

## Mediterranean Marine Science

---

Vol 7, No 2 (2006)

---



### Marine fouling community in the Eastern harbour of Alexandria, Egypt compared with four decades of previous studies

SH.E. RAMADAN, A.M. KHEIRALLAH, KH.M. ABDEL-SALAM

doi: [10.12681/mms.167](https://doi.org/10.12681/mms.167)

---

#### To cite this article:

RAMADAN, S., KHEIRALLAH, A., & ABDEL-SALAM, K. (2006). Marine fouling community in the Eastern harbour of Alexandria, Egypt compared with four decades of previous studies. *Mediterranean Marine Science*, 7(2), 19–30. <https://doi.org/10.12681/mms.167>

**Mediterranean Marine Science**  
Volume 7/2, 2006, 19-29

## Marine fouling community in the Eastern harbour of Alexandria, Egypt compared with four decades of previous studies

SH. E., RAMADAN<sup>1</sup>, A. M., KHEIRALLAH<sup>2</sup> and KH. M., ABDEL-SALAM<sup>1</sup>

<sup>1</sup> National Institute of Oceanography and Fisheries, Kayet-Bey, Alexandria, Egypt

<sup>2</sup> Zoology Department, Faculty of Science, Alexandria University, Egypt

e-mail: sheriframadan2001@yahoo.com

### Abstract

*The aim of the present study is to compare the fouling communities between the years 1960 and 1999 in the Eastern harbour of Alexandria, Egypt and to study the main factors that may be controlling these communities. This comparison is based on monthly durations of panel immersion.*

*By using roughened white polystyrene test panels (12.5x12.5 cm), monthly samples of marine fouling were collected from the harbour from October 1998 through September 1999.*

*It is clear that a remarkable variation in number and diversity of fouling communities throughout the last four decades is evident. The minimum diversities were recorded during the studies of 1960 and 1970 (19 and 20 species respectively), while the maximum diversity (35 species) was achieved during the 1991 study. Moreover, a small shift among the four dominant groups (Polychaeta, Cirripedia, Bryozoa and Amphipoda) was noted during the four decades of the studies.*

*The present comparison indicated that many factors may contribute to this variation, of which nutrient enrichment is the most important and the nature of the applied test panel is less so.*

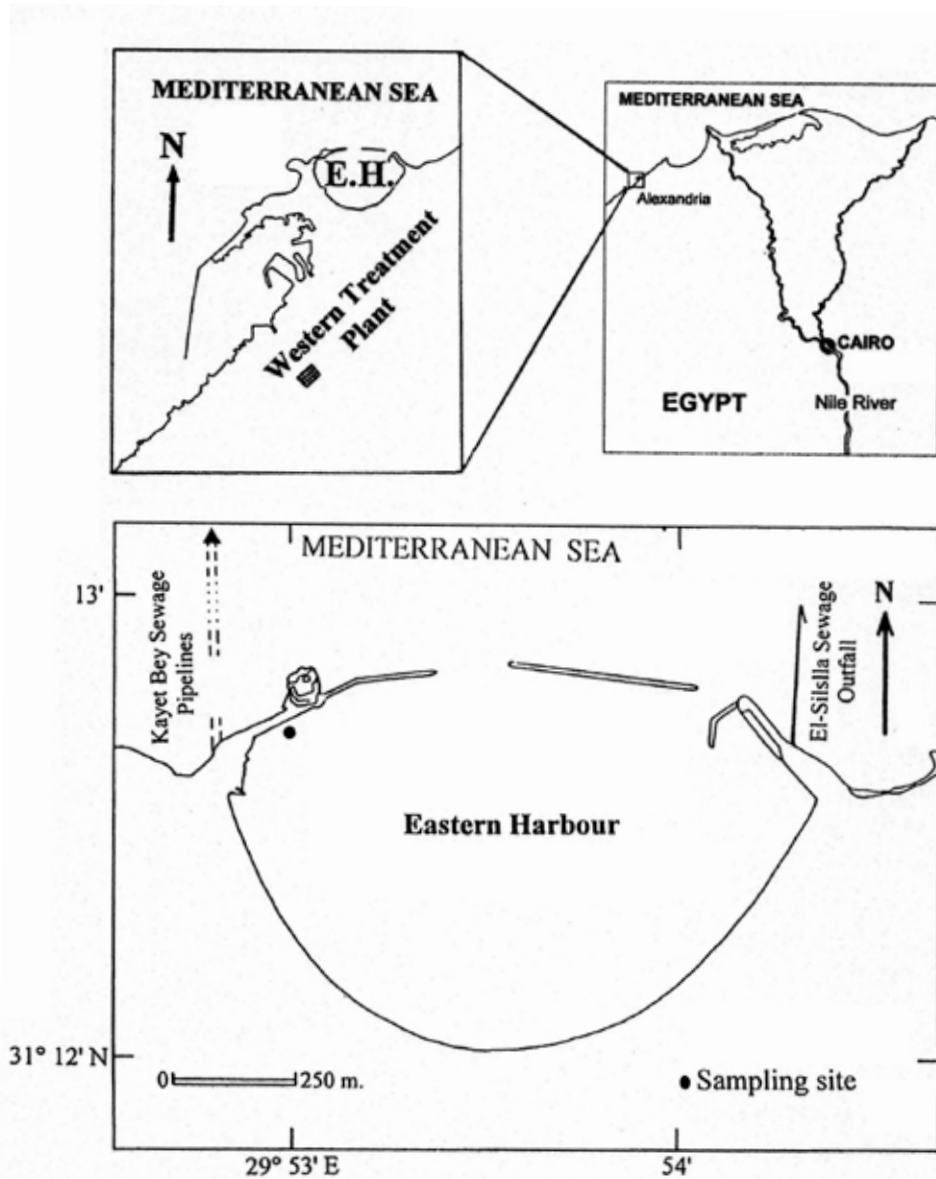
**Keywords:** Ecology; Community; Marine fouling; Eastern harbour of Alexandria; Comparison.

