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Factors controlling marine fouling in some Alexandria Harbours, Egypt

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Abstract

The present work aims to relate the settlement of marine fouling organisms in three different harbours in Alexandria city which present a wide range of ecological/environmental variations. Theses are the Abu Qir, Eastern and El-Dekheila harbours.

Monthly samples of marine fouling were collected from the three harbours by using white roughened polystyrene test panels (12.5x12.5 cm), as well as physicochemical, chemical and other biological data. Results were treated with multivariate statistical analysis (PCA).

At the Abu Qir harbour, it was found that water temperature and salinity are the most important environmental factors controlling the temporal distribution of total fouling density, whereas water temperature and chlorophyll a are the most significant environmental factors controlling the total biomass. At the Eastern harbour it was demonstrated that ammonia and phosphate are the most significant environmental factors controlling the temporal distribution and total biomass of fouling organisms. Concerning El-Dekheila harbour, the total density and total biomass of fouling organisms were inversely correlated with the total zooplankton.

Keywords: Ecology; Marine fouling; Alexandria harbours; Environmental factors; PCA.

Introduction

Studies of fouling organisms in the Egyptian waters go back to BANOUB (1960) who investigated the succession of fouling organisms settled on glass plates in the Eastern Harbour of Alexandria. Recent investigations include those of MEGALLY, 1970; GHOBASHY, 1976 and EL-KOMI, 1991, 1992 a, 1998a, b.

Studies of fouling communities extend to other Egyptian marine waters. GHOBASHY (1977) reported the absence of fouling attachments on the pier or wharf of the Sallum Bay. GHOBASHY *et al*. (1980) made a general survey of fouling in the Suez Canal. RAMADAN (1986) studied the fouling in the northern part of Suez Canal and in the Western harbour of Alexandria. EL-KOMI (1992 b) observed the fouling settlement in El-Ghardaqa water (Red Sea). EL-KOMI *et al*. (1998) and EMARA (2002) studied the ecology and settlement of marine fouling in the Suez Bay.

The present work is the first in the Egyptian waters to deal with the environmental factors controlling the total density and biomass of fouling organisms at the studied harbours.

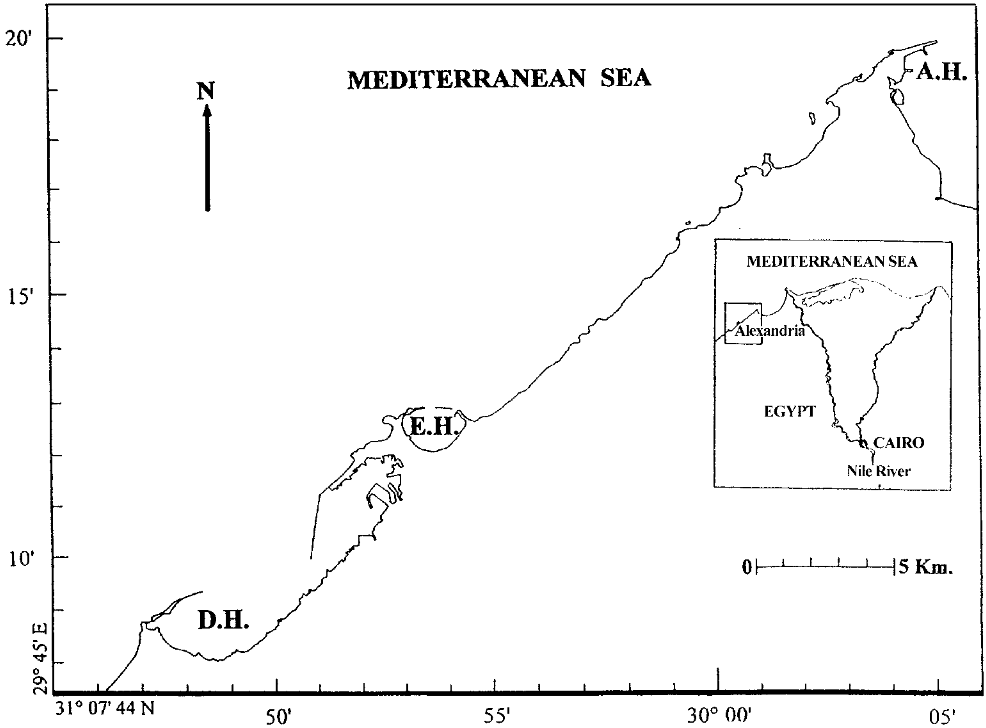

Fig. 1: The area investigated; positions of the three sample harbours along Alexandria coast.

Materials and Methods

The present work was carried out in three harbours in Alexandria city. From east to west these are the Abu Qir harbour (A.H.), the Eastern harbour (E.H.) and the El-Dekheila harbour (D.H.) (Fig.1). For simplicity, these harbours are denoted A, B and C from east to west, respectively.

Abu Qir Harbour (Harbour A):

It is a military harbour situated nearly at the head of the Abu Qir bay between the dead and open seas. The water of Abu Qir bay is affected by three continental discharges. These are the Boughaz El-Maadia opening, the El-Tabia pumping station and the opening of the Rashid Nile branch.

The Eastern Harbour of Alexandria (Harbour B):

This is a relatively shallow semi-circular bay surrounded by the city except on its northern side, where it communicates with the sea through two outlets. LABIB (2002) mentioned that due to water circulation the harbour is subjected to an amount of municipal wastewater from the main sewer of Alexandria (Kayet Bey), located at its western vicinity.

El-Dekheila Harbour (Harbour C):

El-Dekheila Harbour is a semi-enclosed basin constructed recently after 1986 on the western side of El-Mex bay (FAHMY *et al.*, 1997). According to ABDALLA *et al.* (1995) and FAHMY *et al.* (1997), the harbour′s water is subjected to several sources of wastewater. A huge volume of brackish water is discharged into El-Mex bay through the El-Umoum drain. On its western side, near the harbour this bay also receives industrial wastes from several sources. The degree of water contamination of the harbour water from the above-mentioned sources depends on water circulation in the bay.

Sampling techniques

Sampling was carried out monthly at harbour (A) from November 1998 through October 1999 while at harbours (B) and (C) it was conducted from October 1998 through to September 1999.

Water samples were collected at a depth of 0.5 m at the studied harbours. A simple mercury thermometer was used to measure water temperature. Water transparency and salinity were measured using a standard Secchi disc and Beckman induction salinometer (Model RS-7B), respectively. A digital portable pH-meter was used to measure pH. Dissolved oxygen was determined by titration according to the Winkler method explained in APHA (1995).

Data of marine chemistry used in the present statistical analysis are extracted from the works of NASR & EL-RAEY (1999) and ABBAS (2004) who collected their samples from the same locations during the same period as the present study. NASR & EL-RAEY (1999) provide data on nutrients (nitrite, nitrate, ammonia, total nitrogen, phosphate, total phosphorus, reactive silicate) and chlorophyll *a* in sea water, whereas, ABBAS (2004) give concentrations of total copper, zinc, lead, cadmium and chromium in seawater.

Sub-surface water samples were collected using a PVC Niskin Bottle (3 L). They were kept in well–cleaned stoppered polyethylene bottles. Chlorophyll *a* extraction and measurement was measured according to STRICKLAND & PARSONS (1972) and is expressed as (μg/l).

The zooplankton samples were collected by filtering 200 liters of seawater through a 55 μm standard plankton net. The filtrate was preserved in 6 % formalin. In the laboratory, the volume of each sample was standardized to 100 ml and triplicate subsamples (5 ml each) were removed for counting the zooplankton (using 100 X binocular microscope). The average population density.m^{-3} of the total zooplankton was calculated according to the equation:

$$\text{Average total zooplankton} = (N/ 3) \times 100$$

N is the sum of total zooplankton in the three subsamples.

At each harbour, three white roughened polystyrene test panels (each 12.5x12.5 cm) were used to collect fouling samples. These panels were regularly replaced every month. Using a binocular zoom stereo-microscope (20X), the fouling community was investigated to identify the foulers and associated organisms.

The settlement of only countable fouling organisms on test panels was considered. The total biomass (wet weight) of fouling organisms settled on each test panel was measured in gm after removing excess water by blotting paper. The mean of the settling number of countable fouling species as well as the mean of total biomass was then calculated.

