Current Research Journal of Biological Sciences 4(1): 40-47, 2012
ISSN: 2041-0778

Submitted: October 10, 2011 Accepted: October 16, 2011 Published: January 20, 2012

The Influence of Marine Pollution on Distribution and Abundance of Polychaetes

[1]A. El-Gendy, [2]S. Al-Farraj, [2]S. Al-Kahtani and [2]M. El-Hedeny
[1]Department of Zoology, Faculty of Science, Alexandria University, Alexandria, Egypt
[2]Department of Sciences, College of Teachers, King Saud University,
Riyadh, Kingdom of Saudi Arabia

Abstract: Polychaetes are the most abundant taxon recorded in benthic communities of many habitats of Alexandria, Egypt. In the study, six stations were chosen along the Mediterranean coast of Alexandria. In each station water quality variables were measured. A total of 25 polychaete species were encountered. The most common families were Capitellidae and Spionidae both in term of abundance and species richness. *Capitella capitata*, *Minuspio cirrifera*, *Polydora capensis* and *Heteromastus filiformis* were the most abundant and omnipresent polychaete species in the study area, indicating their tolerance and adaptability to various degrees of pollution. Statistical analyses of polychaete data were used to determine the level of environmental degradation in various stations of coast. Shannon's index (H') varied spatially from 1.43 to 2.52, Margalef richness index (d) from 0.50 to 2.59, and evenness index (J) from 0.81 to 0.97 indicating poor polychaete diversity. Comparing with control sites, the impacted stations (1-4) had lower species richness and diversity indicating poor environment that is confirmed with low pH and dissolved oxygen values. Moreover, they displayed high nutrient levels due to the high organic matter input in the area. The poorest environment for polychaetes was in the Eastern Abu Quir "station #1" (S = 5, N = 2275, H' = 1.50, d = 0.51 and J = 0.93). The present data can form a baseline for future monitoring programmers in the area.

Key words: Abundance, Alexandria, distribution, Egypt, pollution, polychaetes

INTRODUCTION

The city of Alexandria has a coastline 31 km long that extends from Abu Quir to El-Dikheila. The coast is generally undulating and interrupted by rocky headlands that form small embayments and pocket beaches ranging from 0.3 to 1.6 km long (UNESCO, 2003). Due to the rapid increase and development of growing population activities, the costal water of Alexandria City is threatened by accumulation of pollutants from terrestrial, industrial and domestic sources. In fact, huge amounts of polluted disposals are discharged into several semi-enclosed basins such as El Mex Bay, Eastern Harbour, western Harbour and Abu Quir Bay.

Semi-enclosed marine basins are among the most altered coastal areas. They usually represent polluted areas with low hydrodynamism, reduced oxygen in the water column, and high concentrations of pollutants in the sediment. Anthropogenic discharges into harbours and shallow bays, where residence times are extended due to partial enclosure, can have severe effects on local pelagic and benthic communities (Danulat *et al*., 2002).

Benthic communities are particularly sensitive to environmental pollutants (Holland *et al*., 1987). When a benthic community is undergoing stress due to unfavorable environmental conditions there are presumed to be notable changes in community parameters such as diversity, abundances, dominance, biomass, and so on (Pearson and Rosenberg, 1978).

Since the polychaetes are commonly a major component of any marine benthic environment (Fauchald and Jumars, 1979), these changes in community structure should be mirrored by the polychaete community (Papageorgiou *et al*., 2006). Moreover, polychaetes are considered one of the most useful marine organisms to detect pollution because they live at the water-sediment interface (e.g., Remani *et al*., 1983; Warwick and Ruswahyuni, 1987; Guerra-García and García-Gómez, 2004; Jayaraj *et al*., 2007; Dean, 2008; Santi and Tavares, 2009 and Shen *et al*., 2010). Many polychaetes species have a high level of tolerance to adverse effects such as pollution and natural perturbations (e.g., Levin *et al*., 1996; Borja *et al*., 2000; Inglis and Kross, 2000; Samuelson, 2001). Despite these and many other studies, little is known concerning the use of polychaetes as indicator species in marine pollution of the Mediterranean coast of Egypt.
The aims of this study are:

- To conduct an analysis of the distribution pattern of polychaetes along Alexandria coast.
- To investigate the key environmental variables affecting the polychaete community structure.