### Introduction

Fouling results from the growth of marine animals and plants on the surfaces of submerged structures (ANON, 1952). Attaching of marine fouling organisms in a remarkable numbers to submerged objects has been demonstrated by several authors as a usual phenomenon in different world harbours (e.g. WISELY, 1959; LEPORE & GHERARDI, 1977; HUANG *et al.*, 1982; NAIR & NAIR, 1987; CAI & LI, 1990; GORDON & MAWARATI, 1992; LI *et al.*, 1996) and in the Mediterranean harbours (e.g. RIGGIO & MAZZOLA, 1976; GALLUZZO, 1980; RAMADAN, 1986)

Pollution creates major differences in benthic community structure (MORAN & GRANT, 1991). Nutrient enrichment significantly affects the composition of marine fouling communities (RASTETTER & COOKE, 1979).

The Eastern harbour of Alexandria, Egypt is a relatively shallow semicircular bay, situated from longitudes 29° 53' to 29° 54' 40" E and latitudes 31° 12' to 31° 13' N (Fig.1). The harbour is surrounded by the city except on its northern side, where it communicates with the sea through two outlets. The area of the harbour is about 2.53X10<sup>6</sup> m<sup>2</sup>, with a maximum depth of 11 m (SELIM, 1997). The average water depth of the bay is about 6.0 m



**Fig. 1:** Location of the Eastern Harbour (E.H.) of Alexandria and sampling site.

and it receives many kinds of vessels, especially fishing boats (AL SAYES & SHAKWEER, 1997). Since 1977, the diversion of municipal wastewater into the harbour has rendered its water eutrophic (HALIM *et al.*, 1980). Although it is supposed that since 1999 the discharge of domestic sewage into the harbour has totally ceased, LABIB

(2002) mentioned that due to water circulation the harbour is subjected to an additional amount of municipal wastewater from the main sewer of Alexandria (Kayet Bey), located in its western vicinity (Fig.1).

Studies of fouling organisms in the Egyptian waters go back to BANOUB (1960), who investigated the succession of foul-

ing organisms settled on glass plates in the Eastern harbour of Alexandria, Egypt. He recorded 19 fouling species. The Eastern harbour of Alexandria has also been studied by MEGALLY (1970); GHOBASHY (1976); EL-KOMI (1991; 1992; 1998).

The present work aims to compare the fouling communities between the years 1960 and 1999 in the Eastern harbour of Alexandria, Egypt and to discuss the factors responsible for controlling these communities.

## Material and Methods

This work was carried out in the Eastern harbour of Alexandria, Egypt. Three replicate test panels fixed to a wooden rack suspended vertically 0.5 m under water level were used to collect monthly fouling samples from the harbour from October 1998 through September 1999.

The surface of the test panels facing seawater was roughened by using sand paper. These panels were regularly replaced every month.

A preliminary study was performed to compare two substrata (the smooth glass and the roughened polystyrene panels). Three smooth glass panels and 3 roughened polystyrene panels (each 12.5x12.5 cm) were immersed in seawater for one month during August (summer) 1998, before the survey was started. The fouling communities on these panels were weighed and identified to species level under (20X) zoom stereo-microscope.

It is worth mentioning that this work and all the previous studies in the Eastern harbour of Alexandria were carried out at the same place (panels were suspended vertically under the jetty of the National Institute of Oceanography and Fisheries, Alexandria, Egypt). The present comparison is based on monthly durations of panel immersion.

## Results

It is clear that there has been a variation in the number and diversity of fouling species throughout the last four decades (Table 1).

BANOUB (1960) investigated the foul-

ing organisms settled on glass plates for a period of 7 months from February to September 1958. He recorded 19 species of fouling organisms which represent the minimum diversity of fouling organisms in the Eastern harbour as compared with the other studies that followed. He mentioned that competition was very evident between the encrusted bryozoa and any other organisms. The most dominant species were the polychaete *Hydroides norvegica*, the barnacle *Balanus amphitrite* and the erect bryozoan *Bugula neritina*. As well, MEGALLY (1970) investigated the marine fouling organisms settled on glass plates for a period of 15 months from October 1968 to December 1969 and recorded 20 fouling species. The most dominant species were the polychaete *Hydroides norvegica*, the barnacle *Balanus amphitrite* and the erect bryozoan *Bugula neritina*. He found that all fouling organisms in the harbour showed marked seasonal variations in abundance.

GHOBASHY (1976) studied the monthly variation and settlement behaviour of the principal fouling organisms that settled on roughened panels made of impact-resistant polystyrene for a period of 12 months from March 1973 to February 1974. He recorded 23 species of fouling organisms and indicated that fouling occurred throughout the year but, the community might have been developing, flourishing and vanishing in a definite period of time. The most dominant species were the polychaete *Hydroides norvegica*, the barnacle *Balanus perforatus* and the erect bryozoan *Bugula neritina*. EL-KOMI (1991; 1992) studied the fouling organisms settled on roughened test panels made of polystyrene for periods of 12 and 14 months from March 1983 to February 1984 and October 1990 to November 1991, respectively. In 1991 he recorded 35 species of fouling organisms which represent the maximum diversity of fouling organisms recorded at the Eastern harbour, while in 1992 he recorded 29 fouling species. In the study of 1991, the most dominant species were the polychaete