Data treatment

The data were treated by factor analysis using the Principal Components Analysis (PCA). A detailed explanation of PCA can be found in LUDWING & REYNOLDS (1988). This analysis was used to determine the most effective factors, which control the total density and biomass of fouling organisms at each harbour. Input data include physicochemical, chemical and biological variables. The biological variables include means of the total fouling density and total biomass. The factor loadings are unrotated. PCA was made by STATISTICA version 5.0 computer package.

To run the program properly; the number of variables (physicochemical, chemical and biological factors) must be equal or less than the number of cases, so a simple correlation coefficient (r) has been done between the total fouling density or total biomass and the other variables to determine the most significant environmental variables which can be used in the program.

Table 1
Monthly records of physicochemical factors at Harbour A.

Factor Month	Water temp.	Transp.(cm)	Salinity PPT	pH	D.O. mg/l
Nov., 1998	21	290	37.73	7.9	6.51
Dec.	18	400	37.33	8.24	4.96
Jan., 1999	17	280	35.98	8.12	4.16
Feb.	18.5	245	36.38	8.29	4.96
Mar.	19.5	185	36.74	8.2	4.16
Apr.	28	65	36.45	7.76	3.44
May	26.5	360	36.14	7.95	3.88
Jun.	29	250	38.57	7.96	5.68
Jul.	30	315	38.81	7.61	4.00
Aug.	29	220	38.97	8.22	4.16
Sep.	27	215	38.81	7.43	8.16
Oct.	24	215	38.81	8.06	10.6
Monthly average	23.9	253	37.5	7.98	5.38

Table 2
Monthly records of physicochemical factors at Harbour B.

Factor Month	Water temp.	Transp.(cm)	Salinity PPT	pH	D.O. mg/l
Oct., 1998	23	140	35.67	7.16	4.8
Nov.	22	200	36.5	8.16	5.1
Dec.	17	205	36.7	8.08	3.68
Jan., 1999	11	200	37.61	8.23	3.52
Feb.	18	230	36.86	8.28	6.08
Mar.	20.5	170	37.14	8.2	3.68
Apr.	24.5	140	37.17	8.25	7.28
May	26.5	190	36.46	8.25	2.48
Jun.	29.5	110	36.86	8.32	3.84
Jul.	30.5	230	38.29	7.48	3.6
Aug.	29	175	36.78	8.08	4.08
Sep.	29	170	36.86	8.13	9.6
Monthly average	23.4	180	36.9	8.05	4.81

Diversity indices

Population density (PD) data of countable taxa of fouling organisms were used to calculate diversity indices: Shannon-Wiener index (H) and Simpson`s index (D). The indices are calculated as described by DESHMUKH (1986).

$$H = -\sum (n_i/N) \ln (n_i/N)$$
$$D = 1-\sum (n_i/N)^2$$

The (D) index gives higher values to the dominant taxa while the (H) index gives more stress to rare taxa.

Trophic State Index (TSI) = 30.6 + 9.8 ln (Chlorophyll *a* as μg/l) was calculated after Carlson equation for Trophic State Index (WETZEL, 2001).

Results

The physicochemical factors recorded at the studied harbours are presented in

Table 3
Monthly records of physicochemical factors at Harbour C.

Factor Month	Water temp.	Transp.(cm)	Salinity PPT	pH	D.O. mg/l
Oct., 1998	26	370	38.01	7.56	8.31
Nov.	22.5	450	38.29	7.85	4.63
Dec.	18	390	37.97	8.25	4.32
Jan., 1999	16	290	30.56	8.04	4.16
Feb.	18.5	190	37.65	8.17	4.16
Mar.	20	105	29.9	7.99	3.52
Apr.	26	75	22.62	7.97	5.84
May	26.5	60	27.87	8.48	7.8
Jun.	29	75	22.62	7.39	5.36
Jul.	30	65	24.89	7.4	5.84
Aug.	27	115	25.72	8.11	4.88
Sep.	26.5	80	21.92	7.62	8.72
Monthly average	23.8	189	29.8	7.9	5.62

Tables 1-3. In general, the lowest water temperatures were recorded in winter months while the highest values were recorded during summer months. The values of transparency varied greatly from one season to another, the minimum value (60 cm) was recorded in May 1999 (spring) while the maximum value (450 cm) was recorded during November 1998 (autumn). These two values were recorded at harbour (C). Generally salinity values were lower at harbour (C) than those recorded at the other harbours, reflecting the effect of the El-Umum drain which discharged a huge volume of brackish water ($7.7X10^6$ m^3/ day) loaded with domestic, agricultural and industrial wastes into the El-Mex bay, while pH values of surface seawater showed a very narrow limit variations in the studied harbours. Regarding the dissolved oxygen values, the minimum concentration (2.48 mg/l) was recorded during May 1999 (spring) at harbour (B) while, the maximum value (10.6 mg/l) was recorded during October 1999 (autumn) at harbour (A).

Tables 4 and 5 show the concentrations of nutrients and some heavy metals in seawater respectively in the studied harbours.

Table 6 demonstrates the mean monthly variations in the standing crop of total zooplankton in the studied harbours. Harbour (B) sustained the highest monthly average of total zooplankton (27,209 indiv. /m^3), while the lowest value (5,066 indiv. /m^3) was recorded at harbour (C). The maximum standing crop (205,267 indiv. /m^3) was recorded during November 1998 at harbour (B), while the minimum value (403 indiv. /m^3) was recorded during June 1999 at harbour (C).

Tables 7-9 show the monthly density of fouling organisms collected per panel area, total of the mean number of individuals of countable species (total fouling density), total biomass and diversity indices in the studied harbours.

It is clear from Table 7 that a total of 27 species in addition to the Cyanophycophyta layer was recorded in harbour (A) during the whole period of study. The highest number of species (15) was recorded during June (summer) and October (autumn) while the lowest number (4 species) was recorded during January (winter). The highest total of the mean number of fouling organisms (2825.7 indiv. / panel area) was recorded during July (summer) while the lowest (89.6 organisms/panel area) was recorded during February (winter), with a monthly average of (1114.4 indiv. / panel area). The maximum biomass value (14.5 gm/panel area) was achieved during July 1999 (summer) whereas the minimum

Table 4
Concentrations of some chemical factors at the studied harbours. a, Nitrite; b, Nitrate; c, Ammonia; d, Total nitrogen; e, Phosphate; f, Total phosphorus; g, Reactive silicate; h, Chlorophyll α. (After Nasr and El-Raey, 1999)

(a) Nitrite (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	0.42	0.5	1.64
Jan. 1999	1.35	0.46	0.33
Mar. 1999	0.46	0.36	0.38
May 1999	2.06	0.48	2.89
Jul. 1999	0.59	0.11	0.35
Sep. 1999	0.76	0.59	0.55
Average	0.94	0.42	1.02

(b) Nitrate (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	5.98	12.8	14.18
Jan. 1999	7.91	4.56	3.6
Mar. 1999	4.48	4.38	5.15
May 1999	9.43	2.23	6.2
Jul. 1999	15.29	1.44	9.89
Sep. 1999	6.46	9.15	10.18
Average	8.25	5.76	8.2

(c) Ammonia (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	5.94	3.14	15.23
Jan. 1999	24.59	0.57	1.49
Mar. 1999	0.33	0.33	0.82
May 1999	5.39	0.33	0.95
Jul. 1999	0.74	0.44	2.2
Sep. 1999	0.53	11.65	1.58
Average	6.25	2.74	3.71

(d) Total nitrogen (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	67.37	73.7	164.2
Jan. 1999	126.9	83.1	131.4
Mar. 1999	37.24	55.17	32.7
May 1999	34.27	34.27	77.65
Jul. 1999	79.32	22.59	25.69
Sep. 1999	32.1	27.6	33.7
Average	62.8	49.4	77.5

(e) Phosphate (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	0.39	0.22	1.44
Jan. 1999	1.28	0.31	0.26
Mar. 1999	0.22	0.18	0.22
May 1999	0.36	0.24	0.28
Jul. 1999	0.14	0.12	0.28
Sep. 1999	0.21	0.53	0.22
Average	0.43	0.26	0.45

(f) Total phosphorus (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	1.28	0.92	3.04
Jan. 1999	2.43	0.9	0.71
Mar. 1999	0.55	0.82	0.55
May 1999	0.93	1.14	0.57
Jul. 1999	1.01	1.12	0.78
Sep. 1999	0.43	1.25	0.38
Average	1.10	1.02	1.00

(g) Reactive silicate (µmol./l)

Month	Harbour		
	A	B	C
Nov. 1998	10.87	2.67	17.27
Jan. 1999	11.53	2.47	5.53
Mar. 1999	1.22	1.22	2.33
May 1999	8.26	2	5.25
Jul. 1999	15.6	1.84	5.86
Sep. 1999	4.39	2.78	16.17
Average	8.64	2.16	8.73

(h) Chlorophyll α (µg/l)

Month	Harbour		
	A	B	C
Nov. 1998	8.35	9.0	16.64
Jan. 1999	2.53	8.41	0.74
Mar. 1999	2.46	10.72	1.51
May 1999	27.52	6.85	18.73
Jul. 1999	10.58	5.76	6.93
Sep. 1999	16.15	1.29	25.68
Average	11.26	7.0	11.7

biomass value was recorded in January 1999 (winter) where the panel collected 0.3 gm of fouling individuals. The monthly average of total biomass amounted to (6.1 gm/panel area).

