Research Article

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson) and SCOPUS
The journal is available on line at http://www.medit-mar-sc.net
DOI: http://dx.doi.org/10.12681/mms.680

Distribution patterns of shallow water polychaetes (Annelida) along the coast of Alexandria, Egypt (eastern Mediterranean)

M.M. DORGHAM[1], R. HAMDY[1], H.H. El-RASHIDY[1], M.M. ATTA[1] and L. MUSCO[2]

[1] Department of Oceanography, Faculty of Science, Alexandria University, Alexandria, 21511, Egypt
[2] Consiglio Nazionale delle Ricerche, Istituto per l'Ambiente Marino Costiero (CNR-IAMC),
Laboratorio di Ecologia Marina, 91014 Castellammare del Golfo, Italy

Corresponding author: mdorgham1947@yahoo.com

Handling Editor: Melih Cinar

Received: 22 October 2013; Accepted: 16 July 2014; Published on line: 1 October 2014.

Abstract

Shallow hard bottom and intertidal soft bottom polychaete assemblages of the Alexandria coast, south-eastern Mediterranean (Levantine Sea), were studied during a complete annual cycle in order to analyze spatial temporal patterns of variation in assemblages, and relevant factors related to polychaete distribution. The present study recorded a total of 73 species, belonging to Syllidae (22 species), Nereididae (9 species), Serpulidae (6 species), Eunicidae (5 species) and another 19 families. The assemblages experienced pronounced spatial and temporal variation throughout the study area, but spatial variation appeared more important in determining the observed patterns. Polychaete distribution related to variation of grain size and sessile macrobenthos cover suggesting that these structural variables accounted more than the physical-chemical ones (namely BOD, dissolved oxygen, organic carbon, organic matter, salinity, temperature, pH) in influencing the patterns of assemblage distribution. A total of 9 alien polychaete species were found solely on hard substrata, of which *Pseudonereis anomala* and *Linopherus canariensis* formed dense population in the area. The present study is the south-eastern-most one dealing with the ecology and distribution patterns of hard bottom polychaetes from the Mediterranean Sea, as well as one of the few studies dealing with intertidal soft bottom polychaetes in the Levant Basin.

Keywords: Polychaeta, hard bottom, soft bottom, Mediterranean Sea, intertidal, algal cover, sediment texture, alien species.

Introduction

Benthic marine assemblages are characterized by spatial heterogeneity in species composition and abundance due to the interplay of various abiotic and biotic processes operating at different spatial scales and depths. Spatial heterogeneity is particularly evident among marine benthic assemblages associated to shallow water habitats, since they commonly experience fluctuation of key environmental factors such as temperature, salinity, wave action, etc. (Benedetti-Cecchi *et al.*, 2000; Therriault & Kolasa, 2000; Sousa, 2001; Witman & Dayton, 2001).

Polychaetes showing remarkable abundance, species richness and functional diversity are dominant in marine benthic communities of both soft and hard bottoms (Knox, 1977; Çinar *et al.*, 2006; Musco, 2012). Due to high levels of adaptation to a wide variety of environmental conditions, polychaetes play key roles in ecosystem functioning and they have been used successfully as surrogates for the estimation of diversity and dynamics of benthic communities (Olsgard *et al.*, 2003; Giangrande *et al.*, 2004; 2005; Papageorgiou *et al.*, 2006). In fact, the analysis of polychaete assemblage structure has been proved to be an efficient tool for assessing environmental health, and it is commonly used as a biological criterion for water quality and also in biomonitoring studies (e.g. Pocklington & Wells,1992; Warwick, 1993; Olsgard *et al.*, 2003; Samuelson, 2001; Giangrande *et al.*, 2005; Ergen *et al.*, 2006; Musco *et al.*, 2009; 2011; Musco *et al.*, in press; Del-Pilar-Ruso *et al.*, 2010; Mikac *et al.*, 2011).

Several papers suggest that polychaete distribution naturally varies alongshore and along depth gradients both on soft and hard bottoms, with variation increasing with decreasing depth and changes in sediment texture and algal cover as factors contributing to assemblage heterogeneity (e.g. Gambi & Giangrande, 1986; Giangrande, 1988; Giangrande *et al.*, 2003; Mutlu *et al.*, 2010; Musco, 2012; Mikac & Musco, 2010).

As far as shallow water assemblages are concerned, Giangrande (1990) suggested that on subtidal rocky shores physical factors play a crucial role in polychaete distribution by directly selecting species and by influencing the composition of the sessile macrobenthos forming the polychaete habitat. In general, it was suggested that polychaetes should be abundant where the substrate provides suitable microhabitats for settlement (Abbiati *et al*., 1987; Giangrande, 1988). For example, structurally complex coralline algae appeared to be a suitable habitat for polychaetes (Tena *et al*., 2000). However, Musco (2012) did not observe a significant correlation between coralline algae and patterns of Syllidae distribution, these last usually dominating hard bottom polychaete assemblages, whilst part of the observed variation was related to the distribution of less structurally complex algae. Further studies examining polychaete assemblages in relation to the distribution of the habitat formers are necessary to fill gaps in our knowledge.

Compared to hard bottom and soft bottom habitats, the intertidal sandy one is usually characterized by low species richness and density. Despite being resilient to several sources of disturbance, intertidal sandy assemblages experience fluctuations of species abundance and diversity following changes of local environmental conditions, with consequent high spatial temporal variability in distribution patterns (e.g. Defeo & Lercari, 2004; Papageorgiou *et al.*, 2006). In this context, sediment texture resulting from the interaction of several local factors (i.e. hydrodynamics, geology, coastal morphology) is considered to play a crucial role in characterizing the patterns of beach fauna distribution (McLachlan, 1990; Raffaelli & Hawkins,1996), with polychaetes being particularly sensitive to variation in particle size (Yamanaka *et al.*, 2010). In the Mediterranean Sea, the tidal range is limited compared to open oceans, with an average amplitude of a few centimetres. This feature that limits available space for faunal settlement might contribute to the intrinsic low faunal density and diversity characterizing Mediterranean intertidal sandy assemblages (Dexter, 1989; Deidun *et al*., 2003; Papageorgiou *et al*., 2006; Pérez-Domingo *et al*., 2008).

During the last decade, an increasing number of studies have been carried out on polychaetes in the Eastern Mediterranean area mostly dealing with taxonomy, faunal analyses, distribution patterns, and alien species (e.g. Çinar & Ergen, 2003; Çinar *et al*., 2003; Aguado & San Martín, 2007; Çinar, 2009; Kurt Şahin & Çinar, 2009; Mutlu *et al*., 2010; Faulwetter *et al*., 2011; Çinar & Dagli, 2012; Çinar *et al*., 2012). An increasing interest in polychaete research is also evident for the Egyptian Mediterranean area, where several studies were recently conducted particularly along the coast of Alexandria (Abd El-Naby, 1999; El Komi *et al*., 2003; Moustafa *et al*., 2007; Abd El-Naby & San Martín, 2010; 2011; Selim *et al*., 2012; El Komi, 2011a, b; 2012 a, b; El Gendy *et al*., 2012) partly filling the gap in recent polychaete research concerning the southern Mediterranean coastline (Musco & Giangrande, 2005). However, the majority of these studies deals with taxonomy and basic faunal analyses, and concentrate on part of the coast. The intertidal benthic assemblages of the Egyptian Mediterranean sandy beaches have been thoroughly studied by Dexter (1989) who provided an interesting faunal report indicating low diversity and density for the majority of the main taxa. Recently, Dorgham *et al*. (2013) provided a detailed description of several polychaete species associated to the intertidal sandy shore and shallow rocky bottoms of the coast of Alexandria, and recorded new species for the area. However, spatial-temporal variation in polychaete assemblages and factors influencing species distribution along the Egyptian Mediterranean coast remain poorly studied, while the ecology and patterns of hard bottom polychaete distribution remain unknown in the area.

The present research aims at describing patterns of abundance and diversity of shallow water polychaetes along the Egyptian Mediterranean coast.

Specifically, focusing on shallow subtidal rocky shores and intertidal soft bottoms, we aim at 1) analyzing spatial temporal patterns of variation in assemblages, and 2) highlighting relevant factors (environmental physicochemical variables and biological variables) related to polychaete distribution during a complete annual cycle along the exposed coastal area of Alexandria.

Materials and Methods

The study area

The coast of Alexandria extends about 35 km along the south-eastern Mediterranean. For several decades, sewage was discharged into the sea from the City of Alexandria through numerous outfalls, but discharge stopped in 1992. At present, effluents are only discharged from lake Mariut to El-Mex Bay, west of Alexandria.

The coast is mostly sandy as on the rest of the Mediterranean Egyptian coast, with some rocky areas intermitted by long sandy beaches. However, since 1998 the coastal road of the City of Alexandria was widened, and thousands of concrete blocks were dumped along the shoreline and inside the sea for shore armouring purposes, thus providing new rocky substrate for faunal settlement.

Four sites some km apart from each other were selected for polychaete collection from both hard and soft bottoms, namely Abu Qir (AQ), El-Mandara (MN), Stanly (ST) and El-Mex (MX) (Fig. 1).

