The Influence of Marine Pollution on Distribution and Abundance of Polychaetes

A. El-Gendy, S. Al-Farraj, S. Al-Kahtani and M. El-Hedeny

Department of Zoology, Faculty of Science, Alexandria University, Alexandria, Egypt
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 cirriferæ, 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 Ruswhayuni, 1987; Guerra-Garcia and Garcia-Gomez, 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.
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 30° 22' E and latitude 31° 16' and 31° 28' 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 m³/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 m³/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 m³/day and 50,000 m³/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 m² 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
Dissolved oxygen (mg/L)

Stations

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 (H₂S), 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)

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

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


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.