**Table 1**  
**Fouling communities recorded on test panels between the years 1960 and 1999 at the Eastern Harbour of Alexandria.**  
**Data from Banoub (1960), Megally (1970), Ghabashy (1976), El-Komi (1991; 1992; 1998) and the present study.**

<i>Author</i>	<i>Banoub (1960)</i>	<i>Megally (1970)</i>	<i>Ghabashy (1976)</i>	<i>El-Komi (1991)</i>	<i>El-Komi (1992)</i>	<i>El-Komi (1998)</i>	<i>present study</i>
	Algae	Algae	Algae	Algae	Algae	Algae	Algae
	<i>Ectocarpus</i> sp.	<i>Enteromorpha compressa</i>	<i>Enteromorpha compressa</i>	<i>Uva intestinalis</i>	<i>Uva lactuca</i>	<i>Uva lactuca</i>	<i>Uva lactuca</i>
	<i>Enteromorpha</i> sp.	<i>Enteromorpha linza</i>	<i>Enteromorpha linza</i>	<i>Cladophora</i> sp.	<i>Enteromorpha</i> sp.	<i>Enteromorpha linza</i>	<i>Corallina officinalis</i>
	<i>Uva</i> sp.	<i>Uva lactuca</i>	<i>Uva</i> sp.	<i>Chaetomorpha</i> sp.	<i>Cladophora</i> sp.	<i>Chaetomorpha aera</i>	<b>Hydrozoa</b>
	<b>Porifera</b>	<i>Ectocarpus irregularis</i>	<i>Ectocarpus</i> sp.	<i>Enteromorpha</i> sp.	<i>Chaetomorpha</i> sp.	<i>Cladophora prolifera</i>	<i>Obelia geniculata</i>
	small unidentified specimen	<b>Erect Bryozoa</b>	<b>Hydrozoa</b>	<i>Ectocarpus</i> sp.	<i>Ectocarpus irregularis</i>	<i>Ectocarpus</i> sp.	<b>Erect Bryozoa</b>
	<b>Hydrozoa</b>	<i>Bugula neritina</i>	<i>Obelia geniculata</i>	<i>Ceramium</i> sp.	<b>Hydrozoa</b>	<i>Ceramium rubrum</i>	<i>Bugula neritina</i>
	<i>Sertularia</i> sp.	<i>Bugula avicularia</i>	<i>Tubularia larynx</i>	<b>Hydrozoa</b>	<i>Obelia geniculata</i>	<b>Hydrozoa</b>	<b>Encrusting Bryozoa</b>
	<i>Tubularia</i> sp.	<i>Zoobotryon pellucidus</i>	<b>Erect Bryozoa</b>	<i>Obelia geniculata</i>	<i>Obelia geniculata</i>	<i>Obelia geniculata</i>	<i>Cryptosula pallasiana</i>
	<b>Platyhelminthes</b>	<b>Encrusting Bryozoa</b>	<i>Bugula neritina</i>	<i>Tubularia larynx</i>	<i>Stylochus</i> sp.	<b>Nematoda</b>	<b>Polychaeta (Sed.)</b>
	unidentified specimen	<i>Schizoporella unicornis</i>	<i>Bugula avicularia</i>	<b>Platyhelminthes</b>	<b>Erect Bryozoa</b>	<i>Epsilonema</i> sp.	<i>Hydroides elegans</i>
	<b>Erect Bryozoa</b>	<i>Watersipora cucullata</i>	<b>Encrusting Bryozoa</b>	unidentified specimen	<i>Bugula neritina</i>	<b>Erect Bryozoa</b>	<b>Bivalvia</b>
	<i>Bugula neritina</i>	<b>Polychaeta (Sed.)</b>	<i>Schizoporella unicornis</i>	<b>Erect Bryozoa</b>	<i>Bugula turbinata</i>	<i>Bugula turbinata</i>	<i>Modiolus barbatus</i>
	<i>Bugula</i> sp.	<i>Hydroides norvegica</i>	<i>Watersipora cucullata</i>	<i>Bugula neritina</i>	<i>Bugula turbinata</i>	<i>Bugula turbinata</i>	<b>Cirripedia</b>
	<b>Encrusting Bryozoa</b>	<i>Spirorbis</i> sp.	<b>Polychaeta (Sed.)</b>	<i>Bugula turbinata</i>	<b>Polychaeta (Erra.)</b>	<i>Zoobotryon verticillatum</i>	<i>Balanus amphitrite</i>
	unidentified specimen	<i>Sabella pavonina</i>	<i>Hydroides norvegica</i>	<i>Zoobotryon</i> sp.	<i>Nereis diversicolor</i>	<b>Polychaeta (Erra.)</b>	<i>Balanus eburneus</i>
<b>Fouling communities</b>	<b>Polychaeta (Erra.)</b>	<b>Cirripedia</b>	<i>Spirorbis corrugatus</i>	<i>Bowerbankia</i> sp.	<b>Polychaeta (Sed.)</b>	<i>Nereis diversicolor</i>	<i>Balanus perforatus</i>
	<i>Nereis</i> sp.	<i>Balanus amphitrite</i>	<i>Dasydotea</i> sp.	<b>Encrusting Bryozoa</b>	<i>Hydroides elegans</i>	<i>Syllis</i> sp.	<i>Balanus</i> sp.
	<b>Polychaeta (Sed.)</b>	<i>Balanus eburneus</i>	<b>Cirripedia</b>	<i>Watersipora</i> sp.	<i>Spirorbis</i> sp.	<b>Polychaeta (Sed.)</b>	<b>Tanaidacea</b>
	<i>Hydroides norvegica</i>	<i>Balanus perforatus</i>	<i>Balanus amphitrite</i>	<b>Polychaeta (Erra.)</b>	<i>Pomatoecerus triquetter</i>	<i>Hydroides elegans</i>	<i>Tanais dilongii</i>
	<b>Bivalvia</b>	<i>Ciona intestinalis</i>	<i>Balanus eburneus</i>	<i>Nereis diversicolor</i>	<i>Serpula vermicularis</i>	<i>Serpula vermicularis</i>	<b>Isopoda</b>
	a single specimen	<i>Syella plicata</i>	<i>Balanus perforatus</i>	<i>Syllis</i> sp.	<i>Polydora ciliata</i>	<i>Polydora ciliata</i>	<i>Cirratana bovina</i>
	<b>Cirripedia</b>	<i>Syella plicata</i>	<i>Balanus perforatus</i>	<b>Polychaeta (Sed.)</b>	<i>Sabella</i> sp.	<i>Sabella pavonina</i>	<i>Sphaeroma walkeri</i>
	<i>Balanus amphitrite</i>	<b>Colonial Ascidian</b>	<b>Amphipoda</b>	<i>Hydroides elegans</i>	<b>Cirripedia</b>	<i>Sphaeroma serratum</i>	<i>Sphaeroma serratum</i>
	<i>Balanus eburneus</i>	<i>Didemnum gelatinosum</i>	<i>Jassa falcata</i>	<i>Spirorbis</i> sp.	<i>Balanus amphitrite</i>	<i>Balanus amphitrite</i>	<i>Paradella ditanae</i>
	<i>Balanus perforatus</i>	<i>Didemnum maculosum</i>	<i>Erichonius brasiliensis</i>	<i>Serpula vermicularis</i>	<i>Balanus eburneus</i>	<i>Balanus eburneus</i>	<i>Cymodoce truncata</i>
	<b>Solitary Ascidian</b>	<b>Solitary Ascidian</b>	<b>Solitary Ascidian</b>	<b>Cirripedia</b>	<i>Balanus trigonus</i>	<i>Balanus perforatus</i>	<b>Amphipoda</b>
	<i>Ciona</i> sp.	<i>Ciona intestinalis</i>	<i>Ciona intestinalis</i>	<i>Balanus amphitrite</i>	<b>Tanaidacea</b>	<i>Tanais carolinii</i>	<i>Corophium acutum</i>
	<i>Syella</i> sp.	<i>Syella plicata</i>	<i>Syella plicata</i>	<i>Balanus eburneus</i>	<i>Tanais carolinii</i>	<i>Tanais carolinii</i>	<i>Corophium sextonae</i>
	<b>Colonial Ascidian</b>	<b>Colonial Ascidian</b>	<b>Colonial Ascidian</b>	<i>Balanus perforatus</i>	<b>Isopoda</b>	<b>Amphipoda</b>	<i>Elaemopus pectenarius</i>

