IJRES 6 (2019) 1-13 ISSN 2059-1977

International Journal of Research in Environmental Studies
www.bluepenjournals.org/ijres

Spatial distributions of macrozoobenthic community and environmental condition of the Manfredonia Gulf (South Adriatic, Mediterranean Sea, Italy)

doi.org/10.33500/ijres.2019.06.001

T. Scirocco*, L. Cilenti, A. Specchiulli, S. Pelosi, R. D'Adamo and F. Urbano

National Research Council - Institute for Biological Resources and Marine Biotechnology (IRBIM) uos of Lesina (FG), Via Pola 4, 71010 Lesina (FG), Italy.

Article History
Received 05 November, 2018
Received in revised form 10 December, 2018
Accepted 13 December, 2018

Keywords:
Macrozoobenthic community,
Spatial distribution,
ABC index,
Mediterranean
Manfredonia Gulf.

Article Type:
Full Length Research Article

ABSTRACT

This study conducted in spring 2014 describes the spatial distribution of the macrozoobenthic community and the environmental condition of the Manfredonia Gulf (South Adriatic, Mediterranean Sea) through the application of the abundance-biomass-comparison (ABC) index. The surface sediments of the Manfredonia Gulf were mostly silt-clay and clayey-silt. A total of 56 species was identified. The Crustaceans had the highest number of species (16 species) followed by Polychaeta with 14 species who possessed the highest number of individuals (57% of total specimens). The Crustacea *Apseudopsis latreillii* and the Polychaeta Capitellidae and Maldanidae family dominated the area. The abundance and wet biomass of the macrozoobenthic fauna was ranged respectively from 132±0.00 to 4605±2950.27 ind m^{-2} and from 2±2.03 to 460.64±664.43 gr m^{-2}. The resulting ABC index (W=0.32±0.26) indicated that the Manfredonia Gulf is a moderately disturbed area. This first ecological survey has revealed that the area presents a general condition of disturbance that deserves to be carefully monitored even in the context of the current global climate change.

INTRODUCTION

The marine ecosystems and particularly the coastal areas are facing great and increasing impacts, including those resulting from physical and chemical transformations, habitat destruction and changes in biodiversity (Serhat et al., 2006). Given recent concerns about global warming, climate change and habitat degradation, the knowledge and protection of marine biodiversity have become paramount and these include studies on benthic community and assemblages in pristine and degraded areas (Basatnia et al., 2015).

Coastal areas represent one of the most important sources of nutrients for neighboring open seas. This is partly due to their enhanced productivity and the strong influence of river inputs. Nutrient discharge may stimulate primary production, and increased amounts of organic material can consequently be deposited in the sediment (Deegan et al., 1986; Nixon et al., 1986). Benthos is an important component of these systems and it plays an important role in the maintenance of ecological balance and in the transfer of matter and energy along the trophic chain, and it also participates directly in biogeochemical processes of the cycling of nutrients such as carbon and nitrogen at the sediment-water interface (Ingole et al., 2006). Biota living within and at the sediments' interface is to some extent, controlled and structured by these inputs or, at least, those which reach the sea floor (Moodley et al., 1998; Alberelli et al., 1999; Danovaro et al., 2000). The abundance and biomass of benthic infauna can increase when nutrient loading from river inputs is transformed into food (Montagna and Yoon,

*Corresponding author. E-mail: tommaso.scirocco@fg.ismar.cnr.it.

1991; Montagna et al., 2002; Semprucci et al., 2010). Some biocenotic structural and functional parameters (for example, specific diversity, standing-crop and productivity) are also related with the substratum types. Abnormal structural changes of the benthic community constitute a clear sign of environmental imbalance, even when the source of stress is temporarily absent (Crema et al., 1983; Bilyard, 1987; Thomson et al., 2003). The benthic community, therefore, represents a source of information at different food-web levels and can be utilized to investigate and characterize the habitat where the community exists. Coastal areas are highly dynamic environments, where local scale natural processes and anthropogenic pressures affect biogeochemical and optical processes, leading to continuous changes in the ecosystems and their services (Mancinelli and Vizzini, 2015). The consequences can be detected on the general state of ecosystems, mainly in inshore waters which are more sensitive and more exposed (Zaouali, 1993; Ayari and Afli, 2003). In view of the general scarcity of integrated information on macrozoobenthic community in the Manfredonia Gulf (southern Adriatic Sea), and given the vulnerability of the area, a survey of the macrozoobenthic community was carried out. Accordingly, this investigation is the first attempt to document the composition and structure of the macrozoobenthic community in a poorly known coastal area of the Adriatic Sea. The aim of this study is to clarify the macrozoobenthic community spatial distribution pattern and evaluate the environmental conditions of the Manfredonia Gulf through the application of the abundance-biomass-comparison (ABC) index, proposed by Warwick (1986). The ABC method is generally used as an impact indicator for different types of physical, biological and anthropogenic disturbances on benthic communities. This method is based on the assumption that increasing disturbance shifts communities from dominance by large-bodied species with low turnover rates toward dominance by small-bodied species with high turnover rates. At less disturbed areas the average biomass of individuals is greater than at more heavily disturbed areas. The ABC method measures this effect by comparing the ranked distributions of abundance and biomass within a given community.

