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IMPACTS OF ENVIRONMENTAL CONDITIONS ON MACRO-BENTHIC DISTRIBUTION ALONG THE SUEZ GULF, EGYPT

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ABSTRACT: Increases in coastal development and human activities leading to sedimentation degrade the quality of water; disturb the natural structure and functions of aquatic communities. The Suez Gulf is a large semi-closed area (~ 625 km long coastline).The assemblages of bottom fauna were studied qualitatively and quantitatively in the shallow intertidal waters along the western coast of the Suez Gulf. The quality of seawater and sediment structures were analyzed. The distribution of macro-benthos included a total of 38 species of Gastropoda and 9 Bivalvia; and 25 species from the other invertebrates included 7 groups namely, Rhizostoma, Polychaeta, Cirripedia, Amphipoda, Isopoda, Decapoda and Echinodermata. The most dominant group among invertebrate groups was the Polychaeta which included 4 species-*Hydroides elegans, Perinereis cultilifera, Perinereis nuntia* and *Ophelina acuminata.* The Cirripedia were represented by 3 species namely, *Balanus amphitrite, Chthamalus challengeri* and *Tetraclita squamosa.* The variations in the numerical abundance and biomass of bottom fauna studied between the observation periods and at sampling sites. There was a marked increase in benthos biomass at St. IV (Ras Gharib) yielding an average of 318.8 g/m^2 in which the gastropod community represented the dominant species in collected samples reaching 270.28 g/m^2 (84.4% of the total biomass) and numerically numbered 116 ind./m^2. Veliger Larvae of bivalves and gastropods appeared to be present in the plankton for long periods and their production seems to be continuous throughout the year. In the intertidal zone of the Suez Gulf, the values of pH varied within narrow limits. Water temperature and salinity seemed to be important in the distribution and abundance of the macro-benthos communities in the study areas. The organic content in shallow intertidal waters and sediments indicated high values in the central part of the Gulf of Suez.

KEY WORDS: Suez Gulf, benthic density, Mollusca, Polychaeta, meroplankton, physiochemical parameters - impact assessment of pollution.

INTRODUCTION

The Suez Gulf is a large semi-closed area with a ~ 350 km long coastline on its western side and a ~275 km long coastline on the eastern side with a relatively shallow flat bottom compared to the Red Sea and Aqaba Gulf, and depths do not exceed 90 m (Badr and Crossland, 1939; Nawar, 1981). It has a high percentage of immigrant species belonging to the Indo-Pacific region in comparison to the percentage of immigrant species belonging to the Mediterranean Sea and none of the endemic species recorded from the Red Sea (Goldschmid, 1999).

Marine invertebrates of the Red Sea are considered one of the richest western Indo-Pacific fauna. Studies on the macro-benthic organisms of the Red Sea including molluscs published by Adam (1958); Engle and Van Eekn (1960); Leloup (1960); Kohn (1965); Biggs and Wilkinson (1966), Fishelson (1971), Yaron (1979); Ayal and Safriel (1981) and Hassan (1983).The spatial distribution of the macro-benthos in the shallow intertidal region along the coastline of the Suez Gulf was studied by El-Komi (1996, 1997).

Many man made structures around the Suez Gulf are associated with oil production and the tourism. Little attention has been paid to study the marine benthos around the Sinai region except for the recently published work on the ecology and distribution of benthos fauna in the shallow waters of Red Sea by Fishelson(1971), the impact of the coastal development of the marine life of the Jordanian coast of the Aqaba Gulf by Mahasneh and Meinesz(1984), the impact of the human activities on the giant clam *Tridacna maxima*, near Jeddah, Red Sea by Bodoy(1984), the impact assessment of pollution on the benthos structure by Hartnail,(1984) and the corals on the fringing reefs near Jeddah by Antonius(1984).

During the last three decades, increased coastal development and human activities leading to sedimentation has degraded quality water, disturbing the natural structure and functions of aquatic communities. Changes in habitats include benthic assemblages with negative effects on the spatial distribution of aquatic organisms, decreasing value of fisheries and recreational areas. In general the marine life along the coast is threatened by increased activities associated with the economics. The coral reefs dominate most of the Red Sea and Suez Gulf coastlines and are a lucrative and essential economic resource. Coral reefs are however extremely fragile and, require protection and management. These communities are important as a protection against sea erosion, a rich area of coral fish and an attractive area for diving and tourism (Smith, 1991). Therefore, it must be protected because uncontrolled exploitation is threatening the living reef associations.

The objective of this study is to compare geographical distribution of macro-benthic organisms in the shallow intertidal region along the western coast of the Suez Gulf, to assess the risk of pollution, and the consequence anthropogenic impacts on the marine ecosystem and the structure of aquatic communities.

MATERIAL AND METHODS

Area of study:

The macro-benthic fauna of the shallow intertidal waters of the western coast of the Suez Gulf and the physico-chemical parameters were collected seasonally from seven stations during the period extended from May 1995 to April 1996 (Fig. 1).

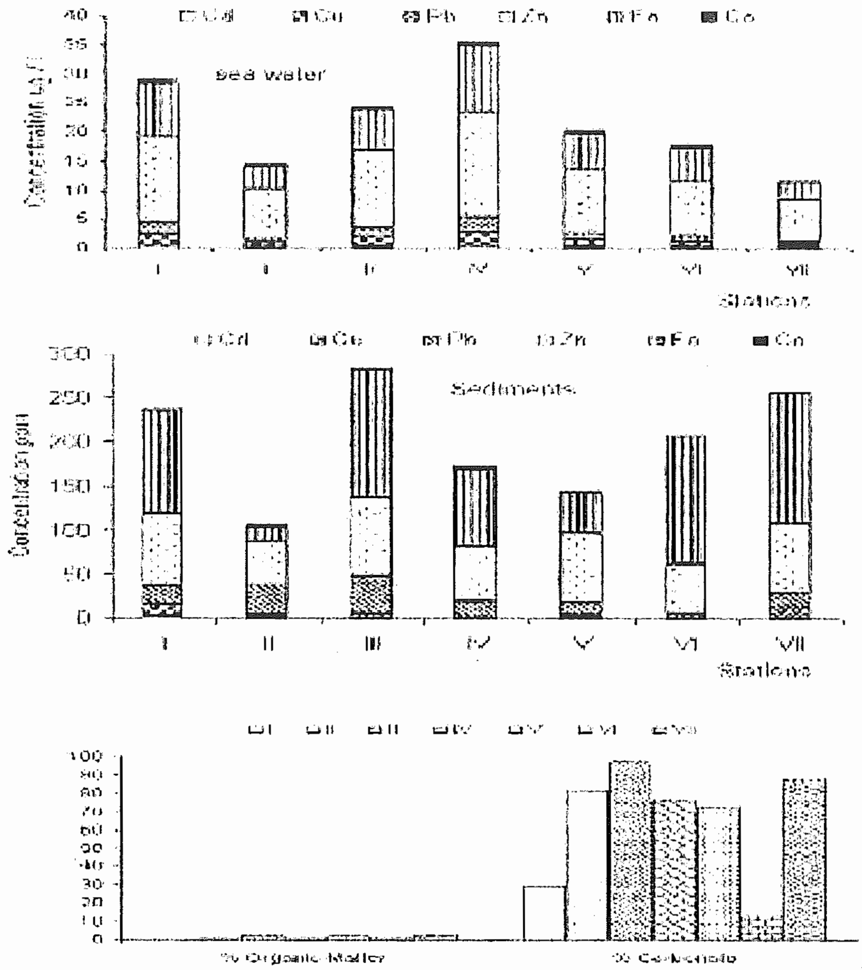

Fig. 1. Map showing sites of the sampling along the Suez Gulf, Egypt.

Adabiya (St. I): This site is exposed to three sources of pollution, domestic drainage, oil refineries and shipping effluent.

El-Ein El-Sukhna (St. II): This site is 10 kms from the SUMED oil pipeline (78 x 10^6 ton/yr in 1981 as was reported by Mancy, 1983) at El-Ein El-Sukhna.

Zaafarana (St.III): This site has a limited amount of oil pollution from shipping effluent.

Ras-Gharib (St. IV): This site is affected by city sewage in addition to the oil pollution from the terminal which produces 1.1 x 10^6 ton/yr (Mancy, 1983).

Ras-Shukeir (St. V): This site is near the oil production company terminals, GAPICO of Ras-Gharib and Ras-Shukeir. It serves as center for oil exploitation activities,oil collection and shipment of oil from oil fields including off shore wells.

Gabal El-Zeit (St. VI): This site has a wide intertidal flat with slight oil pollution being evident along its coast. Strong agitation and upwelling of water were observed for most of the year (El-Sabah and Beltagy, 1983).

Hurghada (St. VII): This site has localized pollution problems mainly due to increasing coastal development activities including large urbanization, tourist centers, and industrial development with indications of coastal oil pollution around the harbour.

Ecological procedures:

During the initial detailed surveys a series of transects perpendicular to the shoreline were carried out at regular intervals. At each transect, quantitative random samples were collected from the sampling sites within a frame quadrate (equivalent to $1m^2$) at intervals of 5 m from the high water mark to about 20 m offshore. Each sample was washed in the field through 0.75-mm mesh sieve to separate the macro-benthos organisms from the sediment. The material retained by the sieve was placed in polythene bag, labeled and frozen until sorting could be carried out in the laboratory. During sorting, the organisms in each sample were carefully removed, identified into species and preserved in 5-10% formalin solution in seawater.

The samples of zooplankton were collected by means of a plankton net with a mesh of ~ 100 microns. At each site a known volume of seawater ($100cm^3$) was filtered and fixed in 5% formalin solution. In the laboratory the numerical density of zooplankton organisms and the species composition were determined and expressed as the number of individuals per cubic meter.