Corresponding author: A. El-Gendy, Department of Zoology, Faculty of Science, Alexandria University, Alexandria, Egypt

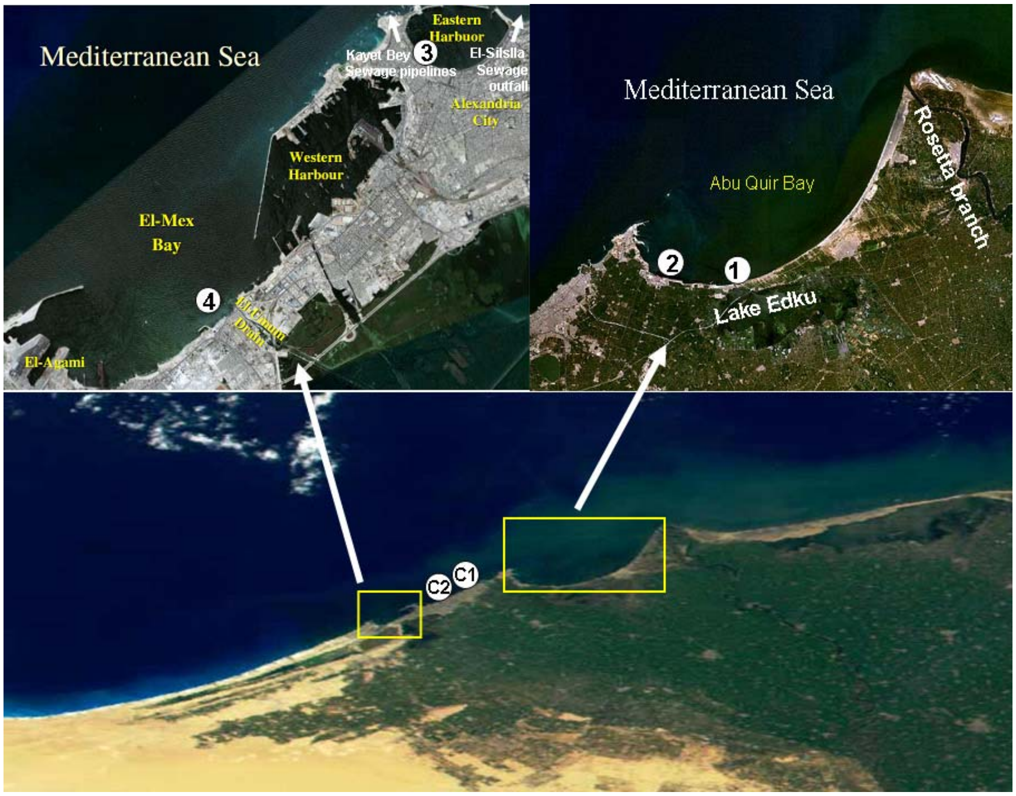

Fig. 1: Satellite images of the present study showing the sampling sites

MATERIALS AND METHODS

Study area: This contribution was focused on the Mediterranean coast of Alexandria. In this study, six stations were taken into consideration (Fig. 1). They were chosen to include four polluted sites, two from the eastern coast (Abu Quir "# 1" and Abu Quir "# 2") and two from the western coast of Alexandria (El Mex "#3" and the Eastern Harbour "# 4"). In addition, two relatively clean stations (Montaza "C1" and Gleem "C2") were selected between the eastern and western stations far from any local source of pollution. Sampling was conducted during June-July 2011.

Sampling locations: Six sampling stations were selected along the Mediterranean coast of Alexandria, to represent four polluted stations and two control sites.

The uncontrolled sites (stations 1-4) are areas with a low rate of water renewal, a high sedimentation rate, and high concentrations of pollutants. Two stations have been chosen in Abu Quir Bay, one from Eastern Harbour and one from El Mex Bay (Fig. 1).The control sites (C1 and C2) are located far removed from obvious sources of metal pollution, with no appreciable human activities. C1 is located in the western side of stations #1 and #2, while C2 is located in the eastern side of stations #3 and #4 (Fig. 1). The studied stations investigated in this study are described below:

Abu Quir Bay: is a small semicircular shallow marine bay with a maximum depth of about 16 m and a shoreline about 50 km long, on the Egyptian Mediterranean coast. It is located between longitude 30˚ 50' and 30º22′ E and latitude 31º16′ and 31º28′ N (about 35 km east of Alexandria). The bay receives considerable amounts of waste waters through three sources: i) polluted waters discharged from the El-Tabia pumping station (TPS) (1.850, 000 m^3/day). These wastes are mainly industrial, with some agricultural and domestic contribution; ii) brackish waters polluted by the agricultural run-off of Lake Edku discharged through Boughaz El-Madiya; and iii) river waters discharged from Rosetta branch of the Nile River (Fahmy, 1997). Such pollutants have a drastic effect on various aquatic fauna and flora.

El Mex Bay: receives large amounts of nutrients, organic compounds, heavy metals and Suspended Particulate Matter (SPM). El Mex Bay having several industrial plants situated close to the coast and directly discharge its effluents into it. In addition this bay is an estuarine zone

of huge agricultural drain (Omoum Drain), which crosses areas of intensive agriculture and a county with rapidly growing population density (domestic sewage) and industrial activities (UNEP, 2007), its discharge rate about 2547.7x106 m^3/year (El-Rayis and Abdallah, 2006).

