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FIELD AND LABORATORY STUDIES ON THE ECOLOGY OF MARINE FOULING IN ALEXANDRIA HARBOUR, EGYPT.

MOHAMED M. EL-KOMI.

National Institute of Oceanography and Fisheries, Alexandria, Egypt.

ABSTRACT

The species composition, seasonal abundance and rate of growth of fouling are investigated on submerged test panels in the field (the Eastern Harbour of Alexandria) and under laboratory conditions from October 1990 to November 1991. Attachment of fouling either on short term or long term exposure panels showed pronounced seasonal changes in abundance over the year. The period of abundance and settlement numbers for several species reveal considerable variations during different periods of observation throughout the last 3 decades. The predominant constituents of fouling were principally Bryozoa, calcareous tube worms, barnacles, Ascidians, and Algae. The continuous reproduction of fouling organisms coincided generally with the warmer seasons, when the temperature exceeded 20°C. The large amount of pollutants discharged into the harbour has a significant influence on the survival and movement of the pelagic larvae and also plays an important role on the species composition, abundance and their rate of growth. The growth and biomass differed greatly in the different seasons depending upon temperature, season of immersion and duration of exposure. Under the field and laboratory conditions, the fouling assemblages on the test panels were highly affected. The settlement intensity, species composition and rate of growth decreased obviously or arrested, due to the unfavorable conditions of incubation. The occurrence of fouling assemblages on exposed test panels depending upon the timing of reproduction of populations of different marine organisms may be divided into three periods; a) annual fouling, b) seasonal fouling and c) monthly fouling. The fouling assemblages on exposed test panels were, in general, poor after a one month exposure period, but often became more dense on panels exposed for 3 successive months. The occurrence of planktonic larvae indicates that rate of fouling accumulation and species composition may differ widely.

INTRODUCTION

The previous studies on the marine fouling in the Eastern Harbour of Alexandria have been carried out on the species composition and seasonal variations of fouling developed on test panels for certain exposure periods (Banoub, 1960; Megally, 1970;Ghobashy, 1976; El-Komi, 1991). Data collected in the previous 30 years on the ecology of fouling indicate that rate of fouling accumulation and dominant members differ greatly. The Eastern Harbour is a semi-closed bay located between the longitudes 29° 53′ to 29° 54′ E and latitudes 31° 12′ to 31° 13′ N with an area ca. 2.8 km^2 and average water depth of 6 meters. A great amount of sewage and waste water ca. 35.18 x 10^6 m^3 discharged annually into the harbour this represents about 2.3 times the volume of the harbour water (Dowidar et al., 1987). During the period 1985-1986 the absolute values of surface water temperature and salinity varied between a minimum of 16.9°C, 34.78 ‰ and a maximum of 29.2°C, 39.21 ‰, respectively. The exchange between the eutrophic harbour and the neritic Mediterranean waters takes place through two main entrances. The planktonic and benthic diatoms in relation to the pollution gradient inside the bay have been investigated by Halim et al., (1980), in which the environmental conditions are greatly varied influencing on the primary production.

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

MATERIALS AND METHODS

The species composition, seasonal abundance and rate of growth of fouling were investigated on submerged test panels, 17.5 x 17.5 cms made of polysterene. These panels were fixed in an iron frame of size 80 x 40 cms and placed regularly at the beginning of each month and successively replaced after one and three successive months of exposure periods. The surfaces of the panels were roughened by sandpaper to avoid the effect of texture (Pomerat & Weiss, 1946). The frame was suspended vertically under the jetty of the National Institute of Oceanography and Fisheries at 1.5 m depth below the sea surface from October 1990 to November 1991.

The growth of fouling in field and under laboratory conditions was followed; the panels after one, two weeks or one month immersion in seawater then were transferred to the laboratory. These panels were immeresed in a large aquarium (ca. 45 l) and maintained for 3, 2 weeks and 2 months, respectively. The seawater was changed every two weeks and under aeration using air bubbles pump.

The fouling collected on the exposure panels was identified and counted in living conditions by using a dissecting microscope of field magnification of 20 x and 40 x. The growth of main fouling groups was estimated by measuring the length, or diameter by an ocular micrometer, the number of bifurcation as in **Bugula** (El-Komi, 1980) or the height of the erect forms. The data are expressed as the number of organisms or colonies of **Bugula** or encrusting forms per 100 cm^2 or the relative abundance of algae per panel area.

In addition vertical plankton samples were collected regularly every month at the same time of the panels replacement. They were taken by a plankton net No. 25 (dimension of aperture, 50 um) from 2.5 m depth to the surface twice every period. It was done to follow the seasonal changes in the occurrence of larvae (no. of organisms $/m^3$) which might occur among the zooplankton population in the study area. The abundance of phytoplankton in seawater was also estimated as the number of cells $/m^3$.

RESULTS

Phytoplankton and zooplankton populations

Throughout the sampling periods, seasonal changes in the total constituents of phytoplankton and zooplankton in the water column are shown in Tables 1.a, 1.b. and 1.c. The October, 1991 bloom was comprised predominantly of dinoflagellates, **Prorocentrum** sp. and **Peridinium** sp. 888383 and 84166 ind. $/m^3$, whereas, in May, 1991 predominated by **Prorocentrum** in less frequent numbers (14125-157579 ind. $/m^3$). It was noticed that the diatomeae had relatively low values, ranging from 565 to 85880 cells $/m^3$, that **Bellerochea** sp., **Coscinojiscus** sp., **chaetoceros** sp. and **Stauroneis** sp. are the predominate forms throughout the year. **Chaetoceros** sp. dominated in 1st November, 1990 sample, reaching 84750 cells $/m^3$. But Halim et al. 1980 found that **Chaetoceros socialis** prevailed in December, reaching 7 x 10^6 cells /l. The 1st January and 7th February, 1991 blooms were composed predominantly of diatoms **Bellrochea** sp. and **Thalassiothrix** sp. yielding 141750 and 29380 cells $/m^3$, respectively.

The increase of zooplankton crop coincides with the period of diatom blooms as was found in 1st November 1990 and 1st January, 1991 (Figure 1). An inverse change was observed in 15th July, 1991, the zooplankton population is higher than phytoplankton crop. The planktonic larval compositions of main fouling groups from seawater samples are presented in Figure 2. The number of the planktonic larvae varied considerably at different periods during the year. Trochophore larvae appeared over the year and had relatively high values ranging from 559 to 15594 larvae $/m^3$ in July, 1991. The number of nauplii larvae of barnacles was the largest during the sampling period and occurred

Table 1. a.

Seasonal changes of phytoplankton and zooplankton populations in the Eastern Harbour of Alexandria (No. org. m^3) during Oct. 1990 to Feb. 1991.