1. AQ (31°20’16.80”N - 30°04’52.12”E) lies east of Alexandria City with sandy bottom intermittent with large natural rocky patches, which are usually covered with rich flora dominated by *Corallina* spp., *Jania rubens* (L.) Lamouroux*, Ulva rigida* C.Agardh, *Hypnea musciformis* (Wulfen) Lamouroux and *Pterocladia* sp. This site is subjected to continuous wave action and is considered an exposed area.
2. MN (31°16’29.85”N - 29°59’52.87”E) is a sandy beach, with occasional patches of calcareous shell fragments, and protected by concrete blocks, extending about 100 m inside the sea and covered by *U. rigida, Corallina* spp. and *Colpomenia sinuosa*

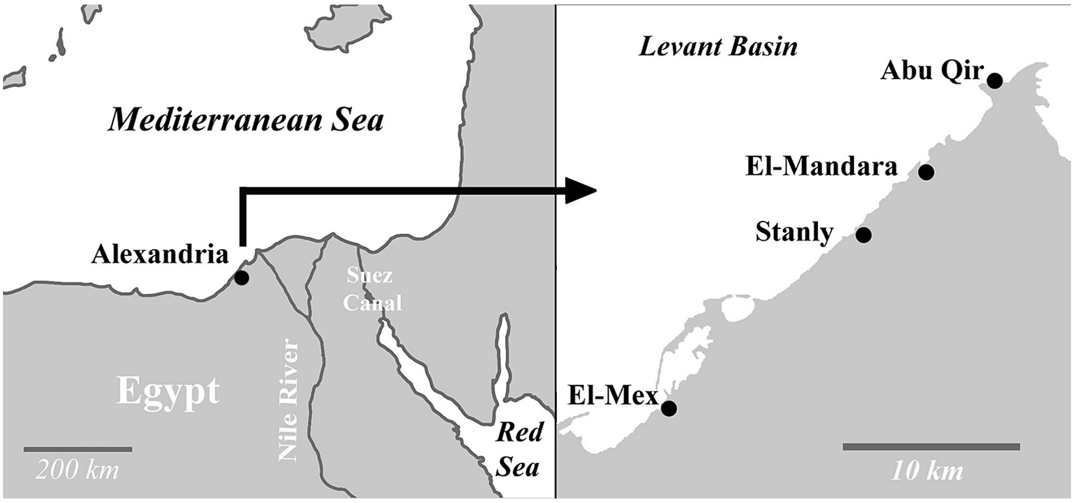

Fig. 1: The coast of Alexandria including the sampling sites.

(Mertens ex Roth) Derbès and Solier.

3. ST (31°14’02.56”N - 29°56’47.82”E) is a semi-circular embayment with sandy bottom surrounded by an old, low, cement wall mostly covered with macro-algal growth dominated by *U. rigida* and *Corallina* spp.
4. MX (31°09’14.93”N - 29°50’52.38”E) is an exposed rocky area with a beach composed of hard debris of different benthic animals. The algae *Ulva rigida* and *Gelidium* sp. co-dominate hard bottoms with sessile invertebrates including *Balanus* sp. and the bryozoan *Schizoporella* sp.

Starting on June 13th 2005, collection of hard bottom and soft bottom samples, and measurements of environmental (physical and chemical) variables were carried out every 30th day ca. at each site during 12 sampling occasions.

Sampling

Physico-chemical parameters

Water temperature was measured in situ, using a simple thermometer, graduated to 100°C; salinity was determined by a calibrated Beckman Induction Salinometer (Model RS- 7C), and pH was measured in situ by digital portable pH-meter (Cyberscan 10^{pH}; pH - ºC Meter). Dissolved oxygen (DO) and Biochemical Oxygen Demand (BOD) were determined according to the methods described by Strickland & Parsons (1972).

Grain size analysis was carried out by sieving 25 g of sediment through a standard set of sieves (Geyer type) arranged in an interval of 1 phi class from top to bottom and mounted on an electric shaker for 10 minutes. Cumulative curves were drawn by plotting the cumulative percentage against phi- diameters according to Folk (1965) and the mean size of the sediment (M_z) was calculated according to Folk & Ward (1957). Organic matter (OM) and organic carbon (OC) were measured according to Thorp (1966).

Polychaete sampling

Polychaetes were collected from both the hard and soft bottoms. Hard bottom polychaetes hiding in dense algal cover and associated with other benthic invertebrates were collected in three replicates some meters apart from each other in the shallow subtidal zone within the bathymetric range of 0.5 – 1 m by careful scraping of the biota on hard substrate inside 0.1 m^2 quadrates at random places of each site during each sampling time. The biota was placed in plastic bags and preserved in 7% neutralized formalin, and the polychaetes were isolated in the laboratory and kept in plastic jars for identification and counting. For each site and sampling time, the associated macrobenthic habitat formers, including algae and sessile invertebrates were identified and coverage (%) was estimated.

Sediment polychaetes were collected through three random cores of 20 cm in length and 38.485 cm^2 surface area from the same sites mentioned above in the intertidal zone, being distant some meters apart from each other. The tidal range in the area does not exceed 30 cm. The sediment cores were placed in plastic bags and preserved in 7% formalin solution.

Both hard and soft bottom samples were gently rinsed with large quantities of filtered sea water on a piece of zooplankton net (100 µ mesh) and the polychaetes were separated and kept in plastic jars. The polychaetes were examined under stereo- and compound microscopes, identified according to several references, and counted (see Dorgham *et al.*, 2013 for further details).

Experimental design and data analyses

The experimental model consisted of two orthogonal factors: “site” (SI), 4 levels fixed, and “time” (TI), 12 levels random. It was used to analyze the patterns of the spatial & temporal distribution of assemblages in the study area. The same design was used to analyze both soft and hard bottom polychaete assemblages.

The pattern of polychaete assemblage distribution was analyzed by permutational MANOVA (multivariate analysis of variance) based on the Bray Curtis similarity index. Each term in the analyses was tested using 9999 random permutations of the appropriate units.

Constrained analyses of principal coordinates (CAP) (Anderson & Willis, 2003) were performed to assess the relative influence of spatial variation on the distribution patterns of polychaete assemblages for both and soft bottoms. The same analyses allowed visualizing correlations of polychaete taxa variables, environmental physical-chemical variables (also including sediment grain size for soft bottoms and sessile macrobenthos variables for hard bottoms) with the canonical axes.

In order to identify potential drivers of variation in hard and soft bottom assemblages, non-parametric multiple regression analyses were performed using the DISTLM-forward procedure (Distance-based multivariate analysis for a linear model using forward selection); covariates included temperature, salinity, pH, BOD, DO for the analysis of both hard and soft bottom polychaete assemblages, OC, OM and sediment grain size for soft bottom assemblages only, and sessile macrobenthos percent coverage (cut-off 1% of total cover) for hard bottom assemblages only. The procedure also provided a multicollinearity check for all pairs of explanatory variables. The analyses were performed using the PRIMER v6 software programme, including the PERMANOVA+ add-on package (Anderson *et al.*, 2008).

Results

Physico-chemical conditions

The physico-chemical parameters and granulometry of coastal water are given in Table 1. The temperature displayed clear seasonal variation between the winter minimum in February and the summer maximum in August. Surface salinity varied within a narrow range at most of the sampling sites, except for a wide range at MX, due to the huge amount of polluted brackish water discharged from Umoum Drain. pH exhibited limited monthly variations at all sites, while dissolved oxygen showed small amplitudes of annual variation at MN and ST and comparatively wide at AQ and MX. In contrast, BOD showed approximately similar ranges at three sites and a markedly wide range at MX.

Shore sediment at AQ and ST was composed of coarse sand, but organic matter and organic carbon at AQ fluctuated seasonally within wider ranges (3.1 - 7.1% & 1.7 - 3.9% respectively) than those at ST (2.5 - 3.6% & 1.4 - 2.0% respectively). At MN, fine sand was dominant with 15.6% coarse silt, 3.2 - 8 % organic matter and 1.8 - 4.4% organic carbon. Coarse sand was dominant at MX with 0.1 % silt, 3.4 -5.0 % organic matter and 1.9 - 2.8% organic carbon.

Hard bottom polychaetes

The polychaete community of the hard substrate comprised 72 species belonging to 59 genera and 23 families (Table 2). Syllidae was represented by 22 species, Nereididae (9 species), Serpulidae (6 species) and Eunicidae (5 species). The community was the most diverse at MN (59 species) as compared to that at ST (49 species), MX (41 species) and AQ (40 species). The number of polychaete taxa experienced clear temporal variations (Fig. 2), with some differences between sites. In particular, at AQ, MN and ST, the number of taxa appeared to increase, in general, from June to December/January, suddenly drop in March and increase again in April/May. A moderate April/May growth was also evident at MX, where, however, spatial-temporal variation appeared less evident. Eleven species were persistent throughout the study area during most of the sampling times, namely *Monticellina* cfr. *hetero-*

Table 1. Minimum and maximum values of the physico-chemical parameters and sediment size composition percentages at the sampling sites. DO- dissolved oxygen; BOD- biochemical oxygen demand; OM- organic matter; OC- organic carbon; VFS, very fine sand; FS, fine sand; MS, medium sand; CS, coarse sand; VCS, very coarse sand.

	Abu Qir		El Mandara		Stanly		El Mex	
	Min.	**Max**	**Min.**	**Max**	**Min.**	**Max**	**Min.**	**Max**
Temp. (^{o}C)	17.4	30	17.5	30	17	29.5	16.6	30
Sal. (‰)	37.2	38.7	37.1	39.5	36.2	39.3	20.8	38.6
pH	7.9	8.5	7.7	8.3	7.65	8.31	7.5	8.6
DO (mg/l)	6.8	10.7	5.8	7.9	6.4	8.6	5.9	10.4
BOD (mg/l)	0.5	3.8	0.5	4.2	0.9	5.3	0.8	10.4
OM (%)	3.1	7.1	3.2	8.0	2.48	3.62	3.4	5.0
OC (%)	1.7	3.9	1.8	4.4	1.38	2.01	1.9	2.8
VCS	6.397 %		1.736 %		7.124 %		7.332 %	
CS	69.099 %		6.848 %		65.932 %		29.544 %	
MS	16.047 %		4.852 %		24.408 %		31.900 %	
FS	8.195 %		42.016 %		2.444 %		29.948 %	
VFS	0.148 %		28.696 %		0.120 %		1.132 %	
Silt	0.020 %		15.600 %		0.012 %		0.076 %	

Table 2. Maximum count (Ct.) and frequent occurrence (Fr.) (months) of the polychaete species of the Alexandria coast. AQ: Abu Qir; MN: El-Mandara; ST: Stanly; MX: El-Mex.