Eastern harbour: is a relatively shallow semicircular bay. It is surrounded by the city except on its northern side, where it communicates with the sea through two outlets. It receives many kinds of vessels, especially fishing boats (Al Sayes and 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). 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 domestic sewage inside the harbour totally ceased and the daily discharge into the open sea decreased to reach 140,000 m^3 /day and 50,000 m^3 /day from the main Kayet Bey pipeline and El-Silslla outfall respectively (Jammo, 2001). The wastes 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.

Montaza (C1): a remote area from the eastern side, far from marine pollutants of stations #1 and #2, with little human activities. (Hence, this location was chosen as a reference site to provide information on health environment).

Gleem (C2): another remote area from the western side, far from the source of pollution in stations #3 and #4, with little human activities. (Hence, this location was chosen as a reference site to provide information on health environment).

Sampling and analytical procedures:

Sampling procedure: Four replicate sediment samples for each of the 6 stations were collected using a van-Veen grab (0.04 m^2 area). In order to minimise the loss of organisms during their transportation ashore, the samples were placed in situ in polyethylene bags. Samples were immediately fixed in 4% formaldehyde (~10% formalin) and rinsed in the laboratory with freshwater. After that, the sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered formaldehyde. The retained polychaetes were sorted under the stereomicroscope, identified to the species level and counted. Sorted and identified animals were preserved in 80% ethyl alcohol. Some physical and chemical variables of the water column were also measured at each sampling site. The temperature, pH and dissolved oxygen were measured with a portable CONSORT Model C535 Water Quality Meter. The salinity was determined by titration of chloride with a special Aquamerck® kit and subsequent conversion of chlorinity to salinity by means of Almazov's formula (Bondar *et al*., 1973). The concentration of nitrates, nitrites, ammonia and phosphates was determined spectrophotometrically with a Merck RQFlex Plus device, which uses special Reflectoquant® strips.

Statistical analyses: The structure of the polychaete community was analysed in terms of species richness (S), total abundance (N), Evenness (D), frequency (F) and diversity. To measure species diversity, we used two indices; the Shannon-Wiener diversity (H') (Shannon index) and the Margalef's index (d).When indices were congruent, we reported the most significant value.

RESULTS AND DISCUSSION

Environmental variables: The values of dissolved oxygen concentration, salinity and pH were higher at Station C1 and C2 than at stations 1-4 (Fig. 2). The highest nutrient concentrations (nitrates, nitrites, ammonia, and phosphates) were recorded at the polluted stations, and the lowest values were at the control site (C1-C2) (Fig. 3). Differences in nutrient levels between station #1 and the other stations were highly significant ($p<0.01$).

The fauna: About 25 polychaete species were identified during this study. The most common families were Capitellidae and Spionidae both in term of abundance and species richness. The four polychaete species, *Capitella capitata*, *Minuspio cirrifera*, *Polydora capensis*, and *Heteromastus filiformis* were common nearly to all sampling stations. Amongst, only *Heteromastus filiformis* were absent in control sites (#1 and #2).

Community pattern: Generally, species richness is significantly higher in unpolluted sites (C1 and C2), than in Abu Quir Bay, Eastern Harbour and El Mex Bay (Table 1 and Fig. 4). Species richness is usually low in regions of the bay that are impacted by anthropogenic factors (Kennish, 1997). Anthropogenic impacts usually reduce the occurrence of rare species in a certain area (May, 1981). The lowest population density at the