Results of Table 8 indicated that a total of 24 species in addition to the Cyanophycophyta layer was recorded at harbour (B) during the whole period of study. The highest number of species (15) was recorded during both August and September (summer and autumn) while; the lowest number (6 spe-

Table 5
Variations of concentration of some heavy metals in seawater of the studied harbours as μg/l. a, Total Copper; b, Total Zinc; c, Total Lead; d, Total Cadmium; e, Total Chromium. (---)= Not recorded (after Abbas, 2004)

(a) Total Copper

Month	Harbour		
	A	B	C
Oct. 1998	----	3.13	2.61
Nov.	7.3	4.89	6.56
Dec.	4.25	2.88	4.39
Jan. 1999	4.34	12.39	3.19
Feb.	3.28	4.95	2.57
Mar.	8.73	4.73	2.62
Apr.	5.76	5.52	5.28
May	7.52	4.9	3.84
Jun.	3.41	3.14	3.41
Jul.	5.05	2.57	2.04
Aug.	9.58	5.31	5.52
Sep.	6.36	4.8	6.25
Oct.	6.36	---	---
Average	5.99	4.93	4.02

(b) Total Zinc

Month	Harbour		
	A	B	C
Oct. 1998	---	2.76	3.68
Nov.	17.21	13.97	14.74
Dec.	15.31	18.51	12.17
Jan. 1999	14.94	17.02	16.43
Feb.	40.02	31.74	20.01
Mar.	14.8	12.13	14.7
Apr.	4.11	15.06	6.8
May	4.31	3.41	2.54
Jun.	5.5	3.44	6.46
Jul.	4.62	15.58	63.49
Aug.	11.72	8.73	6.5
Sep.	6.07	9.68	6.47
Oct.	4.16	---	---
Average	11.89	12.66	14.49

(c) Total Lead

Month	Harbour		
	A	B	C
Oct. 1998	---	5.99	7.18
Nov.	4.97	8.57	11.16
Dec.	1.84	7.46	15.11
Jan. 1999	5.34	12.11	8.79
Feb.	7.36	7.28	7.01
Mar.	1.59	8.95	7.71
Apr.	6.81	8.38	20.46
May	29.77	4.06	2.39
Jun.	5.48	2.15	1.68
Jul.	1.45	2.78	1.63
Aug.	7.93	6.91	11.7
Sep.	9.77	9.67	12.15
Oct.	7.83	---	---
Average	7.51	7.02	8.91

(d) Total Cadmium

Month	Harbour		
	A	B	C
Oct. 1998	---	0.97	0.5
Nov.	1.54	0.62	0.62
Dec.	1.31	1.74	1.35
Jan. 1999	0.23	1.39	0.92
Feb.	0.93	0.46	1.24
Mar.	0.83	0.91	0.75
Apr.	0.64	0.82	0.96
May	1.3	0.46	0.35
Jun.	0.86	0.26	0.21
Jul.	0.3	0.29	0.24
Aug.	1.62	2.08	1.62
Sep.	1.31	1.59	1.12
Oct.	0.77	---	---
Average	0.97	0.96	0.82

(continued)

Table 5 (Continued)

(e) Total Chromium

Month	Harbour		
	A	B	C
Oct. 1998	---	1.43	0
Nov.	0	0.48	1.91
Dec.	1.12	0.48	0.95
Jan. 1999	0.48	0	0.64
Feb.	0.64	3.18	7
Mar.	2.93	2.93	2.53
Apr.	1.67	1.58	1.58
May	4.11	1.98	0.79
Jun.	1.19	1.39	3.37
Jul.	1.27	1.67	3.89
Aug.	1.59	0	0.48
Sep.	0.64	0	0
Oct.	0.64	---	---
Average	1.35	1.26	1.93

cies) was recorded during December (winter). The maximum total of the mean number of fouling individuals (2466.7 indiv. /panel area) was recorded during September 1999 (autumn) while the minimum (52.9 indiv. / panel area) was recorded during February 1999(winter), with a monthly average of (935 indiv. /panel area). Also the highest biomass value (59 gm/panel area) was achieved during September 1999 (autumn) while the lowest biomass value (2 gm/panel area) was recorded during February 1999 (winter), with a monthly average of (14.1 gm/panel area).

It is noticed from Table 9 that a total of 19 species in addition to the Cyanophycophyta layer was recorded during the whole period of study at harbour (C). The maximum number of species (14) was recorded during May 1999 (spring) while the minimum number (1 species) was recorded during November 1998 (autumn). The highest total of the mean number of fouling (750.7 indiv. /panel area) was recorded during February 1999 (winter) while the lowest (2.7 indiv. /panel area) was recorded during November 1998 (autumn), with a monthly average of (137 indiv. /panel area). Moreover, the highest biomass value (6 gm/panel area) was achieved during May 1999 (spring) while the lowest biomass value (0.5 gm/panel area) was recorded during November 1998 (autumn), with a monthly average of (2.2 gm/panel area).

Table 6
Mean monthly variations of the total zooplankton (organisms /m3) ± S.E. recorded at the studied harbours during the period of study.
(---)= Not collected

Month	Harbour		
	A Mean ± S.E.	B Mean ± S.E.	C Mean ± S.E.
Oct. 1998	----	43,967 ± 2745	6,385 ± 326
Nov.	62,366 ± 2546	205,267 ± 15,812	25,200 ± 750
Dec.	8,900 ± 557	11,700 ± 351	2,567 ± 145
Jan. 1999	5,167 ± 121	2,800 ± 265	4,234 ± 788
Feb.	9,067 ± 731	3,467 ± 240	3,200 ± 153
Mar.	1,800 ± 100	667 ± 88	4,767 ± 240
Apr.	9,400 ± 1607	2,967 ± 120	2,367 ± 176
May	17,167 ± 1601	13,367 ± 696	5,667 ± 636
Jun.	71,834 ± 7518	11,067 ± 463	403 ± 58
Jul.	12,134 ± 177	7,800 ± 436	3,600 ± 208
Aug.	5,134 ± 546	13,900 ± 1858	668 ± 67
Sep.	23,834 ± 1419	9,534 ± 694	1,735 ± 176
Oct.	2,400 ± 264	----	----
Monthly average	19,100	27,209	5,066

Table 7

Monthly settlement of fouling organisms on panels (mean no. of organisms/panel area), total of the mean number (total density), total biomass and diversity indices during Nov. 1998 to Oct. 1999 at harbour(A).