MATERIALS AND METHODS

Study area

The Manfredonia Gulf is a shallow bay situated on South-Eastern of the Gargano Promontory (Southern Adriatic Sea) (Figure 1). It represents a transition zone between the northern and southern Adriatic circulation, characterized by limited circulation and high sedimentation rate (Bianchi and Zurlini, 1984, Damiani et al., 1988). Within the Gulf the circulation is affected by winds direction (Nelson, 1972; Sigl, 1973; Spagnoli et al., 2008). The Gulf is a sheltered area with eutrophic water (Chiaudani et al., 1982; Damiani et al., 1988) compared to more southward area along the Apulian coast, characterized by lower concentration of nutrients (Bello et al., 1982; Chiaudani et al., 1982). Continental inputs in the Gulf are mainly represented by the Ofanto River, the largest river flowing into the Adriatic Sea on South of the Gargano Promontory. Others minor rivers are Carapelle, Cervaro and Candelaro that show a seasonal and limited contribution to the sediment content (Simeoni, 1992). The Manfredonia Gulf can be considered a complex area under the potential threats of various waste deriving mainly from urban and agricultural activities (Fiesoletti et al., 2005), it (Southern Adriatic Sea) is an area relevant from an ecological point of view and considered a nursery area for small pelagics (Panfili, 2012; Borme et al., 2013) and bivalve molluscs (Vaccarella et al., 1998). Rather scant and fragmentary are the investigations carried out on the spatial distribution of the benthic macrofauna and the potential disturbances caused by the three rivers on the macrozoobenthic community along the Manfredonia Gulf. The benthic macrofauna, in fact, is defined as an indicator of perturbations of natural and/or anthropic origin (Borja et al., 2000).

Sample collection

An oceanographic survey was carried out aboard the “Dallaporta ship” from 10 to 13 April 2014 in the Manfredonia Gulf, Southern Adriatic Sea, Apulian coast (Figure 1). The study considered 22 sampling stations, located between 10 and 40 mt depth. Three samples were collected at each sampling station, using a Van Veen grab, characterized by a sample area of 152 cm^2. From each sample, a sub-sample small aliquot of superficial sediment was taken to determine of the grain size and content of organic matter % loss of ignition (LOI).

Sediment grain size and % LOI analysis

In laboratory, samples for grain-size determinations were dried at 70°C until constant weight. The classification of fine and coarse sediments followed the scale of Shepard (1954) where sediments were partitioned into % sand (2000–63 µm), % silt (63–4 µm) and % clay (<4 µm). Grain-size analyses were carried out, after elimination of the organic fraction with H_2O_2, by wet sieving, to separate sand from the fine fractions. For sandy fractions, a sieve size>63 µm was used. The weight of the sand trapped by the sieves was measured, and the percentage with respect to the total weight of sandy sediment fraction was