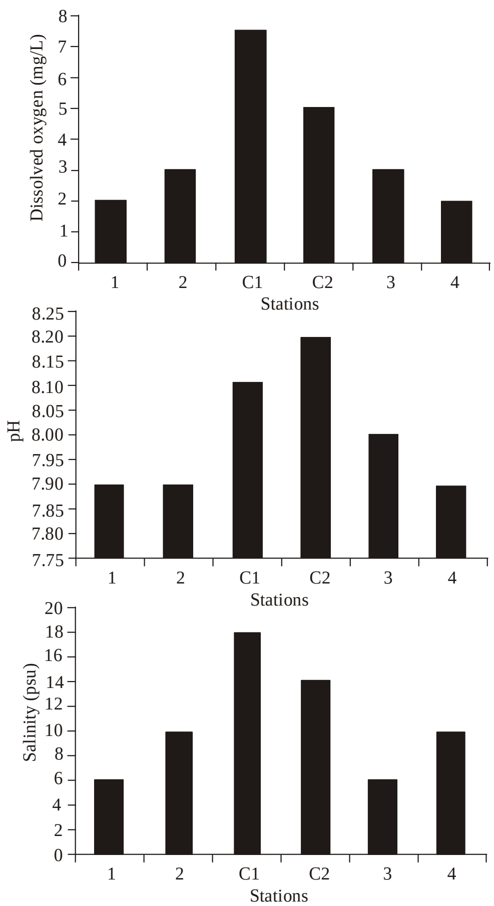

Fig. 2: Mean of environmental variables in each sampling station

polluted area is due to the shortage of the dissolved oxygen concentration, to the sharp decrease of salinity and to the high concentration of toxic compounds resulting from the decomposition of organic matter (hydrogen sulphide and ammonium). Nutrient enrichment significantly affects the composition of marine communities (Larsson *et al*., 1985; Kotta and Kotta, 1997; Kotta *et al*., 2000). Domestic and industrial sewage and drainage water from agricultural land contain organic matter and nutrients (NH4 , NO2, NO3 and PO4). Discharge of nutrients stimulates the growth of phytoplankton (microscopic algae). This process is called eutrophication (Nixon, 1995). Microorganisms in the water column degrade the organic matter and release nutrients. The degradation of discharged organic matter and dead plankton algae consumes oxygen, so when the load of organic matter and nutrients are very high, oxygen depletion may occur, which in turn may adversely affect the marine flora and fauna. The moreover, decline in dissolved oxygen concentrations can also promote the formation of reduced compounds, such as hydrogen sulphide (H_2S), resulting in higher adverse effects on aquatic animals (Diaz and Rosenberg, 1995; Wetzel, 2001; Breitburg, 2002). Recently, UNEP/MAP (2009) considered Abu Quir Bay, Eastern Harbour and El Mex as eutrophic or as being at risk to become eutrophic. UNEP (United Nations Environment Programme) (2007) regarded that eutrophication and the worsening of water quality (abnormal water colours, anoxia in bottom waters and production of hydrogen sulphide) in Egyptian coastal are caused by the combination of:

- Large inputs of fertilizing substances from urban, agricultural and industrial sources
- The long water residence times in the lagoons, partly due to physical barriers
- Salinity stratification of the waters
- Generally high water temperatures

The study area, in general, had moderate Shannon diversity values (1.43-2.52) (Table 1) suggesting environmental deterioration associated with anthropogenic activities. In a healthy environment, the Shannon diversity and Margalef richness are higher and in the range of 2.5-3.5 (Ajmal Khan *et al*., 2004)In addition, the Margalef richness display the same sense with values ranging from 0.50 to 2.59.

The distribution pattern of polychaete species shows different behaviour according to the distance from the source of pollutants (Fig. 5). *Capitella capitata*, *Polydora capensis*, *Minuspio cirrifera* and *Heteromastus filiformis* were the most common polychaete species in nearly all sites with mean density of 3570, 2775, 2450 and 2200 respectively. Pocklington and Wells (1992) reviewed the use of polychaetes in environmental quality monitoring and generalized that members of the families Capitellidae, and Spionidae seemed to be of particular value as pollution indicators. The four species decreased in abundance towards control sites (C1 and C2). In polluted sites (1-4), these species are found in large quantity than in control sites (Fig. 5). Amongst, *Capitella capitata* represents the most abundant polychaete species, in pollutes sites, with mean abundance of 3225. This species reached its maximum density in station #1. These tolerant species are common in organic polluted areas (Gray, 1981; Musale and Desai, 2011), so they are the indicator of organic pollution. On the other hand, there is a remarkable decrease in occurrence of *Capitella capitata* in control sites (C1 and C2). The low abundance of *Capitella capitata* with opportunistic life histories in healthy areas has been ascribed to poor ability to compete against other infauna (Grassle and Grassle, 1974; Kikuchi and Tanaka; 1976; Pearson and Rosenberg, 1976, 1978; Kikuchi, 1979).

Table 1: Polychaete statistics in impacted (1 to 4) and control stations (C1 & C2)

Sites	Shannon-wiener diversity index (H')	Species richness (S)	Total abundance (N)	Evenness (J)	Margalef's index (d)
#1	1.43	5	2275	0.88	0.51
#2	1.55	5	2905	0.96	0.50
C1	2.52	22	3313	0.82	2.59
C2	2.52	20	3333	0.84	2.34
#3	1.77	7	2950	0.91	0.75
#4	1.56	5	2900	0.97	0.50

