 1976, Selim 1978, Hamada 1982 and El-Komi 1991&1992a), in the Suez Canal (El-Komi, 1980 and Ghobashy and El-Komi 1980 a,b), in the Red Sea (El-Komi 1992b) and in the Suez Bay (Emara 1994 & 2002). On the other hand, Amphipoda, Isopoda and Tanaidacea constitute the richest crustacean groups, associated with fouling in Egyptian waters with regard to the number of individuals and species (El-Nassry, 1973; Ghobashy *et. al*., 1980; Mona, 1982).

The objective of this study is to make a comparison of constituents established on artificially exposed test panels and buoys in the Bitter lakes and Lake Timsah and to estimate their seasonal settlement and abundance.

MATERIALS AND METHODS

Suez Canal reaches 170 km long, situated between the latitudes $29^{o}\ 55^{/}$ and $31^{o}\ 16^{/}$ and at the longitude $32^{o}\ 20^{/}$, is bordered in the north by Port Said on the Mediterranean Sea, in the south by Suez on the Red Sea and nearly at its middle lies in Ismailia on Timsah Lake.

Samples were collected seasonally from eight stations represented 2 sectors, sector (A) is the Bitter lakes that divided into 5 stations (I-V) namely; Shandora, Kabret, Fanara, Fayed and Devresoir (I, II, III, IV and V respectively), while sector (B) is the Lake Timsah that divided into 3 stations namely, Ismailia sweet canal, North western and North eastern side of Timsah Lake of the Suez Canal (VI, VII and VIII respectively) from autumn 2002 to summer 2003, Fig. (1). The stations from I-V subjected to fishing by the human activity, agricultural effluents and domestic drainage and the other three stations from VI-VIII in the Lake Timsah, which is almost half way of the Suez Canal. It lies at 76 km from the northern part of the Canal (Port-Said). It is affected by agricultural wastes and land-based activities of Ismailia City, while Bitter lakes lie between Devresoir at 37.5 km and Shandora at 134.5 km from the north. This area is considered as a transit area for ships passing through Canal. It extends $30^{o}\ 30^{/}\ 35^{//}$ north and $32^{o}\ 15^{/}\ 20^{//}$ east. The water of Timsah Lake is salty but fresh water coming from the Nile through the Ismailia canal reduces its salinity as compared to the northern and southern parts of the Canal.

Generally, the water of Suez Canal is almost turbid due to continuous passage of ships and oil tankers as well as the agricultural wastes and land-based activities at Ismailia City, in addition to the human activity for swimming which largely increased the turbidity of Timsah Lake during the period of study. This cause more or less homogently in species distribution and diversity.

The fouling organisms were collected by using an iron frame of 76 x 37 cms, bearing 8 square test panels (18 x 18 cms) made of impact resistant polystyrene that served as collectors. The frame was suspended vertically under the buoy of each station at a depth of 2 m below seawater surface. Panels were exposed for variable periods of time, after which they were replaced by, clean ones. The surfaces of the panels were roughened by sandpaper to avoid the effect of texture (Pomerat & Weiss, 1946; Barnes, 1956 and Wisely, 1959).

The fouling organisms collected on the exposure panels was identified and counted in living conditions using a dissecting microscope of 20x and 40x field magnification. The growth of the main fouling groups was estimated by measuring the length, or diameter by an ocular micrometer. The removed panels were preserved in 5% formalin.

Statisitical analysis:

A) Species diversity (H^-)

Species diversity was calculated for all samples using the information theory indices that developed by Shannon and Weaver index of diversity (1949). The Shannon index assumes that individuals are randomly sampled from an "indefinitely large population" (Pielou 1966). Peet (1974) noted that this index of diversity combines both the evenness and richness of species.

Shannon function is calculated from the equation

$$H^- = -\sum_{i=1}^{n} Pi \ln Pi$$

Where, Pi = n / N is the proportion of individuals of a species (ni) to the total number of individuals (N) in the sample.

B) Species evenness (J^-):

Species evenness (J^-) is the ratio of observed diversity to maximum diversity, sometimes species evenness known as equitability, (Pielou 1966):

$$J^- = H\ (observed)/\ H\ (maximum) = H/ \ln s$$

Where, S = number of species.

RESULTS

1) Environmental conditions:

1.1) Temperature:

The physical parameters are illustrated in Table (1). The average annual fluctuation in temperature of seawater ranged from 17.56 ^{o} C in winter to 30.70 ^{o} C in summer.

1.2) Hydrogen ion concentration (pH):

The values of hydrogen ion concentration in the investigated area of the surface seawater showed a very narrow limit variations, ranging from 8.01 to 8.29 during autumn and spring respectively.

1.3) Salinity:

The Bitter lakes were relatively high in its salinity comparison to Mediterranean waters. The salinity was ranged from 36.10 %o – 41.80 %o with an average of 39.65 %o recorded at Bitter lakes. However, it was ranged from 19.30 %o – 38.0 %o with an average 32.53 %o recorded at Timsah Lake, Table (1).

2) Seasonal succession:

Fouling differed, in density as well as in composition, from one season to the other. A total of 38 species of different marine fouling organisms were recognized on the exposed test panels, Table (2). They belong to 8 main groups of fouling namely, Algae (7 species), Hydroids (3 species), Bryozoa (5 species), Polychaeta (9 species), Barnacles (2 species), Amphipoda (6 species), Isopoda (4 species) and Decapoda (2 species).

2.1) Autumn season (water temperature was 21- 25 ^{o}C):

The water temperature ranged from 21 to 25 ^{o}C. The drop in water temperature after summer months decreased the average weight of fouling biomass which reached 49 gm/panel. The settlement of polychaeta was the cause of heavy fouling that encountered 709 tubes/100cm^2/panel during September due to the strongly increased *Hydroides elegans* that recorded 450 tubes followed by 130 individuals of *Dasychone lacullana*, while this number gradually decreased from 40, 37, 22, 15, 8 and 7 of *Hydroides dirampha*, *Serpula vermicularis*, *Pomatoleios kraussii*, *Spirobranchus tetraceros*, *Hydroides lunilifera* and *Sabella pavonina*, respectively, Table (2).