(continued)

Table 1. (Continued)

Author	Banoub (1960)	Megally (1970)	Ghobashy (1976)	El-Komi (1991)	El-Komi (1992)	El-Komi (1998)	present study
	unidentified specimen		<i>Diplosoma listerianum</i> <i>Botryllus schlosseri</i>	<i>Balanus trigonus</i> <b>Tanaidacea</b> <i>Tanais cavolinii</i>	<i>Cirrolana aegyptiaca</i> <i>Sphaeroma walkeri</i> <b>Amphipoda</b>	<i>Corophium sextoni</i> <i>Elasmopus pectenicrus</i> <i>Erichthonius brasiliensis</i>	<i>Podocerus variegatus</i> <i>Stenothoe gallensis</i> <i>Erichthonius brasiliensis</i>
			<b>Isopoda</b>	<i>Cymodoce truncata</i>	<i>Corophium sextoni</i>	<i>Jassa falcata</i>	<b>Decapoda</b>
				<i>Idotea baltica</i>	<i>Stenothoe gallensis</i>	<i>Halesoma</i> sp.	<i>Liocarcinus depurator</i>
				<i>Dynamene bideniata</i>	<i>Erichthonius brasiliensis</i>	<b>Solitary Ascidian</b>	
			<b>Amphipoda</b>	<b>Amphipoda</b>	<b>Pycnogonida</b>	<i>Ciona intestinalis</i>	
<b>Fouling communities</b>			<i>Corophium sextoni</i> <i>Elasmopus pectenicrus</i> <i>Stenothoe</i> sp.	<i>Corophium sextoni</i> <i>Elasmopus pectenicrus</i> <i>Stenothoe</i> sp.	<i>Pycogonum</i> sp. <b>Solitary Ascidian</b> <i>Ciona intestinalis</i>		
				<i>Erichthonius brasiliensis</i>			
				<i>Jassa falcata</i>			
				<i>Caprella equitibra</i>			
				<b>Colonial Ascidian</b>			
				<i>Diplosoma listerianum</i>			
				<i>Botryllus schlosseri</i>			
No. of fouling species	19 species	20 species	23 species	35 species	29 species	27 species	24 species
Nature of test panels	Smooth glass	Smooth glass	Roughened polystyrene	Roughened polystyrene	Roughened polystyrene	Iron slides	Roughened polystyrene
Dimensions of test panel	19 X 17 cm	12.5 X 20 cm	10 X 12.5 cm	15 X 15 cm	17.5 X 17.5 cm	7 X 2.5 cm	12.5 X 12.5 cm
Date of the experiment	Feb. to Sept. 1958	Oct. 1968 to Dec. 1969	March 1973 to Feb. 1974	Mar. 1983 to Feb. 1984	Oct. 1990 to Nov. 1991	Feb. 1992 to May 1993	Oct. 1998 to Sep. 1999