Hydrographical measurements of seawater were analyzed from samples which were collected seasonally from all stations and included surface seawater temperature, hydrogen ion concentration, salinity, dissolved oxygen, chemical oxygen demand, biological oxygen demand and heavy metals in seawater, the analysis of sediments included heavy metals content, size composition, organic matter, carbonate content and state of pollution.

RESULTS

Hydrographical conditions:

As shown in Table 1 the surface seawater temperature in the Gulf of Suez dropped to 16.43°C mean (SD $\pm$ 0.62) in winter and the highest mean was 27.21 °C (SD$\pm$0.7) in summer. The mean values of the salinity ranged from 39.45 ‰ to 41.44 ‰ (SD $\pm$ 0.39-0.6) at the sampling sites during the different seasons. The values of pH of sea water showed a narrow limit of 8.13-7.90 mean (SD $\pm$ 0.09-0.13). The dissolved oxygen showed low fluctuations whereas the mean values were varied from 4.72 to 5.38 mg O_2/1 (SD $\pm$ 0.62-0.71). The mean values of the chemical oxygen demand (COD) and the biological oxygen demand (BOD) were low at the sampling sites during different seasons.

TABLE 1. Seasonal variation in the values of various physico-chemical parameters of the surface seawater measured at different stations along the western coast of the Suez Gulf, during May 1995 to April 1996.

Parameter	Stations	Winter	Spring	Summer	Autumn
T (°C)	I	15	23	26	16
	II	16	27	27	18.5
	III	17	25	27.5	16
	IV	17	24.5	28	19
	V	17	25	27	18.5
	VI	17	23.5	27	16
	VII	16	25	28	20
Mean		16.43	24.71	27.21	17.71
SD		0.79	1.29	0.70	1.68
pH	I	8.13	8.16	8.32	7.88
	II	8	8.24	8.26	7.9
	III	8.11	8.18	8.26	8
	IV	8.3	8.32	8.31	8.14
	V	8.14	8.16	8.27	7.83
	VI	8.12	8.2	8.28	7.8
	VII	8.13	8.17	8.22	7.78
Mean		8.13	8.20	8.27	7.90
SD		0.09	0.06	0.03	0.13
S (‰)	I	39.14	40.13	40.33	39.54
	II	39.73	40.48	41.43	40.11
	III	39.64	50.53	41.36	40.01
	IV	39	40.2	41.1	39.35
	V	39.4	40.43	41.82	40.13
	VI	40.11	40.8	42.1	40.22
	VII	39.16	40.84	41.91	40.5
Mean		39.45	40.49	41.44	39.98
SD		0.39	0.27	0.60	0.40
DO_2 (mg/L)	I	5.22	5.47	4.8	5.8
	II	5.47	6	5	6.42
	III	5	5.2	4.7	5.53
	IV	3.75	4.15	3.45	4.52
	V	4.05	4.48	3.73	4.92
	VI	4.7	4.46	5.45	5.12
	VII	4.82	5.12	4.38	5.33
Mean		4.72	4.98	4.50	5.38
SD		0.62	0.65	0.71	0.62

Table 1 Continued….

Parameter	Stations	Winter	Spring	Summer	Autumn
COD	I	1.9	2.43	0.7	2.77
	II	1.96	2.31	0.73	3.2
	III	1.18	2.2	0.68	3
	IV	0.37	1.22	0.6	1.38
	V	1.02	1.18	0.64	1.57
	VI	1.3	1.33	0.71	1.57
	VII	1.3	1.78	0.73	2
Mean		1.34	1.78	0.68	2.59
SD		0.45	0.54	0.05	0.28
BOC	St. I	2.74	3.23	2.65	3.38
	St. II	2.99	3.36	2.75	3.78
	St. III	2.79	3.06	2	3.66
	St .IV	2.15	2.3	1.76	2.58
	St. V	2.45	2.74	1.85	2.93
	St. VI	2.63	2.81	2.04	3
	St. VII	2.38	3.14	2.16	3.45
Mean		2.21	2.95	2.17	3.25
SD		0.76	0.36	0.38	0.43

Heavy metals in water:

Data analysis of heavy metal content in the shallow intertidal waters is given in Fig. 2. It reveals that concentration of Cadmium (Cd), Copper (Cu), Lead (Pb), Zinc (Zn), Iron (Fe) and Cobalt (Co) were higher in particular at St. IV (Ras Gharib). Their mean values were measured 0.31 ug/l (SD 0.14), 1.29 ug/l (SD ±0.6), 1.35 ug/l (SD ± 0.75), 11.68 ug/l (SD ±3.92), 6.69 ug/l (SD ± 2.91) and 0.64 ug/l (SD ±0.17) respectively.

Heavy metals in sediments (ppm dry weight):

As shown in Fig. 2 the heavy metal contents in sediments at the sampling sites were relatively high at St. III in Pb and Zn (mean 21.11 ppm, SD ± 12.49 and 71 ppm, SD ±15.03 respectively), at St. I in Cd and Cu (mean 1.43 ppm, SD ± 0.53, 5.30 ppm, SD ± 5.18), at St. VII in Fe (mean 100.17 ppm, SD ± 53.89) and at St. II in Co (mean 3.1 ppm, SD ±1.28).996.

Organic matter in sediment:

The organic matter in the present study is one of the most important sediment components. Its presence in sediments is due to decomposition of plant and animal residues through the action of bacteria. At most of the sampling sites the mean percentage of organic content in sediment was very low at St. IV (0.37 %) but relatively high at St. I (2.67 %) with mean 1.62, SD ± 1.05.

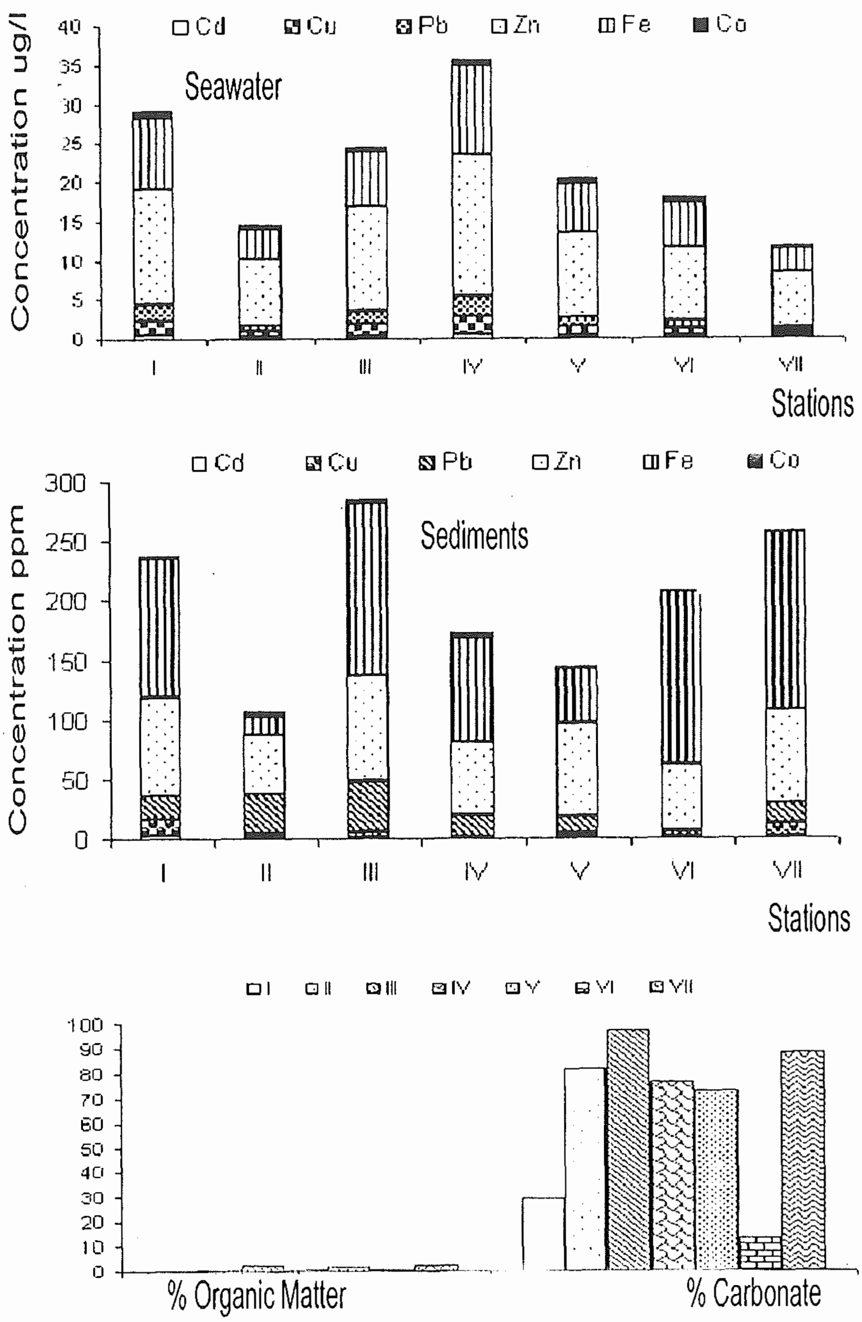

Fig. 2. Average values of heavy metals determined in seawater and in sediments and the percentage of organic and carbonate content in sediments in the Suez Gulf during May 1995 to April 1.

Carbonate content (CaCO3):

The carbonate in sediments at most of the sampling sites ranged from 13.33% at St. VI to content highest percentage 97.33 at St. III with a mean percentage of 65.62%, SD ±31.61.