Months / Species Day	October, 90 15	November 1	November 15	December 1	December 15	January, 91 1	January, 91 15	February 7	February 15
Diatomeae:									
Navicula spp.	170	-	743	-	254	-	-	-	-
Nitzschia spp.	113	565	2202	800	508	-	497	-	446
Biddulphia spp.	-	-	-	400	-	20905	5837	4658	-
Diploneis sp.	-	-	514	-	254	-	-	-	-
Pleurosigma spp.	113	-	-	-	254	5085	-	248	-
Thalassiothrix	-	-	1174	-	2188	29380	18080	114885	-
Bellerochea sp.	170	-	-	-	508	141750	503	-	1339
Coscinodiscus spp.	1639	-	13212	9338	5506	3390	7345	6831	967
Chaetoceros sp.	-	84750	-	-	-	6893	-	-	-
Stauroneis sp.	-	565	2936	534	1186	-	-	-	1860
Dinophyceae:									
Prorocentrum spp.	-	-	-	-	-	-	-	-	-
Peridinium spp.	283	-	881	1267	-	4802	-	-	-
Tintinnidae:									
Favella spp.	170	283	-	-	-	4336	170	124	595
Parafavella spp.	-	-	4551	-	1016	27120	-	-	-
Tintinnopsis spp.	-	-	-	-	-	-	-	497	-
Ciliated protozoa	-	-	-	-	-	-	-	-	1339
Foraminifera:									
Globigerina sp.	-	283	-	-	-	-	-	-	-
Rotifera:									
Synochaeta sp.	396	4803	440	-	254	565	678	1242	298
Brachionus spp.	170	1978	-	-	-	283	226	435	-
Trichocerea sp.	-	-	-	-	-	-	-	-	-
Sponges spicules	57	-	220	-	1325	-	-	-	-
Leptomedusae.	-	-	220	-	169	-	113	-	298
Actinotrocha larvae	57	-	294	267	254	-	-	-	-
Nematoda.	170	113	147	267	-	565	170	-	149
Bivalvia larvae	396	170	220	133	508	565	-	-	-
Gastropoda larvae	-	-	-	-	-	-	226		
Polychaeta:									
Trochophore larvae	1808	2147	2422	2935	1355	6893	3277	9315	298
Spionid larvae	678	-	-	667	339	509	1130	745	298
Brachiopoda:									
Evadene sp.	-	-	-	-	-	-	-	-	-
Podon sp.	-	-	-	-	-	-	-	-	-
Copepoda:	848	7458	10643	3468	1525	8927	1695	-	967
Copepoda nauplii	904	11187	8808	2535	2033	3673	1921	994	595
Cirripedia:									
Barnacles nauplii	396	4238	2055	4269	1355	2730	961	1242	149
Cypris larvae	-	-	-	-	-	-	-	-	-
Bryozoa:									
Bugula larvae	113	-	220	-	254	-	-	186	-
Stolonate capsules	-	170	440	-	-	-	-	-	-
Ascidians larvae	-	-	147	-	-	-	113	-	-
Appendicularia:									
Oikopleura spp.	-	226	220	-	-	283	226	-	149
Chaetognatha:									
Segetta sp.	-	113	-	-	-	-		-	

Table 1. b.

Seasonal changes of phytoplankton and zooplankton populations in the Eastern Harbour of Alexandria (No. org. m^3) during Mar. to June 1991.

Months	March			April			May			June		
Species Day	1	7	15	1	7	15	1	7	15	1	7	15
Diatomeae:												
Navicula spp.	-	-	-	170	339	-	-	-	-	-	339	-
Nitzschia spp.	678	356	-	170	-	283	-	-	-	283	-	-
Biddulphia spp.	2033	3855	1017	-	-	-	-	-	-	622	-	-
Diploneis sp.	-	-	-	-	-	-	-	-	-	-	-	-
Pleurosigma spp.	-	-	-	-	791	-	565	-	1017	-	203	-
Thalassiothrix	-	-	2034	-	-	-	-	-	-	-	-	-
Bellerochea sp.	-	6167	-	-	339	-	226	-	-	-	-	-
Coscinodiscus spp.	1694	4329	4181	452	565	2034	-	565	848	-	-	-
Chaetoceros sp.	2541	-	-	1582	-	-	-	-	-	-	-	-
Stauroneis sp.	-	-	-	-	-	-	283	-	1074	-	-	-
Dinophyceae:												
Prorocentrum spp.	-	-	-	-	-	-	-	14125	157579	-	-	-
Peridinium spp.	-	9785	1413	-	-	-	-	-	678	1017	1898	2147
Tintinnidae:												
Favella spp.	1186	-	2034	-	226	-	1017	1469	735	452	271	678
Parafavella spp.	-	-	-	396	-	-	-	226	-	283	-	565
Tintinnopsis spp.	-	-	1130	-	-	-	-	-	-	-	-	-
Ciliated protozoa	-	-	-	-	-	-	-	-	-	-	-	-
Foraminifera:												
Globigerina sp.	-	119	-	-	-	-	-	-	-	-	-	113
Rotifera:												
Synochaeta sp.	254	-	-	-	-	-	-	1469	356	5085	2441	5820
Brachionus spp.	424	-	-	-	-	-	-	339	735	1413	3322	2373
Trichocerea sp.	-	-	-	-	-	-	-	-	170	-	-	-
Sponges spicules	-	-	-	-	57	-	-	-	-	-	-	283
Leptomedusae.	169	178	283	-	-	-	226	-	-	-	203	170
Actinotrocha larvae	-	-	-	-	-	-	-	-	-	-	-	-
Nematoda.	254	-	170	339	113	283	565	226	-	-	136	113
Bivalvia larvae	254	178	-	-	-	-	226	396	226	565	1627	170
Gastropoda larvae	-	119	-	-	57	-	-	-	-	283	814	170
Polychaeta:												
Trochophore larvae	3303	1127	5368	1017	3503	791	1130	4407	4520	5085	7797	3673
Spionid larvae	424	415	1300	396	678	339	226	339	226	1356	136	1356
Brachiopoda:												
Evadene sp.	-	-	-	-	-	170	-	-	226	-	-	-
Podon sp.	-	-	-	-	170	-	-	-	678	-	-	226
Copepoda:	1016	356	565	-	7910	1130	678	1017	1356	1808	339	565
Copepoda nauplii	3812	178	4238	1808	6215	3616	1808	6215	3503	2543	1085	-
Cirripedia:												
Barnacles nauplii	1355	1008	2938	565	-	238	283	678	678	2034	1220	1808
Cypris larvae	-	-	-	-	57	-	-	-	-	-	203	-
Bryozoa:												
Bugula larvae	254	178	113	170	-	113	-	226	-	226	-	339
Stolonate capsules	-	-	-	-	-	-	-	-	170	-	-	-
Ascidians larvae	169	-	-	-	-	-	-	-	170	-	-	-
Appendicularia:												
Oikopleura spp.	254	237	-	-	-	-	283	339	-	-	-	226
Chaetognatha:												
Segetta sp.	-	-	-	-	170	-	-	-	-	-	-	-

Table 1. c.

Seasonal changes of phytoplankton and zooplankton populations in the Eastern Harbour of Alexandria (No. org. m^3) during July to Oct. 1991.

Months	July			August		September			October		
Species Day	1	7	15	1	7	1	7	15	1	7	15
Diatomeae:											
Navicula spp.	509	170	-	-	-	-	-	-	-	-	-
Nitzschia spp.	283	509	-	226	248	339	-	-	-	-	559
Biddulphia spp.	-	-	565	-	-	-	-	-	-	-	-
Diploneis sp.	-	-	-	-	-	-	-	-	-	-	-
Pleurosigma spp.	-	565	-	-	186	-	-	-	-	-	-
Thalassiothrix	-	-	-	-	-	-	-	-	-	-	-
Bellerochea sp.	13560	678	1243	-	-	-	9040	-	-	-	-
Coscinodiscus spp.	904	-	2174	113	2360	5311	8475	565	-	-	-
Chaetoceros sp.	-	-	-	-	-	-	-	-	-	-	-
Stauroneis sp.	1074	678	-	336	3850	42601	23730	-	-	-	-
Dinophyceae:											
Prorocentrum spp.	-	-	-	-	-	-	-	-	888383	-	-
Peridinium spp.	7063	4803	6498	454	-	76219	7063	5537	84166	2857	559
Tintinnidae:											
Favella spp.	452	226	-	226	124	20058	-	-	-	-	1677
Parafavella spp.	678	-	-	-	-	-	-	-	-	-	-
Tintinnopsis spp.	-	-	-	-	-	-	-	-	-	-	-
Ciliated protozoa	-	-	-	-	-	-	-	-	136	-	-
Foraminifera:											
Globigerina sp.	-	-	-	-	-	-	-	-	-	-	-
Rotifera:											
Synochaeta sp.	1978	15764	6724	452	754	509	735	339	136	-	1118
Brachionus spp.	1187	4012	3474	-	-	961	170	-	-	-	-
Trichocerea sp.	226	-	339	-	124	-	-	-	-	-	-
Sponges spicules	-	-	-	170	-	226	170	-	-	-	-
Leptomedusae.	113	170	-	-	248	-	113	57	-	-	-
Actinotrocha larvae	-	-	-	113	124	-	-	-	-	-	-
Nematoda.	-	396	-	678	124	-	170	339	-	-	-
Bivalvia larvae	1130	2712	1187	1243	869	2034	226	565	-	-	124
Gastropoda larvae	113	-	-	226	124	-	-	-	-	-	-
Polychaeta:											
Trochophore larvae	2712	15594	10961	791	2174	3673	3334	848	678	559	745
Spionid larvae	283	2147	283	133	113	226	2034	170	136	186	311
Brachiopoda:											
Evadene sp.	-	-	-	-	-	-	-	-	-	-	-
Podon sp.	-	-	-	-	-	-	-	-	-	-	-
Copepoda:	565	791	226	339	248	961	15255	2373	2983	1428	373
Copepoda nauplii	1978	1808	-	170	435	1808	5029	3051	5153	559	311
Cirripedia:											
Barnacles nauplii	509	1695	283	565	248	339	2769	1243	1831	248	559
Cypris larvae	-	-	-	-	-	-	509	170	-	-	-
Bryozoa:											
Bugula larvae	283	-	-	-	124	-	113	-	136	186	124
Stolonata capsules	-	452	452	339	-	396	2260	113	-	-	-
Ascidians larvae	113	-	-	-	-	-	283	-	-	-	-
Appendicularia:											
Oikopleura spp.	226	283	113	-	124	170	1582	678	203	248	373
Chaetognatha:											
Segetta sp.	-	-	-	-	-	-	113	-	-	-	-