Month	Nov..1998	Dec..1998	Jan..1999	Feb..1999	Mar..1999	Apr..1999	May.1999	Jun..1999	Jul..1999	Aug..1999	Sep..1999	Oct..1999	Monthly average
Date of immersion	XI.02.1998	XI.30.1998	I.05.1999	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	
Date of collection	XI.30.1998	I.05.1999	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	XI.07.1999	
Taxa Density	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	
Algae													
Cyanophycophyta													
Cyanophycophyta layer (%)	87 ± 3.3	100 ± 0	100 ± 0	100 ± 0	100 ± 0	88 ± 1.6	98 ± 1.6	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	97.7
Cnidaria													
Hydrozoa													
Hydroidea													
Obelia geniculata (%)	77.0 ± 14.4			100.0 ± 0.0	28.0 ± 4.4							77.0 ± 11.5	23.5
Bryozoa													
Ctenostomata													
Bowerbankia gracilis (%)	63.0 ± 4.3												5.2
Cheilostomata													
Bugula neritina (colony)				3.0 ± 0.3	56.0 ± 25.6	329.0 ± 7.3	485.0 ± 2.8	14.0 ± 4.0	3.0 ± 0.7			4.0 ± 0.6	74.5
Celleporaria sp.(%)	6.6 ± 1.7	0.8 ± 0.1						0.5 ± 0.2	5.0 ± 0.6	12.1 ± 1.1	18.3 ± 1.6	3.0 ± 1.1	3.84
Schizoporella sp. (%)	3.0 ± 1.5	2.0 ± 0.5	0.3 ± 0.1	0.6 ± 0.2	0.1 ± 0.1			0.1 ± 0.1	0.4 ± 0.4	1.7 ± 0.8	5.0 ± 0.0	1.2 ± 0.2	1.14
Cryptosula pallasiana (%)					0.5 ± 0.2	1.6 ± 0.2							0.2
Watersipora subovoidea (%)		0.4 ± 0.2		0.67 ± 0.2	0.1 ± 0.1	0.4 ± 0.4		0.5 ± 0.2	0.5 ± 0.15	0.8 ± 0.1	0.6 ± 0.2	0.4 ± 0.05	0.4
Annelida													
Polychaeta													
Sedentaria													
Serpulidae:													
Hydroides eleganes	1187.0 ± 29.9	115.0 ± 4.1	15.7 ± 11.2		5.7 ± 1.2	965.0 ± 4.1	157.0 ± 13.3	619.6 ± 26.9	2644.0 ± 603.6	1198.6 ± 232.5	817.0 ± 19.4	2316.3 ± 93.0	836.7

(continued)

Table 7. (Continued)

Month	Nov.,1998	Dec.,1998	Jan.,1999	Feb.,1999	Mar.,1999	Apr.,1999	May,1999	Jun.,1999	Jul.,1999	Aug.,1999	Sep.,1999	Oct.,1999	Monthly average
Date of immersion	XI.02.1998	XI.30.1998	I.05.1999	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	
Date of collection	XI.30.1998	I.05.1999	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	XI.07.1999	
Taxa Density	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	
Spirobranchus tetraceros								13.6 ± 3.2		5.3 ± 2.3	2.0 ± 0.6	2.6 ± 0.7	1.9
Spirorbis sp.	92.0 ± 12.0		100.3 ± 9.8	17.3 ± 1.2	20.0 ± 3.5		19.3 ± 2.0	29.0 ± 7.5		27.3 ± 2.7	66.3 ± 7.7	18.6 ± 9.3	32.5
Pomatostegus polytrema				1.3 ± 0.7									0.1
Arthropoda													
Crustacea													
Cirripedia													
Balanidae:													
Balanus amphitrite	375.0 ± 25.0	33.6 ± 4.4	70.0 ± 4.5	68.0 ± 3.5	23.7 ± 2.8	51.3 ± 4.3	5.6 ± 2.8	8.0 ± 2.5	160.6 ± 5.5	177.6 ± 25.4	27.3 ± 7.2	64.6 ± 4.6	88.7
Balanus eburneus							13.0 ± 0.6	1.3 ± 1.3	7.6 ± 0.7	11.6 ± 0.3			2.8
Balanus perforatus						445.0 ± 9.7	2.6 ± 2.6	1.0 ± 0.6	0.3 ± 0.3				37.4
Balanus sp.								0.3 ± 0.3	5.0 ± 0.6				0.4
Tanaidacea													
Tanais dulongii						11.3 ± 1.2	13.6 ± 1.2	4.6 ± 1.4	4.6 ± 1.7	3.0 ± 0.6	0.3 ± 0.3	1.3 ± 0.9	3.2
Leptochelia savignyi							0.6 ± 0.7						0.05
Isopoda													
Cymodoce truncata							0.3 ± 0.3						0.03
Gnathia sp.		0.3 ± 0.3											0.03
Amphipoda													
Corophium acutum					0.6 ± 0.3	2.0 ± 0.6	3.0 ± 3.0	0.3 ± 0.3		1.6 ± 0.9	1.3 ± 0.9	0.6 ± 0.3	0.8
Corophium sextonae					0.6 ± 0.3	1.0 ± 0.6	6.0 ± 3.2				0.3 ± 0.3		0.6
Elasmopus pectenicrus						4.0 ± 0.6	38.3 ± 2.6	0.6 ± 0.3	0.6 ± 0.7	1.0 ± 0.6		1.0 ± 0.6	3.8
Podocerus variegatus						2.3 ± 0.3	356.3 ± 11.6	0.6 ± 0.3		2.0 ± 0.6	1.3 ± 0.7	0.6 ± 0.7	30.2
Stenothoe gallensis											0.3 ± 0.3	0.3 ± 0.3	0.05
Ericthonius brasiliensis										1.3 ± 0.7			0.1
Amphipoda tubes					12.0 ± 1.1		94.0 ± 16.9						8.8

(continued)

Table 7. (Continued)

Month	Nov.,1998	Dec.,1998	Jan.,1999	Feb.,1999	Mar.,1999	Apr.,1999	May,1999	Jun.,1999	Jul.,1999	Aug.,1999	Sep.,1999	Oct.,1999	Monthly average
Date of immersion	XI.02.1998	XI.30.1998	I.05.1999	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	
Date of collection	XI.30.1998	I.05.1999	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	XI.07.1999	
Taxa Density	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	
Pycnogonida													
Ammothea sp.												0.6 ± 0.3	0.05
Tunicata													
Styela partita						1.0 ± 1.0					0.3 ± 0.3		0.1
Total biomass (gm)	3.2 ± 0.3	1.2 ± 0.2	0.3 ± 0.05	1.0 ± 0.0	1.7 ± 0.2	8.7 ± 0.2	14.3 ± 0.3	4.7 ± 0.9	14.5 ± 1.7	11.7 ± 1.2	3.0 ± 0.3	9.3 ± 0.9	6.1
Total of the mean number of fouling* (Total density)	1654	148.9	186	89.6	106.6	1811.9	1100.6	692.9	2825.7	1429.3	916.4	2410.5	1114.4
Shannon index (H)	0.73	0.55	0.91	0.7	1.2	1.16	1.4	0.51	0.27	0.58	0.44	0.21	0.99
Simpson index (D)	0.43	0.35	0.56	0.38	0.64	0.62	0.68	0.19	0.12	0.28	0.2	0.08	0.42

(%) indicates area of the panel occupied by a fouling organism. (*) Number of individuals for countable species only.

Table 8

Monthly settlement of fouling organisms on panels (mean no. of organisms/panel area), total of the mean number (total density), total biomass and diversity indices during Oct. 1998 to Sept. 1999 at harbour (B).

Month	Octo.,1998	Nov.,1998	Dec.,1998	Jan.,1999	Feb.,1999	Mar.,1999	Apri.,1999	May,1999	Jun.,1999	Jul.,1999	Aug.,1999	Sep.,1999	Monthly average
Date of immersion	IX.24.1998	X.26.1998	XI.26.1998	XII.27.1998	I.30.1999	III.01.1999	IV.03.1999	V.03.1999	VI.01.1999	VII.04.1999	VIII.05.1999	IX.04.1999	
Date of collection	X.26.1998	XI.26.1998	XII.27.1998	I.30.1999	III.01.1999	IV.03.1999	V.03.1999	VI.01.1999	VII.04.1999	VIII.05.1999	IX.04.1999	X.04.1999	
Taxa density	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	
Algae													
Cyanophycophyta													
Cyanophycophyta layer (%)	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100
Chlorophycophyta													
Ulva lactuca						+							+
Rhodophycophyta													

(continued)

Table 8. (Continued)