HARD BOTTOM SPECIES	**AQ**		**MN**		**ST**		**MX**	
	Ct.	**Fr.**	**Ct.**	**Fr.**	**Ct.**	**Fr.**	**Ct**	**Fr.**
Syllidae								
Myrianida cfr. *prolifera* (O.F. Müller, 1788)	0	0	50	4	10	1	10	2
Branchiosyllis exilis (Gravier, 1900)	190	9	70	5	110	5	0	0
Brania arminii (Langerhans, 1881)	20	3	330	6	110	5	60	1
Brania pusilla (Dujardin, 1851)	20	5	90	7	170	9	40	4
Exogone dispar (Webster, 1879)	0	0	10	1	0	0	10	1
Exogone verugera (Claparède, 1868)	50	2	20	2	210	6	10	1
Salvatoria clavata (Claparède, 1863)	100	6	1100	9	740	9	900	9
Salvatoria limbata (Claparède, 1868)	0	0	0	0	0	0	90	2
Haplosyllis spongicola (Grube, 1855)	0	0	70	1	0	0	0	0
Odontosyllis fulgurans (Audouin & Milne-Edwards, 1833)	40	4	40	4	110	4	0	0
Opisthosyllis brunnea Langerhans, 1879	780	5	580	5	240	5	30	1
Sphaerosyllis hystrix Claparède, 1863	0	0	0	0	0	0	0	0
Sphaerosyllis pirifera Claparède, 1868	80	6	370	7	230	10	1260	2
Syllides fulvus (Marion & Bobretzky, 1875)	10	1	40	3	0	0	0	0
Syllis gracilis Grube, 1840	170	8	620	12	590	11	810	11
Syllis hyalina Grube, 1863	100	7	1260	11	4220	10	2860	11
Syllis cf. *luquei* San Martin, 1984	0	0	30	1	0	0	0	0
Syllis pulvinata (Langerhans, 1881)	1150	11	6660	12	1730	12	140	10
Syllis prolifera (Krohn, 1852)	540	4	60	3	530	5	360	5
Syllis ergeni Çınar, 2005	1140	11	10240	11	2200	11	1750	12
Syllis variegata Grube, 1860	150	9	310	9	420	9	20	4
Trypanosyllis zebra (Grube, 1860)	0	0	50	5	10	1	0	0
Nereididae								
Composetia costae (Grube, 1840)	0	0	0	0	10	2	0	0
Namanereis pontica (Bobretzky, 1872)	0	0	0	0	0	0	30	2
Neanthes caudata (Delle Chiaje, 1827)	0	0	0	0	10	1	0	0
Neanthes succinea (Leuckart, 1847)	0	0	10	1	0	0	10	4
Nereis falsa Quatrefages, 1866	20	8	1100	12	50	7	160	12
Nereis zonata Malmgren, 1867	10	2	0	0	10	3	0	0
Perinereis cultrifera (Grube, 1840)	0	0	10	1	400	7	300	11
Platynereis dumerilii (Audouin & Milne-Edwards, 1834)	960	11	1830	10	20	4	20	3
Pseudonereis anomala Gravier, 1900	1280	12	9390	11	800	9	510	12
Serpulidae								
Hydroides dianthus (Verrill, 1873)	0	0	50	2	20	1	10	1
Hydroides elegans (Haswell, 1883)	0	0	70	2	180	4	150	8
Serpula cf. *concharum* Langerhans, 1880	0	0	20	1	0	0	0	0
Spirobranchus tetraceros (Schmarda, 1861)	0	0	0	0	10	1	0	0
Spirobranchus triqueter (Linnaeus, 1758)	2300	10	5200	12	1800	12	10000	11
Vermiliopsis infundibulum (Philippi, 1844)	10	1	0	0	10	1	0	0
Eunicidae								
Leodice antennata Savigny in Lamarck, 1818	10	1	0	0	0	0	0	0
Eunice vittata (Delle Chiaje, 1828)	0	0	20	3	60	3	10	1
Marphysa sanguinea (Montagu, 1815)	0	0	0	0	50	8	30	1
Lysidice unicornis (Grube, 1840)	50	6	30	2	0	0	0	0
Palola siciliensis (Grube, 1840)	10	1	0	0	0	0	0	0
Phyllodocidae								
Eulalia clavigera (Audouin & Milne Edwards, 1833)	0	0	10	5	0	0	0	0
Eumida sanguinea (Örsted, 1843)	0	0	20	2	0	0	0	0
Nereiphylla rubiginosa (Saint-Joseph, 1888)	0	0	40	5	10	2	0	0
Phyllodoce cf. *longifrons* Ben-Eliahu, 1972	0	0	10	1	0	0	0	0
Hesionidae								
Microphthalmus aberrans (Webster & Benedict, 1887)	0	0	0	0	0	0	10	0
Microphthalmus sczelkowii Mecznikow, 1865	0	0	0	0	0	0	20	1
Oxydromus pallidus Claparède, 1864	0	0	10	1	10	1	0	0
Syllidia armata Quatrefages, 1866	0	0	10	1	0	0	0	0
Capitellidae								
Capitella capitata (Fabricius, 1780)	50	7	40	4	1190	8	4400	10
Dasybranchus caducus (Grube, 1846)	0	0	10	1	0	0	0	0

(continued)

Table 2. *(continued)*

HARD BOTTOM SPECIES	AQ		MN		ST		MX	
	Ct.	Fr.	Ct.	Fr.	Ct.	Fr.	Ct	Fr.
Heteromastus filiformis (Claparède, 1864)	0	0	10	1	0	0	0	0
Amphinomidae								
Eurythoe complanata (Pallas, 1766)	0	0	10	1	0	0	0	0
Linopherus canariensis Langerhans, 1881	360	5	1800	11	20	5	10	2
Spionidae								
Boccardia polybranchia (Haswell, 1885)	0	0	100	4	130	4	10	1
Dipolydora coeca (Örsted, 1843)	50	6	500	11	600	11	170	10
Cirratulidae								
Dodecaceria concharum Öersted, 1843	150	4	50	3	30	3	150	4
Monticellina cfr. *heterochaeta* Laubier, 1961	960	10	1210	11	2370	11	260	10
Lumbrineridae								
Lumbrineris coccinea (Renier, 1804)	10	1	20	1	10	1	10	1
Scoletoma impatiens (Claparède, 1868)	20	1	10	1	0	0	0	0
Chrysopetalidae								
Chrysopetalum debile (Grube, 1855)	270	9	220	8	100	8	0	0
Arenicolidae								
Branchiomaldane vincenti Langerhans, 1881	230	8	230	5	260	10	0	0
Terebellidae								
Loimia medusa (Savigny in Lamarck, 1818)	40	10	90	10	240	9	20	2
Sabellidae								
Amphiglena mediterranea (Leydig, 1851)	60	3	10	2	90	7	20	1
Sabellariidae								
Sabellaria spinulosa (Leuckart, 1849)	0	0	10	1	0	0	0	0
Oenonidae								
Arabella iricolor (Montagu, 1804)	30	4	160	12	20	5	10	1
Opheliidae								
Polyophthalmus pictus (Dujardin, 1839)	330	6	200	7	140	6	20	2
Orbiniidae								
Naineris laevigata (Grube, 1855)	7160	8	2220	10	2890	11	130	10
Polynoidae								
Lepidonotus clava (Montagu, 1808)	10	1	10	1	10	1	0	0
Saccocirridae								
Saccocirrus papillocercus Bobretzky, 1872	0	0	0	0	0	0	830	3
Protodrilidae								
Protodrilus sp.	0	0	0	0	0	0	0	0
Dorvilleidae								
Schistomeringos rudolphi (Delle Chiaje, 1828)	80	6	50	5	70	8	30	4

SOFT BOTTOM SPECIES	AQ		MN		ST		MX	
Syllidae	Ct.	Fr.	Ct.	Fr.	Ct.	Fr.	Ct	Fr.
Salvatoria limbata (Claparède, 1868)	0	0	0	0	0	0	134	3
Sphaerosyllis hystrix Claparède, 1863	0	0	0	0	0	0	2	2
Sphaerosyllis pirifera Claparède, 1868	0	0	0	0	1	1	0	0
Syllis hyalina Grube, 1863	0	0	1	1	2	1	2	1
Nereididae								
Namanereis pontica (Bobretzky, 1872)	0	0	0	0	2	1	24	3
Hesionidae								
Microphthalmus aberrans (Webster & Benedict, 1887)	0	0	0	0	0	0	12	4
Microphthalmus sczelkowii Mecznikow, 1865	92	6	5	4	6	5	0	0
Capitellidae								
Capitella capitata (Fabricius, 1780)	0	0	0	0	0	0	1	1
Spionidae								
Dipolydora coeca (Örsted, 1843)	0	0	0	0	0	0	3	1
Cirratulidae								
Dodecaceria concharum Örsted, 1843	0	0	0	0	0	0	1	1
Monticellina cfr. *heterochaeta* Laubier, 1961	0	0	0	0	0	0	1	1
Orbiniidae								
Naineris laevigata (Grube, 1855)	0	0	0	0	1	2	1	1
Saccocirridae								
Saccocirrus papillocercus Bobretzky, 1872	0	0	1	1	315	12	3400	12
Protodrilidae								
Protodrilus sp.	210	10	728	10	0	0	0	0