continuously throughout the year ranging from 149 to 4238 larvae /m^3. Larvae of Bugula were recorded during most of the year in little number ranging from 113 to 339 larvae /m^3 particularly in November-December, 1990 and from May to June, 1991. Veliger larvae of Bivalvia predominated in June to August, 1991 in numbers ranging from 124 to 2712 larvae /m^3. Throughout the sampling period larvae of Ascidians were found in the least numbers (113 to 283 larvae /m^3) when composed with other larvae over the sampling periods.

FOULING ASSEMBLAGE AND COMPOSITION

The fouling assemblages on exposed test panels were in general poor after one month of exposure period but it was often more dense on panels exposed for 3 successive months. The fouling colonization on test panels were followed to detect the rate of settlement, rate of growth and abundance season of settlement.

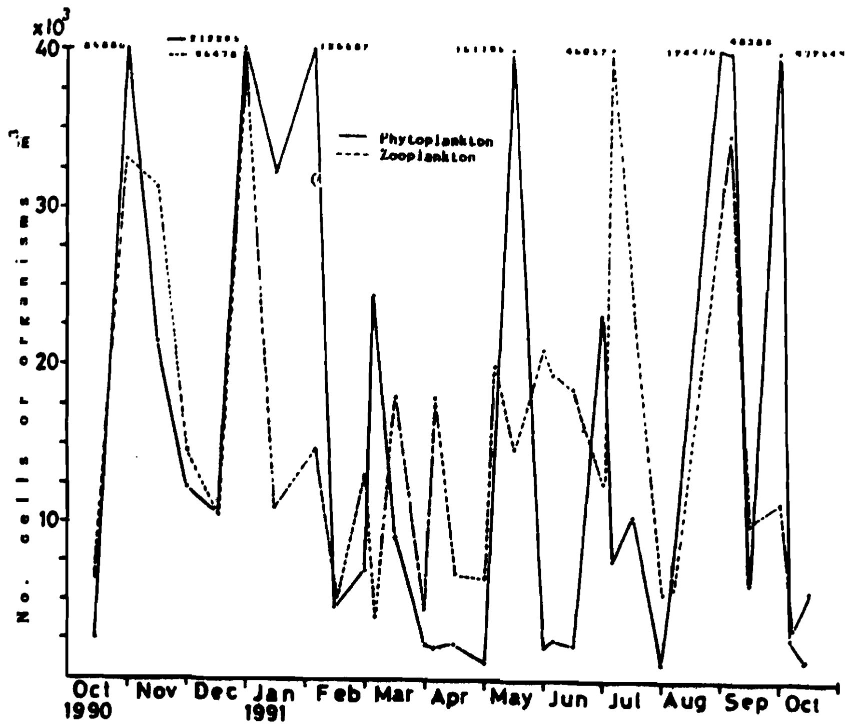

Figure 1- Relationship between the seasonal variation of the total phytoplankton and zooplankton (no. cells or organisms /m^3) recorded in vertical plankton samples at the Eastern Harbour during October 1990 to October 1991.

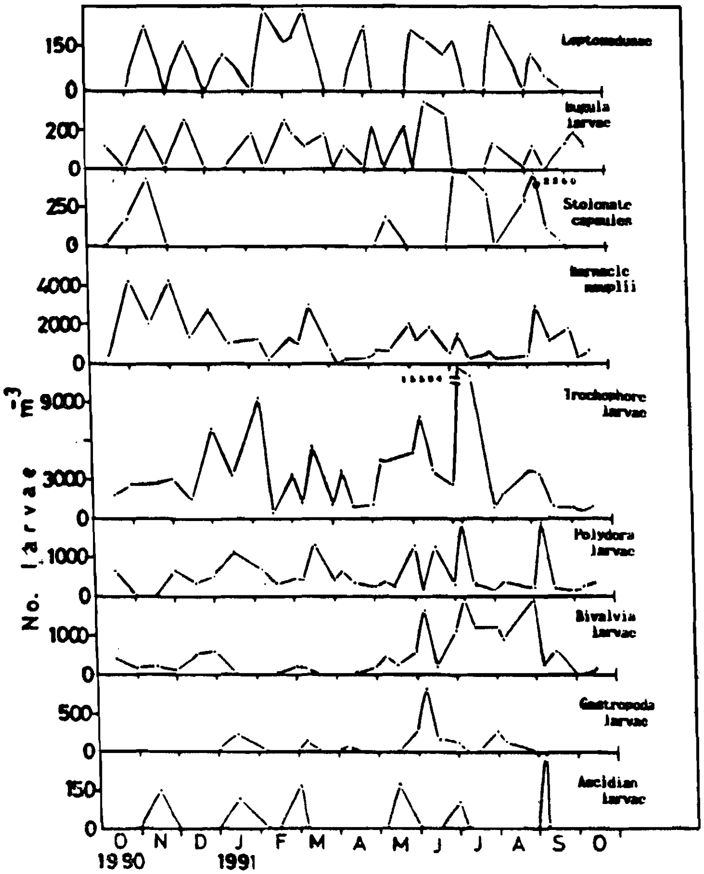

Figure 2- Seasonal changes of the planktonic larvae (no. larvae /m^3) recorded in vertical plankton samples at the Eastern Harbour during October 1990 to October 1991.

SHORT TERM PANELS

FIELD EXPOSURES

The occurrence of fouling assemblages on exposed test panels depending upon the time of reproduction of populations of different marine organisms may be divided into three periods; A) annual fouling, B) seasonal fouling and C) monthly fouling.

A) Annual fouling, is characterized by the appearance of fouling organisms in small or large amounts continuously throughout the year.

1- Bugula neritina (Linne) was the most frequent bryozoan occurring on submerged objects in the Eastern Harbour. It dominated from April to June, 1991 yielded 175 to 311 col. /100 cm^2 (see Table 2 and Figure 3), when the average water temperature and salinity were 24°C and 38.14 ‰ (El-Komi, 1991). During the summer and winter seasons, when water temperature was above 25°C or below 20°C it was represented by a few number of colonies. The rate of growth of B. neritina showed particular differences through out the year as shown in Figure 4. The size achieved 9-10 bifurcations (26-31 mm height) and reached sexual maturity in one month after settlement observed on December, 1990 and January, 1991 panels. The low growth of colonies reached 3-6 bifurcations during the summer and winter seasons.

2- Barnacles, Balanus amphitrite var. denticulata Broch, is the most dominant component of marine fouling in the harbour. It showed great density through most of the year especially in July to October, 1991 ranging from 92 to 605 ind. /100 cm^2, as shown in Table 2 (average water temperature 25.5°C and salinity 37.97 ‰). The settlement rate was less frequent during late fall to spring season (Plate 1). The rate of growth of individuals was relatively high during the period of the maximal attachment (Figure 4). It achieved 8 mm in diameter (rostro-carinal axis) and attained sexual maturity and breed continuously over the year (El-Komi, 1988 and El-Komi & Kajihara, 1991).