Month	Octo.,1998	Nov.,1998	Dec.,1998	Jan.,1999	Feb.,1999	Mar.,1999	Apri.,1999	May,1999	Jun.,1999	Jul.,1999	Aug.,1999	Sep.,1999	Monthly average
Date of immersion	**IX.24.1998**	**X.26.1998**	**XI.26.1998**	**XII.27.1998**	**I.30.1999**	**III.01.1999**	**IV.03.1999**	**V.03.1999**	**VI.01.1999**	**VII.04.1999**	**VIII.05.1999**	**IX.04.1999**	
Date of collection	**X.26.1998**	**XI.26.1998**	**XII.27.1998**	**I.30.1999**	**III.01.1999**	**IV.03.1999**	**V.03.1999**	**VI.01.1999**	**VII.04.1999**	**VIII.05.1999**	**IX.04.1999**	**X.04.1999**	
Taxa density	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	
Corallina officinalis	+					+							+
Cnidaria													
Hydrozoa													
Hydroidae													
Obelia geniculata (%)					1.7 ± 1.9	8.0 ± 1.0						32.0 ± 4.6	3.5
Bryozoa													
Cheilostomata													
Bugula neritina (colony)		1.0 ± 0.6	1.3 ± 0.3	10.0 ± 2.3	2.6 ± 1.8	2.0 ± 0.6	5.6 ± 1.2	7.6 ± 2.9	2.0 ± 0.0		4.6 ± 4.6	6.0 ± 1.5	3.5
Cryptosula pallasiana (%)								0.2 ± 0.2					0.02
Annelida													
Polychaeta													
Sedentaria													
Serpulidae:													
Hydroides eleganes	1194.3 ± 15.5	1827.3 ± 99.9	432.7 ± 51.0	105.3 ± 14.7	5.3 ± 2.7	21.0 ± 4.2	8.3 ± 0.9	141.3 ± 40.6	572.7 ± 31.7	604.7 ± 44.7	1253.3 ± 307.0	537.0 ± 78.6	558.6
Mollusca													
Bivalvia													
Modiolus barbatus											1.7 ± 1.7		0.14
Arthropoda													
Crustacea													
Cirripedia													
Balanidae:													
Balanus amphitrite	64.3 ± 9.9	68.0 ± 8.1	153.7 ± 9.0	160.3 ± 34.0	19.3 ± 2.8	24.0 ± 3.2	48.0 ± 6.7	50.7 ± 16.8	30.7 ± 12.9	128.7 ± 24.2	462.3 ± 103.8	818.0 ± 42.5	169
Balanus eburneus								0.3 ± 0.3	5.7 ± 3.2	9.3 ± 2.0	11.0 ± 1.2	52.7 ± 10.5	6.6
Balanus perforatus				4.3 ± 1.9	2.7 ± 0.3	107.3 ± 5.8	17.3 ± 5.5	4.7 ± 2.3	0.3 ± 0.3				11.4

(continued)

Table 8. (Continued)

Month	Octo.,1998	Nov.,1998	Dec.,1998	Jan.,1999	Feb.,1999	Mar.,1999	Apri.,1999	May,1999	Jun.,1999	Jul.,1999	Aug.,1999	Sep.,1999	Monthly average
Date of immersion	**IX.24.1998**	**X.26.1998**	**XI.26.1998**	**XII.27.1998**	**I.30.1999**	**III.01.1999**	**IV.03.1999**	**V.03.1999**	**VI.01.1999**	**VII.04.1999**	**VIII.05.1999**	**IX.04.1999**	
Date of collection	**X.26.1998**	**XI.26.1998**	**XII.27.1998**	**I.30.1999**	**III.01.1999**	**IV.03.1999**	**V.03.1999**	**VI.01.1999**	**VII.04.1999**	**VIII.05.1999**	**IX.04.1999**	**X.04.1999**	
Taxa density	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	
Balanus sp.												2.7 ± 0.7	0.2
Tanaidacea													
Tanais dulongii	4.0 ± 0.6	3.0 ± 0.6	1.7 ± 0.9	10.7 ± 5.2	7.0 ± 1.5	20.7 ± 4.3	11.0 ± 4.0	11.7 ± 1.9	33.3 ± 22.2	102.0 ± 27.1	30.3 ± 7.8	27.0 ± 4.2	21.8
Isopoda													
Cirolana bovina									1.3 ± 1.3	3.7 ± 2.0	20.0 ± 9.6	18.0 ± 2.1	3.6
Sphaeroma walkeri									0.3 ± 0.3	1.3 ± 1.3	4.7 ± 0.7	26.3 ± 2.2	2.7
Sphaeroma serratum		0.3 ± 0.3											0.03
Paradella dianae							0.7 ± 0.7	0.3 ± 0.3	1.3 ± 0.9				0.2
Cymodoce truncata										0.7 ± 0.7	1.0 ± 1.0	2.0 ± 0.6	0.3
Amphipoda													
Corophium acutum	199.3 ± 65.2	63.3 ± 22.4	10.7 ± 1.8	16.0 ± 3.0	10.0 ± 2.1	4.3 ± 1.5	2.3 ± 1.3	3.3 ± 0.3	4.7 ± 1.2	34.0 ± 7.0	72.0 ± 21.5	283.0 ± 40.1	58.6
Corophium sextonae				0.3 ± 0.3									0.03
Elasmopus pectenicrus	40.0 ± 11.1	47.7 ± 27.3	6.3 ± 0.3	3.0 ± 1.2	1.3 ± 0.3	0.7 ± 0.7	1.3 ± 0.9	2.0 ± 0.0	7.3 ± 6.4	7.3 ± 1.8	217.0 ± 36.5	184.7 ± 15.1	43.2
Podocerus variegatus				1.0 ± 0.6						5.0 ± 2.5	25.0 ± 4.2	61.3 ± 7.5	7.7
Stenothoe gallensis				2.0 ± 1.5	1.0 ± 1.0		1.0 ± 1.0	0.3 ± 0.3	4.3 ± 0.9	5.3 ± 3.0	48.0 ± 13.7	426.0 ± 61.3	40.6
Ericthonius brasiliensis	4.0 ± 2.1	2.3 ± 2.3		9.3 ± 6.9	3.7 ± 0.9	3.0 ± 0.6	2.7 ± 0.7	2.0 ± 0.6	1.7 ± 1.7	1.3 ± 0.7	30.7 ± 6.9	28.0 ± 11.5	7.4
Amphipoda tubes	377.7 ± 98.7	192.3 ± 75.7	25.3 ± 6.8	47.3 ± 9.9	5.7 ± 0.7	23.7 ± 3.2				102.7 ± 12.2	182.3 ± 20.0	98.7 ± 14.2	87.9
Decapoda													
Liocarcinus depurator											0.3 ± 0.3		0.03
Total biomass (gm)	9.3 ± 0.3	17.2 ± 0.6	2.2 ± 0.2	2.3 ± 0.4	2.0 ± 0.3	3.8 ± 0.4	2.5 ± 0.3	3.3 ± 0.4	6.0 ± 1.2	18.8 ± 3.2	42.7 ± 6.2	59.0 ± 1.7	14.1
Total of the mean number of foulings* (Total density)	1506	2013	606.3	322.3	52.9	183	98.3	224.3	665.7	903.3	2177	2466.7	935
Shannon index (H)	0.71	0.42	0.74	1.34	1.84	1.29	1.6	1.14	0.64	1.1	1.35	1.84	1.39
Simpson index (D)	0.35	0.17	0.42	0.64	0.79	0.61	0.71	0.55	0.25	0.52	0.61	0.79	0.6

(%) indicates area of the panel occupied by a fouling organism, (*) Number of individuals for countable species only, (+) rarely represented.

Table 9

Monthly settlement of fouling organisms on panels (mean no. of organisms/panel area), total of the mean number (total density), total biomass and diversity indices during Oct. 1998 to Sept. 1999 at harbour (C).