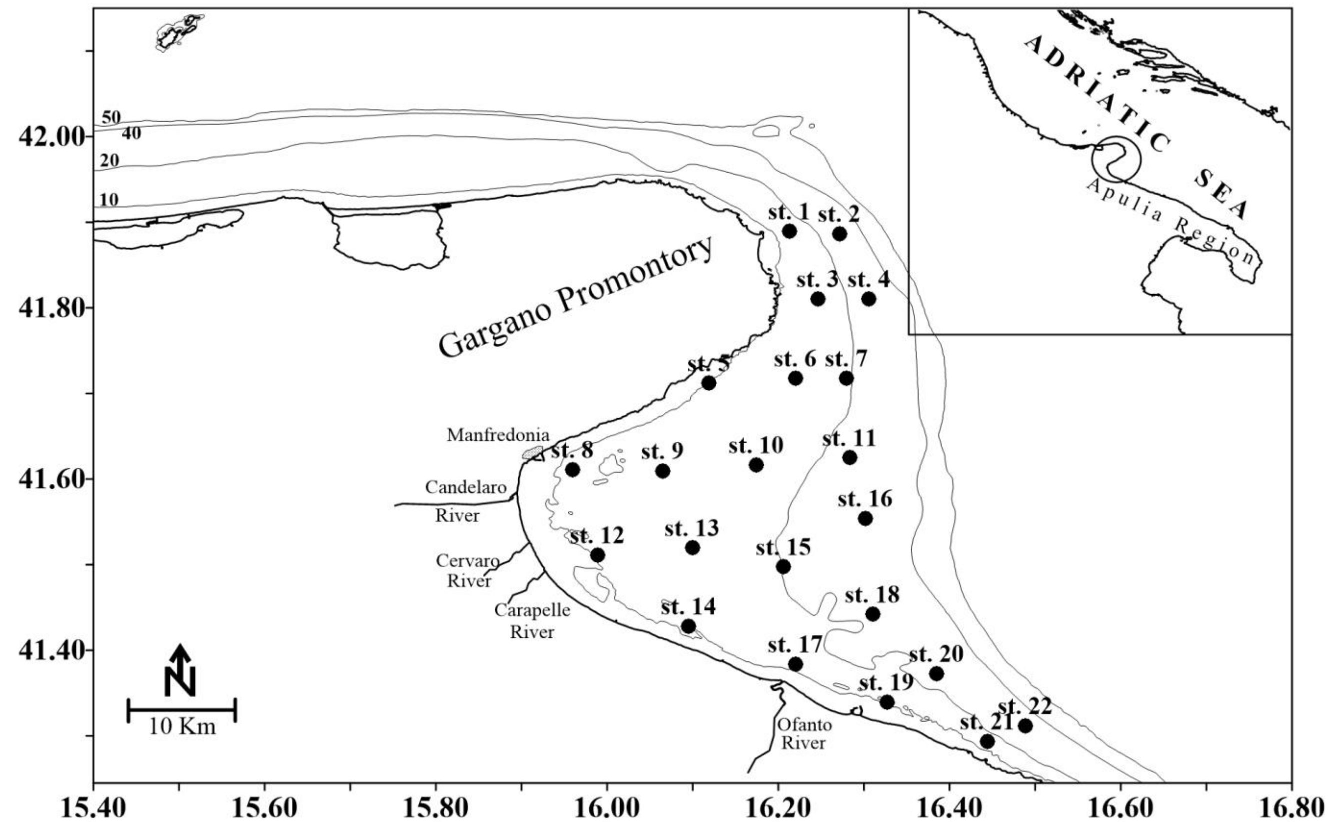

Figure 1. Map of the Gulf of Manfredonia showing sample locations, and depth is in meters.

determined. For fine sediments, a Sedigraph 5100 Micrometrics was employed. This instrument computed the grain size by estimating the transmittance produced by an X-ray beam which crosses the sediment scattered in a water sample. The % LOI was determined by sediment weight difference after ashing at 450°C (Byers et al., 1978).

Macrozoobenthic community

The sediments for the macrozoobenthic analysis were taken from each sampling station, sieved (1 mm mesh size) and fauna was preserved in a 4% formaldehyde–seawater solution buffered. In the laboratory, samples were sorted, identified to the lowest possible taxonomic level and counted. Based on the occurrence of all species in sites during the observation period, the frequency percentage (OF%) was calculated as the presence of each species in relation to total number of station. For each sample, wet biomass (gr m^{-2}), abundance (ind m^{-2}) and Shannon-Wiener (H), Pielou (J), Margalef's (d) and Dominance (D) diversity index were detected.

Statistical analyses

All data were analyzed using univariate and multivariate methods in order to evaluate: differences among sampling sites and between sediment characteristics and macrozoobenthic distribution, and correlation between sediment variables and abundance of the macrozoobenthic community. The statistical analysis of macrozoobenthic community structure was first performed calculating the univariate diversity index: total abundance, number of species, Shannon-Wiener index, Pielou index, Margalef's index and Dominance index. To identify groups of stations characterized by well-defined species assemblages and sediments characteristics hierarchical cluster analysis and non-metric multi-dimensional scaling (MDS) was carried out. The similarity matrix based on Euclidean distance coefficient was then computed on square-root transformed data and used in hierarchical clustering. The differences of the abundance, wet weight and structural index of the macrozoobenthic community were tested among the clusters by ANOSIM test (*ANalisys of SIMilarites*). In order to elucidate the relationships between biotic and abiotic variables, a Spearman's *r* correlation analysis was used. For the