3- Calcareous tube worms, Hydroides elegans (Haswell) are numerically the major marine fouling groups in that Harbour reproduced during most of the year (Figure 2 & Plate 1) where in the period from May to July and from September to October, 1991 the serpulid worms had shown marked variations in attachment rate. Hydroides elegans encountered were ranging from 1112 to 3107 tubes /100 cm^2 (average water temperature and salinity were 25.3°C and 38.18 ‰). They settled in low intensity during late fall to early spring in numbers of 8 to 46 tubes /100 cm^2. The maximum sizes of tube worms measured 20 to 25 mm in length in May to July (24°C - 28°C) and low growth rate was observed during winter month (16°C - 22°C) where the tube length reached about 5 mm one month after settling.

4- Amphipod mud building tubes were fouled less densely on short term panels and much more during summer and fall seasons which yielded 105 to 654 mud tubes /100 cm^2. The predominance of amphipod species forming muddy tubes were as follows: Corophium sextomi Crawford and Tanais cavolinii Milne Edward, were more frequent than Erichthonius brasiliensis Dana, Elasmopus pectenicrus (Bate) and Stenothoe gallensis Walker (Table 2).

B) Seasonal fouling, is characterized by the occurrence of fouling organisms in small or large intensity in 1, 2 or/and 3 seasons in the year.

1- Algae, four species of algae are predominant on the test panels in seawater, Ulva lactuca L., Cladophora

Table 2.

Monthly abundance of fouling organisms assemblage on exposed test panels (No. org. 10^{-2} cm^{-2}) in the Eastern Harbour during October 1990 to November 1991.

Species	Oct. 1990	Nov.	Dec.	Jan. 1991	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Algae:														
Ulva lactuca	-	+	xx	+	xx	xx	xx	-	xx	-	-	-	-	x
Enteromorpha	+	+	xx	-	xx	xx	-	+	-	-	-	-	-	-
Chaetomorpha	x	-	-	-	+	xx	-	x	-	-	-	-	-	-
Cladophora	-	-	-	+	-	-	+	-	-	xx	xx	xx	-	x
Ectocarpus irregularis	-	xx	xxx	xxx	xx	xxx	xxx	-	-	xx	-	-	-	xx
Hydroids:														
Obelia geniculata	-	-	x	+	-	-	-	-	-	-	-	-	-	xx
Bryozoa:														
Bugula neritina	10	27	4	82	20	59	173	311	255	20	4	2	2	8
B. turbinata	-	-	-	-	-	-	6	-	-	-	-	-	-	-
Zoobotryon verticillatum	-	-	-	-	-	-	-	-	-	-	-	2	-	-
Polychaeta:														
Hydroides elegans	1177	1046	46	28	8	22	-	1243	2681	1112	157	1570	3107	474
Spirorbis sp.	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Pomatocerus triqueter	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Polydora ciliata	299	137	13	-	2	-	-	-	-	392	141	157	271	157
Sabella sp.	-	-	-	-	-	-	-	-	-	-	6	-	-	-
Nereis diversicolor	-	-	2	-	-	-	-	-	-	-	-	-	-	
Cirripedia:														
Balanus amphitrite	227	569	69	17	93	23	25	16	21	92	167	605	128	60
B. eburneus	4	222	-	-	-	6	5	85	6	4	54	85	16	5
B. perforatus	-	-	-	-	-	29	7	-	-	3	-	-	-	-
B. trigonus	-	-	-	-	-	-	3	-	-	-	-	-	-	-
Amphipoda:														
Mud tubes	23	281	114	27	8	65	255	169	654	147	105	392	190	74
Corophium sextoni	8	27	9	15	2	-	49	-	-	19	14	-	39	31
Erichthonius brasiliensis	-	-	-	-	-	-	10	8	28	13	-	-	9	-
Stenothoe gallensis	-	-	-	-	-	-	17	8	-	-	-	-	-	-
Tanais cavolinii	1	-	-	6	1	2	104	26	-	-	5	11	-	
Elasmopus pectenicrus	7	-	-	-	-	-	-	-	105	-	-	72	-	-
Isopoda:														
Sphaeroma walkeri	-	-	-	-	-	-	-	-	10	-	-	-	-	-
Cirolana aegyptiaca	-	-	-	-	-	-	-	-	8	-		6	-	-

Table 2 (Cont.)

Pycnogonida:														
Pycogonum sp.	-	-	-	-	-	-	7	-	-	-	-	-	-	-
Platyhelminthes:														
Stylochus sp.	-	-	-	-	-	-	-	-	-	-	1	-	2	-
Ascidians:														
Ciona intestinalis	-	-	-	-	-	-	-	-	2	-	-	-	-	-
Nematodes:	-	-	13	-	-	-	-	-	-	20	49	-	-	54
Ciliates:														
Vorticella sp.	-	-	x	-	-	-	xxx	-	-	x	-	-	-	-
Weight (gm 10^{-2} cm^{-2})	9.5	6.9	1.6	1.6	2.0	2.0	8.2	20.6	45.1	8.8	5.2	16.7	29.4	6.5

xxx Abundant (up to 50 %), xx Common (20 to 49 %), x Present (10 to 19 %), + Rare (less than 9 %) and - absence.

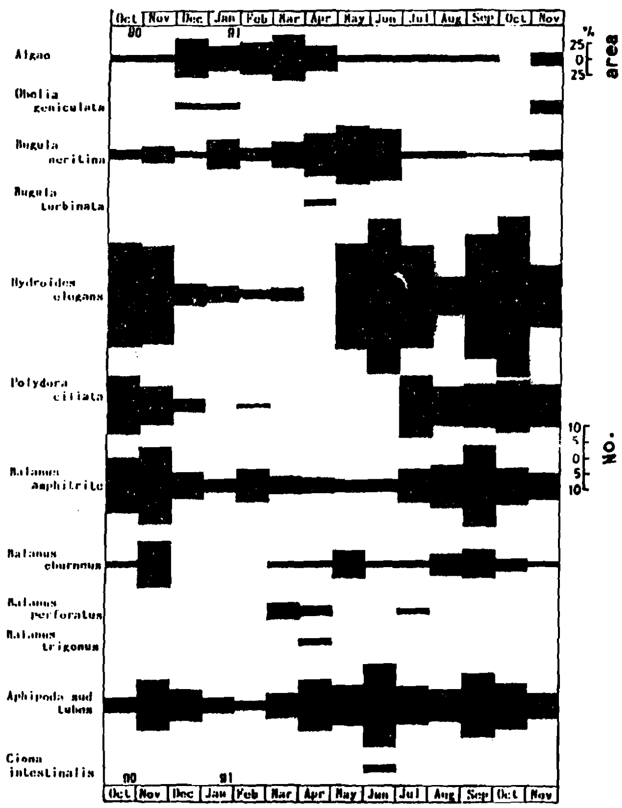

Figure 3- Seasonal variation of settlement of fouling organisms in the Eastern Harbour of Alexandria during October 1990 to November 1991. Ordinates are proportional to the square roots of the settlement per 100 cm^2 /month.