Sed. = Scedentaria, Erra. = Errantia

**Table 2**

**(a). List of fouling species recorded on roughened polystyrene and smooth glass panels experimented at the Eastern Harbour of Alexandria during the same period of immersion during summer 1998.**

Type of panel	Roughened Polystyrene panels	Smooth Glass panels
Recorded species	Cyanophycophyta layer	Cyanophycophyta layer
	<i>Ulva lactuca</i>	<i>Ulva lactuca</i>
	<i>Corallina officinalis</i>	<i>Bugula neritina</i>
	<i>Obelia geniculata</i>	<i>Hydroides elegans</i>
	<i>Bugula neritina</i>	<i>Balanus amphitrite</i>
	<i>Hydroides elegans</i>	<i>Tanais dulongii</i>
	<i>Balanus amphitrite</i>	<i>Corophium acutum</i>
	<i>Balanus perforatus</i>	<i>Stenothoe gallensis</i>
	<i>Tanais dulongii</i>	<i>Erichthonius brasiliensis</i>
	<i>Corophium acutum</i>	
	<i>Stenothoe gallensis</i>	
	<i>Erichthonius brasiliensis</i>	
	<i>Elasmopus pecteniscrus</i>	

**(b). Average number of species and total biomass  $\pm$  S.E. of fouling assembled on roughened polystyrene and smooth glass panels experimented at the Eastern Harbour of Alexandria during the same period of immersion during summer 1998.**

Type of panel	Roughened Polystyrene panel	Smooth Glass panel
Number of species/panel	10.3 $\pm$ 0.9	7 $\pm$ 0.6
Total biomass (gm)/panel	53 $\pm$ 3.4	38 $\pm$ 3.2

*Hydroides elegans*, the amphipods *Erichthonius brasiliensis*, *Corophium sextoni* and the erect bryozoan *Bugula neritina*, while in the study of 1992 the most dominant species were the polychaete *Hydroides elegans*, the barnacle *Balanus amphitrite*, the polychaete *Polydora ciliata* and the erect bryozoan *Bugula neritina*.

EL-KOMI (1998) studied the monthly fouling organisms settled on iron slides from February 1992 to May 1993. He recorded 27 species of fouling organisms in the harbour.

The most dominant species were the polychaete *Hydroides elegans*, the amphipod *Corophium sextoni* and the barnacles *Balanus eburneus* and *B. amphitrite*.

The present work refers to the biota settled on roughened polystyrene test panels for a period of 12 months from October 1998 to

September 1999 and records 24 species of fouling organisms. The most dominant species were the polychaete *Hydroides elegans*, the barnacle *Balanus amphitrite*, the amphipods *Corophium acutum* and *Elasmopus pecteniscrus*. As well as the experiment for the settlement of fouling on the roughened polystyrene and smooth glass, test panels revealed that the roughened ones collected more weight and fouling species than the smooth panels (Table 2).

Concerning the dominant groups, the results indicated that there is a shift from Polychaeta, Cirripedia and Bryozoa during the studies of 1960, 1970 and 1976 to Polychaeta, Amphipoda and Bryozoa during the study of 1991, and a return to the previous dominant groups in the study of 1992. The study of 1998 indicated that there was an-

other shift from Polychaeta, Cirripedia and Bryozoa to Polychaeta, Amphipoda and Cirripedia. Meanwhile, in the present study, the dominant groups are Polychaeta, Cirripedia and Amphipoda.

## Discussion

Recruitment of many sessile invertebrates is influenced by a variety of biological, chemical and physical factors (CRISP, 1984; PAWLIK, 1992; WALTERS *et al.*, 1997). The present results indicate that the maximum diversity of fouling organisms was recorded during the work of EL-KOMI (1991), while the minimum diversity was recorded during the work of BANOUB (1960).

Generally speaking, the fouling communities in the harbour consisted mainly of Algae, Hydrozoa, Bryozoa, Polychaeta, Cirripedia, Amphipoda and Ascidiacea (GHOBASHY, 1976).

BANOUB (1960) indicated the appearance of detrital tubes during the period (May-September, 1958) and he thought that the builder of these tubes was either an amphipod or a worm, since neither of these had been found inside the tubes. GHOBASHY (1976) mentioned the occurrence of Amphipoda tubes and he recorded two species *Jassa falcata* and *Erichthonius brasiliensis*. Moreover, he added that Megally (1970) did not refer to Amphipoda tubes although their attachment constitutes one of the characteristics of this harbour fouling. From these, it could be concluded that during the studies of (1960 and 1970), the Amphipoda group was represented but the authors did not mention the appearance of any species of this group.

The present comparison revealed the appearance of 15 fouling groups in the Eastern harbour of Alexandria. These groups are Algae, Porifera, Hydrozoa, Nematoda, Platyhelminthes, Bryozoa, Polychaeta, Bivalvia, Cirripedia, Tanaidacea, Isopoda, Amphipoda, Decapoda, Pycnogonida and Ascidiacea.

The distribution of fouling groups varies from one study to another, but there are

groups which appeared in all studies (Algae, Bryozoa, Polychaeta and Cirripedia). The groups Hydrozoa and Ascidiacea appear in all studies except one. On the other hand, there are animal groups like Porifera, Nematoda, Decapoda, Pycnogonida which were recorded only in one study. Bivalvia appear in the studies of BANOUB (1960) and the present work. Platyhelminthes were recorded during the studies of BANOUB (1960) and EL-KOMI (1991, 1992). Tanaidacea appear in the studies of EL-KOMI (1991, 1992, and 1998) and in the present work. The Isopoda group appear in the present study and the studies of EL-KOMI (1991 and 1992).