Month	**Octo.,1998**	**Nov.,1998**	**Dec.,1998**	**Jan.,1999**	**Feb.,1999**	**Mar.,1999**	**Apri.,1999**	**May,1999**	**Jun.,1999**	**Jul.,1999**	**Aug.,1999**	**Sept.,1999**	**Monthly average**
Date of immersion	**IX.27.1998**	**X.27.1998**	**XI.30.1998**	**XII.31.1998**	**II.02.1999**	**III.03.1999**	**IV.04.1999**	**V.05.1999**	**VI.06.1999**	**VII.06.1999**	**VIII.07.1999**	**IX.08.1999**	
Date of collection	**X.27.1998**	**XI.30.1998**	**XII.31.1998**	**II.02.1999**	**III.03.1999**	**IV.04.1999**	**V.05.1999**	**VI.06.1999**	**VII.06.1999**	**VIII.07.1999**	**IX.08.1999**	**X.09.1999**	
Taxa Density	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	**Mean no.(± S.E.)**	
Algae													
Cyanophycophyta													
Cyanophycophyta layer (%)	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100
Cnidaria													
Hydrozoa													
Obelia geniculata (%)							8.0 ± 8.0				33.0 ± 3.3		3.4
Bryozoa													
Ctenostomata													
Bowerbankia gracilis (%)												2.3 ± 0.9	0.2
Cheilostomata													
Conopeum reticulum (%)							0.3 ± 0.3	38.0 ± 1.7	18.0 ± 1.0	5.0 ± 0.9	1.0 ± 1.0	4.3 ± 2.0	5.5
Annelida													
Polychaeta													
Errantia													
Nereidae:													
Nereis diversicolor								0.3 ± 0.3					0.03
Sedentaria													
Serpulidae:													
Hydroides eleganes	61.0 ± 9.3	2.7 ± 0.7	1.3 ± 1.3	8.3 ± 1.8	7.0 ± 3.5		2.0 ± 1.0	15.0 ± 11.5	117.3 ± 23.6	16.3 ± 4.9	46.0 ± 10.8	101.7 ± 35.4	31.5
Spirorbis sp.							0.3 ± 0.3						0.03
Pomatoceros triqueter											4.3 ± 2.3	0.7 ± 0.7	0.4

(continued)

Table 9. (Continued)

Month	Octo.,1998	Nov.,1998	Dec.,1998	Jan.,1999	Feb.,1999	Mar.,1999	Apri.,1999	May,1999	Jun.,1999	Jul.,1999	Aug.,1999	Sept.,1999	Monthly average
Date of immersion	IX.27.1998	X.27.1998	XI.30.1998	XII.31.1998	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	
Date of collection	X.27.1998	XI.30.1998	XII.31.1998	II.02.1999	III.03.1999	IV.04.1999	V.05.1999	VI.06.1999	VII.06.1999	VIII.07.1999	IX.08.1999	X.09.1999	
Taxa Density	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	Mean no.(± S.E.)	
Arthropoda													
Crustacea													
Cirripedia													
Balanidae:													
Balanus amphitrite	12.0 ± 1.2		1.3 ± 0.3	0.3 ± 0.3	4.0 ± 0.6	3.3 ± 0.7	19.3 ± 3.3	8.3 ± 2.8	2.3 ± 0.9	4.7 ± 2.0	71.7 ± 20.6	89.3 ± 10.1	18
Balanus eburneus								1.0 ± 0.6			2.0 ± 0.0		0.25
Balanus perforatus			5.7 ± 0.7	86.7 ± 17.1	720.3 ± 49.3	57.7 ± 13.1	51.0 ± 4.9	14.3 ± 2.8					77.9
Balanus trigonus								0.3 ± 0.3					0.03
Tanaidacea													
Tanais dulongii				0.3 ± 0.3	3.7 ± 0.7	2.0 ± 0.0	1.0 ± 0.6	3.0 ± 1.7	0.7 ± 0.7	1.0 ± 1.0	4.3 ± 0.7	2.0 ± 1.0	1.5
Isopoda													
Sphaeroma walkeri			0.3 ± 0.3	0.7 ± 0.3			1.7 ± 1.7	6.3 ± 2.6	2.7 ± 2.2	5.7 ± 3.2	4.7 ± 3.3		1.8
Paradella dianae								4.3 ± 1.8	1.7 ± 1.7				0.5
Amphipoda													
Corophium acutum			4.0 ± 0.6	2.0 ± 0.6	15.3 ± 5.2	7.3 ± 1.3	4.7 ± 1.7	2.0 ± 1.5	1.0 ± 1.0	2.0 ± 1.2	1.3 ± 0.3	0.3 ± 0.3	3.3
Corophium sextonae			0.3 ± 0.3	0.3 ± 0.3	0.3 ± 0.3		0.3 ± 0.3	5.3 ± 2.4					0.5
Elasmopus pectenicrus			1.0 ± 0.6				0.7 ± 0.3		0.7 ± 0.7		0.3 ± 0.3		0.2
Podocerus variegatus							1.7 ± 0.7	3.7 ± 0.9	0.7 ± 0.7		0.3 ± 0.3		0.5
Stenothoe gallensis								1.0 ± 0.0	1.0 ± 0.6				0.2
Amphipoda tubes					36.3 ± 5.0	15.7 ± 3.5							4.3
Total biomass (gm)	1.0 ± 0.3	0.5 ± 0.0	2.0 ± 0.3	2.7 ± 0.3	3.0 ± 0.0	1.2 ± 0.2	1.3 ± 0.2	6.0 ± 1.0	2.5 ± 0.3	1.7 ± 0.3	2.8 ± 0.6	1.8 ± 0.2	2.2
Total of the mean number of fouling* (Total density)	73	2.7	14	98.7	750.7	70.3	82.7	65	128	29.7	135	194	137
Shannon index (H)	0.44	0	1.55	0.49	0.22	0.65	1.19	2.13	0.45	1.24	1.18	0.78	1.23
Simpson index (D)	0.27	0	0.73	0.22	0.08	0.31	0.56	0.85	0.16	0.63	0.6	0.51	0.6

(%) indicates area of the panel occupied by a fouling organism, (*) Number of individuals for countable species only.

Table 10
Values of correlation coefficient (r) between Total fouling densities (Only countable species), Total biomass and various environmental factors at the studied Harbours.

Parameter Factor	Harbours					
	A		B		C	
	Total fouling	Total biomass	Total fouling	Total biomass	Total fouling	Total biomass
Temp.	0.654458	0.770646	0.439341	0.546648	-0.27545	0.06063
Trans.	-0.16573	0.017165	-0.1021	-0.02898	-0.14066	-0.40711
Sal.	0.539927	0.316038	-0.29239	-0.0002	0.19179	-0.18862
pH	-0.52834	-0.31977	-0.29904	-0.09865	0.178305	0.569926
D.O.	0.26858	-0.11743	0.39212	0.543423	-0.15318	0.19168
NO_3	0.694408	0.633809	0.626239	0.350097	-0.40142	-0.45192
NO_2	-0.10109	0.287811	0.167568	0.194272	-0.31799	0.438847
NH_4	-0.54048	-0.54041	0.841056	0.940986	-0.32344	-0.49598
TN	-0.31883	-0.41126	-0.22679	-0.52226	-0.13462	-0.14422
PO_4	-0.46198	-0.535	0.59643	0.565433	-0.32327	-0.4657
TP	-0.40765	-0.45452	0.565559	0.503492	-0.31891	-0.47684
Si	0.404008	0.316392	0.617765	0.305022	-0.24195	-0.40005
Chl.*a*	0.34054	0.65543	-0.50648	-0.79367	-0.28785	0.126076
Cu	0.228835	0.368975	-0.18066	-0.09848	-0.22626	-0.1547
Zn	-0.56168	-0.58255	-0.35358	-0.23138	-0.00292	-0.19126
Pb	0.02632	0.466939	0.088186	0.123842	-0.09368	-0.40943
Cd	-0.13069	0.00293	0.451401	0.496868	0.347521	-0.05134
Cr	-0.09799	0.464309	-0.65809	-0.55022	0.698576	0.022104
Tot.Zoo.	0.024975	-0.13894	0.459579	0.068435	-0.23695	-0.33067

$P_{0.05}$= 0.57

Figure 2 shows results of application of PCA method to data of total fouling density and the most significant environmental factors (Table10) that may affect the temporal distribution of fouling biota at different harbours. At harbour (A), the factor loadings indicate that total fouling density; salinity and water temperature are grouped together in one cluster, while ammonia; phosphate and Zinc are grouped together in another cluster. At harbour (B), the factor loadings indicate that total fouling density; ammonia and phosphate are grouped together in one cluster. Meanwhile at harbour (C), the factor loadings indicate that total zooplankton, phosphate, ammonia, total phosphorus and nitrate are grouped together in one cluster, while water temperature and chlorophyll *a* form another cluster.

Figure 3 shows results of application of PCA method to data of total biomass of fouling and the most significant environmental factors (Table 10) that may affect the total biomass of fouling biota at different harbours. At harbour (A), the factor loadings indicate that total biomass; water temperature and chlorophyll *a* are grouped together in one cluster, while ammonia; phosphate and zinc are grouped together in another cluster. A third cluster which includes nitrate and reactive silicate is detected. At harbour (B), the factor loadings indicate that total biomass; ammonia and phosphate are grouped together in one cluster. Meanwhile at harbour (C), the factor loadings indicate that total zooplankton; transparency, nitrate and reactive silicate are grouped together in one cluster, while ammonia, phosphate and total phosphorus are grouped together in another cluster. These two clusters can form a single large cluster. Nitrite and pH of water are grouped together in a separate cluster.