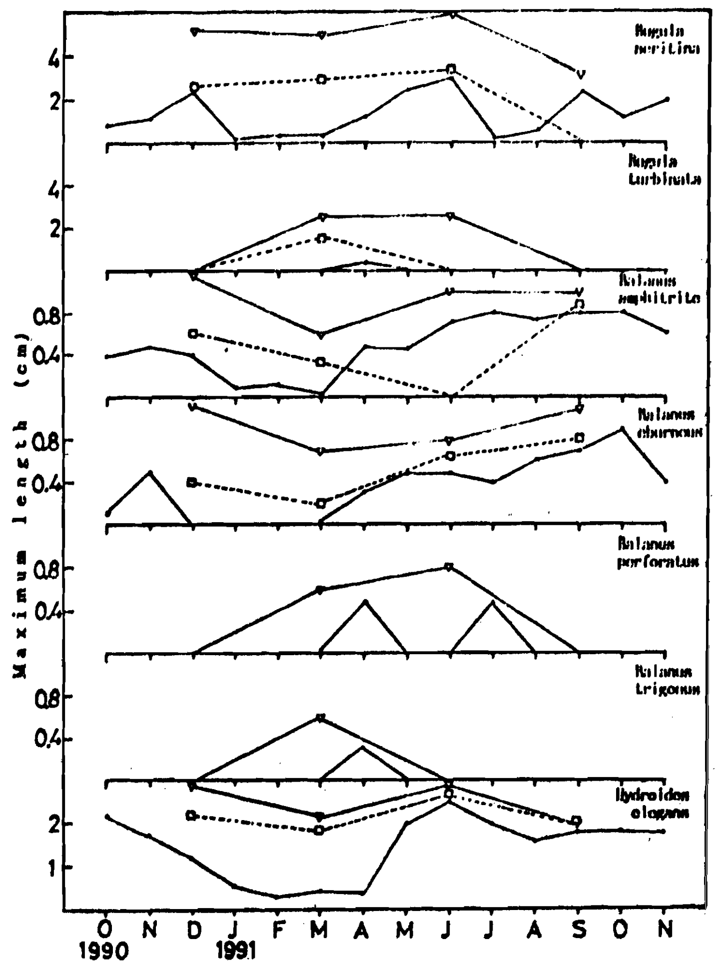

Figure 4- Seasonal changes of the maximum growth of the main fouling groups attained at different exposure periods at the Eastern Harbour.
•—• represents one month exposure in the field,
▼—▼ represents 3 successive months periods exposure in the field and
□---□ represents one month exposure in field and 2 months under laboratory conditions.

prolifera (Roth.) Kutz., Chaetomorpha aerea (Dillwyn) Kutz. and Ectocarpus irregularis Kutz. They are grow during fall, winter and early spring months in relatively high abundance in one month exposure periods as shown in Figure 3. Brown alga, Ectocarpus irregularis occurred in large numbers during December, 1990, January, March and April, 1991. The

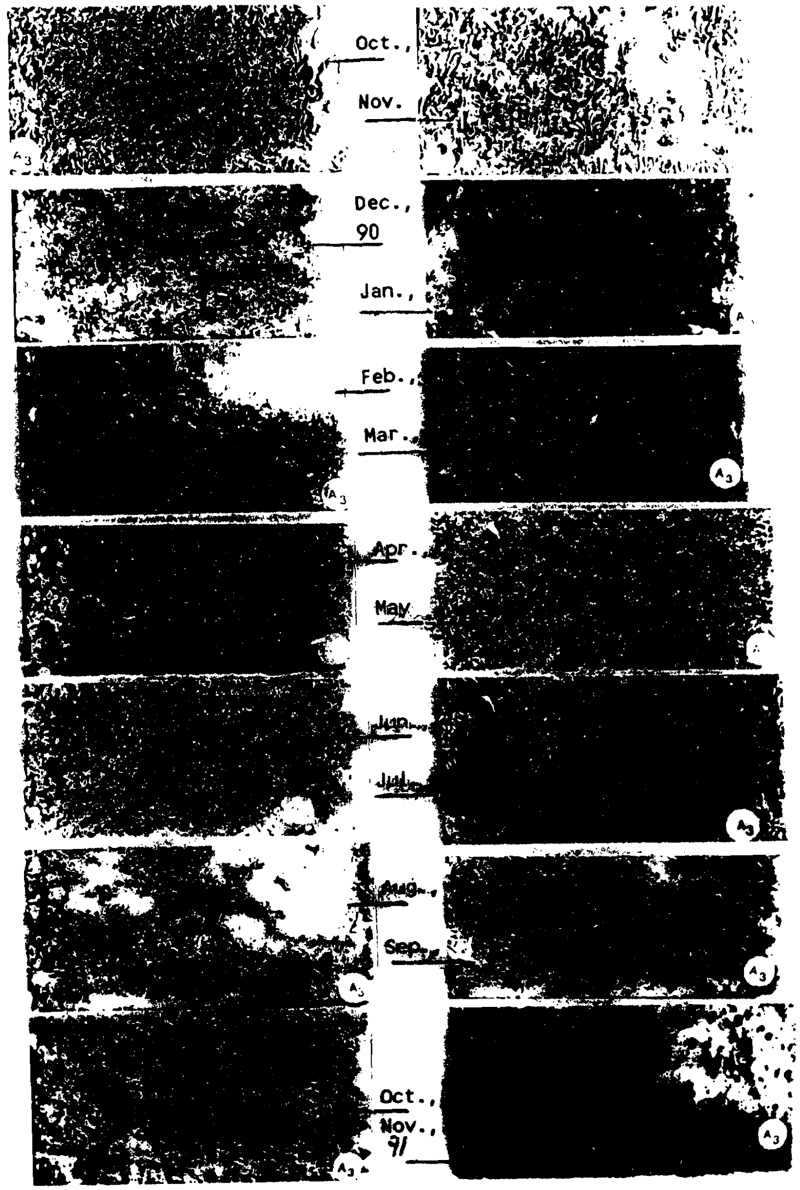

Plate 1. Photographs of the monthly fouling assemblages on the exposed test panels at the Eastern Harbour of Alexandria during October 1990 to November 1991. The size of each illustration is equal to the half of the panel area.

rate of growth of algae was in general low over the year. Their sizes reached 0.5 to 5 mm in length after one month of settlement.

2- Spionid worms, **Polydora ciliata** (Johnston), build up mud tubes on submerged surfaces and heavily attacked calcareous shells of molluscs. Polydora spp. are known to infest the shells of barnacles in Tokyo Bay (El-Komi & Kajihara, 1988). This species was reported among fouling organisms inhabiting the Eastern Harbour waters especially on long term panels ((El-Komi, 1991). Polydora ciliata was found in greatest numbers on summer and fall months panels which encountered 137 to 392 individuals Per 100 cm^2.

3- Barnacles, **Balanus eburneus** Gould appeared on panels through most of the year except in the winter season when temperature dropped below 20°C. The settling number was high during November, 1990, May and September, 1991 ranging from 85 to 222 ind. /100 cm^2.

C) Monthly fouling, is characterized by the appearance of fouling organisms in a scatter number of months over the year.

1- Hydroids, **Obelia geniculata** (L.) was less frequent and appeared on December, 1990, January and November, 1991 panels.

2- Bryozoa, **Bugula turbinata** Alder and stolonate from, **Zoobotryon verticillatum** Della Chiaje occurred in small numbers on April and September, 1991 panels, respectively.

3- Polychaetes, **Pomatocerus triqueter** (L.), Spirorbis sp., and **Sabella** sp. are reprsented by few numbers 4 individuals in October, 1990, March, and August, 1991, respectively.

4- Barnacles, **Balanus perforatus** Bruguiere and B. **trigonus** Darwin are occurred in small numbers ranging from 3 to 29 ind. /100 cm^2. The former species appeared on March-April and July, 1991 panels, whereas, B. trigonus was found once in Abril.

5- Isopoda, **Sphaeroma walkeri** Stebbing and Cirolana **aegyptiaca** El-Nassery, were found also in few numbers 6-10 individuals during April and September, 1991.

6- Pycnogonida, **Pycnogonum** sp. was found once in April, 1991 represented by 7 Ind. /100 cm^2.

7- Platyhelminthes, **Stylochus** sp. appeared on August and October, 1991 panels (1-2 individuals).

8- Ascidian, **Ciona intestinalis** Linnaeus was the only species recorded on short term panels and was represented by 2 individuals.

9- Nematodes were most frequent in December, 1990, July, August and November, 1991 panels ranging from 13 to 54 ind. /100 cm^2

10- Stalked ciliates, **Vorticella** sp. were most dense on April panels.

LABORATORY EXPOSURES

The general picture of fouling developed on the test panels immersed in the field for 1 or 2 weeks and continued for further 3 or 2 weeks respectively under laporatory conditions (water temperature ranging from 18 to 26°C) was very poor (Figure 5) in comparison to the fouling accumulated during the corresponding months in the field as mentioned before (see Table 2). Moreover, the fouling constituents showed a great reduction inspected after 1 or 2 weeks exposure periods in seawater (El-Komi and El-Sherif 1992).