It is clear that, the appearance or disappearance of animal groups may be related to some environmental changes in the Eastern harbour. BANOUB (1960) mentioned that the Alexandria sewage pumping station discharged very near to the harbour, which was occasionally slightly affected. MEGALLY (1970) indicated that the harbour was moderately polluted due to both sewage disposal and waste material dumped from fishing boats.

Pollution creates major differences in community structure (MORAN & GRANT, 1991). It is worth mentioning that the discharge of domestic sewage into the harbour started in 1977 (HALIM, 1980). During 1983, a total of 230,137 m<sup>3</sup>/day of this waste was discharged in the Eastern harbour. At Kayet Bey pumping station, 200,000 m<sup>3</sup> of wastes were discharged daily into the open sea and the remainder was discharged into the Eastern harbour of Alexandria. This means that the daily amount of discharge of domestic sewage inside the harbour was 30,137 m<sup>3</sup> / day in 1983. This amount varied with time. It gradually increased to reach 63,014 m<sup>3</sup> / day in 1986 (SAID & MAIYZA, 1987) and 95,134 m<sup>3</sup> /day in 1987 (FARAGALLAH, 1995). Recently during 1999-2000, after the construction of the western treatment plant (which primarily treats the sewage and industrial wastes from the central and western parts of Alexandria), the discharge of domes-



tic sewage inside the harbour totally ceased and the daily discharge into the open sea decreased to reach 140,000 m<sup>3</sup>/day and 50,000 m<sup>3</sup>/day from the main Kayet Bey pipeline and El-Silslla outfall respectively (JAMMO, 2001). The waste discharged from the Kayet Bey pipeline may enrich the environment inside the harbour with nutrients, depending on the direction of both water current and wave action.

Nutrient enrichment significantly affects the composition of marine fouling communities (RASTETTER & COOKE, 1979). The discharge of sewage can stimulate autotrophic production in planktonic food sources and in the fouling community itself, or depress the abundance of species sensitive to toxins in the effluent and low oxygen levels associated with eutrophication. Biotic diversity in terms of species number usually increases when pollution is moderate (MOR *et al.*, 1970), but drops again in heavily disturbed areas. This was the case in 1983 when the daily amount of discharge of domestic sewage inside the harbour was moderate, reaching 30,137 m<sup>3</sup>/day. This amount may support the maximum diversity of fouling organisms (35 species) in the Eastern harbour during the study of EL-KOMI (1991), meanwhile the increased or the decreased amounts of domestic sewage inside the harbour may not support the settlement of larger numbers of fouling organisms. That is to say that the daily amount of about 30,000 m<sup>3</sup>/day of sewage may be the optimum amount for fouling diversity in the Eastern harbour.

It is well established that most of the sedentary animals settle preferably on rough rather than on smooth surfaces (RAMADAN, 1986; MCGUINNESS & UNDERWOOD, 1986; MCGUINNESS, 1989; ANDERSON & UNDERWOOD, 1994). Indeed, a preliminary study in the Eastern harbour of Alexandria indicated this. The roughened polystyrene panel hosted more species with higher biomass (10.3±0.9 species and 53±3.4 gm respectively) than the smooth glass panel with the same area (7±0.6 species and 38±3.2 gm)

during the same period of immersion (Table 2). This may be an explanation of the low diversities of fouling organisms during the studies of (1960 & 1970) which used smooth glass surfaces.

The present comparison revealed that the polychaete *Hydroides elegans* was the most dominant species in all the studies. It is worth noting that the previous studies in the Eastern harbour (1960, 1970 and 1976), mentioned *Hydroides elegans* as *H. norvegica*. ZIBROWIUS (1971) discriminated between the two similar species in the shape of byonet setae and in the operculum, as well as in the habitats. *H. elegans* is an introduced species commonly found in Mediterranean harbours and polluted waters while *H. norvegica* inhabits deeper, unpolluted waters. SCHELEMA (1975) reported that the calcareous tube worm *Hydroides* is an important fouling organism in warm temperate and tropical seas. Moreover, it has already been shown that the development of an epibenthic community is influenced by interspecific or intraspecific epigrowth competitions. Despite the fact that epigrowth competitions should be far more frequent on smaller panels than on larger ones, LEVIN & PAINE (1974) observed that on a larger surface where many species compete for the available space, the chances of survival in the presence of spatial competition are relatively small. KARANDE & SWAMI (1988) indicated that the polychaete *Hydroides* showed no preference for any particular area. This may favor the dominance of this species in any panel area.

The comparison indicated that there is a small shift between the four dominant groups (Polychaeta, Cirripedia, Bryozoa and Amphipoda) during the four decades of studies.

Regarding the results of dominant species, there are few alien species occurring in the harbour. Alien species are those occurring outside their historically known range as a result of direct or indirect introduction or care by humans (ZENOTOS *et al.*, 2005). In the Mediterranean Sea the polychaete *Hydroides elegans* is considered as a cryp-

togenic invasive species and the amphipod *Elasmopus pecteniscus* is an established alien species (ZENOTOS *et al.*, 2005). The cryptogenic species are those whose probable introduction has occurred in early times (ZENOTOS *et al.*, 2005). This may explain the early records of *Hydroides elegans* in many parts of the Mediterranean Sea. In spite of the fact that the barnacle *Balanus amphitrite* is a tropical species, it exists in the Mediterranean and Black Sea areas, as well as in harbours on the Atlantic coast (SOUTHWARD & CRISP, 1963). It may migrate to the Mediterranean through the Suez Canal or it may transfer to the northern areas with fouling on ship's hulls. The barnacle *Balanus perforatus* is a southern species, occurring in the Mediterranean and along the eastern Atlantic seaboard from south-west Wales to West Africa (CRISP & SOUTHWARD, 1953). Of the other dominant species, the erect bryozoan *Bugula neritina* is found in numerous temperate and subtropical regions worldwide (RUSSELL *et al.*, 1999); *Erichthonius brasiliensis*, *Corophium sextoni* and *C. acutum* are the best known amphipod fauna of the north-east Atlantic and the Mediterranean region (RUFFO, 1982; 1989 and 1993). The abundance of *Erichthonius brasiliensis* and *Corophium sextoni* during the study of EL-KOMI (1991) may be related to available food content (total phytoplankton and/or total zooplankton) which depends on the nutrient enrichment of the harbour. RUFFO (1998) reported that the littoral amphipods seem to be greatly impacted by variations in food sources and temperatures.