During this season, about 120 barnacles, 110 individuals of *Balanus amphitrite* and only 10 individuals of *B. eburneus* covered the panel, while some species of *B. eburneus* being dead or their shells invaded by amphipods and isopods.

Suddenly the drop of the amphipod tubes from 235 tubes during summer to 75 tubes/100cm^2/panel during autumn. The panel dominated by *Erichthonius brasiliensis*, *Elasmopus pectenicrus* and *E. rapax*, respectively, Table (2). Also, Isopoda recorded 137 tubes/100 cm^2/panel, dominated by *Cirolana bovina* (70 individuals), while *Cymodoce truncata* recorded 3 individuals/100cm^2/panel.

The bryozoans flourishing during this season, where the community of fouling included 4 species, a common one was *Bowerbankia imbricata* and the other species were present namely, *Bugula neritina*, *B. turbinata* and *Membranipora crustulenta*. On the other hand, Hydroids represented by the 2 common species of *Obelia geniculata* and *Bougainvillia racemosa*, while the algae represented by the most abundant species of green algae, *Ulva lactuca* followed by other 3 species of *Cladophora prolifera*, *Enteromorpha prolifera* and *E. linza* and the other red algae, *Ceramium rubrum*.

The prevailing groups of the fouling communities along the Bitter lakes and Lake Timsah consists in their majority of Algae, Porifera (sponges), Hydroids, Bryozoa, Polychaeta, Crustacea, Mollusca and Ascidians. The forms constituting each group will be dealt with in the following account.

2.2) Winter: (water temperature, 16.50-19^{o}C).

This is the season of the poorest fouling. The total wet weight (biomass) fluctuated between 8-10 gm per panel/month, in spite of the increasing of average seasonal settlement, which reached 33.5 gm, Table (3). The high average resulted from the flourishing growth of *Hydroides elegans* and *Dasychone lacullana* reached 3200 worms per 100 cm^2/panel by an average of 500 and 350 individuals of the previous two species respectively, Table (2).

The paucity of animal fouling during this season attained the algal predominance on the panel species specially *Ulva lactuca*, *Cladophora prolifera* and *Enteromorpha prolifera* (green algae) and *Ceramium rubrum* (Red algae). The major constituents of fouling during winter included polychaeta, Barnacles, Amphipoda and Isopoda. Bryozoa and Decapoda were scarce.

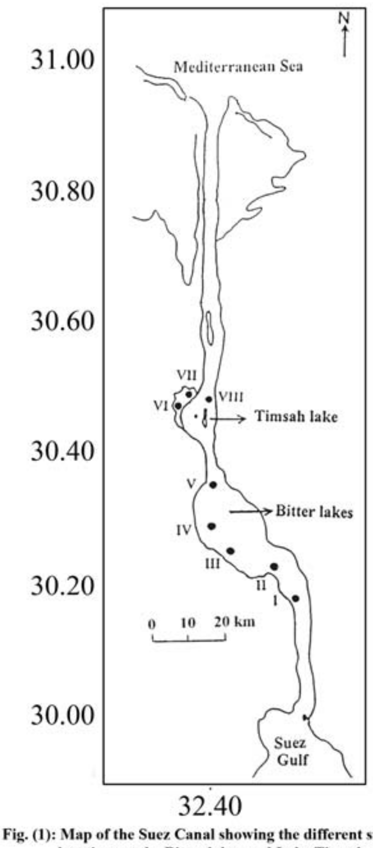

Fig. (1): Map of the Suez Canal showing the different studied locations at the Bitter lakes and Lake Timsah.

Table (1): Seasonal changes of the physico-chemical parameters (temperature, pH and salinity) at the different stations on the test panels at the Bitter lakes and Lake Timsah.

Parameters / Stations	Temperature (°C)				PH				Salinity (%o)			
	autumn (2002)	winter (2003)	spring	summer	autumn (2002)	winter (2003)	spring	summer	autumn (2002)	winter (2003)	spring	summer
I	21.0	17.50	19.00	29.00	8.10	8.24	8.17	7.97	40.30	36.35	39.30	41.80
II	21.5	18.00	20.00	29.50	8.04	8.12	8.20	7.97	40.40	36.10	39.35	41.77
III	22.0	19.00	21.00	30.00	8.05	8.10	8.25	8.04	40.20	36.55	39.45	41.70
IV	23.5	18.00	22.00	31.00	8.01	8.05	8.29	8.09	40.35	37.75	39.15	40.90
V	24.0	17.50	21.00	31.50	8.06	8.05	8.21	8.02	39.80	37.10	39.10	40.50
VI	25.0	17.00	20.00	31.00	8.12	8.18	8.14	7.88	19.30	38.00	26.40	24.70
VII	24.5	17.00	20.50	32.00	8.18	8.02	8.14	8.06	38.20	30.90	37.50	28..70
VIII	24.0	16.50	20.00	31.50	8.06	8.00	8.21	8.12	29.50	31.90	25.10	30.20
Average	23.19	17.56	20.44	30.70					36.01	35.58	35.67	36.28

Table (2): Abundance of fouling assemblages per 100 cm^2 on test panels during different four seasons of exposure periods in the Bitter lakes and Lake Timsah.

Species	Autumn 2002	Winter 2003	Spring	Summer
Algae :				
- *Ulva lactuca* C.Ag.	xxx	xxx	xx	xx
- *Cladophora prolifera* (L.) Kutz.	x	x	xxx	xx
- *Enteromorpha prolifera* (Mull.) J.Ag.	x	x	xx	x
- *Enteromorpha linza* (L.) J.Ag.	x	-	x	xxx
- *Chaetomorpha aurea* (Dillywn) Kutz.	-	-	+	x
- *Jania rubens* (Linnaeus) Lamouroux	-	-	xx	x
- *Ceramium rubrum* (Huds.) C.Ag.	xx	xx	x	xx
Hydroids :				
- *Obelia geniculata* L.	xx	-	x	x
- *Bougainvillia racemosa* V. Ben.	xx	-	-	xx
- *Eudendrium rameum* Pall.	-	-	x	x
Bryozoa :				
- *Bugula neritina* (Linne)	x	-	x	-
- *Bugula turbinata* Alder	x	x	-	-
- *Scrupocellaria scruposa* (Linne)	-	-	xx	-
- *Bowerbankia imbricata* (Adams)	xx	-	-	x
- *Membranipora crustulenta* Linnaeus	x	-	xx	x
Polychaeta :				
- *Hydroides elegans* (Haswell)	450	500	1000	340
- *Serpula vermicularis* Linne	37	50	63	0
- *Pomatoleios kraussii* (Baired)	22	25	350	70
- *Hydroides dirampha* (Morch)	40	45	50	425
- *Hydroides lunilifera* (de Rioja)	8	-	11	73
- *Dasychone lacullana* (Della Chiajia)	130	350	225	19
- *Sabella pavonina* Savgny	7	9	8	384
- *Spirobranchus tetraceros* Schmarda	15	35	75	20
- *Perinereis nuntia floridana* (Ehlers)	-	4	-	100 5