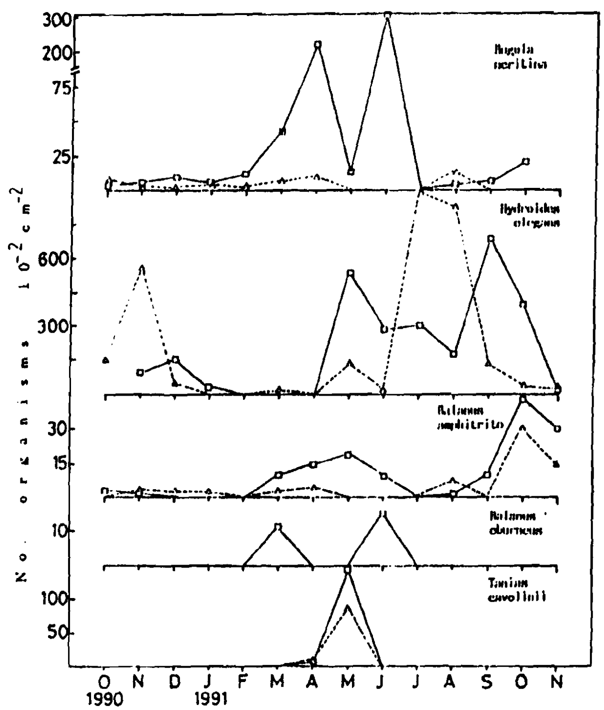

Figure 5- Seasonal changes of the fouling assemblages on test panels after one month exposure periods. ▲--- ▲ represents one week in the field and 3 weeks under laboratory conditions and □——□ represents 2 weeks in the field and 2 weeks under laboratory conditions.

The fouling biomass on each panel did not exceed more than 2 gms /100 cm^2 for one month exposure. Therefore, the development of fouling on test panels was arrested and consequently was very reduced when incubated for further 3 or 2 weeks under laboratory conditions.

Bugula **neritina, Hydroides elegans,** Balanus amphitrite and brown **alga, Ectocarpus irregularis** showed a relatively marked dominance successfully growing on exposed panels for 2 weeks in the field and 2 weeks in the laboratory throughout the year. B. **neritina** appeared in large numbers in April and June, 1991 (average, 263 col. /100 cm^2), H. **elegans** was more dense in May to October, 1991 (average, 393 tubes /100 cm^2) and **B. amphitrite** settled more in October and November, 1991 (average, 37 ind. /100 cm^2) and **Tanais cavolinii** was recorded in large numbers in May (160 ind. /100 cm^2). **E. irrugularis** was more prevailing on panels during the fall and winter seasons than Ulva lactuca, **Chaetomorpha aerea, Cladophora prolifera** and **Enteromorpha compressa.**

The rate of growth of individuals was very low. Colonies of B. **neritina** achieved only 4- bifurcations and B. **amphitrite** measured 3 mm in basal diameter. whereas, calcareous tubes of **Hydroides** elegans reached larger sizes of 15 to 20 mm in length.

FOULING BIOMASS

Figure 6 illustrates the seasonal changes in the fouling biomass accumulated on test panels at different exposure periods. The fouling biomass is given as wet weight in grams per 100 cm^2. The total fouling was more dense during May, June, September and October, 1991 periods weighing respectively, 20.6, 45.1, 16.7 and 29.4 gms. The frequency of the most dominant fouling groups collected on monthly panels listed in Table 3. The calcareous tubs worms represented 4-10 % in May, June and October, 1991, Bugula neritina predominated in June month, representing 15 % and barnacles were more dense in September and October, 1991 representing 7-8 % of the total fouling biomass over the year. The fouling biomass on each panel exposed for 1 or 2 weeks in the field and incubated for further 3 or 2 weeks under laboratory conditions did not exceed more than 2 gms /100 cm^2 for one month of exposure. This indicates that the development of fouling on test panels was arrested and consequently was very reduced when incubated for further 3 or 2 weeks under laboratory conditions.

LONG TERM PANELS

FIELD EXPOSURES

The periods of exposures for 3 successive months in seawater were as follows: October-December, 1990, January-March, April-June and July-September, 1991. Each panel represents the fouling of successive seasons over the year: autumn, winter, spring and summer. Data in Table 4

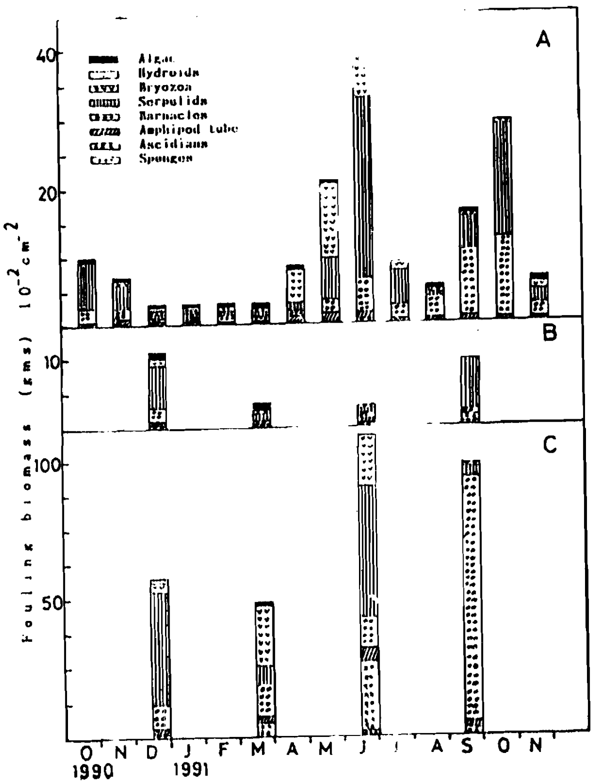

Figure 6- Seasonal changes of fouling biomasses (gms /100 cm^2) accumulated on test panels at different exposure periods: A) One month in the field, B) One month in the field and 2 months under laboratory conditions and c) 3 successive months in the field.

Table 3.

The seasonal changes in the frequency of fouling biomass of the most predominant fouling groups at different exposure periods. The frequency of the groups from the total biomasses collected over the year appears in brackets.

Duration	Tube worms %	Bryozoa %	Barnacles %	Ascidians %	Total wet weight
May	32 (4)	51 (6)	10 (1)	-	20.6
June	29 (8)	55 (15)	11 (3)	1 (<1)	45.1
September	1 (<1)	28 (3)	68 (7)	-	16.7
October	56 (10)	1 (<1)	42 (8)	-	29.4
Oct-Dec, 90	76 (14)	5 (1)	13 (2)	1 (<1)	58.2
Jan-Mar	12 (2)	47 (7)	24 (4)	12 (2)	48.7
Apr-Jun	43 (15)	17 (6)	11 (4)	25 (8)	107.9
Jul-Sep, 91	4 (1)	1 (<1)	92 (28)	1 (<1)	97.1

Table 4.

Seasonal abundance (No. org. 10^{-2} cm^{-2}) and the rate of growth (appears between brackets in mm) of fouling organisms assemblage on exposed test panels for 3 successive months. (A) in field and (B) for one month in field and 2 months under laboratory conditions during October 1990 to September 1991.