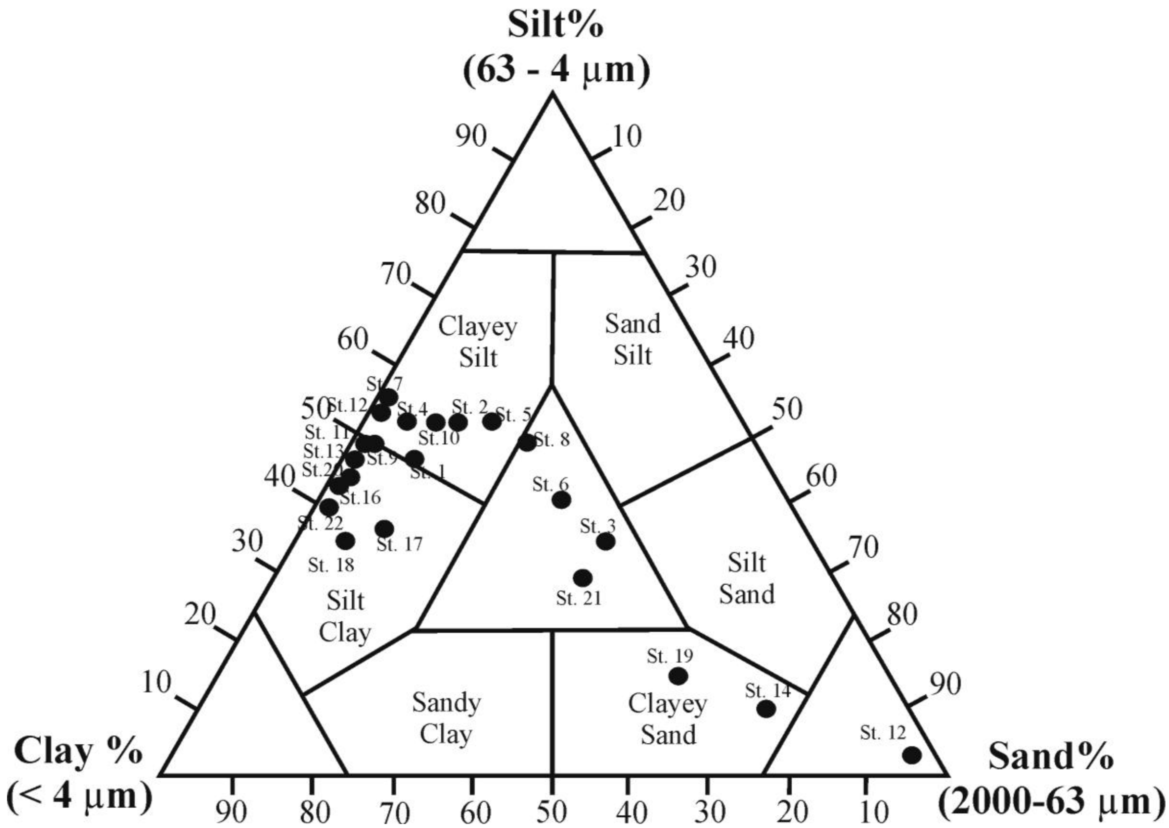

Figure 2. Shepard ternary diagram of surface sediments in Manfredonia Gulf.

evaluation of the environmental quality of the Manfredonia Gulf for each sampling station, ABC index proposed by Warwick (1986) was applied. This index provides for the integration of the abundance and biomass data of the benthic macrofauna community. The index was scaled so that complete biomass dominance and an even abundance distribution gives a value of +1 (undisturbed) and the reverse case a value of -1 (grossly disturbed) (Clarke, 1990). The Primer 6 software was used to apply the statistical analyses.

RESULTS

Grain-size and %LOI distribution

The sediments of the Manfredonia Gulf were mostly silt-clay and clayey-silt (Shepard, 1954) (Figure 2). The spatial distribution of particle size fractions and %LOI of surface sediments of Manfredonia Gulf: (a) % sand (>63 mm), (b) % silt (63.4 mm), (c) % clay (<4 mm), (d) % LOI, are shown in Figure 3a, b, c and d. The coarser sediments (sand> 30%) were dominant in two shallow areas (10-15 meters) that extend parallel to the coast, the first south of the mouth of the Carapelle River, the second located south of the mouth Ofanto River (Figure 3a). Silt dominated (silt>40%) to the south of the Promontory of Gargano (Figure 3b) and the central area of the Gulf (>15 m of depth). The clay (>30%) dominated in the central area of the Gulf (>15-35 m of depth) (Figure 3c). The sediments of the Manfredonia Gulf were characterized by an average content of % LOI 3.97±1.38%. The minimum content (0.83%) was detected in the station 12, while the maximum (6.64%) in the station 8 (Figure 3d).

Structural analysis of the macrozoobenthic community

A total of 1381 individuals was counted, 56 species, 31 genera and 11 families were identified. The list of the organisms detected during the sampling is shown in the Table 1. The Polychaeta with 14 species and 791 individuals constituted 57% of the total individuals, the Crustaceas with 16 species and 366 individuals constituted 27%, the Bivalvia with 12 specie and 162 individuals constituted 12% and the Echinodermata with 5 species and 56 individuals constituted 4% of the assemblage. The most abundant species was *A.*