Cirripedia :				
- *Balanus amphitrite* Broch.	110	200	38	
- *Balanus eburneus* Gould	10	100	26	150
				15
Amphipoda :				
- *Elasmopus rapax* Costa	13	34	15	
- *Elasmopus pectenicrus* (Bate) Walker	16	22	18	65
- *Erichthonius brasilensis* Dana	30	46	32	88
- *Melita fresnellii* (Audin)	9	5	10	45
- *Corophium sextoni* (Crawford)	4	8	5	17
- *Tanis cavolnii* Mile-Edward	3	3	6	11
				9
Isopoda :				
- *Sphaeroma serratum* Fabricius	28	35	60	
- *Sphaeroma walkeri* Stebbing	36	50	40	69
- *Cymodoce truncata* Leach	3	6	10	55
- *Cirolana bovina* Barnard	70	85	110	35
				125
Decapoda :				
- *Carcinus maenas* Linnaeus	-	2	-	3
- *Liocarcinus corrugata* (Pinnant)	2	-	1	2

xxx Abundant : up to 50 % ; xx Common : 20 to 49 % ; x Present : 10 to 19 %
+ Rare : less than 9 % ; - Absent : 0 %

Table (3): Seasonal changes of fouling biomasses (gms/100 cm^2) accumulated on test panels at different stations in the investigated area.

Seasons / Stations	Autumn (2002) (Sep.-Nov.)	Winter (2003) (Dec.-Feb.)	Spring (Mar.-May)	Summer (Jun.-Aug.)
	Total biomass (gm. 10^{-2} cm^{-2})	Total biomass (gm. 10^{-2} cm^{-2})	Total biomass (gm. 10^{-2} cm^{-2})	Total biomass (gm. 10^{-2} cm^{-2})
I	35	24	32	43
II	38	26	35	50
III	42	29	38	51
IV	46	31	42	55
V	52	35	46	58
VI	56	37	50	63
VII	63	44	56	70
VIII	60	42	53	67
Average	49	33.5	44	57.1

Seven species of sedentary polychaeta were dominant settlers on the buoys reached 70 % of the total fouling namely, *Hydroides elegans*, *Serpula vermicularis*, *Pomatoleios kraussii*, *Hydroides dirampha*, *Dasychone lacullana*, *Sabella pavonina* and *Spirobranchus tetraceros*.

Balanus amphitrite followed by *B. eburneus* in its settling but Decapoda was found in small numbers.

2.3) Spring: (water temperature, 19-22 ^oC).

The animal fouling organisms increased progressively with the approach of spring, when the water temperature increased from 19 ^oC to 22 ^oC during this season.

Barnacles were few in number with the comparison of other seasons (not more than 38 and 26 specimens of *Balanus amphitrite* and *B. eburneus*). Amphipoda and Isopoda was increased to 86 and 220 individuals/100cm^2/panel, on average during spring season. The increasing of the latter was due to the high record number of *Cirolana bovina* (110 individuals) followed by 60 and 40 individuals of *Sphaeroma serratum* and *S. walkeri*, Table (2). The total wet weight reached 44 gm/100 cm^2/panel in average during spring months (March, April and May), Table (3).

The serpulid number was markedly high that recorded 1782 worms in average per panel, (Table 6 & Fig. 3). The flourishing of *Hydroides elegans* and *Pomatoleios kraussii* overcrowded all the panel during this season was observed, which recorded 1000 and 350 worms in average, respectively.

2.4) Summer: (water temperature, 29-32 ^{o}C)

Algae, Hydroids, Barnacles, Polychaeta, Amphipoda, Isopoda and Decapoda dominated the fouling communities attached to the exposed test panel.

Algae, Hydroids, Polychaeta, Amphipoda and Isopoda prevailing including extensive growth. Algae; *Ulva lactuca*, *Cladophora prolifera*, *Enteromorpha prolifera*, *E. linza*, *Chaetomorpha aurea*, *Jania rubens* and *Ceramium rubrum*, Hydroids; *Obelia geniculata*, *Bougainvillia racemosa* and *Eudendrium rameum*, Polychaeta; *Hydroides elegans* reached a large number of the test panel/month (3400 worms), while, *Pomatoleios kraussii* reached 425 worms followed by *Dasychone lacullana* which reached 384 worms, Table (2). The maximum density of barnacles was observed during this season. Two layers of these cirripedia (*Balanus amphitrite* and *B. eburneus*) covered the panels, the uppermost being the smallest.

Amphipoda reached to its maximum peak during this season, where the amphipod tubes increasing that overcrowded the test panel in 235 tubes. Similarly, Isopoda spread on the test panel surface on less than 55% that returned for increasing from 176 tubes (winter), 220 tubes (spring) and 284 tubes (summer), represented by 4 species, *Sphaeroma serratum*, *S. walkeri*, *Cymodoce truncata* and *Cirolana bovina.*

Summer seemed to be the season for the flourishing of Isopoda that jumped to about 284 individuals/100 cm^2/panel in average. The heavily number due to the high number record of *Cirolana bovina* (125 individuals), followed by 69 and 55 individuals of *Sphaeroma serratum* and *S. walkeri*, respectively. The fouling biomass accumulated in the test panel at station VII recorded 70 gms/panel/100cm^2 (Table, 3) and also overcrowded of the bulk community of fouling during summer especially at the same station that reached 850 individuals/100cm^2/panel, (Table 5 & Fig. 2).