Results of non-dominant species in the harbour during the four decades of study indicated that the barnacles *Balanus eburneus* and *B. trigonus* are cryptogenic established species, while the amphipod *Stenothoe galensis* and the isopods *Sphaeroma walkeri* and *Paradella dianae* are regarded as established alien species (ZENOTOS *et al.*, 2005).

## References

- AL SAYES, A.A. & SHAKWEER, L.M., 1997. Development of fouling organisms on fishing net materials in relation to the environmental conditions in the Eastern Harbour (Alexandria, Egypt). *Bulletin of National Institute of Oceanography and Fisheries*, A.R.E., 23: 351-388.
- ANDERSON, M.J. & UNDERWOOD, A.J., 1994. Effects of substratum on the recruitment and development of an intertidal estuarine fouling assemblage. *Journal of Experimental Marine Biology and Ecology*, 184: 217-236.
- ANON, 1952. Marine Fouling and its prevention. U.S. Naval Institute, Annapolis, Maryland, 388p.
- BANOUB, M.W., 1960. Notes on the fouling of glass plates submerged in the Eastern Harbour. Alexandria, 1958. *Alexandria Institute of Hydrobiology, Notes and Memories*, 64: 1-17.
- CAI, L. & LI, F., 1990. Temporal and spatial variations of quantity of shipworm *Teredo Navalis* in Xiamen harbour. *Journal of Oceanography*, Taiwan Strait / Taiwan Haixia, Xiamen, 9, (3): 212-216.
- CRISP, D.J. & SOUTHWARD, A.J., 1953. Isolation of intertidal animals by sea barriers. *Nature*, 172: 208-209.
- CRISP, D.J. 1984. Overview of research on marine invertebrate larvae, 1940-1980. p. 103-126. In: *Marine biodeterioration: an interdisciplinary study*, edited by J.D. Costlow & R.C. Tipper, Annapolis, Maryland, Naval Institute Press.
- EL-KOMI, M.M., 1991. Incidence and Ecology of marine fouling organisms in the Eastern Harbour of Alexandria, Egypt. *Bulletin of National Institute of Oceanography and Fisheries*, A.R.E., 17, (1): 1-16.
- EL-KOMI, M.M., 1992. Field and laboratory studies on the ecology of marine fouling in Alexandria harbour, Egypt. *Bulletin of National Institute of Oceanography and Fisheries*, A.R.E., 18: 115-140.

- EL-KOMI, M.M., 1998. Spatiotemporal distribution of fouling and plankton composition in the coastal waters of Alexandria, Egypt. *Journal of the Egyptian German Society of Zoology*, (D- Invertebrate Zoology and Parasitology), 27: 183-207.
- FARAGALLAH, H.M.M., 1995. Sediment-water interface chemistry in the Eastern Harbour, Alexandria. M.Sc.Thesis, Faculty of Science, Alexandria University, 277p.
- GALLUZZO, G., 1980. Study of Catania harbour's fouling communities: Bryozoans. *Memorie di biologia marina e di Oceanografia*. Messina, 10, (6): 187-192.
- GHOBASHY, A.F.A., 1976. Seasonal variation and settlement behavior of the principal fouling organisms in the Eastern Harbour of Alexandria. *Proceeding of the 4<sup>th</sup> international Congress on Marine Corrosion & Fouling*, p. 213-220.
- GORDON, D.P. & MAWATARI, S.F., 1992. Atlas of marine fouling Bryozoa of New Zealand ports and harbours. *Miscellaneous Publication of New Zealand Oceanographic Institute*, 107: 1-52.
- HALIM, Y., KHALIL, A. & AL-HANDHAL, A.Y., 1980. Diatoms flora of a eutrophic bay, the Eastern Harbour of Alexandria. *Acta Adriatica*, 21, (2): 271-298.
- HUANG, Z., CAI, E. & CAI, R., 1982. Studies on the ecology of fouling organisms of Qinglan harbour. *Acta Oceanologica Sinica*, 4, (2): 215-222.
- JAMMO, K.M., 2001. Water quality and level of some trace elements and their effects on phytoplankton availability in the Alexandria Eastern Harbour, Egypt. M.Sc. Thesis, Faculty of Science, Alexandria University, 275p.
- KARANDE, A.A. & SWAMI, B.S., 1988. Importance of test coupons in the assessment of marine biofouling community development in the coastal waters of Bombay, India. *Indian Journal of Marine Science*, 17: 317-321.
- LABIB, W., 2002. Phytoplankton variability in the Eastern Harbour (Alexandria, Egypt). *Egyptian Journal of Aquatic Biology and Fisheries*, 6, (2): 75-102.
- LEPORE, E. & GHERARDI, M., 1977. Osservazioni sul Fouling del porto di Brindisi (Adriatico meridionale). *Oebalia*, III: 65-84.
- LEVIN, S.A. & PAINE, R.T., 1974. Disturbance, patch formation, and community structure. *Proceedings of the National Academy of Sciences of the United States of America*, 71: 2744-2747.
- LI, C., HUANG, Z., ZHENG, C. & WANG, J., 1996. Ecological studies on fouling organisms in Shantou harbour. *Journal of Oceanography*, Taiwan Strait / Taiwan Haixia, 15, (1): 19-24.
- MCGUINNESS, K.A. & UNDERWOOD, A.J., 1986. Habitat structure and the nature of communities on intertidal boulders. *Journal of Experimental Marine Biology and Ecology*, 104: 97-123.
- MCGUINNESS, K.A., 1989. Effects of some natural and artificial substrata on sessile marine organisms at Galeta Reef, Panama. *Marine Ecology Progress Series*, 52: 201-208.
- MEGALLY, A.H., 1970. Ecological study on marine fouling organisms in the Eastern Harbour of Alexandria. M. Sc. Thesis, Faculty of Science, Alexandria University, 240p.
- MOR, E., SESSI, E. & RELINI, G. 1970. Fouling di zone inquinate. Osservazioni nel Porto di Genova. Caratteristiche ambientali e metodi di studio. *Pubblicazioni della Stazione Zoologica di Napoli*, 38: 34-54.
- MORAN, P.J. & GRANT, T.R., 1991. Transference of marine fouling communities between polluted and unpolluted sites: Impact on structure. *Environmental Pollution*, 72: 89-102.
- NAIR, U.N. & NAIR, N.B., 1987. Marine biofouling dynamics in and around the Cochin harbour, *Proceedings of the National seminar on Estuarine Management*, Trivandrum. P.501-510.