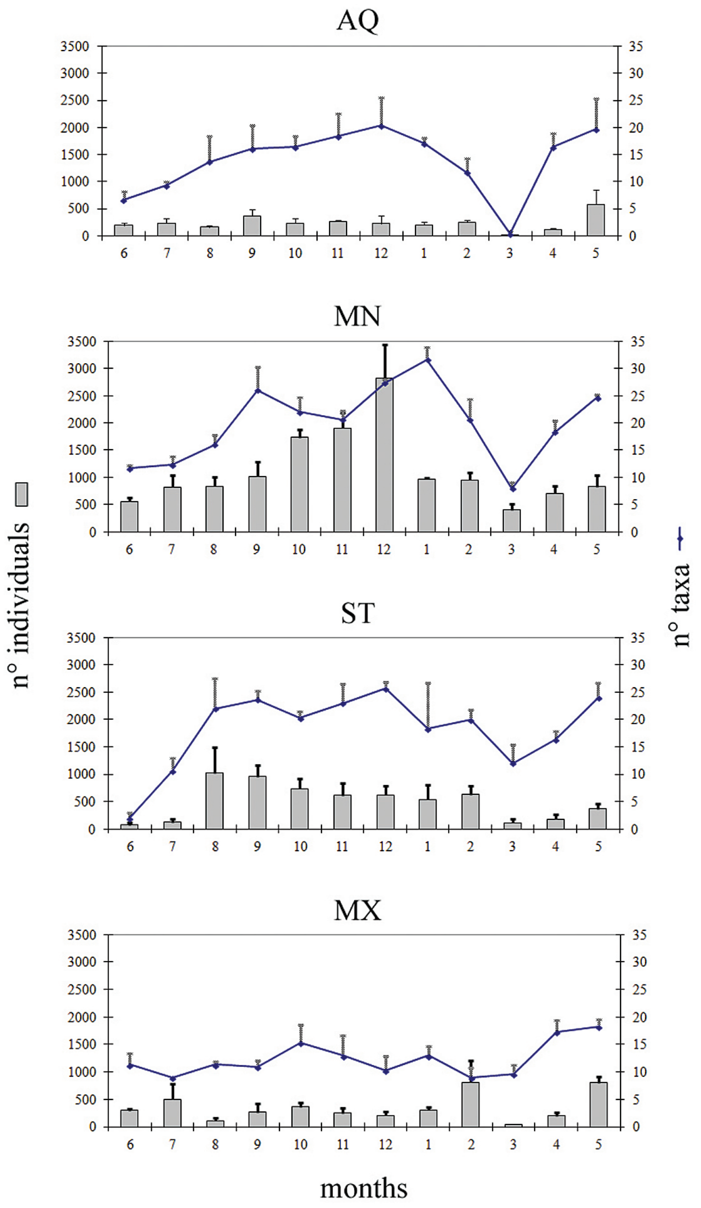

Fig. 2: Monthly mean abundance and number of species of hard bottom polychaetes at the sampling sites. AQ: Abu Qir; MN: El-Mandara; ST: Stanly; MX: El-Mex.

Table 3. Permutational MANOVA. Analysis of spatial temporal variation in hard bottom (a) and soft bottom (b) polychaete assemblages in the study area. TI, time; SI, site. Significant p-values are given in italics, in bold-italics the p-values of ecological interest.

(a)

	df	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Unique perms**
TI	11	68420	6220	16.09	*0.0001*	9856
SI	3	73590	24530	8.21	*0.0001*	9894
TI×SI	33	98553	2986.5	7.72	*0.0001*	9714
Res	96	37121	386.7			
Total	143	277680				

(b)

	df	**SS**	**MS**	**Pseudo-F**	**P(perm)**	**Unique perms**
TI	11	38535	3503.2	4.53	*0.0001*	9877
SI	3	134650	44883	14.64	*0.0001*	9918
TI×SI	33	101190	3066.3	3.96	***0.0001***	9804
Res	96	74321	774.2			
Total	143	348700				

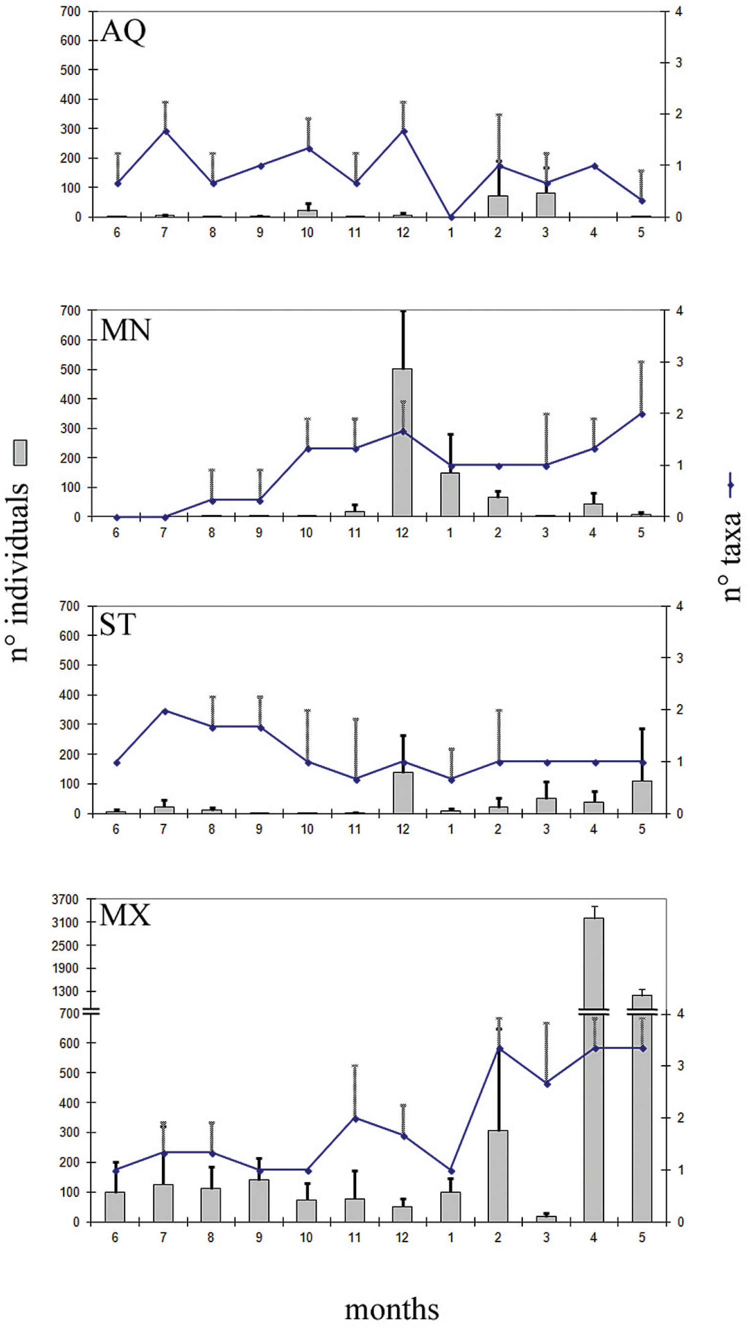

Fig. 3: Monthly mean abundance and number of species of soft bottom polychaetes at the sampling sites. AQ: Abu Qir; MN: El-Mandara; ST: Stanly; MX: El-Mex.

chaeta, *Dipolydora coeca*, *Salvatoria clavata, Naineris laevigata*, *Nereis falsa*, *Pseudonereis anomala*, *Spirobranchus triqueter, Syllis gracilis, S. hyalina, S. pulvinata* and *S. ergeni*. Meanwhile, another eleven species appeared to persist at most of the sites and very poorly occurred at MX, such as *Brania pusilla, Branchiomaldane vincenti, Branchiosyllis exilis, Chrysopetalum debile, Linopherus canariensis, Loimia medusa, Sphaerosyllis pirifera, Syllis variegata, Polyopthalmus pictus, Schistomeringos rudolphi* and *Capitella capitata.* In addition, some species were found to be common at one or two sites such as *Arabella iricolor* at MN, *Platynereis dumerilii* at AQ and MN, *Perinereis cultrifera* at ST and MX, *Hydroides elegans* at MX and others (*Amphiglena mediterranea, Brania arminii, Exogone verugera* and *Marphysa sanguinea*) occurred at ST or AQ for 6-8 months.

The abundance of hard bottom polychaetes displayed great variations, attaining pronouncedly higher annual average at MN (± SD)(11,303 ± 7,006 ind/m^2) than at ST (4,965 ± 3,604 ind/m^2), MX (3,470 ± 2,708 ind/m^2) and AQ (2,340 ± 1,620 ind/m^2). At AQ, a small peak was observed in September and a large one in May (Fig. 2). Both peaks were due mainly to *S. ergeni*, *P. anomala* and *S. pulvinata,* but *P. dumerilii* co-dominated in September and *N. laevigata* co-dominated in May. At MN, one marked peak occurred in December and a comparatively high count was recorded

Table 4. DISTLM-forward analysis based on Bray-Curtis dissimilarities of the hard bottom polychaete assemblage distributions in a linear regression model with tests by permutation (4999). Results of the forward selection procedure with the sequential tests. Significant p-values are given in italics. Prop.: proportion of explained variation; Cumul: cumulative proportion of explained variation; BOD: Biochemical oxygen demand; DO: dixolved oxygen; S: salinity; T: temperature.

Variable	SS(trace)	Pseudo-F	P	Prop	Cumul	res. df
Jania rubens	23964	13.41	*0.001*	0.086	0.086	142
Gelidium sp.	15875	9.41	*0.001*	0.057	0.143	141
Enteromorpha sp.	13081	8.15	*0.001*	0.047	0.191	140
Petalonia sp.	9815.5	6.35	*0.001*	0.035	0.226	139
Schizoporella sp.	7857.9	5.24	*0.001*	0.028	0.254	138
Ulva rigida	7652.2	5.26	*0.001*	0.028	0.282	137
Corallina spp.	6053.9	4.26	*0.001*	0.022	0.304	136
Colpomenia sinuosa	4910.3	3.52	*0.001*	0.018	0.321	135
Hypnea musciformis	4899	3.58	*0.003*	0.018	0.339	134
BOD	4799.8	3.57	*0.001*	0.017	0.356	133
DO	4214.7	3.19	*0.002*	0.015	0.371	132
Bowerbankia sp.	3864.6	2.97	*0.003*	0.014	0.385	131
S	3849.8	3.00	*0.007*	0.014	0.399	130
Caulerpa cylindracea	3196	2.52	*0.009*	0.012	0.411	129
T	2833.1	2.26	*0.020*	0.010	0.421	128
Padina sp.	2535.1	2.03	*0.033*	0.009	0.430	127
Balanus sp.	2515.5	2.03	*0.033*	0.009	0.439	126
pH	2432.9	1.98	*0.043*	0.009	0.448	125
Bugula neritina	2203.9	1.81	0.074	0.008	0.456	124
Obelia sp.	2086.8	1.72	0.090	0.008	0.463	123

during October/November. *Syllis ergeni*, *S. triqueter*, *S. pulvinata* and *P. anomala* were dominant from October to December as well as throughout the year. At Stanly, high abundance was recorded from August to February, particularly in August/September. *Syllis hyalina*, *S. ergeni, S. pulvinata*, *N. laevigata*, *M.* cfr. *heterochaeta* and *S. triqueter* were the main species during the August/September peak. Polychaete abundance at MX displayed two small peaks in July and October and two larger peaks in February and May. *Spirobranchus triqueter* was absolutely dominant during July and February, forming 83.3 - 95.4% of the total count, dropped to 32.3% in October and became very small (4.1%) in May; *Sphaerosyllis pirifera*, *S. ergeni*, *S. hyalina* and *P. anomala* co-dominated in October. The May peak was attributed to *C. capitata*, *S. hyalina* and *S. gracilis*.