During this season, the test panels heaviely carried eleven species of Polychaeta that counted 4496 worms/100 cm^2/panel during summer, (Table 6 & Fig. 3). On the other hand, flourishing of the appearance of *Ascidia melanostoma* (black solitary) during this season that counted 4 individuals.

3) Species composition and settlement of fouling groups on exposed test panels and buoys:

A total 114 species of fouling assemblages were recorded on the exposed test panels and buoys in the investigation period extended from autumn 2002 to summer 2003 in Bitter lakes and Lake Timsah, Table (4). These species belonged to 9 main groups namely, Algae, Sponges, Hydroids, Bryozoa, Polychaeta, Barnacles, Amphipoda, Isopoda, Decapoda, in addition to Mollusca and Ascidians.

3.1) Algae:

Several algal types (Green, Brown and Red) are present in the investigated area. However, the most prevailing kinds on the submerged test panels were *Ulva lactuca*, *Enteromorpha prolifera*, *E. linza*, *Cladophora prolifera*, *Chaetomorpha aurea* of green algae and *Jania rubens* and *Ceramium rubrum* of red algae.

The green algae are the most common and appeared throughout the different species in the study area. In general, the plant growths predominated only when the animal fouling was relatively scarce when it was cold and in the region south to the Bitter lakes. *Ulva* blades were numerous and about 21 cm long at the north of Timsah Lake, 10 cm long at station V of the Bitter lakes of the exposed test panels during summer, while settlement of *Cladophora*, *Enteromorpha* and *Chaetomorpha* as well as the brown and red algae takes place in winter at the different stations of the Bitter lakes and Lake Timsah. *Ceramium rubrum* and *Gelidium latifolium*, the previous only two red algal kinds, flourishes at station V during summer (July) constituted 80% of the bulk community of algal fouling on the buoy, while, *Hypnea cornuta* represented the common one.

3.2) Porifera (sponges):

Calcareous sponge named, *Leucosolenia* sp. represented by a few colonies that found on piers at station V during winter particularly at February. No sponges encountered on the test panels.

3.3) Hydroids:

The hydroids colonies belong to 3 species namely; *Obelia geniculata*, *Bougainvillia racemosa* and *Eudendrium rameum*.

A large number of polyps, mature and about 11cm long exclusively dominated the station VI of Lake Timsah particularly *Bougainvillia ramosa* (winter), *Obelia geniculata* (spring). The previous two species were recorded during autumn in the same station. Settlement of *Obelia* and *Bougainvillia* which comes next to *Tubularia larynx* is more severe at station V of Bitter lakes and station VI and VII of Lake Timsah than in other stations. The other hydroids lead by *Eudendrium rameum* whose colonies crowded at stations III and VIII during summer and autumn respectively.

3.4) Polychaeta:

Both sedentary and errantic forms that predominated among fouling growths represented Polychaeta. The sedentarians were represented by different 14 species namely, *Hydroides elegans*, *H. dirampha*, *H. lunilifera*, *vermioliopsis infundibulum*, *Serpula vermicularis*, *Spiroribis borealis*, *Pomatoleios kraussii*, *Dasychone lacullana*, *Sabella pavonina and Spirobranchus tetraceros*, *Chaetozone setosa*, *Cirratulus cirratus*, *Polydora ciliata* and a new record species *prinospio* sp., Table (4). Among the errantians met with in the fouling collections are: *perinereis cultilifera floridana*, *Syllis zebra* and *S. variegata.*

On the buoys, the number of species of errantia forms increased than of all panels investigated containing *Perinereis nuntia brevicirris*, *P. n. heterodonta*, *Lumbriconereis funchalenesis*, *Ceratonereis costae*, *Lepidontes spuamatus*, *Syllis variegata*, *S. zebra*, *Leonnates decipiens* and *Eunice tubifex.*

All the investigated panels were collecting tube worms varying from about 10 worms for panels of station I to over 12,000 worms per panel at station V during June, July and August. Serpulids are abundant in Lake Timsah particularly at station VI, but the other two stations VII and VIII, respectively appeared during the majority of the year during the different seasons of the lake.

Serpula settled with *Hydroides* on many panels and few *Pomatoleios* worms as well as of *Spirorbis* settled at stations IV and V of the Bitter lakes, respectively. *Pomatoleios* was high encountered in Timsah Lake particularly at station VII.

3.5) Bryozoa:

Settlement of the encrusting species of Bryozoa was more outstanding at stations II and III during winter. Meanwhile; at stations II, VII and VIII of Timsah Lake respectively during spring and station II and VII of the lake during autumn and finally, station III during summer.

The principal bryozoan species in the Suez Canal was *Bugula neritina* followed by the appearence of *B. turbinate*. On the test panels, the other forms appeared occasionally in varying quantities. These forms are, *Scrupocellaria scruposa*, *Membranipora* *crustulenta*, *Scruparia chelata*, *Bowerbankia imbricata* and *Schizoporella errata*. Season of settlement of both species of *Bugula* was longer and their colonies of *Bugula turbinate* were also markedly more abundant at station I and *B. stolonifera* at station VII of Lake Timsah during winter. Both the two previous species reappeared again at station II during spring.

The colonies of *Scrupocellaria scruposa* and *Membranipora crustulenta* of encrusting bryozoa constituted about 30% of the fouling at station II during spring (March) and 45% of *Bowerbankia imbricata Membranipora crustulenta* at stations II and III of Bitter lakes respectively during winter (December). *Schizoporella errata* associated with other mollusca such as *Patella caerulea*, *Brachidontes variabilis* and *Modiolus auriculatus* were found in samples scraped from the pier most of the year at station V.

3.6) Crustacea:

Different 4 groups of crustacea were recorded, subclass Cirripedia (a corn barnacles), order Amphipoda, order Isopoda and order Decapoda.

3.6.1) Cirripedia:

The most common barnacle in the Suez Canal is *Balanus amphitrite* var. *denticulata*. This species exceeded in numbers per test panels per 100cm^2 encountered 200 individuals, in addition to 100 individuals of *Balanus eburneus* during winter and the low number of the first species was recorded during spring encountered 38 individuals and 10 individuals only at autumn season of the second species (*B. eburneus*). *B. amphitrite* was still the leading barnacle of this class that flourishing during winter and summer and flactuated in its density on the test panels from one station to the other. On the other hand, *B. amphitrite* outnumbered *B. eburneus* at stations IV, V of the Bitter lakes respectively and thier both largely settled from December, January and February.