Appendix (TABLE 1) Seasonal average of the density (no.org./m^2) of the bottom funa recorded along the western coast the Suez Gulf through year 1995.

Species /Stations	I	II	III	IV	V	VI	VII	Total	Average
Rhizostoma:									
Cassopeia sp.	0.5	0.8	0.0	0.0	0.0	0.0	0.3	1.5	0.2
Polychaeta									
Hydroides elegans (Haswell, 1883)	1.0	0.0	0.0	0.3	0.0	0.3	0.3	1.8	0.3
Perinereis cultilifera percipili (Gube,1840)	0.8	1.0	0.3	0.8	0.0	0.5	0.5	3.8	0.5
Perinereis nuntia heterodonta (Gravier, 1899)	2.0	0.3	0.3	0.5	0.0	0.3	0.0	3.3	0.5
Ophelina acuminate Orested, 1843	0.0	1.0	0.0	0.3	0.0	0.8	0.5	2.5	0.4
Cirripedia:									
Balanus amphirite var.denticulata Broch, 1927	1.0	0.0	1.0	1.0	0.0	1.0	0.3	4.3	0.6
Chthamalus stellatus Poli, 1795	0.5	0.0	0.0	1.0	0.0	0.3	0.0	1.8	0.3
Tetraclita squanosa Bruguiere, 1792	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.1
Amphipoda									
Corophium volutator Pallas	0.5	0.0	0.0	0.0	0.3	0.5	0.3	1.5	0.2
Elasmopus pectenicrus (Bate) Walkeri, 1904	1.0	0.8	0.5	0.8	1.0	1.5	1.8	7.3	1.0
Gammarus sp.	0.8	0.0	0.0	0.0	0.0	0.5	0.0	1.3	0.2
Stenothoe gallenesis Walkeri, 1904	0.8	0.3	0.3	0.5	0.0	1.0	0.5	3.3	0.5
Isopoda:									
Cymodoce truncate Leach, 1814	1.0	0.0	0.3	0.3	0.0	1.0	0.8	3.3	0.5
Sphaeroma serratum Fabricius, 1787	1.0	0.8	0.5	0.5	1.0	1.5	1.0	6.3	0.9
Decapoda									
Anapagrus sp.	0.0	0.5	0.0	0.0	0.3	0.0	2.3	3.0	0.4
Leptodius exaratus	0.0	0.5	0.0	0.5	0.0	0.8	0.5	2.3	0.3
Lissocarcinus sp.	0.3	0.0	0.0	0.3	0.0	0.3	0.8	1.5	0.2
Metapograpsus messor	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.8	0.1

(Appendix) Table 1continued...

Species / Stations	I	II	III	IV	V	VI	VII	Total	Average
Porcellana sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.1
Trapezia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.1
Polyplacophora:									
Acanthopleura haddoni Winkworth, 1972	0.3	1.8	0.0	0.0	0.3	0.0	1.5	3.8	0.5
Gastropoda:									
Clanculus pharaonis (Linneaus, 1758)	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	0.2
Monoonta canilifera Lamarck, 1816	0.0	12.0	0.0	0.0	0.0	0.0	0.0	12.0	1.7
Monoonta neritoides Phillippi	0.0	10.3	0.0	0.0	0.0	0.0	0.0	10.3	1.5
Tectus dentatus (Forskal, 1775)	2.0	0.0	0.8	0.8	0.3	0.5	2.0	6.3	0.9
Nerita albicilla linneaus, 1758	5.0	6.0	1.3	1.5	0.0	3.0	12.5	29.3	4.2
Nerita forskallii (Rechuz)	3.0	4.5	1.3	2.5	0.0	0.3	19.5	31.0	4.4
Nerita polita Linneaus, 1758	0.0	3.8	0.0	1.5	0.0	0.0	20.3	25.5	3.6
Neverita josphinia Risso, 1826	0.0	0.0	0.0	0.0	0.0	0.0	5.0	5.0	0.7
Turbo aeggrotomus (Linnaeus, 1758)	0.3	0.0	0.5	0.0	0.0	0.0	0.3	1.0	0.1
Patella caerulea Linnaeus, 1758	1.3	11.3	1.3	13.0	1.3	0.0	3.8	31.8	4.5
Cerithium caeulum Sowerby	1.0	1.0	5.0	26.3	0.0	0.5	0.8	34.5	4.9
Cerithium erythraeonese Lamarck	0.5	0.0	1.5	0.0	0.0	0.0	2.0	4.0	0.6
Cerithium scabridium (Philippi)	1.5	0.0	0.0	0.0	0.5	0.0	0.0	2.0	0.3
Cerithium vulgatum (Bruguiere, 1792)	1.8	1.8	0.0	5.0	0.0	0.5	1.0	10.0	1.4
Clypeomorus bifasciatus (Sowerby, 1855)	2.3	2.5	0.0	7.3	0.0	0.0	12.3	24.3	3.5
Clypeomorus concisus (Homb. & Jacquinot, 1854)	0.0	2.0	0.0	0.0	0.0	0.0	6.0	8.0	1.1
Pirenella conica (Linneaus, 1758)	6.8	3.8	1.3	13.8	0.8	26.5	20.0	72.8	10.4
Strombus fasciatus Born, 1778	2.0	0.0	0.0	0.0	1.0	0.0	0.5	3.5	0.5
Strombus tricornis Humphrey, 1786	0.3	0.0	0.3	0.3	0.0	0.5	0.0	1.3	0.2
Cymatium vespaceum (Lamarck, 1822)	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.1
Turritella communis (Risso, 1826)	0.0	0.0	0.0	0.5	0.0	0.0	1.5	2.0	0.3
Bittium reticulatum (Da costa)	0.0	0.0	0.0	3.3	0.3	10.0	1.5	15.0	2.1
Planaxis sulcatus (Born, 1778)	3.3	5.0	1.8	8.8	0.8	0.0	5.3	24.8	3.5
Polynices olderi (Forbes)	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.1
Conus ventricosus Gmelin, 1791	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.1
Conus virgo Linneaus, 1758	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.3	0.2

(Appendix) Table 1 continued.....

Species / Stations	I	II	III	IV	V	VI	VII	Total	Average
Hinia reticulata (Linnaeus, 1758)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0
Fusus marmoratus Chemnitz, 1784	1.3	2.5	0.8	32.8	0.8	1.8	1.3	41.0	5.9
Fusus rostratus (Olivi, 1792)	0.0	0.0	0.8	15.8	0.0	0.8	0.0	17.3	2.5
Fusus syracusans (Linneaus, 1758)	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.1
Murex ramosus Linnaeus, 1758	0.0	1.0	0.0	0.0	0.0	0.0	0.8	1.8	0.3
Murex tribulus Linneaus, 1758	1.8	0.0	0.5	0.0	0.0	0.8	0.3	3.3	0.5
Morula granulata (Duclos, 1832)	0.0	6.3	0.0	0.0	0.0	0.5	1.8	8.5	1.2
Thais savigyni (Deshayes, 1844)	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	0.1
Nassarius comiculus (Olivi, 1792)	0.0	11.5	0.0	0.0	0.0	0.0	0.0	11.5	1.6
Vexillum amabilie (Reeve, 1844)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0
Volema pyrum (Gmelin,1791)	0.5	0.0	0.0	0.0	0.0	0.0	4.0	4.5	0.6
Xenoturris cingulifera erythraea (Weinkauff, 1875)	0.0	0.0	0.0	5.8	0.0	0.0	0.0	5.8	0.8
Bivalvia:									
Barbatus barbatus (Linneaus, 1758)	0.3	0.0	0.0	0.0	0.0	0.3	0.0	0.5	0.1
Brachiodontes variabilis (Krauss, 1848)	11.3	1.0	4.5	8.0	2.5	2.8	3.0	33.0	4.7
Modiolus auriculatus (Krauss, 1848)	0.3	0.0	5.0	3.8	0.5	0.3	2.8	12.5	1.8
Pinctada radiata (Leach, 1814)	0.3	0.0	1.8	0.0	3.5	1.5	0.0	7.0	1.0
Chlamys glabra (Linneaus, 1758)	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.1
Mactra glauca Born, 1778	0.5	0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.1
Venerupis aurea Gmelin, 1791	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1
Venerupis rhomboides (pennant, 1777)	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.2
Pinna rudis Linneus 1758	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Echinodermata									
Echinometra mathaei	0.0	0.8	0.3	0.3	0.0	0.5	0.3	2.0	0.3
Holothuria avenicola	0.0	0.0	0.0	0.0	0.0	0.5	0.5	1.0	0.1
Laganum depressum	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.1
Total No. of ind./ m2	59.7	95	32.2	157.5	14.8	62.5	147.3	569	80
No. of spp.	36	26	19	25	15	28	46	195	27.9

State of pollution:

The state of pollution from field observations were detected as the percentage of oil and litter inside each frame as the type of oiling (patchy, thin film, tar balls), the degree of oiling (light, medium, heavy) and the age of oiling (fresh, aged). In general the areas surrounding the oil production localities of Adabiya and middle part of the Suez Gulf were highly polluted. Also, the area of Zaafarana was a zone of intense aged oil patches accumulation, with a large percentage covering about 80 % of the shoreline area. On the other hand, the litter is concentrated at Sts. IV and VII and less so at Sts. II and VI.

Nature of substratum:

The nature of substrate in the shallow intertidal region exhibited wide variations where the hard bottom was the common bottom texture at the different sampling sites. The intertidal zone of the western coast of Suez Gulf is usually extended to a wide distance from the shoreline in particular at Sts. VI and VII.