- PAWLIK, J.R., 1992. Chemical Ecology of the Settlement of Benthic Marine Invertebrates. *Oceanography and Marine Biology: An Annual Review*, 30: 273-335.
- RAMADAN, S.H.E. 1986. Ecological and systematic studies on the marine fouling of the northern part of the Suez canal. Ph.D. Thesis, Faculty of Science, Mansoura University, 428p.
- RASTETTER, E.B. & COOKE, W.J., 1979. Responses of marine fouling communities to sewage abatement in Kaneohe Bay, Oahu, Hawaii. *Marine Biology*, 53:271-280.
- RIGGIO, S. & MAZZOLA, A., 1976. Preliminary data on the fouling communities of the harbour of Palermo (Sicily). *Archo di Oceanografia e Limnologia*. 18 suppl, 3: 141-151.
- RUFFO, S., 1982. The Amphipoda of the Mediterranean, part 1 (Gammariidea), *Mémoires de L'Institut Océanographique*, Monaco, N° 13:1-364.
- RUFFO, S., 1989. The Amphipoda of the Mediterranean, part 2 (Gammariidea to lysianassidae), *Mémoires de L'Institut Océanographique*, Monaco, N° 13: 365-576.
- RUFFO, S., 1993. The Amphipoda of the Mediterranean, part 3. [Gammaridea aridea (Melphidippidae to Talitridae), Ingolfiellidea, Caprellidea], *Mémoires de L'Institut Océanographique*, Monaco, N° 13:577-814.
- RUFFO, S., 1998. The amphipoda of the Mediterranean, part 4 (Addenda to parts 1-3, Key to families, Ecology, Faunistics and Zoogeography, Bibliography, Index), *Mémoires de L'Institut Océanographique*, Monaco, N° 13:815-959.
- RUSSELL, G.K., RICHARD, V. & STACEY, S.K., 1999. Identification and Biosynthetic Origins of Sterols in the Marine Bryozoan *Bugula neritina*. *Journal of Natural Production*, 62: 468-470.
- SAID, M.A. & MAIYZA, I.A., 1987. Effect of municipal sewage discharge on the hydrographic regime of the Eastern Harbour of Alexandria. *Bulletin of Institute of Oceanography and Fisheries*, A.R.E., 13(2): 1-20.
- SCHELTEMA, R.S., 1975. The significance of pelagic larval development to marine fouling organisms. P. 27-47. *Proceedings of the U.S. - U.S.S.R. workshop*, edited by J.D.Costlow, 16-23 November.
- SELIM, S.A., 1997. Assessment of polychaete fauna in the Eastern Harbour of Alexandria, Egypt. *Bulletin of High Institute of Public Health*, 27, (1): 131-146.
- SOUTHWARD, A.J. & CRISP, D.J. 1963. Barnacles of European waters, Catalogue of main marine fouling organisms, Volume 1. Barnacles. O.E.C.D. Publications, 46p.
- WALTERS, L.J., HADFIELD, M.G. & DEL KARMEN, K.A., 1997. The importance of larval choice and hydrodynamics in creating aggregations of *Hydroides elegans* (Polychaeta: Serpulidae). *Invertebrate Biology*, 116: 102-114.
- WISELY, D., 1959. Factors influencing the settling of principal marine fouling organisms in Sydney harbour. *Australian Journal of Marine and Freshwater Research*, 10, (1): 30-44.
- ZIBROWIUS, H., 1971. Les espèces Méditerranéennes du genre *Hydroides* (polychaeta, Serpulidae). *Tehtys*, 2: 691-746.
- ZENETOS, A., CINAR, M.E., PANCUCCI-PAPADOPOULOU, M.A., HARME-LIN, J.G., FURNARI, G., ANDALORO, F., BELLOU, N., STREFTARIS, N. & ZIBROWIUS, H., 2005. Annotated list of marine alien species in the Mediterranean with records of the worst invasive species. *Mediterranean Marine Science*, 6, 2: 63-118.

*Accepted in April 2007*