3.6.2) Amphipoda

There are 12 species of Amphipoda grow abundantly in Ismailia, particularly in Lake Timsah and in some other stations of Bitter lakes. Tubes formed by the amphipods *Elasmopus rapax*, *E. pectenicrus*, *Erichthonius brasilienesis*, *Melita fresnellii* and *Corophium* sp. and by other frequently encrusted heavily panels immersed in the majority of the canal during winter and the highest number during summer. Their increase was observed to occur side by side with that of barnacles.

3.6.3) Isopoda:

Many Isopods were found inhabiting dead barnacles settling at station VI during spring (March). Disappearence of Isopoda at station V in July during summer, while this class increased at station VI during winter. The collected and identified isopods are *Sphaeroma serratum, S. walkeri, Cymodoce truncata* and *Cirolana bovina*. The total number of Isopoda ranged from 137 to 248 individuals /100cm^2/panel/month on the exposed test panel during autumn 2002 and summer 2003 respectively and this number increased after long duration of immersion (3 successive months) during summer.

3.6.4) Decapoda:

Two species of Decapoda, *Carcinus maenas* and *Liocarcinus corrugata* settled on the exposed test panels represented a very few numbers during spring (1 individual) of *L. corrugata* and absent during winter. While the first species *C. maenas* present during winter and summer but absent during spring and autumn. This number increased with the long term exposure panels particularly during July (summer) that recorded 6 individuals/100cm^2/panels with different sizes.

3.7) Mollusca:

There is no settling of Mollusca (Gastropoda & Bivalvia) on the submerged test panels. Several colonies of the bivalves, *Brachidontes variabilis* and *Modiolus auriculatus* grow vigorously on the shores of the Bitter lakes stations as well as on the buoys of Lake Timsah.

Heaviely increasing number of Mollusca appeared on the buoys, rocks and stones of inshore and offshore sites. 11 species of Bivalvia and 10 species of

Gastropoda were recorded in the investigated area. Both *Brachidontes variabilis* and *Modiolus auriculatus* are the dominant species at all the different stations.

Planaxis sulcatus, *Clypeomorus bifasciatus* and *Cerithium vulgatum* settled and enormously appeared at station IV of the Bitter lakes. Station V is the richest site with gastropod limpet of *Patella caerulea* associated with *Fusus leptorhynchus, F. polygonoides, Cerithium vulgatum* and *Trochus maculates.*

4) Planktonic larvae of fouling organisms:

4.1) Gastropod and bivalves larvae:

The bivalves and gastropod veliger larvae were the major components of the plankton samples of the buoys throughout the whole investigation period during summer and less in winter, but they contained considerable quantities during spring. *Bugula* larvae were also encountered. Mytilidae were the majority forms among the larvae of bivalves that dominated the plankton samples; reaching more than 80 veligers per subsample.

4.2) Polychaete larvae:

The production of these larvae was continued throughout the year. Plankton of Bitter lakes stations particularly kabret plankton was rich of polychaete larvae. *Hydroides* larvae were almost rare during summer but those of *Polydora* and *Lepidonotus* were prevailing.

4.3) Cirriped larvae:

The cirriped nauplii appeared among all the year round the Suez Canal especially in the investigation area. The plankton samples of the cirriped larvae would be expected from the numbers of adults found on the test panels. Barnacle nauplii were also numerous during winter. On the other hand, Buoys were surmounted with foulers, mostly barnacles, bivalves and ascidians.

4.4) Decapod larvae:

The decapod larvae occurred in very low number with the appearance at the different 3 stations of Timsah Lake and station IV of Bitter lakes during summer.

5) Long term exposure panels:

The records show differences between the amounts of fouling on a panel exposed for along period and those on the panels exposed for the same period but instalments. For instance, a panel immersed for three months (January, February and March 2002) gained 107.49 gm fouling at station III during spring. The main settlers are the great variety of polychaetes (*Hydroides elegans* mixed with *Dasychone lacullana* and a few number of *Serpula vermicularis*), barnacles (*Balanus amphitrite*) and two species of red algae, *Ceramium rubrum* and *Gelidium crinale*). In another period (May, June and July) the long term panels received half of the weight of fouling in comparison with the majority immersion during the same period.

6) Statisitical parameters of fouling community:

The obtained data showed that the winter season (December-February) recorded the highest species diversity and evenness (2.19 & 0.72) respectively and the summer season (June-August) recorded the lowest species diversity and evenness (1.48 & 0.49) respectively, Table (8). The diversity was generally lowest in samples with faunal densities and tends to decrease, when the community becomes numerically dominated by one or few species. Moreover, the species diversity and evenness among the fouling assemblages in the Bitter lakes and Timsah Lake could be arranged in the following sequence, winter > autumn > spring > summer of the season levels, while among main groups were arranged as follow Polychaeta > Isopoda > Amphipoda > Cirripedia > Decapoda.

Table (4): The following list of the species composition of macrofouling organisms recorded on the submerged surface in the Bitter lakes and Lake Timsah.