Species composition:

The results of bottom fauna structure in the shallow intertidal waters at the different sampling sites revealed that most of species constituents of benthos were recorded over the year. A total of 71 macro-benthos species were identified (Appendix, Table 1).From the collected samples species Mollusca dominated the bottom fauna communities both in their species compositions and their intensities. This represented 87.6% of the total number of species (Table 2). The other 7 groups such as Polychaeta, Cirripedia, Amphipoda, Isopoda, Decapoda and Echinodermata accounted for 1.4-8.4% of the total number of species.

Mollusca:

The Mollusca was the most abundant of benthic community structure. Overall 48 species of molluscs were identified among the collected benthic invertebrates along the area of investigation. Gastropoda dominated the molluscan community accounting for approximately 53.5 % mainly from the taxa, Cerithiidae, Fasciolariidae and Neritidae. The bivalves were the second largest group and comprised 12.7% of the total number of species. The Mytilidae was the most dominant in the intertidal shallow waters attaching to hard substrates. The numerical density of mollscans varied from 2 to 16 individuals/m^2. The most dominant species' included *Nerita* spp. (15.5%), *Pirenella conica* (13.1%), *Fusus* spp. (10.7%), *Cerithium* spp. (9.1%), *Brachiodontes variabilis* (6.0%) *Patella caerulea* (5.5%) and *Modiolus auriculatus* (2.3%) of the total number of benthos.

Polychaeta:

A few polychaet species were found among the bulk of bottom fauna. Their corresponding numerical density contributed 2.0% of the total number of benthos. They included the following species: *Hydroides elegans*, *Perinereis cultilifera, P. nuntia* and *Ophelina acuminata.*

Amphipoda:

This community is represented by four species and their numerical density was only 2.4% of the total abundance of macro-benthic fauna. *Elasmopus pectenicrus* was more frequent than the other species namely *Corophium volutator, Gammarus* sp. and *Stenothoe gallenesis.*

Isopoda:

Only two species of Isopoda, *Sphaeroma serratum* and *Cymodoce truncate*, were present and contributed 1.7% of the total benthos. Their average numbers reached 3.3 and 6.3 ind/ m^2 respectively.

Cirripedia:

Among the acorn barnacles, three species were recorded at the sampling sites forming 1.2% of the total benthos. *Balanus amphitrite* var. *denticulata* and *Chthamalus stellatus* had an average of 4.3 and 1.8 ind./m^2 respectively. The third species *Tetraclita squamosa* was only recorded at St. IV, Ras Gharib although many were observed on the rocky bottoms from Zaafarana to Ghardaga.

Decapoda:

In this study 6 species of Decapoda were recorded and comprised 1.6% of total numerical abundance of the living bottom fauna. The average number of *Anapagrus* sp, *Leptodius exaratus* and *Lissocarcinus* sp. was low scoring 0.2 -0.4 ind. / m^2 in average.

Rhizostoma:

One genus of Hydromedusa, *Cassopeia* sp. was identified and this represented only 0.3% of the total density of bottom fauna in shallow intertidal waters.

Echinodermata:

The occurrence of Echinodermata was represented by only 0.5 ind /m^2 on average and included *Echinometra mathaei, Laganum depressum* and *Holothuria* sp. Their percentage abundance reached 0.6% of the total biota along the study area.

Distributions and abundance of the benthic fauna:

The variations in the numerical abundance and biomass of bottom fauna were between the observation periods and at sampling sites as seen in Tables 2 and 3. Only the populations of gastropods indicated high variations in density over the different periods of collection at the sampling sites. They were more abundant at St IV (Ras Gharib) and VII (Hurghada) yielding about 118 ind. /m^2 with mean 58.8 ind. /m^2 and SD $\pm$46.0. At the remaining sites their density varied from 16.6 (at St. III) to 73.8 ind/m^2. In contrast the total biomass of benthos was significantly increased at St. IV (yielding 318.8 g/m^2) and declined to 88.4 g/m^2 at St. I (Adabiya) with a mean of 147.9 g/m^2, SD $\pm$81.0.

The gastropod community representing the most species composition in collected samples reaching 270.28 g/m^2 (84.4% of the total biomass). *Patella caerula* is considered one of the main constituents of the gastropods inhabits the rocky surfaces in the infratidal zone. Its annual density reached 11.3 13 ind./m^2 at St. II and St. IV with mean 4.4 ind./m^2, SD $\pm$5.5. Also, the density of the bivalve populations varied from 2 (St. II) to 11.5 ind. /m^2 (St. I) and 11.8 ind. /m^2 with mean 8.2 ind. /m^2, SD $\pm$4.4. The other benthic groups such as polychaetes, crustaceans and echinoderms showed a low variation in their numerical numbers.

The Bivalvia communities were less frequent and revealed a less variation ranging from one individual to 29 ind. /m^2 over of the period of collection. In general the maximal number was 29 ind. /m^2 during summer and 18 ind. /m^2 during winter at St. I. (Adabiya).

The other groups of bottom fauna such as polychaetes, crustaceans and echinoderms showed a low variation in their numerical numbers that fluctuated between a total of 2-15 ind./m^2 at Zaafarana, St. III and Ras Shukier, St. V over the year.

The general biomass pattern recorded for bottom invertebrates in the shallow intertidal waters can be arranged as the following sequence-Gastropoda > Bivalvia > other bottom fauna > *P. caerulea*. The intensity levels on the side of the benthos were higher at Sts.

IV and VII than the remaining stations. While their seasonal occurrence can be ranked as following: spring > autumn > winter > summer.

St. # I Adabiya station is a harbour located at the northwestern part of the Suez Bay. It is exposed to some sources of pollution such as ships effluent, oil refineries and sewage. A total of 38 species were recorded during the period of collection. Gastropods and bivalves dominated the constituent of benthos and contributed 51.6% and 25.8% of the total abundance of benthos respectively (Table 2).

St. # II El Ain El Sukhna is located in the southwestern part of Suez Bay. This area has a narrow intertidal zone with a sandy bottom. Many facilities for tourism were constructed along, most of its coast. At this site the average annual abundance and biomass of the benthos attained 17% and 14% respectively.

St. # III Zaafarana station is located at about 110 km south of Suez and is subjected to less pollution because it is located south of Suez Bay and at the beginning of the Gulf of Suez.

St. #IV Ras Gharib station lies at the most northwestern coast of the Red Sea. This area is exposed to high amounts of oil and domestic pollutants. This area has a wide intertidal zone and varies in the nature of the bottom with a high percentage of litter, hard bottom, cobbles and moved stones are concentrated along the shoreline. At this station the percentage of the average annual of density the bottom fauna abundance and biomass were maximal at 26.7% and 31% respectively. Its numerical density per year reached an average of 157.5 ind. $/m^2$ and its biomass was the largest yielding at 318.8 g/m^2.

St. #V Ras Shukier represents one of the most polluted areas. This station and the previous one are the two centers for collection and shipment of oil from a number of oil fields including off shore wells at the western of Gulf of Suez, Red Sea. The shore area is covered by high percentage of aged oil, litter and the nature of the bottom showed variations in hard bottom, cobbles, and moved stones. Also the intertidal zone extended some considerable distance from the shoreline. Here the average annual density at the benthos was the lowest of 14.8 ind.$/m^2$ and its biomass yielded only 83.4 g/m^2. Their percentage was estimated at 2.7% and 8% of the total abundance and biomass of the benthos respectively.

St. #VI Gabal El-Zeit is located south of Ras Shukier with a wide intertidal flat slightly polluted with oil because it is exposed to strong agitation and water movement with a high percentage of cobbles and moved stones along most of its shoreline. The average of the annual density of benthos yielded 62.8 ind.$/m^2$ (11.3% of the total abundance) and its biomass weigh 165.4 g. $/m^2$ (15% of the total biomass).

TABLE 2. The total abundance (as mean of no. ind. /m² during different seasons) and percentage of main benthic groups recorded at the sampling stations along the western coast of the Suez Gulf through year 1995.

Parameters/stations	I	II	III	IV	V	VI	VII	Mean	Sd. Dev	%
Rhizostoma	0.5	0.8	0.0	0.0	0.0	0.0	0.3	0.2	0.32	0.3%
Polychaeta	3.8	2.3	0.5	1.8	0.0	1.75	1.3	1.6	1.24	2.0%
Cirripedia	1.5	0.0	1.0	2.5	0.0	1.3	0.3	0.9	0.92	1.2%
Amphipoda	3.0	1.0	0.8	1.3	1.3	3.8	2.3	1.9	1.13	2.4%
Isopoda	2.0	0.8	0.8	0.8	1.0	2.5	1.8	1.4	0.70	1.7%
Decapoda	0.3	1.0	0.0	0.8	0.3	1.3	5.5	1.3	1.90	1.6%
Polyplacophora	0.3	1.8	0.0	0.0	0.3	0.0	1.5	0.5	0.76	0.7%
Gastropoda	33.0	73.8	16.6	116.0	5.6	46.5	120.3	58.8	46.02	73.8%
Bivalvia	14.3	2.0	11.5	11.8	6.5	4.8	6.5	8.2	4.41	10.3%
Patella caerulea	1.3	11.3	1.3	13.0	0.0	0.0	3.8	4.4	5.48	5.5%
Echinodermata	0.0	1.3	0.3	0.3	0.0	1.0	0.8	0.5	0.51	0.6%
Total no. ind. /m²	59.8	95.8	32.6	148.0	14.8	62.8	144.0	80	63.4	100%
%	10.8%	17.3%	5.9%	26.8	2.7%	11.3%	26.0%			
No. of spp	36	26	19	25	15	28	46			
% of species	18%	13%	10%	13%	8%	14%	24%			