Permutational MANOVA (Table 3a) suggested a large degree of spatial temporal variation in the hard bottom polychaete assemblages of the study area. The significance of the interaction term “SI×TI” indicated that hard bottom polychaete assemblages varied among sites but in different ways depending on sampling time. Considering the estimate of the variance components, some difference characterized the analyzed factors with a larger source of variation associated to the factor site in respect to the factor time (598.43 *vs* 486.11 respectively).

CAP (Fig. 3) indicated separation among the 4 groups of replicates representing the analyzed sites during the entire sampling period. The CAP allocation success was 97.2%. The 2 canonical axes had high canonical correlations with the multivariate assemblages (CAP1 $\delta2 = 0.8858$; CAP2 $\delta2 = 0.8377$). The assemblages at ST appeared in an intermediate position among the others, while MN, AQ and MX separated quite well on the canonical plot. After using a 0.4 Pearson correlation cut-off for lower contributions, several polychaete taxa correlated with the canonical axes (Fig. 3a), a larger number of species characterized MN (*S. triqueter*, *S. ergeni*, *P. anomala*, *S. pulvinata*, *S. gracilis*, *L. canariensis*, *N. falsa*, *D. coeca*, *A. iricolor*, B. *arminii*). Three species, namely *C. capitata*, *P. cultrifera* and *H. elegans*, characterized MX and four species (*B. exilis*, *P. pictus*, *P. dumerilii* and to a lesser extent *C. debile*) characterized AQ. Several sessile macrobenthic taxa appeared correlated to the canonical axes as well, suggesting that hard bottom polychaete assemblage distribution in the study area is related to the distribution of habitat formers (Fig. 3b). Specifically, *Gelidium* sp., *Schizoporella* sp. and *Balanus* sp. characterized MX, *C. sinuosa* characterized MN and *H. musciformis* and *J. rubens* characterized AQ, while *Corallina* spp. appeared related to both MN and AQ assemblages. As far as the physical and chemical variables are concerned, a correlation of polychaete assemblages with variation in BOD and salinity was detected (Fig. 3c). As far as the other environmental variables are concerned, their correlation with CAP1 appeared relatively low compared to the aforementioned ones.

Table 4 reports the results of the DISTLM-forward analysis. The sequential test (i.e. fitting each variable one at a time, conditional on the variables that are already included in the model) selected 18 variables (13 biotic, 5 abiotic) that significantly explained 44.8 % of the assemblage variation. *Jania rubens* ranked first among the analyzed predictor variables, thus significantly explaining 8.6 % of the overall assemblage variation, followed by *Gelidium* sp. (5.7 %) and *Enteromorpha* sp. (4.7 %). The top nine predictor variables of the hard bottom assemblage variation were percent coverage of macrobenthic taxa. Altogether, algal coverage significantly explained 38.3 % of the observed variation. The significant contributions of the analyzed physical-chemical predictor variables (namely BOD, DO, S, T and pH in order of importance) were individually low and altogether explained 6.5 % of the overall variation. Collinearity among T, S and pH, as well as collinearity between *Schizoporella* sp. and *Bugula neritina* was detected.

Soft bottom polychaetes

Fifteen species were found in the sediment samples (Table 2), but all of them also existed among the hard bottom representatives, except for *Sphaerosyllis hystrix* and *Protodrilus* sp. MX was inhabited by 12 species, followed by ST (7 species), and 3-4 species at the other sites. Most of the sediment polychaetes were found once or twice during the study period in low count, but *Saccocirrus papillocercus* was perennial at ST and MX, and *Protodrilus* sp. at MN and AQ, while both species showed overall abundances, at least 1 order of magnitude higher than any other species (17,105 and 2,950 total individual count respectively).

Sediment polychaetes annual average densities (± SD) were 118,899 (± 235,327) ind/m^2 at MX, 17,395 (± 39,522) ind/m^2 at MN, 8,827 (± 18,386) ind/m^2 at ST and 6,294 (±12,860) ind/m^2 at AQ, thus indicating large spatial variation among sites and evident temporal variation at each site. High abundances were recorded at some sites, such as MN in December, and particularly at MX in April and May respectively (Fig. 4), mainly due to the dominance of *S. papillocercus* and *Protodrilus* sp.

As far as the number of species is concerned, the soft bottom system was characterized by low diversity with one or two of the 15 species recorded, being present at a given site at the same sampling time apart from MX where 3-4 species co-existed from February to May (Fig 4).

Permutational MANOVA (Table 3b) suggested a large degree of spatial & temporal variation in the study area. In particular, the significance of the interaction term “SI×TI” indicated that soft bottom polychaete assemblages varied among sites but in different ways depending on sampling time. Considering the estimate of the variance components however, an evident difference characterized the analyzed factors, with the greater source of variation being associated to the factor site compared to the factor time (1161.6 *vs* 227.42 respectively).

CAP (Fig. 5a,b) indicated unclear separation among the 4 groups of replicates representing the analyzed sites during the entire sampling period. CAP allocation success was 62.5%. The circular arrangement of the replicates in the bi-plot, however, suggested a gradient in polychaete assemblage distribution in the area with a gradual change from MX to AQ and MN, and ST in an intermediate position. The first canonical axis had high canonical correlation with the multivariate assemblages (CAP1 $\delta 2$ = 0.7927); while CAP2 had weak correlation ($\delta 2$= 0.2479). After using a 0.3 Pearson correlation cut-off for lower contributions, five polychaete taxa, namely *Namanereis pontica*, *S limbata*, *Microphthalmus sczelkowii*, *S. papillocercus* and *Protodrilus* sp., appeared correlated with the canonical axes. However, the analysis suggested that *S. papillocercus* and *Protodrilus* sp. were the taxa responsible for the observed pattern due to higher correlation with CAP1 (Fig. 5a). As far as the physical-chemical variables are concerned, the gradual variation of soft bottom polychaete assemblages in the study area appeared related with changes in BOD and salinity, and especially with sediment grain size variation from medium and very coarse sand at one site (MX) and silt and very fine sand at others (MN, AQ) (Fig. 5b). As far as the other environmental variables are concerned, their correlation with CAP1 appeared relatively low compared to the aforementioned ones.

Table 5 presents the results of the DISTLM-forward analysis. The sequential test selected 8 variables that significantly explained 46.6 % of assemblage variation. Medium sand (MS) ranked first among the analyzed predictor variables significantly explaining 28.9 % of overall assemblage variation, followed by very coarse sand (VCS)(6.4 %) and very fine sand (VFS) (3.3 %). Multi-collinearity among the sediment texture variables was detected (i.e. R>0.7 or R<-0.7) apart from MS with coarse sand (CS) (R=0.37), and MS with fine sand (FS) (R=-0.38). Sediment texture variables significantly explained 38.6 % of the observed variation. The significant contributions of the other predictor variables (namely T, BOD, S, OM and OC in order of importance) were individually low and altogether explained 7.2 % of overall variation.

A total of 9 alien species were found on hard substrata along the Alexandria coast. *Pseudonereis anomala* was the most abundant alien species, constituting 3.2 – 21.8% of the total polychaetes at the sampling sites, *Linopherus canariensis* formed dense populations at some sites (maximum 900 ind/m^2). *Loimia medusa* appeared at three sites in most of the year was usually represented by a low population density (maximum 113 ind/m^2). Both *Hydroides elegans* and *Hydroides dianthus* were less frequent, *H. elegans* displayed a wider distribution and higher abundance. The other alien species were represented by a few number of individuals at sites.