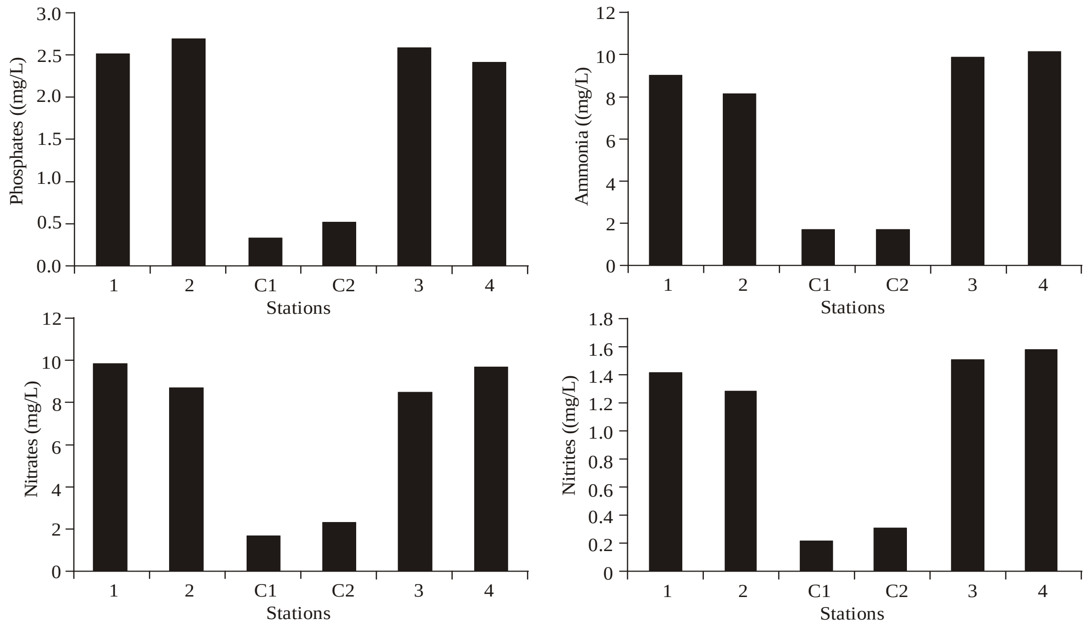

Fig. 3: Mean of nutrient concentrations in impacted (1 to 4) and control stations (C1 & C2)