Species / Stations	I	II	III	IV	V	VI	VII
Rhizostoma	0.8%	0.8%	0.0%	0.0%	0.0%	0.0%	0.2%
Polychaeta	6.3%	2.3%	1.5%	1.2%	0.0%	2.8%	0.3%
Cirripedia	2.5%	0.0%	3.1%	1.7%	0.0%	2.0%	0.2%
Amphipoda	5.0%	1.0%	2.3%	0.8%	8.4%	6.0%	1.6%
Isopoda	3.3%	0.8%	2.3%	0.5%	6.8%	4.0	1.2%
Decapoda	0.4%	1.0%	0.0%	0.5%	1.7%	2.0%	3.8%
Polyplacophora	0.4%	1.8%	0.0%	0.0%	1.7%	0.0%	1.0%
Gastropoda	55.2%	77.0%	50.8%	78.4%	37.5%	74.1%	83.5%
Bivalvia	23.8%	2.1%	35.3%	7.9%	43.9%	7.6%	4.5%
Patella caerulea	2.1%	11.7%	3.8%	8.8%	0.0%	0.0%	2.6%
Echinodermata	0.0%	1.3%	0.8%	0.2%	0.0%	1.6%	0.5%
Total %	100%	100%	100%	100%	100%	100%	100%

Table 2 continued……

Seasons

Group /Seasons	Winter	Spring	Summer	Autumn	Mean	St.Dv	%
Rhizostoma	0.4	0.1	0.0	0.3	0.2	0.36	0.3%
Polychaeta	2.1	1.3	1.6	1.4	1.6	0.23	2.0%
Cirripedia	0.7	1.1	1.1	0.7	0.9	0.20	1.2%
Amphipoda	2.0	2.0	2.0	1.6	1.9	0.15	2.4%
Isopoda	1.4	1.1	1.4	1.4	1.4	0.17	1.7%
Decapoda	1.1	1.1	1.4	1.4	1.3	0.17	1.6%
Polyplacophora	0.3	0.7	0.6	0.6	0.5	21.234	0.7%
Gastropoda	71.3	75.6	52.0	31.0	58.2	3.26	73.5%
Bivalvia	9.6	7.3	11.7	4.1	8.2	0.40	10.3%
Patella caerulea	4.3	4.0	4.9	4.7	4.5	0.29	5.6%
Echinodermata	0.3	0.6	0.9	0.3	0.5	22.82	0.6%
Total no. ind./m^2	93.6	98.0	77.6	47.6	79.2	0.36	100%
Total %	30%	31%	24%	15%			

TABLE 3. The total weight (g/m2) of gastropods, bivalves, bottom fauna and *Patella caerulea* at the different stations along the western coast of the Suez Gulf.

Groups	I	II	III	IV	V	VI	VII	Mean	Sd .dev	%
Gastropoda	72.70	116.58	74.97	270.28	32.60	138.22	103.82	115.59	76.33	78.2%
Bivalvia	10.19	45.57	29.13	4.40	49.55	15.43	3.54	16.69	17.07	11.3%
bottom fauna	4.08	7.04	2.98	1.69	1.21	1174	16.31	7.72	5.44	5.2%
Patella caerulea	1.39	18.53	0.83	33.41	0.00	0.00	0.71	7.84	13.12	5.3%
Biomass g/m^2	88.4	14.6	107.9	318.8	83.4	165.4	124.4	147.9	81.0	
% of biomass	8.5%	14.2%	1.4%	30.8%	8.1%	16.0%	12.0%			
Total no. ind /m^2	59.8	95.8	32.6	148.0	14.8	62.8	144.0	79.9	63.4	
No. of spp.	36	26	19	25	15	28	46	27.9	10.4	
A / S	1.7	3.7	1.7	5.9	1.0	2.2	3.1	2.8	1.8	
B /A	1.5	1.5	3.3	2.2	5.6	2.6	0.9	2.5	1.6	
%										
Group/Stations	I	II	III	IV	V	VI	VII	Mean		
Gastropoda	82.3%	79.5%	69.5%	84.8%	39.1%	83.6%	83.5%	76.6%		
Bivalvia	11.5%	3.1%	27.0%	1.4%	59.4%	9.3%	2.8&	16.4%		
bottom fauna	4.6%	4.8%	2.8%	3.4%	1.4%	7.1%	13.1%	5.3%		
Patella caerulea	1.6%	12.6%	0.8%	10.5%	0.0%	0.0%	0.6%	3.7%		
Total%	100%	100%	100%	100%	100%	100%	100%	100%		

Seasons

Group/seasons	Winter	Spring	Summer	Autumn	Mean	St.Dv	%
Gastropoda	45.42	132.41	31.51	54.86	66.05	39.2	782.2%
Bivalvia	6.77	18.76	7.52	5.09	9.53	5.4	11.3%
bottom fauna	3.43	5.01	4.2	5	4.41	0.7	5.2%
Patella caerulea	2.12	9.2	3.01	3.59	4.48	2.8	5.3%
Total weight g/m^2	57.75	165.4	46.25	68.54	84.48	47.4	100%
%	17.1%	48.9%	13.7%	20.3%	25.0%	14%	

St. #VII The last station, Hurghada, is located in front of the Marine Research Station. There are many indications of the previous oil production activities around the Hurghada Harbour. But the main source of pollution is due to the increase of coastal development including large urbanization, tourist centers and industrial development. This area has a wide intertidal zone with a high percentage of cobbled and hard bottom. It is surrounded by numerous coral patches, which extended along the coastal area. At this station the annual average percentage of benthos abundance and biomass contributed 26% and 12% respectively. Its numerical density per year reached average of 144 ind./m^2 and its biomass yielding 124.4 g/m^2.

Distribution and species composition of benthic flora:

The regional distribution and constituents of the algal population and their prevalence in the shallow intertidal waters at the sampling sites along the western coast of the Suez Gulf are listed in Table 4. Twenty-eight species of algae can be identified including 8, 12 and 8 from green, brown and red algae respectively, and one species of sea grass represented macrophytes. Among the coral reef population the algal meadows were densest. During winter, the green alga *Cladophora prolifera* was dominant at St. I. *Ulva lactuca* was recorded in higher densities at Sts I, III and VI during winter, spring and autumn respectively. The Phaeophyceae, *Cystoseira* spp. (*Cystoseira adriatica, C. barbata* and *C. spinosa*) and *Sargassum* spp. (*Sargassum aminarium* and *S. latifolium*) were found associated with each other forming a dense belt at Sts VI and VII during spring and autumn while *S. vulgare* and *Dictyota dichotoma* were less frequent at St. VII during autumn.The Rhodophycea, *Laurencia obtuse* and *L. papules* developed well at Sts II, IV and VII during spring, and *Jania rubens* was the most common red algae found at Sts. II, IV, VII (winter), Sts VI, VII (spring), St. IV (summer) and St VI (autumn).

Gelidium crinale and *G. latifolium* were less common at St. IV during spring. The majority of the algal vegetation in the intertidal and shallow sublittoral regions was brown algae, and it covered about 60 % of substrate with dense beds growing in coral patches. Also the sea grass *Halophila stipulosa* was presented by approximately equal quantities at Sts IV and VI. The total number of algal species was higher on hard bottom and cobble substrates, but totally absent from muddy sand and sandy bottoms. The northern part of the Gulf was in general inhabited by a limited number of macro-benthic algae, which became denser in the southern region.

Meroplanktonic:

The following groups of meroplankton can be identified from the sampling sites. In general polychaete and gastropod larvae were most frequent in the zooplankton (as shown in detail in Table 5). During the low water temperature period (winter) their density was calculated at 700 and 750 larvae/m^3 at St. IV with a total number of 2730 larvae/m^3. (mean 455 larvae/m^3,_SD + 266 respectively). Their occurrence in spring season at St. IV reached densities of 4000 larvae/m^3 (Polychaeta) and 1000 larvae/m^3 (Gastropoda) with a total number of 7937 larvae/m^3 mean 1323 larvae/m^3, SD + 1374. Polychaete and gastropod larvae were encountered as 1400 larvae/m^3 and 1000 larvae/m^3 respectively during summer season with a total number of 4225 larvae/m^3. mean 747-larvae/ m^3, SD +533. During autumn at St. VII the polychaete larvae were maximal with 1010 larvae/ m^3, while gastropod larvae were represented by 1200 larvae/m^3 with a total number of 3704 larvae/m^3. mean 2132 larvae/ m^3, SD +/-3931.

TABLE 4. Distribution of macro-benthic flora in shallow water of the intertidal zone along the western coast of the Suez Gulf during the period of investigation.