Group	**Group**
Algae : a) Green algae - *Ulva lactuca* C. Ag. - *Cladophora prolifera* (Linnaeus) Kutzing - *Enteromorpha prolifera* (Mull.) J. Ag. - *Enteromorpha linza* (Linnaeus) Greville - *Chaetomorpha aerea* (Dillywn) Kutz. - *Caulerpa racemosa* (Forssk) - *Polysiphonia* sp. - *Halimeda tuna* (Ellis&Solander) Lamouroux b) Red algae - *Jania rubens* (Linnaeus) Lamouroux - *Laurencia obtusa* (Hudson) Lamouroux - *Hypnea cornuta* (Kutzing) J. Agardh - *Ceramium rubrum* (Huds.) C. Ag. -*Gelidium latifolium* (Greville) Bornet &Thuret - *Gracilaria follifera* (Forsskal) Borgesen c) Brown algae - *Cystoseria barbata* (Good.&Wood.) C. Ag. - *Saragassum vulgare* C. Agardh - *Padina pavonia* (Linnaeus) Thivy **Sponges :** - *Leucosolenia* sp. **Hydroids :** - *Obelia geniculata* L. - *Bougainvillia racemosa* V. Ben. - *Eudendrium rameum* Pall. - *Plumularia halecioides* Linnaeus - *Tubularia larynx* Ell. **Bryozoa :** a) Erect bryozoans - *Bugula neritina* (Linne) - *Bugula turbinata* Alder - *Bugula stolonifera* Ryland - *Scruparia chelata* (Linne) - *Schizoporella errata* Waters b) Encrusting bryzoans - *Scrupocellaria scruposa* (Linne) - *Bowerbankia imbricata* (Adams) - *Membranipora crustulenta* Linnaeus	**Crustacea :** a) Cirripedia - *Balanus amphitrite* var. *denticulate* Broch - *Balanus eburneus* Gould b) Amphipoda - *Elasmopus rapax* Costa - *Elasmopus pectenicrus* (Bate) Walker - *Melita fresnellii* (Audin) - *Erichthonius brasilienesis* Dana - *Stenothoe gallenesis* Walker - *Podoceros variegatus* Leach - *Corophium acutum* Chevreux - *Corophium sextoni* (Crawford) - *Corophium volutator* (Pallas) - *Corophium bidentatum* Mona & Shoukr - *Tanis cavolinii* Milne-Edwards - *Caprella equilibra* Say c) Isopoda - *Sphaeroma serratum* Fabricius - *Sphaeroma walkeri* Stebbing - *Cymodoce truncata* Leach - *Cirolana bovina* Barnard - *Paradella heptaphymata* (Shoukr *et al*.) - *Podoceros variegatus* Leach - *Dynamene edwardsi* (Lucos) a) Decapoda - *Carcinus maenas* (Linnaeus) - *Liocarcinus corrugata* (Pinnant) - *Pilumnus maenas* - *Maja squinado* (Herbst) **Polychaeta :** a) Sedentary forms - *Hydroides elegans* (Haswell) - *Hydroides dirampha* (Morch) - *Hydroides lunilifera* (de Rioja) - *Vermiliopsis infundibulum* (Philippii) - *Serpula vermicularis* Linne - *Spiroribis borealis* Daudin - *Pomatoleios kraussii* (Baired) - *Dasychone lacullana* (Della Chiajia) - *Sabella pavonina* Savgny - *Spirobranchus tetraceros* Schmarda - *Chaetozone setosa* (Malmagren) - *Cirratulus cirratus* (O.F. Muller)

Group	Group
- *Polydora ciliata* (Johnston) - *Prinospio* sp. b) Errantia forms - *Perinereis nuntia brevicirris* (Grube) - *Perinereis nuntia heterodonta* (Gravier) - *Perinereis cultilifera floridana* (Ehlers) - *Lumbriconereis funchalensis* (Kimberg) - *Nereis (Ceratonereis) costae* (Malmgren) - *Lepidonotes squamatus* (Linnaeus) - *Syllis* (*Typosyllis*) *variegata* (Grube) - *Syllis* (*Trypanosyllis*) *zebra* (Grube) - *Leonnates decipiens* (Fauvel) - *Eunice tubifex* (Crossland) **Mollusca :** a) Bivalvia - *Brachidontes variabilis* (Krauss) - *Modiolus auriculatus* (Krauss) - *Barbatus barbatus* (Linnaeus) - *Pinctada radiata* (Leach) - *Cardium auricula* Forskal - *Gafrarium pectinatum* (Linnaeus) - *Plicatula plicata* (Linnaeus) - *Spondylus marisrubri* Roding - *Tellinella staurella* (Lamarck) - *Tapes sulcarius* (Lamarck) - *Pitar hebraea* (Lamarck)	b) Gastropoda - *Patella caerulea* (Linnaeus) - *Planaxis sulcatus* (Born) - *Trochus maculatus* Linnaeus - *Pirenella conica* (Linnaeus) - *Nassarius concinnus* (Powys) - *Murex tribulus* Linnaeus -*Fusus leptorhynchus* (Tapparone-Canefri) - *Fusus polygonoides* Lamarck - *Clypeomorus bifasciatus* (Sowerby) - *Cerithium vulgatum* (Brug.) **Ascidians :** - *Styela plicata* (Lesueur) - *Styela partita* (Stimpson) - *Morchelium argus* (Milne-Edwards) - *Microcosmus vulgaris* Coq. - *Microcosmus sulcata* Coq. - *Ascidia aspersa* (Muller) - *Ascidia melanostoma* - *Ascidia mentula* (Muller) - *Botrylloides leechii* (Savigny) - *Botryllus schlosseri* (Pallas) -*Ciona intestinalis* (Linnaeus) **Echinodermata :** - *Holothuria* sp. - *Ophiothrix fragilis* Abild

Table (5): Total number of organisms of fouling accumulated during each season at the different stations of the Bitter lakes and Timsah Lake.

Season / Stations	Autumn (2002)	Winter (2003)	Spring	Summer	Average
I	80	140	160	440	820
II	90	155	190	550	985
III	100	180	215	565	1060
IV	120	194	250	620	1184
V	133	215	288	650	1286
VI	160	220	300	740	1420
VII	190	270	420	850	1730
VIII	170	240	330	770	1510
Total	1043	1614	2153	5185	9995

Table (6): Abundance of the fouling assemblages settled on the submerged test panels per 100 cm^2 at the different investigated seasons in the Bitter lakes and Lake Timsah.

Season / Group	Autumn (2002)	Winter (2003)	Spring	Summer	Total	%
1) Hydroids	xx	-	x	xx		
2) Bryozoa	xx	x	xx	x		
3) Polychaeta	709	1018	1782	4496	8005	80.1 0
4) Barnacles	120	300	64	165	649	6.49
5) Amphipoda	75	118	86	235	514	5.14
6) Isopoda	137	176	220	284	817	8.17
7) Decapoda	2	2	1	5	10	0.10
Total	1043	1614	2153	5185	9995	100

Table (7): Total abundance of the fouling groups settled on the submerged test panels per 100 cm^2 at the different investigated seasons in the Bitter lakes and Timsah Lake.