Species	(A)				(B)			
	Autumn Oct-Dec 1990	Winter Jan-Mar 1991	Spring Apr-Jun	Summer Jul-Sep	Autumn Oct-Dec 1990	Winter Jan-Mar 1991	Spring Apr-Jun	Summer Jul-Sep
Algae:								
Ulva lactuca	-	-	xxx(2)	-	-	xx(1)	-	
Enteromorpha	-	-	-	-	-	-		
Chaetomorpha	-	-	-	-	x(3.2)	xx(4.4)	-	
Cladophora	-	-	-	-	x(5.0)	x(8.5)		-
Ectocarpus irregularis	-	-	-	-	xx(10)	xx(12)	-	-
Hydroids:								
Obelia geniculata	xxx(6)	-	-	-	-	-		
Bryozoa:								
Bugula neritina	17(52)*	137(50)*	262(60)*	26(32)	28(26)	52(30)	14(34)	
B. turbinata	-	28(26)	3(26)	-	-	4(16)	-	
Bowerbankia gracilis	-	5(15)	-	-				
Polychaeta:								
Hydroides elegans	4900(30)	587(22)	4900(35)	458(16)	1504(22)	92(18)	30(22)	602(20)
H. dirampha	-	9(20)	-	-	-	-	-	
Pomatocerus triqueter	7(18)	-	-	-	-		-	
Polydora ciliata	105(9)	303(8)	-	23(6)	3(6)			
Sabella sp.	9(12)	-	-	-	-			
Nereis diversicolor	-	8(23)	5(20)	-	-			
Cirripedia:								
Balanus amphitrite	39(12)*	31(6)	19(10)*	531(10)*	44(6)	12(3)		9(9)
B. eburneus	24(11)*	12(7)	23(8)*	239(11)*	9(4)	7(2)	5(4)	1(8)
B. perforatus	-	67(6)	6(8)	-	-	-		
B. trigonus	-	4(6)	-	-		-	-	
Amphipoda:								
Mud tubes	654	262	991	883	13	82	92	
Corophium sextoni	-	26(3)	-	105(4)	-	-		
Erichthonius brasiliensis	-	-	-	36(4)	39(4)			
Stenothoe gallensis	-	9(5)	-	-	-			
Tanais cavolinii	-	3(5)	-	-	1(2)	6(3)		
Elasmopus pectenicrus	27(6)	-	268(5)	52(5)				

Table 4 (Cont.)

Podocerus variegatus		17(3)		·		-	-	·
Isopoda:								
Sphaeroma walkeri	·		15(8)		·	-	-	-
Cirolana aegyptiaca		10(7)	27(7)	31(9)	-	-	-	-
Pycnogonida:								
Pycogonum sp.	·	-	9(5)	-	-	-	-	-
Platyhelminthes:								
Stylochus sp.	·	6(6)	12(8)	-	-	-	-	-
Sponges:	-	·	1(20)	-	-	-	-	-
Ascidians:								
Ciona intestinalis	·	17(22)	12(20)	-	1(15)	-	3(35)	15(18)
Styela partita	7(3)	-	27(11)	6(10)	-	-	-	-
S. plicata	·	·	9(10)	-	-	-	-	-
Diplosoma listeranum		3(10)	·	-	1(4)	-	-	-
Nematodes:	56(10)	44(12)	16(9)	-	-	-	-	-
Ciliates:								
Vorticella sp.	xxx		·	-	-	-	-	-
Weight (gm 10^{-2} Cm^{-2})	58.2	48.7	107.8	97.1	12.2	3.6	2.3	8.5

xxx Abundant (up to 50 %), xx Common (20 to 49 %), x Present (10 to 19 %),
+ Rare (less than 9 %) and - absence. * Individuals reached sexual maturity.

illustrates the fouling established on the panels at different seasons in comparison to that maintained under laboratory conditions. The settlement density of fouling developed on panels varied considerably ranging from 1588 to 6602 ind. /100 cm^2. The total fouling encountered in the winter season had a relatively low value (1588 ind.) as compared with other seasons. Over these periods of exposure the most predominant organisms was the calcareous tube worm, **Hydroides elegans** (average, 2711 tubes); Bryozoa, **Bugula neritina** (average, 111 col.), **B. turbinata** (average, 8 col.); barnacles, **Balanus amphitrite** (average, 155 ind.), **B. eburneus** (average, 75 ind.), **B. perforatus** (average, 18 ind.) and Ascidians, **Ciona intestinalis** (average, 7 ind.), **Styela partita** (Stimpson) (average, 10 ind.), **S. plicata** Leseur (average, 2 ind.). Colonies of **B. neritina** prevailed on the spring panel, while **H. elegans** was more dominant during the fall and spring seasons. **B. amphitrite** and **B. eburneus** was most common on the summer panels (Plate 2) yielding 531 and 239 ind. /100 cm^2, respectively.

The rate of growth was obviously greater on long term panels exposed during the different seasons (Figure 4) on the autumn panel **B. neritina** colonies grew to 20-bifurcations about 52 mm in height and **H. elegans** reaching 30 mm in length whereas, **B. amphitrite** and **B. eburneus** measured 12 mm in basal diameter after 3 months of

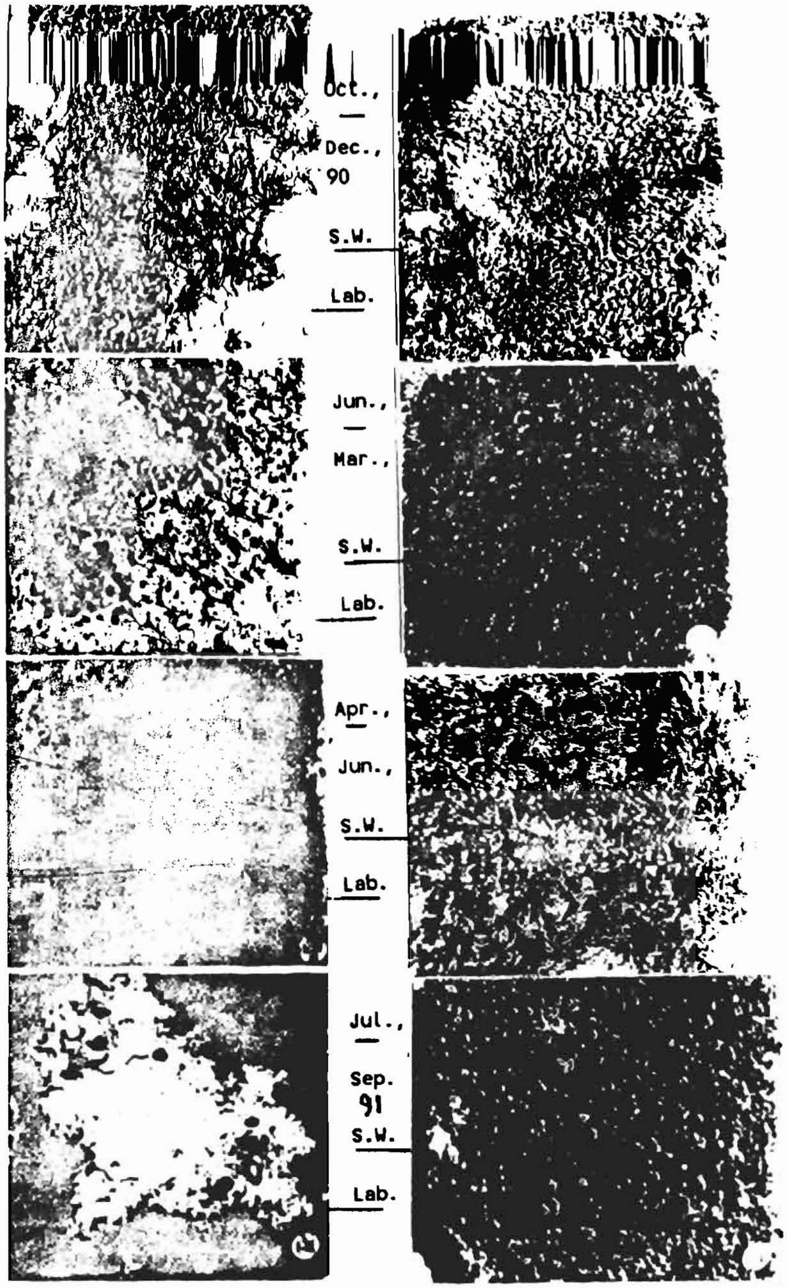

Plate 2. Photographs of the seasonal fouling assemblages on the exposed test panels at the Eastern Harbour of Alexandria for 3 successive months. A 4 represents the exposure panels for 3-month periods in the field (Right), L 3, L 4 represents the exposure panels for 3-month periods, one month in field and incubated for further 2 months in the laboratory (Left)

exposure. However, the growth of fouling attained low marked seasonal variations on long term panels over the year when compared to that noticed on monthly panels.

LABORATORY EXPOSURES

The settlement intensity of fouling after one month in the field and followed for another 2 months in the laboratory under room temperature was in general poor as previously recorded on monthly panels. Tube worms, H. elegans (average, 557 tubes) and B. neritina (average, 24 colonies) were more abundant on these panels than B. amphitrite and B. eburneus had of about 6 individuals /100 cm^2.