It is clear from Figures 2 & 3 that water temperature and salinity are the most important environmental factors controlling the temporal distribution of total fouling density at harbour (A) whereas chlorophyll *a* and water temperature are the most important environmental factors controlling the total biomass. Ammonia and phosphate are the most important environmental factors controlling the temporal distribution and total biomass of fouling biota at harbour (B). At harbour (C) the total density and total biomass of fouling biota are inversely correlated with the total zooplankton.

Discussion

Settlement and recruitment of marine benthic invertebrates are influenced by a wide variety of biotic factors (e.g. competition, predation) and abiotic factors (e.g. environmental conditions, substratum types, water flow) (MEADOWS & CAMPBELL, 1972; CRISP, 1984; PAWLIK, 1992; HARVEY *et al*., 1995; WALTERS *et al*., 1997).

The analysis of PCA indicated that water temperature and salinity of water are the most important environmental factors controlling the temporal distribution of total fouling density at harbour (A), meanwhile, chlorophyll *a* and water temperature are the most important environmental factors controlling the total biomass of fouling biota at that harbour.

The importance of water temperature for the total density and biomass of fouling fauna has been investigated by many authors. WISELY (1959), LEPORE & GHERARDI (1977) and RAMADAN (1986) indicated that settlement of fouling fauna was heaviest during the summer months in Sydney harbour (Australia), Brindisi harbour (Italy) and in Port Said and Western harbour of Alexandria (Egypt), respectively. MONTANARO & TURSI (1983) mentioned that the settlement of encrusting forms of Bryozoa is influenced by high temperatures, since it facilitates fixation of calcium carbonate. EL-KOMI (1992a) indicated that the continuous reproduction of fouling organisms at the Eastern Harbour of Alexandria coincides generally with the warmer season, when the temperature exceeds 20ºC. He added that growth and biomass differed greatly in the different seasons depending upon temperature, season of immersion and duration of exposure to seawater. TSUKAMOTO (2002) mentioned that low water temperature has a stronger influence than low food density on inhibiting the growth of the barnacle *Balanus amphitrite* under culture conditions. This was the case at harbour (A) where the maximum total of the mean number of fouling individuals (2825.7 indiv. /panel area) and maximum total biomass (14.5 gm/panel area) were recorded during July (summer) whenever the water temperature reached its maximal value (30 °C). On the other hand, the minimum fouling density (89.6 indiv. /panel area) and total biomass (0.3 gm/panel area) were recorded during February and January (winter) when the water temperature decreased to reach 18.5 and 17 °C, respectively.

FOSTER (1970) indicated that salinity might act as a limiting factor influencing the dominance of fouling organisms as well as their survival and growth. ANWAR & MOHAMED (1970) reported that the increase in the salinity of seawater leads to an increase in the concentration of calcium carbonate, which supports the settlement of more shelled animals (barnacles, mollusks, and polychaetes with calcareous tubes) so this may increase the number of recorded species and total density of fouling organisms. Results of salinity at the studied harbours indicated that harbour (A) has the highest values of salinity with a monthly average of 37.5 PPT which supported the highest number of recorded species (27 species), the highest

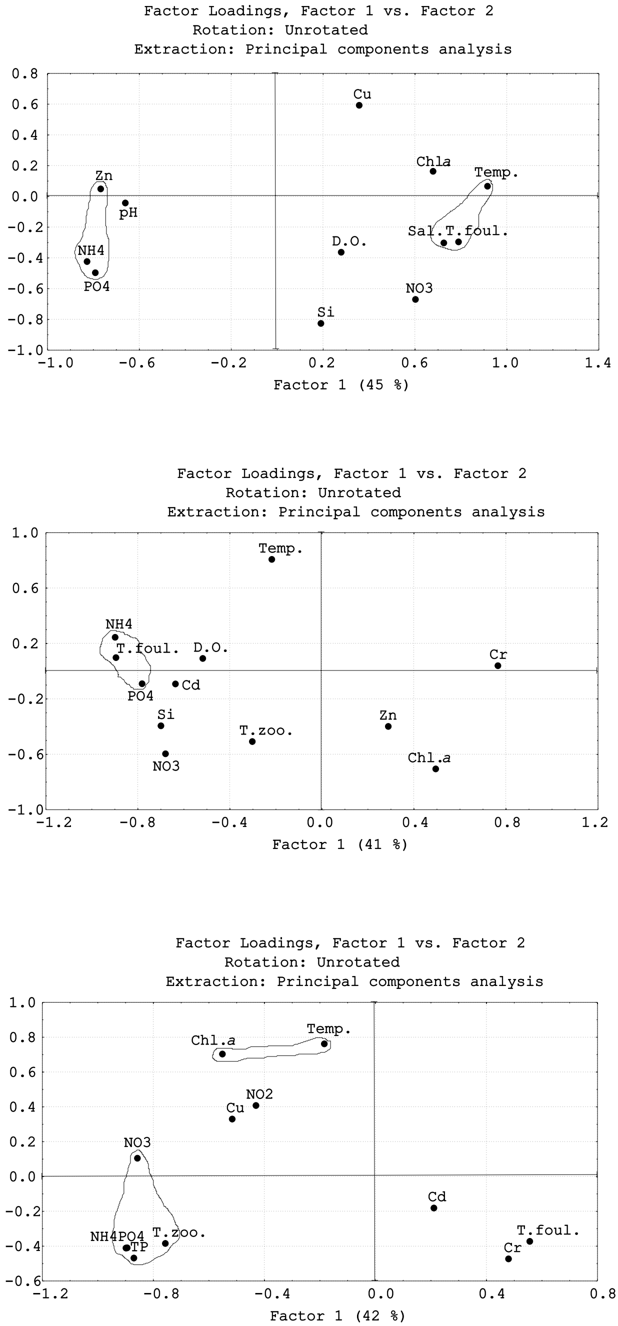

Fig.2: Graphical representation of the application of PCA method to monthly data of total fouling density and the most significant environmental factors that may affect the temporal distribution of fouling organisms at different harbours. T.foul. =Total fouling density; Sal. = Salinity; Temp. =Water Temperature; Chl.*a* = Chlorophyll *a*; D.O. =dissolved oxygen; Si = reactive silicate; TP = Total phosphorus; T.Zoo. =Total Zooplankton.

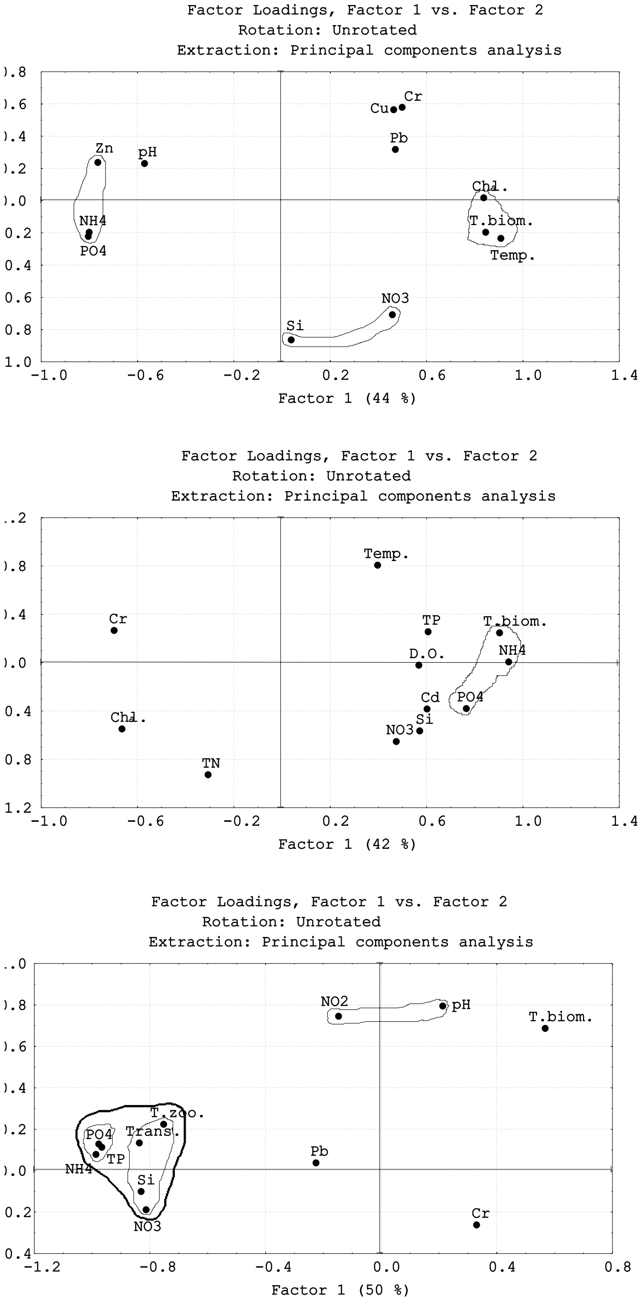

Fig.3: Graphical representation of the application of PCA method to monthly data of total biomass and the most significant environmental factors that may affect the total biomass of fouling organisms at different harbours. T.biom. =Total biomass; Temp. =Water Temperature; Trans. =Transparency; Chl.*a* = Chlorophyll *a*; D.O. =dissolved oxygen; Si = reactive silicate; TN =Total nitrogen; TP = Total phosphorus; T.Zoo. =Total Zooplankton.