Species	Abundance > 30 %	Common 10-30 %	Present < 10 %
Algae			
A) Chlorophyceae			
1) *Chaetomorpha area* (Dillywn) Kutz.	-	-	I
2) *Cladophora prolifera* (Roth) Kutz.	-	I	-
3) *Codium bursa* (Linnaeus) C.Ag.	-	-	IV
4) *Codium dichotoma* (Huds.) Setschell	-	-	III,V,VII
5) *Enteromorpha linza* (L.) J. Agardh	-	-	I
6) *Enteromorpha prolifera* (Muller) J. Agardh	-	-	I,IV
7) *Ulva lactuca* (Linnaeus) Thuret	I,III,V	-	II,IV,VII
8) *Valonia macrophysa* Kutz.	-	-	VII
B) Phaeophyceae			
1) *Cystoseira adriatica* Sauvageau	-	I,VI,VII	-
2) *Cystoseira barbata* (Good et.Wood W.C. Ag.)	-	II,III,VI	-
3) *Cystoseira linifolium* Turn	-	-	II
4) *Cystoseira spinosa* Sauvageau	-	VI,VII	-
5) *Dictyota dichotoma* (Hudsen) Lamaroux	-	-	II,VI,VII
6) *Ectocarpus irregular* (Roth)	-	-	III
7) *Hydroclathathrus clathrams* (C. Agardh) Howe	-	-	VI,VII
8) *Padina pavonia* (Linnaeus) Thivy	VI,VII	II	III
9) *Sargassum hornschushi* C. Ag.	-	-	VI
10) *Sargassum latifolium* (Turn.) Ag.	IV	VII	VI
11) *Sargassum vulgare* (C. Agardh)	-	-	VII
C) Rhodophyceae			
1) *Gelidium crinale* (Thurner) Lamouroux	-	VI	VII
2) *Gelidium latifolium* (Grev.) Bornet & Thuret	-	VI	VII
3) *Halymenia dichotoma* J. Ac. Aufrecht	-	-	I
4) *Jania rubens* (Linnaeus) Lamouroux	-	VI,VII	II
5) *Laurencia obtusa* (huds.) Lam.	-	VI,VII	I,II
6) *Laurencia papillosa* (C. Ag.) Grev.	-	VI	I,II,VII
7) *Lomentaria linearis* Zanard	-	-	I
8) *Pterocladia capillacea* (Gmelin) Bornet &Thuret	-	-	I
D) Sea grasses			
1) *Halophila stipulacea* (Forskal) Ascherson	-	-	IV, VI

TABLE 5. The seasonal variations of meroplankton recorded in the water shallow (No. of larvae/m^3) along the western coast of the Suez Gulf through year 1995 in Numerical numbers of meroplankton No. larvae/m^3.

Stations	Seasons	Lamelli-Branchia	Gastropoda	Polychaeta	Cirripedia	Decapoda	Pteropoda	Total
St I	Winter	50	200	500	200	250	25	1225
St II		150	350	250	250	50	20	1070
St III		100	400	40	500	50	18	1108
St IV		300	700	750	450	500	30	2730
St V		0	0	0	200	100	19	319
St VI		67	600	333	166	333	30	1529
St VII		190	87	278	111	555	22	1243
Mean		122.4	333.9	307.3	268.1	262.6	23.4	
St.Dv.		100.6	258.1	259.4	148.1	209.7	5	
St I	Spring	49	200	650	350	300	35	1584
St II		50	500	350	270	50	33	1253
St III		130	470	750	500	50	30	1930
St IV		900	4000	1000	750	1250	37	7937
St V		0	0	350	333	150	27	860
St VI		333	1000	1333	999	666	40	4371
St VII		233	1100	1333	999	333	45	4043
Mean		242.1	1038.6	823.7	600.1	399.9	35.3	
St.Dv.		312.7	1364.5	415.2	314.5	431.1	6.1	

Table 5 continued...

Stations	Seasons	Lamelli-	Gastropoda	Polychaeta	Cirripedia	Decapoda	Pteropoda	Total
St I		100	450	1000	400	350	45	2345
St II		150	600	515	450	50	40	1805
St III		400	1000	1333	511	75	37	3356
St IV	Summer	250	1350	1200	670	720	35	4225
St V		50	250	450	112	200	28	1090
St VI		500	1000	1400	1200	333	47	4480
St VII		470	1230	1217	1200	333	50	4500
Mean		274.3	840	1016.4	649	294.4	40.3	
St.Dv.		183.4	412.6	386	411.6	225.1	7.7	
St I		50	300	750	212	225	30	1567
St II		65	485	400	300	50	25	1325
St III		200	1000	1022	415	60	17	2714
St IV	Autumn	175	1125	1050	520	600	20	3490
St V		50	200	200	95	120	19	684
St VI		200	800	1225	845	600	23	3693
St VII		250	1200	10100	1000	220	24	12794
Mean		141.4	730	2106.7	483.9	267.9	22.6	
St.Dv.		84	404.3	3543.8	332.1	237.1	4.4	

Polychaete larvae:

These formed 18.49 %, 35.78 % and 29.73 % of the total density of larvae during winter, spring, summer and autumn respectively.

***Molluscan larvae*:**

It was found that the production of the lamellibranch veligers at the sampling sites continued throughout the year showing higher densities during the summer, 8.08 % in average. Lamellibranch and gastropod veligers comprised 7.28 %, 5.65 %, 8.08 % and 5.71 % during winter, spring, summer and autumn, respectively of the total zooplankton counts (Fig.4).

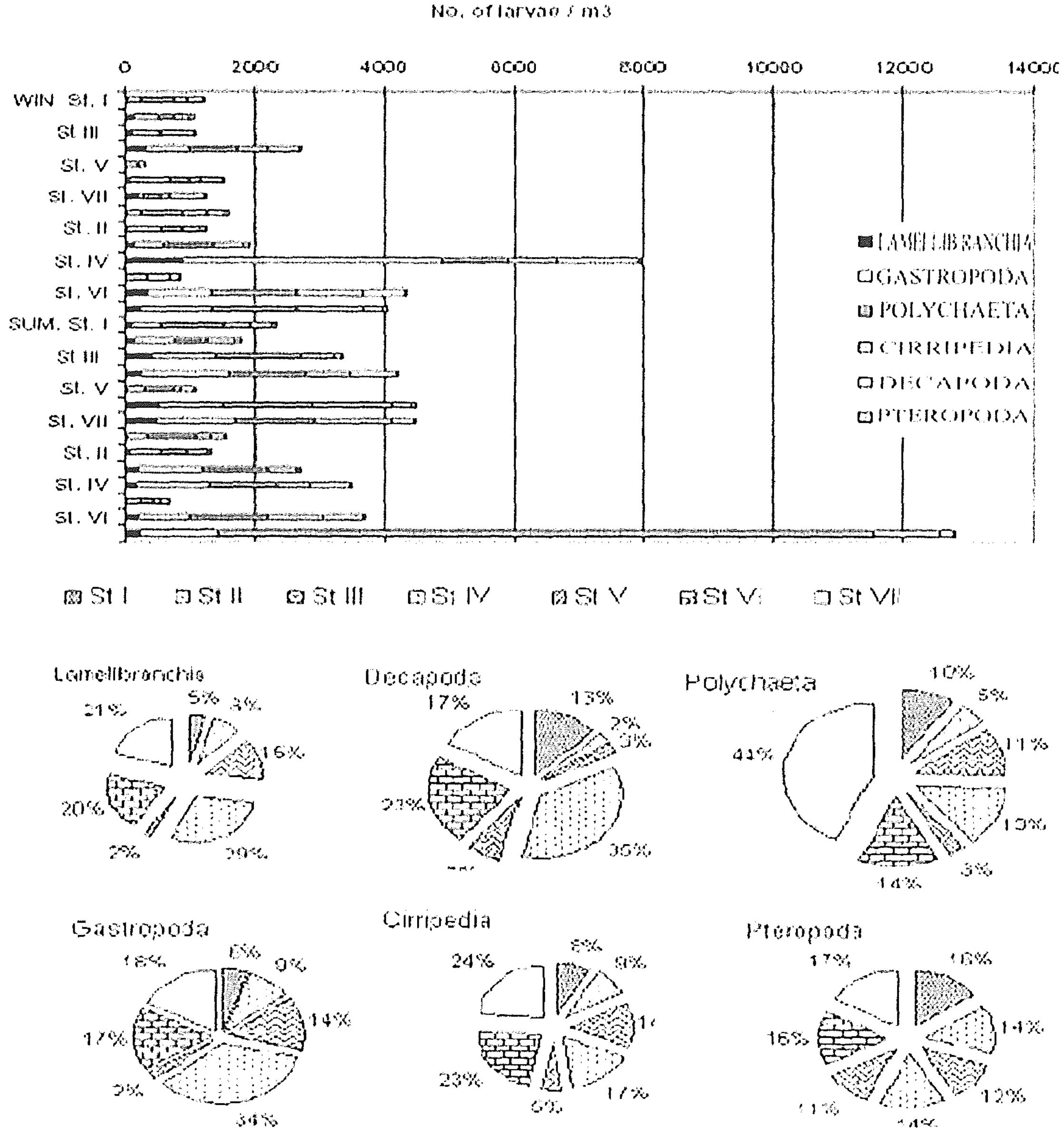

Fig. 4. The seasonal and percentage variations of meroplankton groups recorded at the sampling sites in the shallow intertidal waters during May 1995 to April 1996.

Cirriped larvae: Cirriped nauplii were less common among the zooplankton population and they contributed about 23.58 % of the total density of larvae. The seasonal zooplankton production of cirriped nauplii were denser at Sts VI and VII during summer.

Decapod larvae: This group of meroplankton comprised the commercial penaeid shrimp larvae. They were calculated on average as 9.98 % of the total density of larvae over the year. The production of Decapoda larvae was most common during spring (mean 1250 larvae/m^3) at St. IV with 15.95 % of the total percentage 0.09 %.

Pteropod larvae: Pteropod larvae were recorded in small numbers at St.VII during summer and the minimum value was 17 larvae/m^3 at St. III during autumn.

Statistical analysis:

Linear regression analysis:

The correlation between the benthic and hydrographical data was the most significant. By using the square matrix at the 95% confidence (Pearson correlation coefficient (r)) at P level < 0.05 some signifitant factors were indicated (Table 6):

- The numerical density of cirripedes is positively correlated with the value of pH, concentration of Cd, Cu, Pb, Zn and Fe in seawater.
- The numerical density of bivalves is significantly and negatively correlated with the value of S%o. It is positively correlated with the content of Cd, Cu,Pb, Zn and Fe in seawater.
- The numerical density of Rhizostoma is significantly and positively correlated with the concentration of DO, COD and BOD in water and the percentage of medium sand in the sediment.
- The gastropods biomass is positively correlated pH and negatively correlated to the percentage to the fine sand in the sediment.
- The total benthic biomass is positively correlated to pH and the percentage of fine sand in the sediment.
- The density of *Patella caerula* is significantly and negatively correlated to the organic matter content in the sediment. But its biomass is positively correlated to the pH of seawater.
- The abundance of echinoderms is correlated negatively to the Cd content in the sediment.
- The numerical density of polychaetes showed a negative correlation to the percentage of medium sand in the sediment.
- The density of amphipods and isopods is negatively correlated to the percentage of carbonate in the sediment.
- The biomass of bivalves is negatively correlated to the degree of water temperature.
- The total abundance of benthos is negatively correlated to the percentage of fine sand in the sediment.
- Gastropod biomass is positively correlated to pH and negatively correlated to the percentage of fine sand in the sediment.