Discussion

To our knowledge, the present study is the south-eastern-most one dealing with the ecology and distribution patterns of hard bottom polychaetes from the Mediterra-

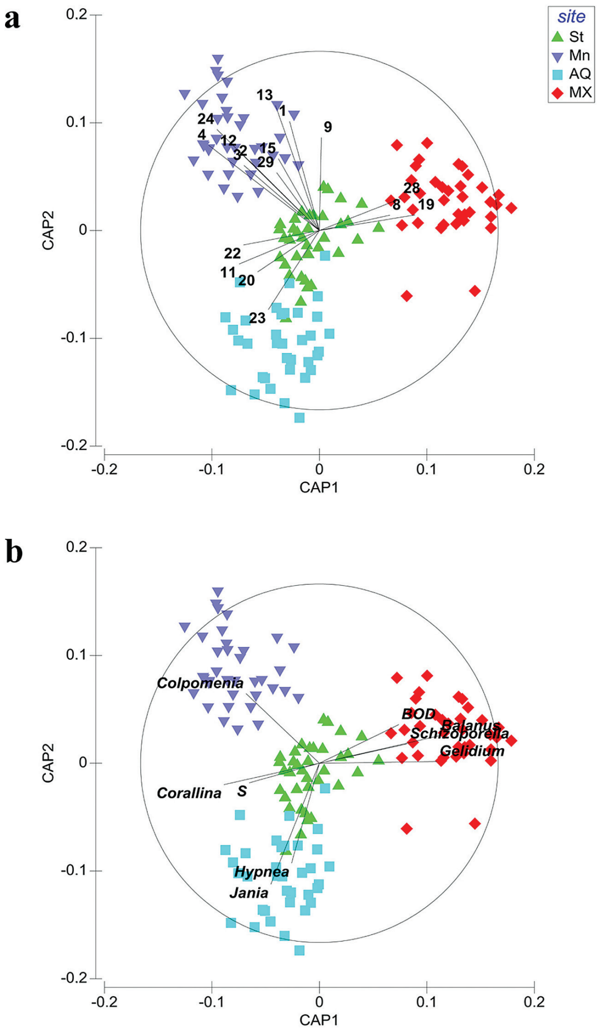

Fig. 4: Canonical analysis of the principal coordinates (CAP) plot showing canonical axes that best discriminate hard bottom polychaete assemblages at the 4 sites and correlations of original taxa variables (a), sessile macrobenthos abundance, and physical chemical variables (b) (cut-off 0.4 Pearson correlation). Numbers used as abbreviations for the taxa variables also indicate their abundance ranking in the study area: 1, *S. triqueter*; 2, *S. ergeni*; 3, *P. anomala*; 4, *S. pulvinata*; 8, *C. capitata*; 9, *S. gracilis*; 11, *P. dumerilii*; 12, *L. canariensis*; 13, *N. falsa*; 15, *D. coeca*; 19, *P. cultrifera*; 20, *P. pictus*; 22, *C. debile*; 23, *B. exilis*; 24, *A. iricolor*; 28, *H. elegans*; 29, B. *arminii*. Abbreviations of physical-chemical variables: BOD, Biochemical Oxygen Demand; S, Salinity.

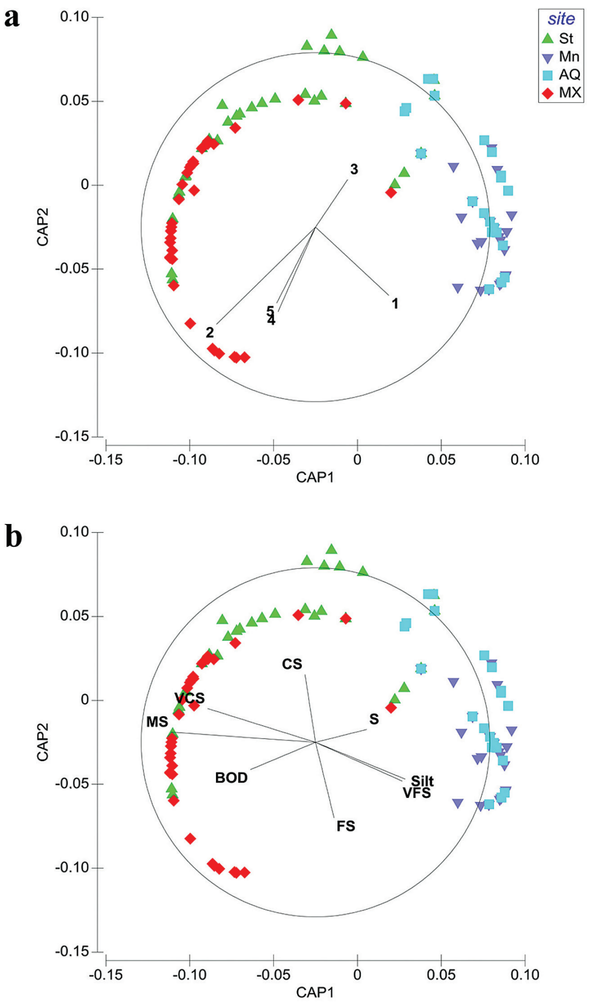

Fig. 5: Canonical analysis of the principal coordinates (CAP) plot showing canonical axes that best discriminate soft bottom polychaete assemblages at the 4 sites and correlations of original taxa variables (a), and physical chemical variables (b) with the canonical axes (cut-off 0.3 Pearson correlation). Numbers used as abbreviations for the taxa variables also indicate their abundance ranking in the study area: 1, *Protodrilus* sp.; 2, *S. papillocercus*; 3, *M. sczelkowii*; 4, *G. limbata*; 5, *N. pontica*. Abbreviations for the physical-chemical variables: BOD, Biochemical Oxigen Demand; S, Salinity; VFS, very fine sand; FS, fine sand; MS, medium sand; CS, coarse sand; VCS, very coarse sand.

nean Sea, as well as one of the few studies dealing with intertidal soft bottom polychaetes in the Levant Basin. Furthermore, the used sieve size (100 μ) allowed obtaining an almost complete and detailed picture of the polychaete assemblages, including meiofaunal and macrofaunal taxa during a complete year, which is not common in studies dealing with distribution patterns of benthic taxa.

The abundance of intertidal soft bottom polychaetes appeared low and variable, with few species characterizing the assemblages, and two taxa, namely *Protodrilus* sp. and *S. papillocercus*, were clearly dominant. This observation confirms the results of previous studies carried out in the Mediterranean Sea, including the Egyptian coast, indicating that Mediterranean intertidal assemblages are characterized by low diversity if compared to other areas in the world (Dexter, 1989; Deidun *et al.*, 2003; Papageorgiou *et al.*, 2006; Pérez-Domingo *et al.*, 2008).

On the other hand, hard bottom assemblages were rich both in number of taxa and individuals, with several polychaete species forming abundant communities throughout the study area and research period. Among the recorded polychaete families, the Syllidae appeared dominant and

Table 5. DISTLM-forward analysis based on Bray-Curtis dissimilarities of the intertidal soft bottom polychaete assemblage distributions in a linear regression model with tests by permutation (4999). Results of the forward selection procedure with the sequential tests. Significant p-values are given in italics. Prop.: proportion of explained variation; Cumul: cumulative proportion of explained variation. BOD: Biochemical oxygen demand; DO: dixolved oxygen; OM: organic matter; OC: organic carbon; S: salinity; T: temperature; VFS: very fine sand; MS: medium sand; VCS: very coarse sand.

variable	SS(trace)	Pseudo-F	P	Prop.	Cumul.	res.df
MS	100750.0	57.70	*0.001*	0.289	0.289	142
VCS	22353.0	13.97	*0.001*	0.064	0.353	141
VFS	11549.0	7.55	*0.001*	0.033	0.386	140
T	6962.3	4.67	*0.002*	0.020	0.406	139
BOD	6400.9	4.40	*0.003*	0.018	0.424	138
S	3182.4	2.21	*0.045*	0.009	0.434	137
OM	3117.3	2.18	*0.050*	0.009	0.443	136
OC	5398.9	3.86	*0.005*	0.015	0.458	135
DO	2710.2	1.95	0.083	0.008	0.466	134
pH	1471.7	1.06	0.368	0.004	0.470	133

highly diverse. This last finding confirms that syllids are the most representative polychaetes in shallow hard bottoms, hence deserving special attention when the ecology of this habitat is analyzed (Musco, 2012).

In spite the obvious differences in faunal composition and diversity, both hard and soft bottom polychaete assemblages were characterized by a large degree of spatial and temporal variation. Some differences, however, distinguished the two analyzed factors, since the spatial dimension appeared more important than the temporal one in structuring the polychaete assemblages, particularly those associated to intertidal soft bottoms. This last observation is in accordance with Papageorgiou *et al.* (2006) suggesting that the pattern of the sandy beach macrofauna of some Mediterranean locations, including Crete in the Levant Basin, is mostly spatial other than temporal. Spatial variation was also more significant than temporal variation on shallow hard substrates but to a lesser extent if compared to that observed for soft bottom polychaete assemblages. Evidences suggest that spatial variation of hard bottom polychaete assemblages might depend on the scale of observation, being high at small spatial scales but lower at the scale of kilometres (Musco, 2012), the spatial scale used herein. On the other hand, the seasonal variation of macrobenthic coverage may influence species abundance and diversity, thus increasing the temporal variation in assemblages. In this study, the biological and structural features of the analyzed habitats appeared particularly related to the spatial and temporal distribution of polychaetes in the area. These observations suggest that the distribution patterns of the Alexandria polychaete assemblages are mostly driven by the local features of the sampling sites and their variation along the analyzed stretch of coast.

The intertidal soft bottom assemblages appeared distributed along a gradient moving from MX to AQ. The distribution of polychaete species in soft substrates is mainly linked to sediment particle size (e.g. Gambi & Giangrande, 1986). In our observations spatial & temporal variation of soft bottom polychaetes appeared to be primarily related to the spatial variation of sediment texture. MX sediment showing a more balanced distribution of particles compared to the other sites, contained a significantly high number of polychaete species, but this last site also experienced the massive increase of *S. papillocercus* abundance during spring possibly due to a successful reproductive event only detectable by using adequate mesh size. Similarly, this last species had a spring peak of abundance at ST but the number of individuals was ten times lower than at MX. Both the above mentioned sites had a similar composition in medium sand with some differences in coarse sand and fine sand (see Table 1). *Saccocirrus papillocercus* was predominant in the coarse sands of the Romanian beaches of the Black Sea and recorded in supra littoral ground waters of the sandy beaches of the same area (Surugiu, 2011). But during the present study it appeared also on the hard bottom of MX during spring, attaining a high count in April, indicating that its recruitment could settle on the hard bottom and grow well inside the algal cover. The mesh size used was also important in detecting the recruitment event of the other relevant taxon, *Protodrilus* sp., showing a clear increase in abundance during winter at MN and to a lesser extent at AQ. These last sites, however, were quite different in granulometry, with MN strongly characterized by fine and very fine sand and AQ characterized by coarse sand. Thus, it is difficult to associate *Protodrilus* sp. spatial temporal distribution with peculiarities in the grain size of the analyzed area. At the assemblage level, however, grain size appeared as the most probable driver of the assemblage distribution pattern. DISTLM-forward analysis showed that the percentage of MS ranked first among the explanatory variables of the observed pattern, followed by VCS and VFS. On the other hand, the detected collinearity among sediment texture variables suggests that the assemblage distribution pattern in the area is not strictly related to the variation of a single sediment category (i.e. MS) but to local changes in ratios among all grain size categories. CAP analysis, in fact, suggested that the gradient in assemblage distribution from AQ to

MX is related to a combination of sediment variables roughly corresponding to the changes in grain size composition, from the coarser particles to the finest ones. This last analysis also revealed that variation in BOD and salinity might have influenced the observed pattern in the study area as well, but the multivariate analyses performed suggest that the relation of physical-chemical variables with assemblage distribution was limited when compared to sediment structural variables.