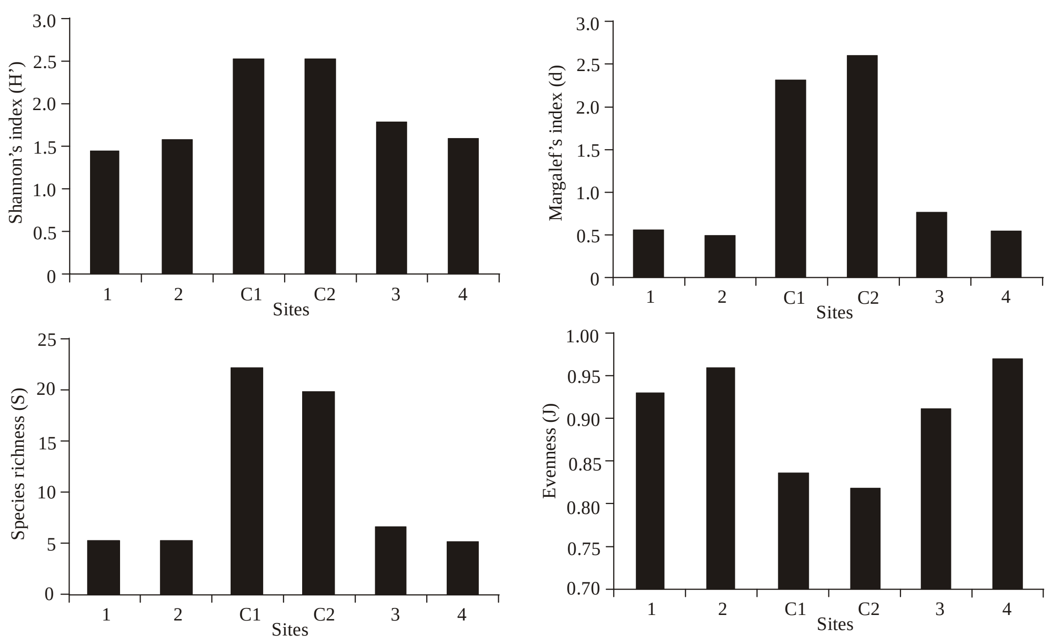

Fig. 4: Variation in univariate measures of the polychaete communities

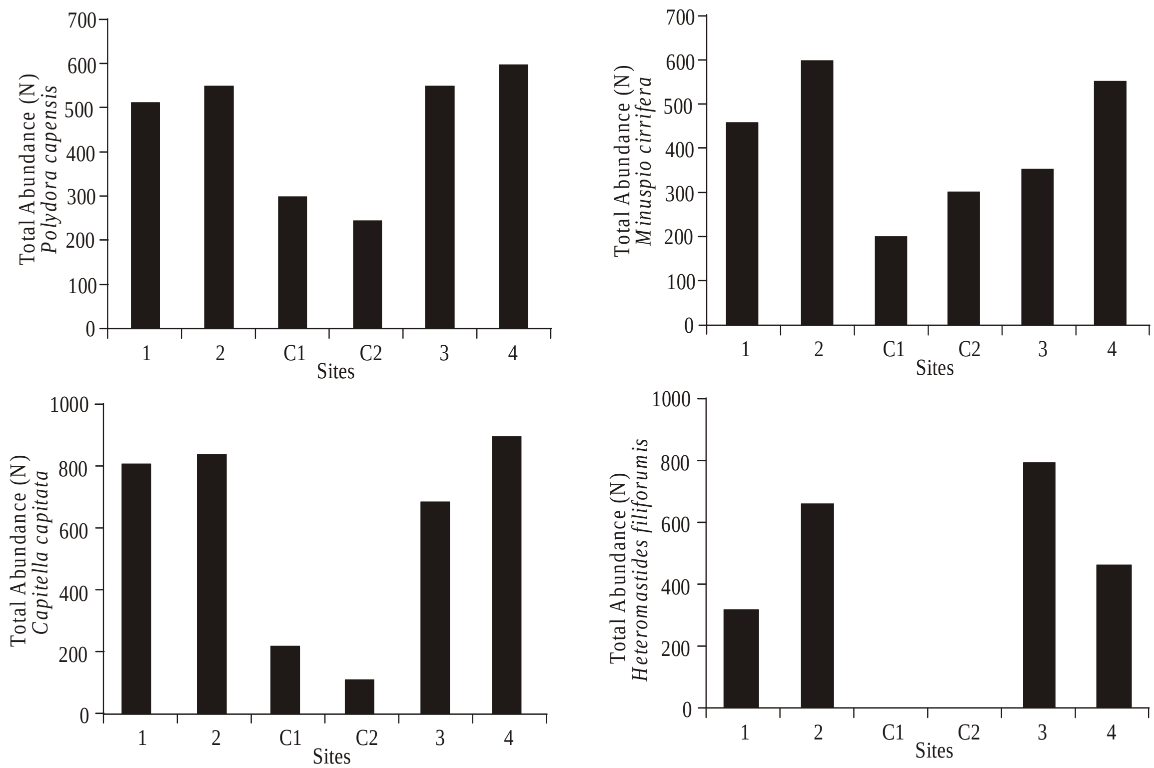

Fig. 5: Average densities of the four common polychaete species

However, the common positive indicators of a stressed community due to pollution include the capitellids *C. capitata*, (Méndez *et al.*, 1998; Belan, 2003; Rivero *et al*., 2005) and *Heteromastus filiformis* (Ahn *et al*., 1995). Both *C. capitata* and *Polydora* spp. had been previously characterized by Pearson and Rosenberg (1978) as indicators of organic enrichment. Rygg (1985) considers *Polydora* species to be very tolerant to pollution as they are present in large number in areas characterised by low diversity. On the other hand, *Minuspio cirrifera* are very useful sedentary worms that can be used as indicator of organic pollution (Elias *et al*., 2004).

Although no sedimentation measurements were made in the present study, the continental runoff is likely higher during the rainy season, increasing the amount of fine sediments and pollutants that reach the Alexandria coastal (UNESCO, 2003). This condition may changes the soft-bottom habitat to some extent, and thus the biological processes.

CONCLUSION

- Polychaetes are the most abundant taxon recorded in benthic communities of many habitats of Alexandria, Egypt.
- Polychaete species richness and diversity decreased from control to impacted sites.
- The lowest diversity and species richness at the polluted area is due to the shortage of the dissolved oxygen concentration, to the sharp decrease of salinity and to the high concentration of toxic compounds resulting from the decomposition of organic matter.
- The study area, in general, had moderate Shannon diversity values (1.43-2.52) suggesting environmental deterioration associated with anthropogenic activities
- The most common families were Capitellidae and Spionidae both in term of abundance and species richness. Their occurrences in great abundance reflect serious changes in the environmental conditions and anthropogenic activities of the coastal area studied.
- *Capitella capitata*, *Notomastus aberans*, *Polydora capensis*, *Minuspio cirrifera* and *Cirriformia filigera* were the most abundant and omnipresent polychaetes in the study area indicating their tolerance and adaptability to various degrees of pollution.
- The dominance of tolerant species, such as *Capitella capitata* (Capitellidae) in station #1 and *Minuspio cirrifera* (Spionidae) in station #2, is a good indicator of organic pollution.
- The poorest environment for polychaetes was in the

Eastern Abu Quir "station #1"

- Further monitoring studies are needed to confirm that polychaetes can be used as bioindicators of marine pollution in bottom sediments of the studied area.

ACKNOWLEDGMENT

The authors wish to express their appreciation to the Deanship of Scientific Research at King Saud University for funding the work through the research group project No. RGP-VPP-012

REFERENCES

Ahn, I.Y., Y.C. Kang and J. Choi, 1995. The influence of industrial effluents on intertidal benthic communities in Panweol, Kyeonggi Bay (Yellow Sea) on the west coast of Korea. Mar. Pollut. Bull., 30: 200-206.