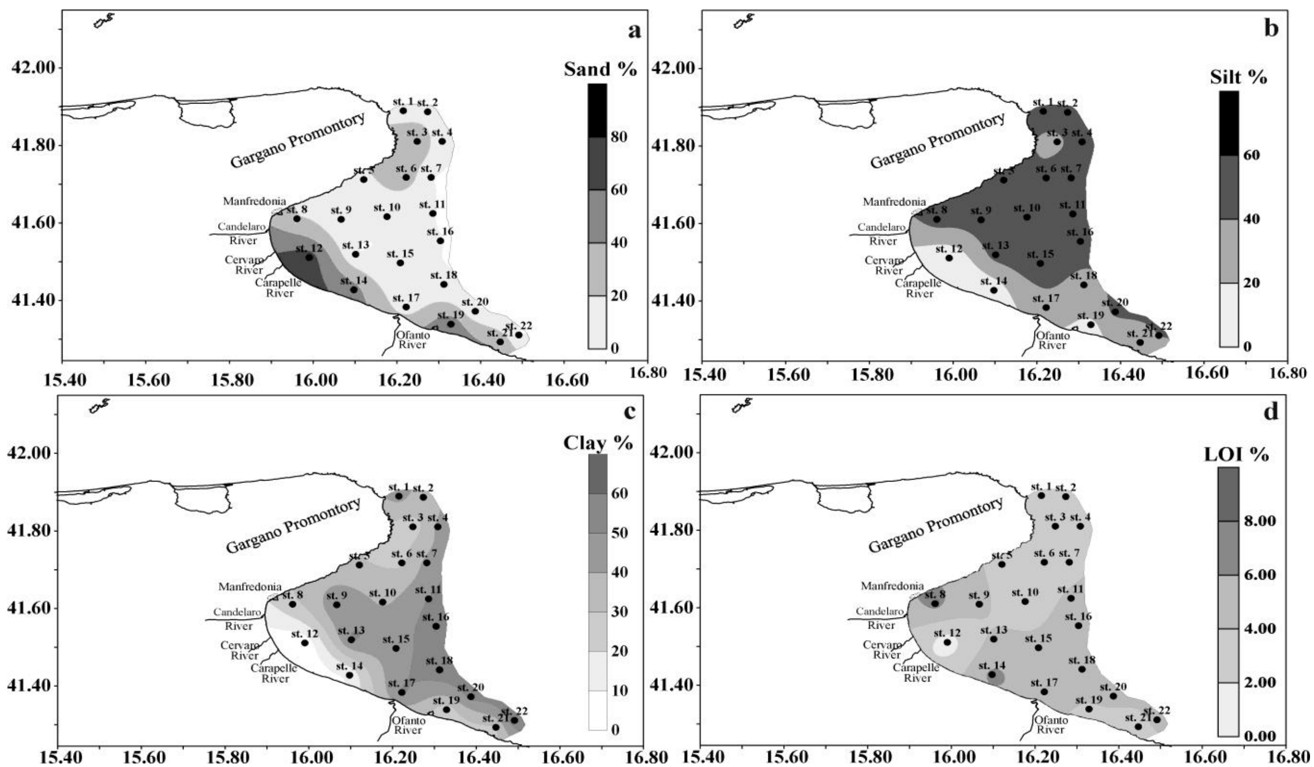

Figure 3. Spatial distribution of particle size fractions of surface sediments in Manfredonia Gulf: (b) % sand (>63 mm), (c) % silt (63.4 mm), (d) % clay (<4 mm). Areas were contoured using kriging interpolation method.

Table 1. List of the organisms detected during the sampling.

Phylum	Classe	Family	Genus	Species	Phylum	Class	Family	Genus	Species
Mollusca	**Bivalvia**	Tellinidae	Moerella	*Moerella pulchella* (Lamarck, 1818)	**Arthropoda**	**Malacostraca**	Apseudidae	Apseudopsis	*Apseudopsis latreillii* (Milne Edwards, 1828)
		Tellinidae	Peronaea	*Peronaea planata* (Linnaeus, 1758)			Ischyroceridae	Erichtonius	*Erichtonius brasiliensis* (Dana, 1853)
		Tellinidae	Tellina	*Tellina donacina* Linnaeus, 1758			Leucothoidae	Leucothoe	*Leucothoe spinicarpa* (Abildgaard, 1789)
		Tellinidae	Tellina	*Tellina* spp.			Oedicerotidae	Kroyera	*Kroyera carinata* Spence Bate, 1857
		Nuculidae	Nucula	*Nucula sulcata* Bronn, 1831			Ampeliscidae	Ampelisca	*Ampelisca* spp.
		Nuculidae	Lembulus	*Lumbulus pella* (Linnaeus, 1758)			Corophiidae	Medicorophium	*Medicorophium rotundirostre* (Stephensen, 1915)
		Corbulidae	Corbula	*Corbula gibba* (Olivi, 1792)			Corophiidae	Corophium	*Corophium* spp.
		Semelidae	Abra	*Abra prismatica* (Montagu, 1808)			Dexaminidae	Dexamine	*Dexamine spinosa* (Montagu, 1813)
		Semelidae	Abra	*Abra* spp.			Maeridae	Maera	*Maera* spp.
		Veneridae	Dosinia	*Dosinia lupinus* (Linnaeus, 1758)			Gammaridae		
		Lucinidae	Lucinella	*Lucinella divaricata* (Linnaeus, 1758)			Caprellidae	Caprella	*Caprella* spp.
		Solecurtidae	Solecurtus	*Solecurtus strigilatus* (Linnaeus, 1758)			Alpheidae	Alpheus	*Alpheus glaber* (Olivi, 1792)

Table 1. Contd.