TABLE 6. Correlation between the different hydrographical parameters of the shallow intertidal waters and sediments at the sampling sites along the Suez Gulf during May 1995 to April 1996. = Pearson correlation coefficient (marked correlations are significant at p < 0.005).

Cirripedia Abund.	pH	Cd wa	Cu wa	Pb wa	Zn wa	Fe wa
	0.828 p=.022	0.877 p=.010	0.809 p=.028	0.858 p=.014	0.86 p=.0.1 5	0.867 p=.012
Bivalvia Abund.	S%o	Cd wa	Cu wa	Pb wa	Zn wa	Fe wa
	-0.767 p=.044	0.799 p=.032	0.865 p=.012	0.844	0.796 p=.032	0.792 p=.034
Riizostoma Abund.	DO	COD	BOD	%Med.san		
	0.816 P=.026	0.804 P=.030	0.808 P=.028	0.93 P=.002		
Gastropoda Biom.	pH	%fin.sand				
	0.814 p=.026	-0.933 p=.002				
Total biomass	pH	%fin.sand				
	0.86 P=.015	0.872 P=.011				
Pattela caerula	%org,mat.					
	-0.773 P=.042					
Echinoderms Abund.	Cd sd					
	-0.78 P=.043					
Polychaetes – Abund.	%Med.sand					
	0.780 P=.039					
Amphipods Abund.	%carbonate					
	-0.804 P=.030					
Isopoda Abund.	%carbonate					
	-0.8 P=.031					
Bivalves Biom.	Temp					
	-.08085 P=.028					
Patella caerula Biom.	pH					
	0.804 P=.030					
Total Abundance	% fin.sand					
	-0.77 P=.045					

Multivariate analysis:

Principal Components Analysis (PCA)

The factor loadings plots for the principal components analysis of sites, the physicochemical parameters of seawater, and of the sediments and constituents of benthic assemblages recorded at the sampling sites are shown in Table 7.

Using numerical and biomass data, the PCA analyis for the factor loadings used hydrographical parameters in seawater and in sediments as independent variables with the common benthic groups as dependent variables. The values of salinity and pH and concentrations of Cd, Cu, Pb, Zn, Fe and Co in the seawater are shown to be positively correlated with principal component of factor 1. The cirripedes and bivalves are highly positively correlated with the independent variables that contributed to principal component of factor 1. These variations in the independent variables may be attributed to the variation in the abundance of cirripedes and bivalves at the sampling sites.

TABLE 7. Extraction of principal components of factor 1 Eigenvalues, factor loading and factor scores.

Factors	Eigenval	% total variance	Cumul. Eigenval	Cumul. %
1	11.64	29.09	11.64	29.09
2	9.20	22.99	20.83	52.09
3	6.15	15.06	26.98	67.46
4	6.03	15.06	33.01	82.53
5	2.23	8.08	36.24	90.60
6	2.14	5.35	38.38	95.95

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Rhizostom. No.	-0.18	0.11	-0.85	0.04	0.08	0.42
Polychaeta No.	037	0.23	-0.66	0.54	0.12	0.18
Cirripeda No.	0.85	0.21	0.14	0.21	0.24	-0.27
Amphipoda No.	-0.10	0.25	0.00	0.93	-0.10	-0.12
Isopoda No.	-0.19	0.19	0.01	0.91	-0.14	-0.22
Decapoda No.	-0.50	0.80	0.08	0.04	-0.23	-0.02
Polyplacop. No.	-0.16	0.34	-0.48	-0.24	0.05	0.34
Gastrop. No	0.00	0.91	0.01	-0.15	0.31	0.06
Bivalvia No.	0.84	0.03	0.04	0.07	-0.48	-0.12
Patella No.	-0.01	0.37	0.15	-0.35	0.70	0.43

Table 7 continued......

Echind. No.	-0.62	0.29	-0.34	0.01	0.58	-0.21
Gastrop. Biomass	0.47	0.52	0.17	-0.08	0.65	-0.10
Bivalvia biomass	0.47	-0.11	-0.45	0.52	-0.43	0.25
Fauna biomass	-0.25	0.86	0.12	0.20	0.23	-0.21
Patella Biomass	0.46	0.32	-0.03	-0.38	0.66	0.25
Abundance	0.14	0.91	-0.02	-0.12	0.31	0.09
Biomass	0.47	0.44	0.26	-0.15	0.67	-0.06
No. species	-0.09	0.87	0.24	0.31	-0.17	0.13
Temp.-water	-0.37	0.36	0.27	-0.71	0.28	0.21
S %o water	-0.86	-0.06	0.24	0.05	0.14	-0.36
pH water	0.80	0.20	0.25	-0.29	0.36	-0.03
DO2 water	-0.32	-0.11	-0.19	0.01	-0.13	-0.07
COD water	-0.08	-0.13	-0.93	-0.11	-0.23	-0.02
BOD water	-0.36	-0.15	-0.88	0.00	-0.18	-0.03
CD-water	0.97	0.02	0.06	0.05	0.09	0.10
CU water	0.96	-0.16	0.05	-0.05	-0.05	-0.01
PB water	0.97	-0.05	0.11	-0.04	0.01	0.02
ZN water	0.96	-0.08	0.13	-0.10	0.08	0.01
FE water	0.95	-0.10	0.17	0.03	0.09	0.05
CO water	0.80	-0.27	0.06	0.41	-0.10	0.25
CD sediment	0.48	-0.11	-0.08	0.10	-0.52	0.66
CU sediment	0.05	0.32	-0.50	0.25	-0.72	0.19
PB sediment	0.09	-0.23	-0.58	-0.70	-0.15	-0.25
ZN sediment	0.23	-0.14	0.12	-0.19	-0.91	-0.14
FE sediment	0.11	0.32	0.14	0.34	-0.42	-0.73
CO sediment	0.14	-0.03	-0.28	-0.36	0.08	0.85
%ORG.MATTER	-0.04	-0.02	-0.08	0.03	-0.97	-0.07
%CARBONA	-0.17	0.26	0.01	-0.90	-0.10	0.20
%MED.SAND	0.02	0.32	-0.82	0.06	0.27	0.32
%FIN_SAND	-0.35	-0.60	-0.03	-0.17	-0.61	0.29
Expl. Var	11.11	6.15	6.06	5.29	6.56	3.22
Prp. Totl	0.28	0.15	0.15	0.13	0.16	0.08

Factor loading (unrotated), Extraction: Principal components. Marked loading are > 0.007

Factor Scores (unrotated) Extraction: Principal components.

On the other hand, some dependent variables, namely density of decapods, gastropods, other bottom faunal biomass, the total abundance of benthos and the total number of species are positively correlated with principal the component of factor 2. DO, COD and BOD contents in seawater are highly negatively correlated among the component of factor 3 but this factor cannot be used to interpret the variations in the benthic data. The percentage of total variance accounted for by the first three factors is 67.5% (Table 7), of which the components of accounted for 29.1%. Station I and IV are highly positive, and St VII negative, on PCA of; St VII is highly positive and St V negative on PAC 2 Fig. 5 shows the eingen values as a plot indicating that the sum of the first four factors loading that counted 67.5% of the total % of variance, which may be correlated to environmental conditions in area of study.