total fouling density (with monthly average 1114.4 indiv./panel area) and a high number of encrusting bryozoan species (4 species). On the other hand, the decrease in number of recorded species and total fouling at harbour C (19 species and monthly average of 137 individuals/panel area) may be associated with lower salinity (Table 3). That agrees with DHARMARAJ & NAIR (1981) who demonstrated that the numbers of species of sedentary fouling animals collected on test panels has a direct correlation with salinity on the southwest coast of India.

Concerning the importance of chlorophyll *a* in water for the total biomass of fouling organisms at harbour A, the high content of chlorophyll *a* at harbour (A) with average of (11.26 µg/l) (Table 4) indicates a relatively high phytoplankton biomass which leads to high productivity of water and high food content available for fouling organisms. This may increase the total biomass of fouling biota.

Results of total fouling biomass at the studied harbours indicated that the highest monthly average (14.1 gm/panel area) was recorded at harbour (B). This could be related to the highest mean number of settled barnacles having heavy calcareous shells (187.2 individuals/ panel area) whereas the recorded numbers of barnacles at harbours (A) and (C) were 129.3 and 96.1 individuals/panel area. The monthly averages of total biomass at these harbours were 6.1 gm/panel area and 2.2 gm/panel area, respectively.

At harbour (B), the PCA revealed that ammonia and phosphate are the most important environmental factors controlling the temporal distribution and total biomass of fouling organisms.

The food requirements of all marine animal life ultimately depend on the photosynthetic production of organic matter by the phytoplankton. The growth of phytoplankton is dependent on many factors including sunlight, nutrients (N, P, Si), temperature, growth promoting compounds such as auxins, gibberellins, vitamin B_{12} and certain metals such as K, Ca, Mg and Fe (TOPPING & MCINTYRE, 1972). The effects of the addition of nitrogen and phosphorus normally operate mainly through the primary producers (phytoplankton and/or macro-algae), and their effects on the environment or the rest of the food chain may follow (MCINTYRE & JOHNSTONE, 1974).

According to WAFER *et al*. (1986), ammonia has been recognized as a useful alternative nitrogen source for several aquatic plants and in most environments it may even be assimilated in preference to nitrate. Although the concentrations of ammonia and phosphate were not the maximum at harbour (B), their supplies might be adequate to establish the phytoplankton community at that harbour. This, in turn may increase the available food sources (total phytoplankton and/or total zooplankton) for fouling settlement and biomass at harbour (B). This agrees with our results which indicate that this harbour sustained the highest monthly average of total zooplankton (27,209 indiv. /m^3).

At harbour (C) the PCA indicated that total density and total biomass of fouling organisms are inversely correlated with the total zooplankton. The PCA of factors affecting the total fouling density (Figure 2) shows that the factor loadings group total zooplankton, phosphate, ammonia, total phosphorus and nitrate in one cluster, while at figure (3) concerning total biomass, the factor loadings indicate that total zooplankton, transparency, nitrate and reactive silicate are grouped together in one cluster. Meanwhile, ammonia, phosphate and total phosphorus are grouped together in another cluster. These two clusters can form a single large cluster. This means that the total zooplankton is positively correlated with phosphate, ammonia, total phosphorus, nitrate, reactive silicate and transparency. Although the concentrations of most of these variables are high at harbour (C), the density of total zooplankton at that harbour is low (monthly average is 5,066 indiv. /m^3). This means that there may be other effective factors which have not been used in the analysis, but have negative effects on the total zooplankton at this harbour, such as planktivorous fish. MCQUEEN *et al*. (1986) and ZIMMER *et al*. (2001) indicated the negative effect of planktivorous fish on the species composition and abundance of zooplankton in the pelagic ecosystems.The negative correlation between the total fouling density or total biomass and total zooplankton indicates that the fouling organisms may graze on zooplankton.

Results of diversity indices might be related to degrees of eutrophication and/or industrial pollution at each harbour (Tables 4 and 5). The Trophic State Index showed that the estimated values of (TSI) at harbours A, B and C are 54.3, 49.6 and 54.7 respectively.

Thus, harbour (B) represents a mesotrophic basin, with the minimum concentrations of all nutrient salts (Table 4) and almost without an industrial source of pollution has the highest diversity indices (with monthly average of H=1.39, D=0.6), although due to water circulation the harbour may be subjected to additional amount of municipal wastewater from the main sewer of Alexandria (Kayet Bey), located in its western vicinity (LABIB, 2002). Meanwhile, harbour (C) representing a eutrophic, polluted, semiclosed basin, with the highest concentrations of nitrite, total nitrogen, phosphate, zinc, lead and chromium (Tables 4 and 5), has intermediate values of diversity indices (with monthly average of H=1.23, D=0.6). This harbour is mainly affected by the El-Umoum drain which discharges about 7.7X10^6 m^3/day of brackish water loaded with domestic, agricultural and industrial wastes, and by industrial wastes from a chloro-alkali plant, cement plant, oil refinery and other sources (ABDALLA *et al*., 1995 and FAHMY *et al*., 1997). ABDALLA *et al*. (1995) indicated that the El-Dekheila harbour might be considered as a eutrophic region. Moreover, ZAGHLOUL *et al*. (1995) mentioned that the eutrophication in the El-Dekheila harbour is caused by brackish water from the El-Umoum drain. The circulation pattern of brackish water discharged from the El-Umoum drain took a clockwise direction in the El-Mex bay (EMARA & SHERIADAH, 1991), which resulted in an increase of eutrophication and decrease of salinity at the El-Dekheila harbour. Harbour (A) represents a eutrophic polluted exposed harbour, with the highest concentrations of nitrate, ammonia, total phosphorus, copper and cadmium (Tables 4 and 5), has the lowest values of diversity indices (with monthly average of H=0.99, D=0.42). MOHAMED & EL-MARADNY (2001) indicate that the water of the Abu Qir Bay is affected by continental discharges. They mentioned that the most important of these discharges is the slightly brackish water flowing from Edku Lake via Boughaz El-Maadia opening at a rate of about 6X10^6 m^3/day. They added that this water is mainly agricultural drainage. The other source is the El-Tabia pumping station. Its average daily discharge amounts to about 2X10^6 m^3 including drainage water from the El Behera governorate as well as industrial waters from 22 different factories. Industrial wastes include fertilizers, textile, dyes, weaving industries and food processing and canning plants (SAID *et al*., 1995). SAMAAN & MIKHAIL (1990) attributed the eutrophication of the Abu Qir bay to continental discharges, which are rich in nutrients. Also, NESSIM & EL-DEEK (1993) advocated the effect of allochthonous water on the eutrophication condition of the bay.

It is clear from the results that harbour (B) has diversity indices higher than the other harbours. Harbour (A) has the lowest diversity indices. Harbour (C) is intermediate. This model of diversity differs from that of EMARA (2002) at Suez Bay where a maximum fouling diversity index was recorded at the polluted station but it agrees with that of KOCAK *et al*. (1999) in the Aegean Sea (Turkey) where the diversity index and evenness in the polluted site (suffering from industrial and domestic discharge) were relatively low compared with those in the unpolluted ones.

A decline in diversity indices usually indicates significant pollution (GRAY, 1980), but predation, competition, spatial heterogeneity and successive change may also influence diversity indices.

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