Group	Bitter lakes	**Timsah lake**	**Total**
1) Hydroids	x	xx	
2) Bryozoa	xx	x	
3) Polychaeta	4587	3418	8005
4) Barnacles	270	379	649
5) Amphipoda	121	393	514
6) Isopoda	351	466	817
7) Decapoda	6	4	10
Total	5335	4660	9995

Table (8): Determination of species diversity (H^-) and species evenness (J^-) of the main fouling groups settled on the submerged test panels during the different seasons in the Bitter lakes and Lake Timsah compared with the surrounding region of the Suez Bay (2002).

Group / Season	**Winter**		**spring**		**Summer**		**autumn**	
	H^-	J^-	H^-	J^-	H^-	J^-	H^-	J^-
	2002 present study	2002 present study	2002 present study	2002 present study	2002 present study	2002 present study	2002 present study	2002 present study
Polychaeta	1.06 1.09	0.66 0.52	0.01 1.24	0.63 0.59	0.93 0.92	0.58 0.42	0.89 0.35	0.55 0.17
Barnacles	0.38 0.43	0.55 0.62	0.35 0.12	0.50 0.17	0.36 0.12	0.50 0.16	0.46 0.28	0.66 0.40
Amphipoda	0.47 0.30	0.34 0.17	0.52 0.20	0.32 0.11	0.54 0.21	0.34 0.12	0.54 0.25	0.34 0.14
Isopoda	0.10 0.36	0.14 0.26	0.07 0.35	0.11 0.25	0.08 0.23	0.12 0.16	0.09 0.41	0.12 0.29
Decapoda	- 0.008	- 0.01	- 0.004	- 0.005	0.03 0.01	0.01 0.01	0.08 .012	0.11 0.02

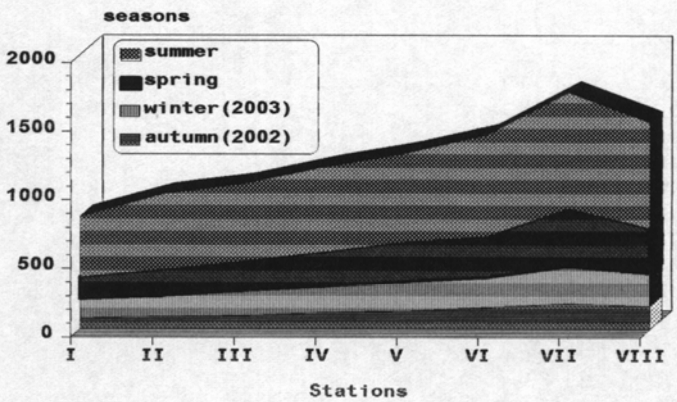

Fig. (2): Total number of fouling organisms accumulated during each season of the different stations at the Bitter lakes and Timsah Lake.

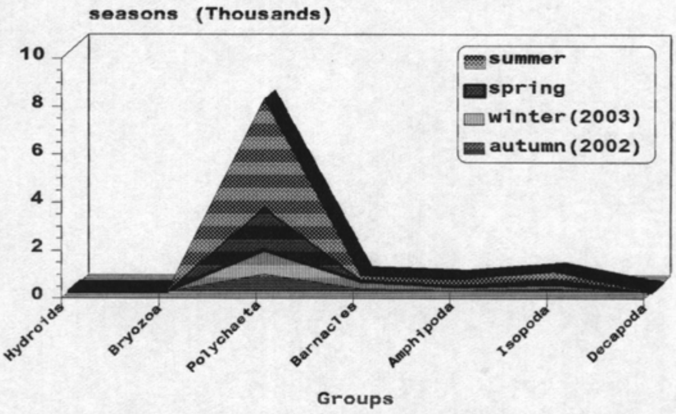

Fig. (3): Abundance of the fouling assemblages settled on the submerged test panels per 100 cm^2 at the different investigated seasons in the Bitter lakes and Timsah Lake.

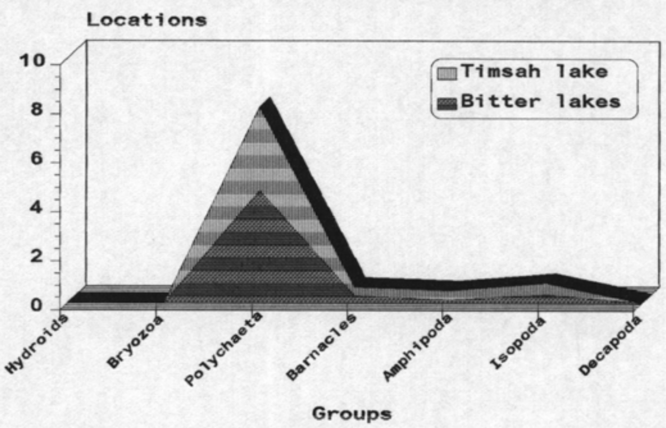

Fig. (4): Total abundance of the fouling groups settled on the submerged test panels per 100 cm^2 at the different investigated seasons in the Bitter lakes and Timsah Lake.

DISCUSSION

The fouling community on the exposed test panels were dominated by barnacles, tube worms, Bryozoa and Amphipoda on which Barnacles community were firstly settled and followed by tube worms, colonial and solitary ascidians and erect Bryozoa. The foulers colonized panels submerged for long durations were considerably more dense than the total foulers collected on short term panels exposed successively during the same period. According to Meadows (1969), the correlation between short and long term fouling biomass is 1:2:3 after one, two and three months exposure, respectively. This condition may apply under the same conditions of growth, life span and density of fouling.

According to Morcos (1960), agitation caused by the strong wind, in the Gulf of Suez by the swift currents of tides which range between 80 and 140 cm in neap and spring tides respectively that obviously result into getting silt as the major settler at the Suez region. In such state, metamorphosing larvae will be prevented from reaching the attachment stages, and if some succeed, further growth will be smothered. The paucity of fouling in the southern region of the Suez Canal was observed by El-Komi (1980) and in the Red Sea, (El-Ghardaqa) by El-Komi (1992b), where barnacles and encrusting bryozoans were attached to exposed test panels besides the present study of the Bitter lakes and Lake Timsah. Such paucity of foulers couled not produce enough larvae to form dense fouling community in the Red Sea region.

The stations of the Bitter lakes subjected to fishing by human activity, agricultural and domestic effluents. In the present study, the major fouling constituents are tube worms, barnacles, Amphipoda, Isopoda besides (*Ulva lactuca*, *Enteromorpha prolifera* and *Cladophora prolifera*) represented green algae and (*Ceramium rubrum* and *Jania rubens*) represented red algae.