		Psammobiidae	Gari	*Gari depressa* (Pennant, 1777)			Nannosquillidae	Platysquilla	*Platysquilla eusebia* (Risso, 1816)
		Psammobiidae	Psammobia	*Psammobia* spp.			Processidae	Processa	*Processa* spp.
		Gastrochaenidae	Rocellaria	*Rocellaria dubia* (Pennant, 1777)			Callianassidae	Callianassa	*Callianassa* spp.
		Cardiidae	Papillicardium	*Papillicardium papillosum* (Poli, 1791)			Goneplacidae	Goneplax	*Goneplax rhomboides* (Linnaeus, 1758)
		Veneridae	Venus	*Venus verrucosa* Linnaeus, 1758			Parthenopidae	Parthenopides	*Parthenopides massena* (Roux, 1830)
	Gastropoda	Muricidae	Bolinus	*Bolinus brandaris* (Linnaeus, 1758)			Polybiidae	Liocarcinus	*Liocarcinus depurator* (Linnaeus, 1758)
		Turritellidae	Turritella	*Turritella communis* Risso, 1826			Polybiidae	Liocarcinus	*Liocarcinus maculatus* (Risso, 1827)
		Philinidae	Philine	*Philine quadripartita* Ascanius, 1772			Leucosiidae	Myra	*Myra* spp.
Annelida	**Polychaeta**	Glyceridae	Glycera	*Glycera tridactyla* Schmarda, 1861			Crangonidae	Pontophilus	*Pontophilus* spp.
		Capitellidae	Pseudoleiocapitella	*Pseudoleiocapitella fauveli* Harmelin, 1964			Bodotriidae	Iphinoe	*Iphinoe serrata* Norman, 1867
		Capitellidae	Notomastus	*Notomastus* spp.			Bodotriidae	Bodotria	*Bodotria scorpioides* (Montagu, 1804)
		Capitellidae					Leuconidae	Leucon	*Leucon mediterraneus* Sars, 1878
		Sternaspidae	Sternaspis	*Sternaspis scutata* (Ranzani, 1817)			Nannastacidae	Cumella	*Cumella limicola* Sars, 1879
		Paraonidae	Aricidea	*Aricidea fragilis* Webster, 1879	**Echinodermata**	**Holothuroidea**	Synaptidae	Oestergrenia	*Oestergrenia digitata* (Montagu, 1815)
		Polynoide	Harmothoe	*Harmothoe extenuata* (Grube, 1840)			Synaptidae	Leptosynapta	*Leptosynapta inhaerens* (O.F. Müller, 1776)
		Polynoide	Malmgrenia	*Malmgrenia lunulata* (Delle Chiaje, 1830)			Synaptidae	Leptosynapta	*Leptosynapta* spp.
		Polynoide	Harmothoe	*Harmothoe* spp.			Phyllophoridae	Phyllophorus	*Phyllophorus urna* Grube, 1840
		Polynoide	Lagisca	*Lagisca* spp.			Phyllophoridae	Thyone	*Thyone fusus* (O.F. Müller, 1776)
		Cirratulidae	Chaetozone	*Chaetozone corona* Berkeley & Berkeley, 1941			Cucumariidae	Leptopentacta	*Leptopentacta elongata* (Düben & Koren, 1846)
		Cirratulidae	Caulleriella	*Caulleriella* spp.		**Ophiuroidea**	Amphiuridae	Amphiura	*Amphiura chiajei* Forbes, 1843
		Cirratulidae					Amphiuridae	Amphipholis	*Amphipholis squamata* (Delle Chiaje, 1828)
		Onuphidae	Onuphis	*Onuphis eremita* Audouin & Milne Edwards, 1833		**Echinoidea**	Schizasteridae	Ova	*Ova canalifera* (Lamarck, 1816)
		Onuphidae	Aponuphis	*Aponuphis brementi* (Fauvel, 1916)			Loveniidae	Echinocardium	*Echinocardium cordatum* (Pennant, 1777)
		Onuphidae	Hyalinoecia	*Hyalinoecia* spp.					
		Onuphidae	Onuphis	*Onuphis* spp.					
		Maldanidae	Euclymene	*Euclymene oerstedii* (Claparède, 1863)					
		Maldanidae	Euclymene	*Euclymene lombricoides* (Quatrefages, 1866)					
		Maldanidae	Euclymene	*Euclymene* spp.					
		Maldanidae	Leiochone	*Leiochone* spp.					
		Maldanidae							
		Oweniidae	Owenia	*Owenia fusiformis* Delle Chiaje, 1844					
		Eunicidae	Lysidice	*Lysidice unicornis* (Grube, 1840)					
		Eunicidae	Marphysa	*Marphysa* spp.					
		Eunicidae	Eunice	*Eunice* spp.					
		Eunicidae							
		Nephtyidae	Nephtys	*Nephtys hombergii* Savigny in Lamarck, 1818					
		Nephtyidae	Nephtys	*Nepthys* spp.					
		Nereididae	Nereis	*Nereis* spp.					
		Phyllodocidae	Phyllodoce	*Phyllodoce* spp.					
		Phyllodocidae	Eteone	*Eteone* spp.					
		Phyllodocidae	Eulalia	*Eulalia* spp.					
		Glyceridae	Glycera	*Glycera* spp.					
		Flabelligeridae	Stylarioides	*Stylarioides* spp.					
		Terebellidae	Pista	*Pista* spp.					
		Terebellidae							
		Spionidae	Prionospio	*Prionospio* spp.					
		Spionidae							
		Lumbrineridae							
		Sabellidae							
		Fabriciidae							
		Ampharetidae							