Habitat structural features were also shown to be potential drivers of assemblage distribution patterns for hard bottom polychaetes. Sessile macrobenthos coverage appeared as the most important source of variation explaining the distribution patterns of Alexandria hard bottom polychaetes. Algal coverage is a well known structuring factor enhancing small scale habitat variation, thus supporting a higher number of polychaete species than less complex habitats (Abbiati *et al.*, 1987; Giangrande, 1988). In this study, *J. rubens* coverage ranked first among the predictor variables of hard bottom assemblage distribution. Due to its structural complexity, this alga might represent a suitable habitat for polychaetes. This result supports previous research suggesting that calcified complex algae are particularly suitable as polychaete habitats (Tena *et al*., 2000). However, other algae with less complex thalli (i.e. *Enteromorpha* sp., *Petalonia* sp., *U. rigida*, *C. sinuosa*) contributed significantly to explaining the variation of Alexandria hard bottom polychaete assemblages, as observed elsewhere (Musco, 2012). In fact, the complexity of algal thalli may represent an important factor influencing polychaete settlement, but other algal features that do not necessarily depend on algal tridimensionality (i.e. production of deterrent metabolites, epiphyte colonization, palatability for herbivorous species, capability to entrap sediment etc.) should be considered and their potential influence on polychaete distribution should be studied. It is interesting to note that the predictor variables considered in this study explained part of assemblage variation; however, a considerable portion remains unexplained. At MX, the distribution pattern of polychaete assemblages appeared related to the abundance of filter feeder invertebrates (i.e. barnacles and bryozoans). In this particular case, in addition to algae, invertebrates might create suitable conditions for polychaete settlement. However, other kinds of interaction among polychaetes and other benthic invertebrates and also among polychaete species, including predation, competition etc., should be considered since they might be related to part of the unexplained polychaete assemblage variation (Gambi *et al*., 1995; Musco, 2012).

The experimental design used in this study does not allow assessment of the eventual effects of anthropogenic activities on polychaete distribution. Nonetheless, our results cannot exclude some effects on polychaete distribution. In particular, the general correlation of polychaete assemblage variation with BOD, OC, OM and salinity, as well as the temporal variability of BOD and salinity at MX might be an indication of the effects of wastewater discharge from Lake Mariut to El-Mex Bay. The fouling community, including barnacles, bryozoans and high densities of serpulids such as *S. triqueter* observed at MX suggests that El-Mex Bay might experience more eutrophic conditions if compared to the other sampling sites. Eutrophic conditions were documented in El-Mex Bay (Dorgham, 2011). CAP indicated algae belonging to *Corallina* as related to both AQ and MN polychaete assemblages, while *J. rubens* and *Hypnea musciformis* particularly related to AQ, this being further away from El-Mex Bay. Areválo *et al.* (2007) suggested that change in algal coverage from *U. rigida* to *Corallina* spp and from this last species to *J. rubens* and *H. musciformis* reflects the progressive reduction of the effects of sewage on benthic assemblages. Further research with proper experimental design and analyses might indicate whether the above mentioned clues actually reflect the environmental impact of urban activities on local biota.

Although 43 alien polychaete species were recorded from the Egyptian Mediterranean coast (Dorgham *et al*., 2013), only nine of them were found along the Alexandria coast, which lies about 250 km at the west of the Suez Canal, the passage of the majority of the Indo-Pacific immigrants to the Mediterranean Sea. This indicates the difficulty of transfer of these species westward to the Alexandria coast due to the eastward current prevailing on the Egyptian Mediterranean Coast. However, the dense populations of some of these species reflect their adaptation to the Alexandria coast, displaying sometimes pronounced contribution to the total polychaete count (Dorgham and Hamdy, in press).

Acknowledgements

Valuable comments and suggestion by two Anonymous Referees and the Editorial Assistance by Prof. M.E. Çinar noticeably improved the quality of the paper.

References

Abbiati, M., Bianchi, C.N., Castelli, A., 1987. Polychaete vertical zonation along a littoral cliff in the west Mediterranean. *PSZN I: Marine Ecology,* 8, 33-48.

Abd-Elnaby, F.A., 1999. Composition and Distribution of Some Bottom Fauna Associations Along the Alexandria Coast, Mediterranean Sea. M.Sc. Thesis, Faculty of Science, Alex. Univetsity, 272 pp.

Abd-Elnaby, F.A., San Martín, G., 2010. Eusyllinae, Anoplosyllinae, and Exogoninae (Polychaeta: Syllidae) for the mediterranean coasts of Egypt, together the description of one new species. *Life Science Journal,* 7 (4), 132-139.

Abd-Elnaby, F.A., San Martín, G., 2011. Syllinae (Syllidae: Polychaeta) from the Mediterranean coast of Egypt with the description of two new species. *Mediterranean Marine Science,* 12 (1), 43-52.

Aguado, M.T., San Martín, G., 2007. Syllidae (Polychaeta) from Lebanon with two new reports for the Mediterranean Sea. *Cahiers de Biologie Marine*, 48 (2), 207-224.

Anderson, M.J., Willis, T.J., 2003. Canonical analysis of principal coordinates: A useful method of constrained ordination for ecology. *Ecology*, 84 (2), 511-525.

Anderson, M.J., Gorley, R.N., Clarke, K.R., 2008. PERMANOVA+ for PRIMER: guide to software and statistical methods. PRIMER-E, Plymouth.

Areválo, R., Pinedo, S., Ballesteros, E., 2007. Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: Descriptive study and test of proposed methods to assess water quality regarding macroalgae. *Marine Pollution Bulletin*, 55, 104-113.

Benedetti-Cecchi, L., Bulleri, F., Cinelli, F., 2000 The interplay of physical and biological factors in maintaining midshore and low-shore assemblages on rocky coasts in the north-west Mediterranean. *Oecologia,* 123, 406-417.

Çinar, M.E., 2009. Alien polychaete species (Annelida: Polychaeta) on the southern coast of Turkey (Levantine Sea, eastern Mediterranean), with 13 new records for the Mediterranean Sea. *Journal of Natural History,* 43 (37-38), 2283-2328.

Çinar, M.E., Dagli, E., 2012. New records of alien polychaete species for the coasts of Turkey. *Mediterranean Marine Sci*ence, 13 (1), 103-107.

Çinar, M.E., Ergen, Z., 2003. Eusyllinae and Syllinae (Annelida:Polychaeta) from Northern Cyprus (Eastern Mediterranean Sea) with a Checklist of Species Reported from the Levant Sea, *Bulletin of Marine Science*, 72, 769-793.

Çinar, M.E., Ergen, Z., Benli, H.A., 2003. Autolytinae and Exogoninae (Annelida: Polychaeta) from Northern Cyprus (Eastern Mediterranean Sea) with a checklist of species reported from the Levant Sea, *Bulletin of Marine Science*, 72 (3),741-767.

Çinar, M.E., Katagan, T., Öztürk, B., Dagli, E., Açik, S. *et al*., 2012. Spatio-temporal distributions of zoobenthos in Mersin Bay (Levantine Sea, eastern Mediterranean) and the importance of alien species in benthic communities. *Marine Biology Research*, 8, 954-968.

Çinar, M. E., Katagan, T., Öztürk, B., Egemen, Ö., Ergen, Z. *et al*., 2006. Temporal changes of soft bottom zoobenthic communities in and around Alsancak Harbor (Izmir Bay, Aegean Sea), with special attention to the autoecology of exotic species. *Marine Ecology*, 27, 229-246.

Defeo, O., Lercari, D., 2004. Testing taxonomic resolution levels for ecological monitoring in sandy beach macrobenthic communities. *Aquatic Conservation: Marine and Freshwater Ecosystems,* 14, 65-74.

Del-Pilar-Ruso, Y., de-la-Ossa-Carretero, J.A., Giménez-Casalduero, F., Sánchez-Lizaso, J.L., 2010. Sewage treatment level and flow rates affect polychaete assemblages. *Marine Pollution Bulletin*, 60 (11), 1930-1938.

Deidun, A., Azzopardi, M., Saliba, S., Schembri, P.J., 2003. Low faunal diversity on Maltese sandy beaches: fact or artefact? *Estuarine, Coastal and Shelf Science*, 58S, 83-92.

Dexter, D.M., 1989. The sandy beach fauna of Egypt. *Estuarine, Coastal and Shelf Science*, 29, 261–271.

Dorgham, M.M., 2011. Eutrophication Problem in Egypt. In: *Eutrophication: Causes, Consequences and Control*. Ansari, Singh, Lanza, Rast (Eds). Volume 1 (Chapter 8). Springer Press.

Dorgham, M.M., Hamdy, H. 2014. The Contribution of Alien Polychaetes along the Alexandria Coast, Egypt, *International Journal of Environmental Research* (in press).

Dorgham, M.M., Hamdy, H., El-Rashidy, H.H., Atta, M.M., 2013. First records of polychaetes new to Egyptian Mediterranean waters. *Oceanologia*, 55 (1), 235-267.

El-Gendy, A., Al-Farraj, S., Al-Kahtani, S., El-Hedeny, M., 2012. The Influence of Marine Pollution on Distribution and Abundance of Polychaetes. *Current Research Journal of Biological Sciences,* 4 (1), 40-47.