The settlement of marine fouling organisms were relatively increased at station VI (Timsah Lake) of low salinity 19.30 ‰ at the same station. This may be due to its water that coming from the Nile through Ismailia canal reduces its salinity as compared to the northern and southern parts of the Suez Canal.

All marine fouling animals grow abundantly particularly in Timsah lake and in some seasons, the exposed sites became exclusively inhabited by a big population of one or two species i.e. *Hydroides elegans* that ranged from 450 to 3400 tubes/100cm^2/month in the investigated area. This serpulid tube worm *H. elegans* represented as bioindicator for a pollution by domestic drainage, agricultural wastes and heavy metals, which affects its survival, since this species is the most abundant polychaete in Egyptian Harbours (Ghobashy, 1984). Udhayakumar & Karande (1996) noticed that, the tube worm *Hydroides elegans* is one of the major sedentary organisms that fouls the ships berthed in confined, polluted waters of wet basin in Bombay Harbour.

Salinity is considered as a characterisitic factor for seawater quality, it is an indicator for wastes and pollutants discharged into the area of investigation according to Table (1), the salinity was ranged from 36.10 %o – 41.80 %o with an average 39.65 %o in Bitter lakes. While, it was ranged from 19.30 %o – 38.0 %o with an average 32.53%o in Timsah Lake. It is clear that low S %o recorded in Timsah Lake reflecting high agricultural activities concerned at Ismailia City with high content of fresh water discharged into the lake. So, the fertility of the Lake increases and consequently phytoplankton and zooplankton flourish (Steemann, 1961). Such plankton-rich water results into fouling flourish not only in Ismailia (Timsah Lake) but also in the whole area bordering it, This also may be due to Ismailia canal, brings some fresh water from river Nile to the Lake which reduces its salinity (Gerges, 1976). On the other hand, the average total settlement number of marine organisms were relatively increased with the stations of less salinity values of the investigated area (VI, VII and VIII) of Timsah Lake. The calcareous forms of fouling namely, encrusting bryozoans, tube worms, barnacles and mollusca were prevailing in the southern part of the Great Bitter lakes particularly at Kabret station of the Suez Canal and declined quantitatively until the Suez Harbour (El-Komi 1980, Ghobashy and El-Komi 1980b), these may be attributed to the high concentration of calcium carbonate owing to raise of salinity. Anwar and Mohamed (1970) reported that the increase in seawater salinity leads to an increase in the concentration of calcium carbonate and this support the settlement of shelled animals.

Settlement of large variety of organisms suggests the occurrence of their larval stages in the water, but failure of the adult to reach maturity in the majority of cases is an evidence of having these larvae come to the area from outside. On the other hand, the presence of invertebrate larvae in the Suez region is also demonstrated in the heavy attack of the local timber by ship worms and other wood borers (Hassan, 1979). According to the shallowness of the canal water many meroplanktonic larvae were frequently recorded in the plankton hauls. The veligers of mollusca were mostly spread to the canal with maximum persistence in summer. The polychaete larvae were also observed in the canal with the high occurrence in summer. The cirriped larvae showed its maximum distribution during winter. Other larvae as decapod and echinoderm were scarcely observed.

Devresoir (station V) is built on the northern entrance of the great Bitter lakes and received a severity of fouling. The ascidians were also dominating particularly the buoys as *Styela plicata*, *S. partite*, *Ascidia aspersa*, *A. melanostoma*, *A. mentula*, *Botrylloides leechii*, *Botryllus schlosseri* and *Ciona intestinalis*, where there is no ascidians on the test panels. The bulk community of the fouling organisms weighed the maximum during summer reached 58 gm/m^2.

Meadows (1969) postulated a correlation between short and long-term fouling biomass that may be apply to poorly fouled areas where attachment, in short periods, may still leave ample space for further attachments. Under the present study, even during the months of relatively poor fouling, panels exposed for long periods carried a large load of fouling than those exposed one month.

Lake Timsah, which lies almost half-way the Suez canal, is highly populated with fouling assemblages than the Bitter lakes consisting of algae, hydroids, tube worms, bryozoans, barnacles, amphipods, molluscs and ascidians, this is may be due to the lake of Timsah subjected to different source of pollution coming from domestic drainage of Ismailia city, agricultural effluents and human activity by fishing and swimming. Tube worms (*Hydroides elegans*), barnacles (*Balanus amphitrite* and *B. eburneus*) and amphipod tubes represented the major fouling constituents. Heaviest settlement occurred from May to August and during this period a panel immersed only for one month was covered with a thick layer of fouling organisms. Fouling was slight in the coldest month (December-February) and these data coincides with (Ghobashy *et al*., 1980).

The continuous reproduction of fouling organisms coincided, in general with the warmer months, when the temperature exceeded above 20 ^{o}C. The fouling biomass accumulation was maximal during June, 1991 yielding 20 gms, Banoub (1960); 38 gms, El-Komi (1991); 45.1 gms/100cm^2, El-Komi (1992); 37 gms/100cm^2 during August in the Suez Bay, Emara (1994); 27.8 gms/100cm^2 during August in the Suez Bay, Emara (2002) and finally increased to 70 gms/m^2 during July in the present study.

The community of fouling is accompained by an increase in diversity, decreased dominance and a more equal distribution of species within the assemblage. However, the obtained data showed that polychaeta recorded the highest species diversity and evenness (1.24 & 0.59) respectively during spring and the decapoda recorded the lowest values of both parameters (0.0036 & 0.005) during spring also. This may be due to the greater variation among faunal dominance. The diversity was generally lowest in samples with faunal densities and tends to decrease, when the community becomes numerically dominated by one or few species. Moreover, the species diversity and evenness among the fouling assemblages in the Bitter lakes and Timsah Lake could be arranged in the following sequence, winter > autumn > spring > summer of the season levels, while among main groups were arranged as follow Polychaeta > Isopoda > Amphipoda > Cirripedia > Decapoda. Silt covers the objects submerged in Suez-Kabret (the southernmost part of the Suez Canal) and prevents attachment of organisms and hence this part is the poorest fouled region. While, Timsah Lake waters is the highly fouled region of the Suez Canal.

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