Table 2. Values of the abundance data (ind m^{-2}), wet biomass (gr m^{-2}), Warwick index (W), depth and the structural indices of the macrozoobenthic community detected for at each station.

staz.	ind m^{-2}	SD	gr m^{-2}	SD	d	SD	J	SD	H'	SD	D	SD	Depht (m)	W
st. 1	175	76	2.16	2.03	1.68	0.42	1.00	0.00	1.33	0.58	0.42	0.14	16-20	0.642
st. 2	197	66	3.72	3.53	1.51	0.63	0.97	0.05	1.31	0.60	0.44	0.16	26-30	0.471
st. 3	1623	639	48.73	31.25	2.28	0.76	0.71	0.10	2.17	0.70	0.35	0.17	16-20	0.06
st. 4	241	211	3.46	3.07	0.95	1.15	0.56	0.50	0.99	1.15	0.30	0.35	26-30	0.197
st. 5	3772	1199	460.64	664.43	3.04	0.55	0.67	0.06	2.49	0.05	0.30	0.02	10-15	0.177
st. 6	3706	846	125.80	28.25	3.73	0.35	0.79	0.06	3.17	0.28	0.17	0.04	10-15	0.08
st. 7	965	166	43.24	29.92	2.38	0.38	0.90	0.03	2.58	0.19	0.20	0.03	16-20	0.179
st. 8	680	266	30.88	38.62	2.06	0.34	0.93	0.04	2.30	0.21	0.23	0.03	10-15	0.295
st. 9	2303	724	20.60	16.06	2.58	0.49	0.72	0.12	2.41	0.51	0.31	0.13	10-15	-0.03
st. 10	1162	725	20.15	17.37	2.85	0.74	0.89	0.04	2.73	0.53	0.20	0.06	10-15	0.187
st. 11	373	311	75.86	56.10	1.80	0.61	0.96	0.04	1.70	0.82	0.36	0.16	21-25	0.487
st. 12	3969	1852	125.03	174.65	3.95	0.43	0.80	0.07	3.23	0.17	0.16	0.03	10-15	0.255
st. 13	417	100	38.06	39.82	2.03	0.42	0.96	0.04	2.13	0.20	0.24	0.04	16-20	0.568
st. 14	482	428	6.86	10.95	1.70	1.55	0.63	0.55	1.73	1.54	0.46	0.47	10-15	0.508
st. 15	1579	1443	190.39	160.49	1.38	0.59	0.65	0.14	1.39	0.29	0.52	0.10	16-20	0.115
st. 16	482	385	18.11	24.08	1.45	0.71	0.84	0.14	1.46	0.68	0.44	0.21	31-35	0.194
st. 17	526	342	7.78	7.53	1.25	1.10	0.57	0.50	1.39	1.20	0.53	0.41	10-15	0.143
st. 18	219	137	58.41	99.38	1.10	0.98	0.64	0.55	1.14	1.01	0.55	0.39	26-30	0.66
st. 19	2544	1185	92.72	76.89	4.34	1.29	0.89	0.08	3.54	0.50	0.12	0.05	10-15	0.217
st. 20	132	0.00	13.23	22.44	1.44	0.00	1.00	0.00	1.00	0.00	0.50	0.00	26-35	0.853
st.21	4605	2950	27.79	16.93	4.09	0.81	0.84	0.10	3.43	0.25	0.13	0.03	10-15	-0.05
st. 22	132	132	28.90	42.96	1.20	1.10	0.67	0.58	1.00	1.00	0.25	0.25	31-35	0.757