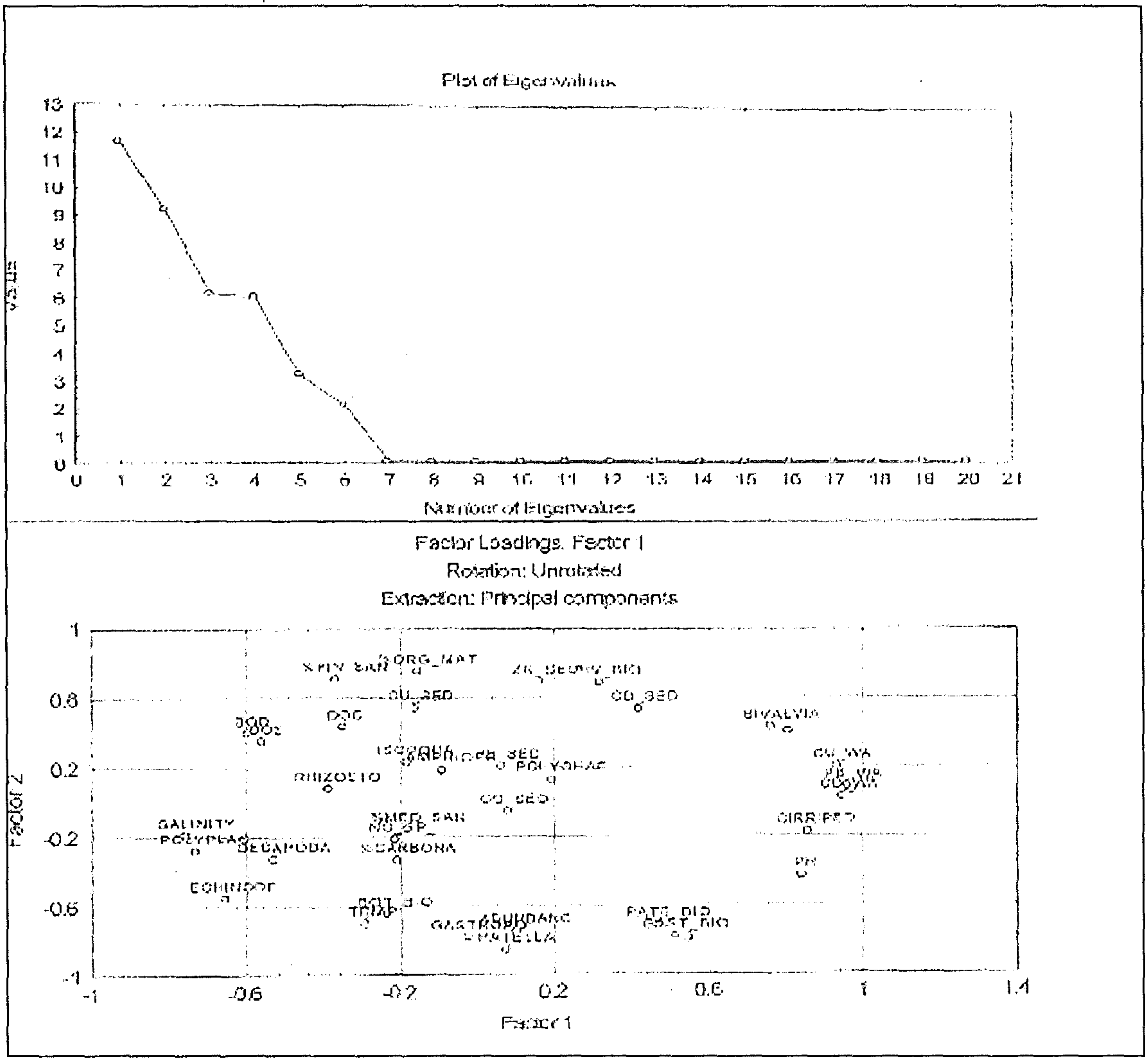

Fig. 5. Eigenvalues as a screen plot showing that the sum of 4 factors may be related to the hydrographical conditions. The below plot showing the factor analysis of physio-chemical parameters with some biological aspects.

DISCUSSION

Data analyses confirmed a clear variation in overall community structure between the investigated sites. Community structure of sandy shores at St. I (Adabiya) is characterized by lower density, fewer species and the highest evenness. Ras- Gharib (St. IV), Hurghada (St VII) and El-Ein El-Sukhna (St. II) show significant differences in the numerical abundance, biomass and diversity of macro benthos assemblages. The bivalves, *Brachiodontes variabilis* and *Modiolus auriculatus* are more common along the western coast of the Suez Gulf.

The majority of intertidal benthic communities are dependent upon several factors such as type of the substrate, level of pollution, distance from the shoreline and depth of seawater. Abbott (1966) related the varying degrees of faunal affinity to the effect of ocean currents, land and sea barriers, thermal conditions in inshore water, the timing and duration of spawning season and the incidence of larvae capable of prolonged plankton existence. In the present work a great variability in the number of species and density of benthic community was found as a consequence of the nature of bottom and state of pollution in combination with the physical and chemical structures prevailing along the western coast of the Suez Gulf. The same observation was reported by El-Komi (1996, 1997).

Rocky intertidal regions support much richer and more interesting fauna and flora than do sandy regions as recorded in Sts IV, VI and VII along the western coast of the Suez Gulf. The nature of substratum, according to Connell (1961), may be responsible for the distribution of animals and the range of distribution of a species may also be decreased in the presence of another species with similar requirement for their competition for space. Thorson (1960) reported that the bottom substratum has proved to be the "master factor" responsible for nearly all pelagic larvae settling in large quantities and is another factor in determining the composition of bottom fauna. On the other hand, the environmental factors are generally affecting most planktonic or pelagic organisms with a much shorter time rather than benthos population. Extensive pollution oil caused a greater reduction in environmental conditions and limited benthic growth in some areas. Sandy and muddy sand intertidal areas sustained the lowest concentration of benthos of which the bivalves such as *Mactra glauca*, *Chlamys glabra* (St. VII) and *Venerupis aurea* and *V. rhomboides* (St. I) burrow into the substratum were found in great abundance. Gastropoda such *Bittium reticulatum* and *Pirenella conica* at Sts VI and VII were found in great abundance. Many species were recorded in small numbers. Therefore, it can be concluded that the distribution of these organisms along the shallow intertidal areas point to a pronounced pollution effect in the middle part of the Gulf, adjacent to the area associated with petroleum companies.

As mentioned before the distribution of algae seems to be unaffected by oil pollution because the petroleum hydrocarbons in seawater are not essentially in soluble forms (Widdows *et al.,* 1982). The following species were recorded in most polluted area as well as the least polluted, *Sargassum latifolium*, *Padina pavonia*, *Laurencia obtusa* and *L. papillosa.*

Thus, the information on the distribution of benthic animals in the shallow intertidal region may be used as data base for correlation of the major constituents of biota with the various environmental conditions particularly pollution (El-Komi 1996, 1997). Previously, Mergner and Svoboda (1977) showed marked seasonal changes in the algal cover and mobile organisms in selected reef areas in the Gulf of Aqaba. The brown algae existed in higher quantities than both the green and red algae. Dorgham (1991) found that the green algae were poor in Qatari waters (Arabian Gulf) in comparison to other tropical regions. The total number of algal species was higher on hard bottoms and cobble substrate, while the macro algae were totally absent from muddy sand and sandy bottoms as was found on the shoreline of the Suez Gulf during summer 1992 (El- Komi, 1996, 1997). This was attributed to the effect of strong wind action prevailing in the area, which creates unsuitable bottom for the attachment and growth of algae in such shallow intertidal waters. According to Thorson (1960) and Connell (1961) the distribution of animals and their species composition depends upon the nature of substrata that is affected by competition for space.

In general the hydrography of characters in the Suez Gulf is characterized by elevation of temperature and salinity of seawater in the south rather than of the northern part. This depends upon the air temperature, turbulence in water mass and the topography of the area (Talling, 1976; Abdel Salam, 1981). Other characters such as oxygen content, pH and oxidizable organic matter (COD, BOD) showed random distribution due to oil pollution and sewage discharged in the study area.

In Egypt, soil and aquatic heavy metal pollution, particularly involving lead and cadmium, have become serious problems and are currently topics of active debate (Lasheen 1987; Sillanpaa and Jansson, 1992; Ali, 1993). In the present investigation, cadmium appears to be lower in summer (0.07, 0.11 and 0.13 at Sts VII, I and IV respectively) the affect of municipal sewage providing a good habitat phytoplankton and alga growth. Beltagy, 1984 GESAMP (1982) and EL- Moselhy, 1993 indicated that the content of lead is higher in the northern part of the Gulf of Suez than in the other Egyptian areas. This may be due to the precipitation of decomposed organic matter coming from municipal sewage and other industrial waste of the Suez City. The higher values of dissolved copper in water and sediments are recorded at Sts. I and IV. This may be related to hulls of ships being coated with anti-fouling paint and exposition sewage, and petroleum hydrocarbons. Zinc plays an important role in the biology and geological processes where the optimum growth of phytoplankton is dependent on the adequate supply of essential heavy metals in the present study.

The zinc content in water, ranged between 5.45 ppb at St. VII (summer) to 18.83 ppb at St. I (winter). The low values in summer are related to consumption by phytoplankton that increased in spring and summer as stated by Salah (1959). This may agree with Thompson *et al.* (1932) who reported that the removal of zinc from water is by phytoplankton, which is abundant in spring and summer. From the results of the present studying it can be concluded that the seasonal variation of trace elements may be attributed to 1) the selective utility of these elements by different marine organisms; 2) decomposition of dead organic matter; 3) air-borne material transported to the sea by strong winds during winter time.

Further or higher concentration value of heavy metals was recorded in the water at St. IV and a lower concentration value was recorded at St. VII. Also a, high concentration value was observed during winter and the low concentration value of heavy metals was observed during summer. Moreover, the concentrations of heavy metals in the coastal waters of the Gulf of Suez could be arranged in the following sequence -Zinc > Iron > Lead > Copper > Cobalt > Cadmium, while their levels at the different stations were IV > I > III > V > VI > II > VII and their seasonal occurrence during winter > spring > autumn > summer around the year.

Regarding the implications for human health it appears that none of the samples analyzed contained levels of trace elements, which would indicate the existence of potential public health problems. Concentration of the iron and lead were particularly high but did not approach a level, which would give rise to concern. The fatal doses are about 10 gm for iron (Kamel and Gamal El-Din 1986) and 2 gm for lead. (Simpson, 1979). So, the concentration of these two metals is not sufficiently widespread to endanger public health from the consumption of locally cultured bivalves. All other elements were at acceptable levels. The content of carbonate in sediments is associated with the highest sand content. The calcareous constituent of bivalves and gastropods shell fragments together with foraminifer tests and ostracod shells make up a larger portion of the sand. In contrast, muddy substrates with high proportions of silt and clay impede degradation processes. In general, carbonate contents in sediments are richer at the sites with abundant Molluscan species (Gastropoda and Bivalvia) and coral reefs community. The carbonate content in sediments increased gradually from stations VII > II > III > IV > I > V > VI respectively at distances 5, 10 and 15 meters from the shoreline. From the previous literature, it was noted that there is no relationship between the organic matter and calcium carbonate content in sediment study.Generally, the organic content in shallow intertidal waters and its sediments is higher in the central part of the Gulf of Suez. (El-Askary *et al.* 1988).

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