Ajmal Khan, S., P. Murugesan and P.S. Lyla, 2004. A new indicator macro-invertebrate of pollution and utility of graphical tools and diversity indices in pollution monitoring studies. Curr. Sci., 87: 1508-1510.

Al Sayes, A.A. and L.M. Shakweer, 1997. Development of fouling organisms on fishing net materials in relation to the environmental conditions in the Eastern Harbour (Alexandria, Egypt). Bull. National Institute Oceanography Fisheries, A.R.E., 23: 351-388.

Belan, T.A. 2003. Benthos abundance patterns and species composition in conditions of pollution in Amursky Bay (the Peter the Great Bay, the Sea of Japan). Mar. Pollut. Bull., 46: 1111-1119.

Bondar, C., V. Roventa and I. State, 1973. Marea Neagra in zona litoralului romanesc. *Monografie hidrologica*. Institutul de meteorologia si hidrologie, Bueuresti, pp: 516.

Borja, A., J. Franco and V. Pérez, 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos with in European estuarine and coastal environments. Mar. Pollut. Bull., 40: 1100-1114.

Breitburg, D., 2002. Effects of hypoxia and the balance between hypoxia and enrichment, on coastal fishes and fisheries. Estuaries., 25: 767-781.

Danulat, E., P. Muniz, J. Garca-Alonso and B. Yannicelli, 2002. First assessment of the highly contaminated harbour of Montevideo, Uruguay. Mar. Pollut. Bull., 44: 551-576.

Dean, H.K., 2008. The use of polychaete (Annelida) as indicator species of marine pollution: A review. Revista de Biología Tropical, 56: 171-185.

Diaz, R.J. and R. Rosenberg, 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr. Mar. Biol. Annual. Rev., 33: 245-303.

Elias, R., E.A. Vallarino, M. Scagliola and F.I. Isla, 2004. Macrobenthic distribution patterns at a sewage disposal site in the inner shelf off Mar del Plata (SW Atlantic). J. Coastal Res., 20: 1176-1182.

El-Rayis, O.A. and M.A.M. Abdallah, 2006. Contribution of nutrients and some trace metals from a huge Egyptian drain to the SE-Mediterranean Sea, West of Alexandria. Mediterr. Mar. Sci., 7(1): 79-86.

Fahmy, M.A., F.T. Tayel and M.M. Sheriadah, 1997. Spatial and seasonal variations of dissolved trace metals in two contaminated basins of the coastal Mediterranean Sea, Alexandria, Egypt. Bull. Faculty Sci. Alexandria Univ., 37(2): 187-198.

Fauchald, K. and P.A. Jumars, 1979. The diet of worms: a study of polychaete feeding guilds. Oceanogr. Mar. Biol. Annu. Rev., 17: 193-284.

Grassle, J.F. and J.P. Grassle, 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. J. Mar. Res., 32: 253-284.

Gray, J.S., 1981. The Ecology of Marine Sediments. Cambridge University Press, Cambridge.

Guerra-García, J.M. and J.C. García-Gómez, 2004. Polychaete assemblages and sediment pollution in a harbour with two opposing entrances. Helgoland Mar. Res., 58: 183-191.

Halim, Y., A. Khalil and A.Y. Al-Handhal, 1980. Diatoms flora of a eutrophic bay, the Eastern Harbour of Alexandria. Act. Adriatica, 21(2): 271-298.

Holland, A.F., A. Shaughnessy and M.H. Heigel, 1987. Long-term variation in mesohaline Chesapeake Bay benthos: Spatial and temporal patterns. Estuaries, 10: 227-245.

Inglis, G.J. and J.E. Kross, 2000. Evidence for systematic changes in the benthic fauna of tropical estuaries as a result of urbanization. Mar. Pollu. Bull., 41: 367-376.

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, pp: 275.

Jayaraj, K.A., K.V. Jayalakshmi and K. Saraladevi, 2007. Influence of environmental properties on Macrobenthos in the Northwest Indian shelf. Environ. Monit. Assess., 127: 459-475.

Kennish, M.J., 1997. Pollution Impacts on Marine Biotic Communities. CRC Press, Boca Raton, Florida, pp: 310.

Kikuchi, T., 1979. Some aspects of ecology, life cycle and taxonomy of the polychaete *Capitella capitata*, so called pollution indicator: A review. Benthos Res., 17(18): 33-51.

Kikuchi, T. and M. Tanaka, 1976. Some aspects on the ecology of a short-lived semelid bivalve, *Theora lata* (HINDS), with special reference to its opportunistic life history. Physiol. Ecol. Jpn., 17: 261-271.