El-Komi, M.M., 2011a. Biological mapping for macro benthos in Abu Qir Bay, Mediterranean Sea, *Egyptian Journal of Aquatic Research*, 37 (4), 325-334.

El-Komi, M.M., 2011b. A Review on the macro benthic communities in Abu Qir Bay, Mediterranean Sea, Egypt. *Egyptian Journal of Aquatic Research*, 37 (4), 335-349.

El-Komi, M.M., 2012a. Distribution of benthic polychaetes populations affected by human activities in the west coast of Alexandria, Mediterranean Sea, *Egyptian Journal of Aquatic Biology and Fisheries*, 16 (1), 1-19.

El-Komi, M.M., 2012b. Distribution of benthic communities affected by human activities In the west coast Of Alexandria, Mediterranean Sea, *Egyptian Journal of Aquatic Biology and Fisheries,* 16 (1), 41-59.

El-Komi, M, Atta, M., Zakaria, H., Dowidar, N., 2003. Population dynamics and reproductive activity of epifaunal amphipods in Alexandria harbour, Egypt. *Pakistan Journal of Marine Science*, 12 (2), 119-139.

Ergen, Z., Çinar, M. E., Dağli, E., G. Kurt, 2006. Seasonal dynamics of soft-bottom polychaetes in Izmir Bay (Aegean Sea, eastern Mediterranean). In: *Scientific Advances in Polychaete Research*, ~~R.~~ Sarda, R., ~~G.~~ San Martin, G., Lopez, E., Martin D., George, D. (Eds.), *Scientia Marina*, 70S3, 197-207.

Faulwetter, S., Chatzigeorgiou, G., Galil, B.S., Nicolaidou, A., G. Arvanitidis, 2011. *Sphaerosyllis levantina* sp. n. (Annelida) from the eastern Mediterranean, with notes on character variation in *Sphaerosyllis hystrix* Claparède, 1863, In: *Smith V, Penev L (Eds) e-Infrastructures for data publishing in biodiversity science. ZooKeys,* 150, 327-345.

Folk, R.L., 1965. Petrology of sedimentary rocks, *Syllabus, Univ. of Texas, Hemphill's, Austin, Texas.* 170 pp.

Folk, R.L., Ward, W.E., 1957. Brazon river bar: a study in the significance of grain size parameter. *Journal of Sedimentary Petrology*, 27, 3-26.

Gambi, M.C., Giangrande, A., Martinelli, M., Chessa, L.A., 1995. Polychaetes of a *Posidonia oceanica* bed off Sardinia (Italy) - spatiotemporal distribution and feeding guild analysis. *Scientia Marina,* 59, 129−141.

Gambi, M.C., Giangrande, A., 1986. Distribution of soft-bottom Polychetes in two coastal areas of the Tyrrhenian sea (Italy): structural analysis. *Estuarine Coastal and Shelf Science,* 23, 847-862.

Giangrande, A., 1988. Polychaete zonation and its relation to algal distribution down a vertical cliff in the western Mediterranean (Italy): a structural analysis. *Journal of Experimental Marine Biology and Ecology*, 120, 263-276.

Giangrande, A., 1990. Distribution and reproduction of syllids (Annelida, Polychaeta) along a vertical cliff (West Mediterranean). *Oebalia,* 16, 69−85.

Giangrande, A., Delos, A.L., Fraschetti, S., Musco, L., Licciano, M. *et al*., 2003. Polychaete assemblages along a rocky shore on the South Adriatic coast (Mediterranean Sea): patterns of spatial distribution. *Marine Biology,* 143, 110-1116.

Giangrande, A., Delos, A.L., Musco, L., Licciano, M., Pierri, C., 2004. Polychaete assemblages of rocky shore along the

South Adriatic coast (Mediterranean Sea). *Cahiers de Biologie Marine*, 45: 85-95.

Giangrande, A., Licciano, M., Musco, L., 2005. Polychaetes as environmental indicators revisited. *Marine Pollution Bulletin*, 50, 1153-1162.

Knox, G.A., 1977. The role of Polychaetes in benthic soft-bottom communities. In: *Essays on Polychaetous Annelids in memory of Olga Hartmann.* Special Publication. Los Angeles, CA, Allan Hancock Foundation, 547-604.

Kurt Şahin, G.K., Çinar, M.E., 2009. Eunicidae (Polychaeta) species in and around İskenderun Bay (Levantine Sea, Eastern Mediterranean) with a new alien species for the Mediterranean Sea and a re-description of *Lysidice collaris, Turkish Journal of Zoology*, 33, 331-347.

McLachlan, A., 1990. Dissipative beaches and macrofauna communities on exposed intertidal sands. *Journal of Coastal Research,* 6, 57-71.

Mikac, B., Musco, L., 2010. Faunal and biogeographic analysis of Syllidae (Polychaeta) from Rovinj (Croatia, northern Adriatic Sea). *Scientia Marina,* 74, 353−370.

Mikac, B., Musco, L., Đakovac, T., Giangrande, A., Terlizzi, A., 2011. Long-term changes in North Adriatic soft-bottom polychaete assemblages following a dystrophic crisis. *Italian Journal of Zoology,* 78(sup1), 304-316.

Moustafa, H.M., Atta, M.A, El Sammak, A.A., Sarawi, M.A., 2007. Assessment of Marine bottom fauna at Damietta Port, Eastern Mediterranean. In: *Proceeding of the Eight International Conference on the Mediterranean Environment MEDCOAST* 07,*13-17 November 2007* Alexandria, Egypt.

Musco, L., 2012. Ecology and diversity of Mediterranean hard-bottom Syllidae (Annelida): a community-level approach. *Marine Ecology Progress Series,* 461, 107-119.

Musco, L., Giangrande, A., 2005. Mediterranean Syllidae (Annelida: Polychaeta) revisited: species diversity, biogeography and faunal fidelity to environmental features. *Marine Ecology Progress Series*, 304, 143-153.

Musco, L., Terlizzi, A., Licciano, M., Giangrande, A., 2009. Taxonomic structure and the effectiveness of surrogates in environmental monitoring: A lesson from polychaetes. *Marine Ecology Progress Series*, 383, 199-210.

Musco, L., Mikac, B., Tataranni, M., Giangrande, A., Terlizzi, A., 2011. The use of coarser taxonomy in the detection of long-term changes in polychaete assemblages. *Marine Environmental Research,* 71, 131-138.

Musco, L., Andaloro, F., Mikac, B., Mirto, S., Vega Fernández, T. *et al*., *in press*. Concern about the spread of the invader seaweed *Caulerpa taxifolia* var. *distichophylla* (Chlorophyta: Caulerpales) towards the West Mediterranean. *Mediterranean Marine Science* (In press).

Mutlu, E., Çinar, M.E., Ergev, M.B., 2010. Distribution of soft-bottom polychaetes of the Levantine coast of Turkey, eastern Mediterranean Sea. *Journal of Marine Systems*, 79, 23-35.

Olsgard, F, Brattegard, T, Holthe, T. 2003. Polychaetes as surrogates for marine biodiversity: Lower taxonomic resolution and indicator groups. *Biodiversity and Conservation,* 12, 1033-1049.

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

Pérez-Domingo, S., Castellanos, C., Junoy, J., 2008. The sandy beach macrofauna of Gulf of Gabès (Tunisia). *Marine Ecology*, 29 Suppl. 1, 51-59.

Pocklington, P., Wells, P.G., 1992. Polychaetes: key taxa for marine environmental quality monitoring. *Marine Pollution Bulletin,* 24, 593-598.

Raffaelli, D.G., Hawkins, S., 1996. Intertidal Ecology. Chapman and Hall, London.

Samuelson, G.M., 2001. Polychaetes as indicators of environmental disturbance on subartic tidal flats, Iqaluit, Baffin Island, Nunavut territory. *Marine Pollution Bulletin,* 42 (9), 733-741.

Selim, S.A, Rzhavsky, A.V., Britayev, T.A. 2012. *Dialychone* and *Paradialychone* (Polychaeta :Sabellidae) from the Mediterranean coast of Egypt with description of *Dialychone egyptica* sp. n., *Invertebrate Zoology*, 9 (2), 105-114.

Sousa, W.P., 2001. Natural disturbance and the dynamics of marine benthic communities. In: *Marine community ecology.* Bertness, M.D., Gaines, S.D., Hay, M.E., (Eds). Sinauer Associates, Sunderland, MA.

Strickland, J.D.H., Parsons, T.R., 1972. A practical hand book of sea water analysis. *Fishery Research Board of Canada. Bulletin*, 167, 2nd Ed., 310 pp.

Surugiu, V., 2011. Polychaete research in the Black Sea, *Romanian Journal of Aquatic Ecology,* 1 (1), 101-122.

Tena, J., Capaccioni-Azzati, R., Torres-Gravila, F.J., Garcia-Carrascosa, A.M., 2000. Polychaetes associated with different facies of the photophilic algal community in the Chafarinas archipelago (SW Mediterranean). *Bulletin of Marine Science,* 67, 55-72.

Therriault, T.W., Kolasa, J., 2000. Explicit links among physical stress, habitat heterogeneity and biodiversity. *Oikos,* 89, 387-391.

Thorp, V.A., 1966. Studies of the moisture, ash, and organic content of Peat samples. *J. Official methods of analysis of the Association of Official Analytical Chemists* (AOAC), 49 (4), 860-865.

Warwick, R. M., 1993. Environmental impact studies on marine communities: Pragmatical considerations. *Australian Journal of Ecology*, 18, 63-80.

Witman, J.D., Dayton, P.K., 2001. Rocky subtidal communities. In: Bertness, M.D., Gaines, S.D., Hay, M.E., (Eds) *Marine community ecology*. Sinauer Associates, Sunderland, MA

Yamanaka, T., Raffaelli, D., White, P.C.L., 2010. Physical determinants of intertidal communities on dissipative beaches: Implications of sea-level rise. *Estuarine, Coastal and Shelf Science*, 88, 267-278.