The growth of fouling after 3 months exposure was relatively low in comparison to that recorded during the same period (Figure 4). The maximum size of B. neritina achieved 30 mm in height (6-bifurcations), tube worms 22 mm in length and B. amphitrite and B. eburneus measured 8-9 mm in basal diameter, respectively.

FOULING BIOMASS

The seasonal changes in the fouling biomass accumulated on test panels for long exposure periods was greatly varied and more dense in the spring and summer seasons yielding 107.8 and 97.1 gms, respectively (see Figure 6). Biomass is given as wet weight in grams /100 cm^2. The frequency of the most common fouling groups collectively developed on test panels is listed in Table 3. The calcareous tube worms represented 14 and 15 % in the fall and spring, Bugula neritina predominated in the winter and spring months representing 7 and 6 %, and barnacles contributed 28 % in the summer season of the total biomasses accumulated on the four seasons panels.

On the other hand, the fouling biomass on each panel exposed for one month in the field and subsequented with 2 months in laboratory was small ranging from 2 to 12.1 gms, recorded on panel exposed during October to January. Furthermore, the development of fouling on test panels was arrested and consequently was very reduced when incubated for a further 2 months under laboratory conditions.

DISCUSSION

All fouling assemblages either on short term or long term exposure panels showed pronounced seasonal changes in abundance over the year. Also many species revealed considerable variations in abundance and attachment numbers during the different observation periods which reviewed in Table 5. The predominant fouling constituents on the monthly test panels consisted principally of Bryozoa, Bugula neritina; calcareous tube worms, Hydroides elegans,

Table 5.

Occurrence, settlement and rate of growth of the main fouling groups recorded on the monthly test panels during different observation periods.

Observation periods	Banoub,1960 Feb.- Sep.,58	Megally,1970 Oct., 68- Dec., 69	Ghobashy,1976 Mar.,73- Jun.,74	El-Komi, 1991 Mar.,83- Jun.,84	Present work Oct., 90- Nov. 91
Bugula neritina					
Appearrence period	Apr-Jun	Feb-Aug	Over the yr except Mar	Over the yr except Aug & Sep	Over the yr
Max. settlement		Apr(236)	Apr(481)	Apr(188)	Apr(193)
(No. 10 cm^2)	May(17)	May(290)	May(1640)	May(88)	May(311)
	Jun(31)	Jun(34)	Jun(140)	Jun(41)	Jun(255)
Max. growth rate(mm)	33	7	-	26 (9-bif.)	31 (10-bif.)*
B. turbinata					
Appea. period	-	Mar-May **	Mar-Jul	Apr	Apr
Max. settlement (No. 10 cm^2)	-	May(17)	May(35)	Apr(1)	Apr(6)
Max. growth rate(mm)	-	10	-	-	5 (4-bif.)
Balanus amphitrite					
Appea. period	Apr-Sep	Over the yr except in Feb.	May-Dec	Over the yr	Over the yr
Max. settlement	Aug(93)	Aug(29)	Aug(174)	Aug(4)	Aug(167)
(No. 10 cm^2)	-	Sep(54)	Sep(29)	Sep(5)	Sep(605)
	-	Oct(107)	Oct(36)	Oct(12)	Oct(227)
	-	Nov(12)	Nov(42)	Nov(36)	Nov(569)
Max. growth rate(mm)	4	9	-	-	8*
B. eburneus					
Appea. period	-	-	Autumn, Winter and Summer	Jun-Aug	Winter, Spring and Summer
Max. settlement	-	-	Aug(474)	Few no.	May(85)
(No. 10 cm^2)	-	-	Oct(62)	(2)	Sep(85)
	-	-	Nov(42)	-	Nov(222)
B. perforatus					
Appea. period	-	-	Over the yr	Apr-Aug	Mar-Apr & Aug
Max. settlement	-	-	Mar(802)	Jun(32)	Mar(29)
(No. 10 cm^2)	-	-	Aug(697)	-	
B. trigonus					
Appea. period	-	-	Jun-Sep	Jun-Jul	Apr
Max. settlement (No. 10 cm^2)	-	-	Few no. (2)	Few no. (1)	Few no. (3)

Table 5 (Cont.)

Hydroides elegans					
Appea. period	May-Sep #	Over the yr # except in Feb.	Over the yr	Over the yr except in Mar.	Over the yr
Max. settlement (No. 10 cm^2)	May(6660)	Jul(640)	Aug(3520)	Jun(5280)	May(1243)
	-	Aug(570)	Sep(5730)	Oct(4400)	Jun(2681)
	-	Sep(512)	Oct(1310)	Nov(2640)	Oct(3107)
Max. growth rate(mm)	20	22	-	-	25 -
Ciona intestinalis					
Appea. period	Jun	Apr	Feb-Aug	-	Jun
Max. settlement (No. 10 cm^2)	Jun(60)	Apr(1)	Mar(28) Apr(66)	-	Jun(2)
Max. growth rate(mm)	36	8	-	-	15
Wet weight (gm 10^{-2} cm^{-2})	Jun(20)	-	-	Jun(38)	Jun(45.1)

* Reached sexual maturity ** Bugula avicularis

\# Hydriodes norvegica

barnacles, **Balanus amphitrite**, **B. eburneus** and **B. perforatus**; Ascidian, **Ciona intestinalis**, and Algae, **Ulva lactuca**, **Enteromorpha compressa**, and **Ectocarpus irrigularis**. In the periods 1973-1974 (Ghobashy, 1976), 1983-1984 (El-Komi, 1991) and 1990-1991 (the present work) the fouling characterized by a predominance of **B. neritina**, **B. amphitrite** and **H. elegans** which reproduced continuously over the year and the larvae were found in the plankton populations throughout the year. The continuous reproduction of fouling organisms coincides, in general, with the warmer seasons when the temperature raised above 20°C. The fouling biomass accumulation was at its maximum during June, 1991 in different observation periods yielding 20 gms (Banoub, 1960), 38 gms (El-Komi, 1991) and 45.1 gms /100 cm^2 in the present work.

Attachment of fouling occurred in greatest amount on long term panels which consisted of considerable number of organisms, biomass and rates of growth. Meadows, (1969) correlated the ratio between one, two and three months fouling biomass by 1: 2: 3. But the biomass accumulated on three successive months was much greater than cumulatively collected on the monthly panels during the same periods. El-Komi, (1991) stated that this can be applied if the conditions of growth, life span and the density of fouling were the same.

The large amount of pollutants discharged to the Harbour have a significant influence on the survival and movement of pelagic larvae, in particular, of fouling organisms and thus play an important role on the constituent, abundance and rate of growth of the fouling population. Both rate of growth and biomass differ greatly at different seasons which depend upon, temperature, season of immersion and duration of exposure. In addition, attachment is affected by combination of biological factors such as the age and density of adults releasing larvae (Connell, 1961 & 1974) and environmental factors such as temperature (Orton, 1919; Yasuda 1968), salinity (Foster, 1970) and water current (Pyefinch, 1948).

B. **neritina** dominated during the period from April to June, 1991 when the temperature was above 20°C and became small in number in temperatures above 25°C. The same phenomenon was reported in Biscayne Bay, Florida by Weiss, (1948), where B. **neritina** occurred in great numbers in November when temperature was below 24°C and disappeared at temperature above 29°C in June.

Under the field and laboratory conditions the fouling assemblages on the test panels were highly affected. The settlement intensity, species composition and rate of growth was obviously decreased or arrested due to the unfavorable conditions of incubation. It is difficult to decide what are the optimum conditions for the culture a fouling community in the laboratory. This is necessary for identifying, evaluating the relative influence of certain toxic compounds on fouling developmental stages or assessing the degree to which fouling populations have been affected. This is well known on larvae of barnacles (Crisp et al., 1967; Kondo et al., 1983), serpulids (Wisely, 1964), sea urchins (Kobayashi, 1990) and spores and growth of algae (Fletcher & Chamberlain, 1975; Miyauti, 1981). The performance of experiments will be needed to demonstrate the fouling settlement behaviour under certain controlled conditions such as temperature, salinity, light intensity and length of incubation period.

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