Kotta, I. and J. Kotta, 1997. Changes in Zoobenthic Communities in Estonian Waters between the 1970´s and 1990´s. An Example from the Southern Coast of Saaremaa and Muuga Bay. In: Ojaveer, E. (Ed.), Proceedings of the 14th Baltic Marine Biologists Symposium Estonian Academy Publishers, Pärnu, Estonia, pp: 70-79.

Kotta, J., I. Kotta and I. Viitasalo, 2000. Effect of diffuse and point source nutrient supply on the low diverse macrozoobenthic communities of the northern Baltic Sea. Boreal Environ. Res., 5: 235-242.

Labib, W., 2002. Phytoplankton variability in the Eastern Harbour (Alexandria, Egypt). Egyptian J. Aquati. Biol. Fisheri. 6(2): 75-102.

Larsson, U., R. Elmgren and F. Wulff, 1985. Eutrophication and the Baltic Sea: Causes and consequences. Ambio, 14: 9-14.

Levin, L., H. Caswell, T. Bridges, C. DiBacco, D. Cabrera, and G. Plaia, 1996 Demographic responses of estuarine polychaetes to pollutants: life table response experiments. Ecol. Appl., 6: 1295-1313.

May, R.M., 1981. Patterns in Multi-Species Communities. In: May, R., (Ed.), Theoretical Ecology: Principles and Applications. Blackwell, pp: 197-227.

Méndez, N., J. Flos and J. Romero, 1998. Littoral soft bottom polychaetes communities in a pollution gradient in front of Barcelona (Western Mediterranean, Spain.) Bull. Mar. Sci., 63: 167-178.

Musale, A.S. and D.V. Desai, 2011. Distribution and abundance of macrobenthic polychaetes along the South Indian coast. Environ. Monitoring Assessment, 178: 423-436.

Nixon, S.W., 1995.Coastal marine eutrophication: A definition, social causes and future concerns. Ophelia, 41: 199-219.

Papageorgiou, N., C. Arvanitidis and A. Eleftheriou, 2006. Multicausal environmental severity: A flexible framework for microtidal sandy beaches and the role of polychaetes as an indicator taxon. Estuarine Coastal Shelf Sci., 70: 643-653.

Pearson, T.H. and R. Rosenberg, 1976. A comparative study of the effects on the marine environment of wastes from cellulose industries in Scotland and Sweden. Ambio, 5: 77-79.

Pearson, T.H. and R. Rosenberg, 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Annu. Rev., 6: 229-311.

Pocklington, P. and P.G. Wells, 1992. Polychaetes-Key taxa for marine environmental quality monitoring. Mar. Pollut. Bull., 24: 593-598.

Remani, K.N., K.S. Devi, P. Venugopal and R.V. Unnithan, 1983. Indicator organisms of pollution in Cochin backwaters. Mahasagar, 16(2): 199-207.

Rivero, M.S., R. Elías and E.A. Vallarino, 2005. First survey of macrofauna in the Mar del Plata Harbor (Argentina) and the use of polychaetes as pollution indicators. Revista de Biología Marina y Oceanografía, 40: 101-108.

Rygg, B., 1985. Distribution of Species along Pollution-induced Diversity Gradients in Benthic Communities in Norwegian Fjords. Mar. Pollut. Bull., 16(12): 469-474.

Samuelson, G.M., 2001. Polychaetes as indicators of environmental disturbance on subarctic tidal flats, Iqaluit, Baffin Island, Nunavut Territory. Mar. Pollut. Bull., 49: 733-741.

Santi, L. and M. Tavares, 2009. Polychaete assemblage of an impacted estuary, Guanabara Bay, Rio de Janeiro, Brazil. Braz. J. Oceanogr., 57(4): 287-303.

Shen, P.P., H. Zhou and J.D. Gu, 2010. Patterns of polychaete communities in relation to environmental perturbations in a subtropical wetland of Hong Kong. J. Mar. Biol. Assoc. U.K., 90(5): 923-932.

Unesco, 2003. Towards Integrated Management of Alexandria’s Coastal Heritage.Coastal Region and Small Island Papers 14, UNESCO, Paris, pp: 79.

UNEP, 2007. Approaches to the assessment of eutrophication in Mediterranean coastal waters (First draft). Mediterranean Action Plan. Review Meeting of MED POL Monitoring Activities and the use of indicators Athens, 12-14 December 2007. UNEP (DEPI)/MED WG.321/Inf.6 3 December.

UNEP/MAP, 2009. Review of MED POL marine monitoring activities assessment of the state of the environment and pollution trends. UNEP (DEPI)/MED WG.343/3, 18 November, Athens.

Warwick, R. and M. Ruswahyuni, 1987. Comparative study of the structure of some tropical and temperate marine soft bottom macro benthic communities. Mar. Biol., 95: 641-649.

Wetzel, R.G., 2001. Limnology. 3rd Edn., Academic Press, New York.