SD, Standard Deviation; **d,** Margalef index; **J,** Pielou index; **H',** Shannon index; **D,** dominance index; **W,** Warwick index; **st.,** station.

latreillii (292 individuals, the 21% of the total) with mean abundance of 873±1468 ind m^{-2}, following by Capitellidae (185 ind m^{-2}, 13% of the total), with average abundance of 553±753 ind m^{-2}, *Corbula gibba* (68 individuals, 5%), with mean abundance of 203±670 ind m^{-2} and *Sternaspis scutata* (27 individuals, 2%) with mean abundance of 81±187 ind. m^{-2}. The Capitellidae was found in 18 stations (82 OF%), *A. latreillii* in 16 stations (73 OF%), *C. gibba* was found only at 3 stations (14 OF%). Mean data of abundance, wet biomass of macrozoobenthic community detected and depth in each station are reported in Table 2. The abundance and wet biomass was ranged respectively from 132±0.00 ind m^{-2} at the station 20 to 4605±2950.27 ind m^{-2} at the station 21, and 2±2.03 gr m^{-2} at the station 1 to 460.64±664.43 gr m^{-2} at the station 5. The spatial distribution of the abundance and wet biomass are shown in Figure 4a and b respectively. From an environmental point of view, the reporting of presence of the Spermatophyta *Cymodocea nodosa* (Ucria) Ascherson, 1870 at the station 12 (Red list IUCN, 2010) and the Anthozoa *Cladocora caespitosa* (Linnaeus, 1767) at the station 14 and 19 (Red list IUCN, 2015) is particularly interesting. The seagrasses such as the Spermatophyta Cymodocea are able to support diverse fish assemblages and exert a paramount role as nursery grounds for juveniles of many commercially important fish species (Pollard, 1984; Bell and Pollard, 1989). Seagrass beds have long been considered as the most productive and architecturally complex systems of the coastal zones on a world-wide scale (Den Hartog, 1970). While *C. caespitosa* represents the main bioconstructor of the Mediterranean basin, a few studies (Rodolfo-Metalpa et al., 2000; Garrabou et al., 2002), concerning the ecology of this species, suggest that *C. caespitosa* could represent a valid indicator of climate change.

Spatial distribution of diversity indices of macrozoobenthic community

The mean values of the structural index of the macrozoobenthic community recorded for each station are shown in Table 2. The Shannon-Wiener index (H) varied from a minimum of 0.99±1.15 detected at the station 4, to a maximum of 3.54±0.50 recorded at the station 19. While the Margalef index (d) varied from a minimum of 0.95±1.15 detected at the station 4 to a

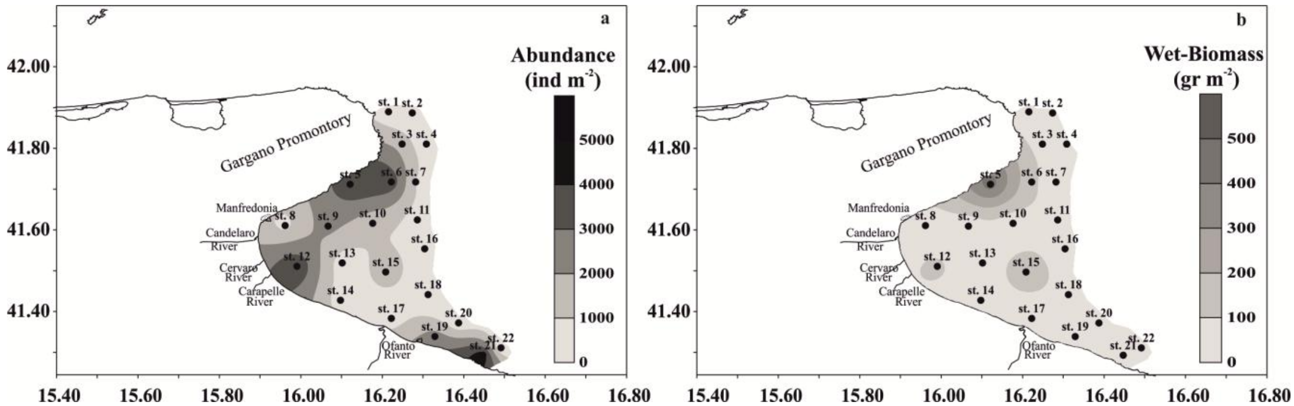

Figure 4. Spatial distribution of the (a) abundance data (N° Indm^{-2}) and (b) wet biomass (gr/m^2) for at each station. Areas were contoured using kriging interpolation method.

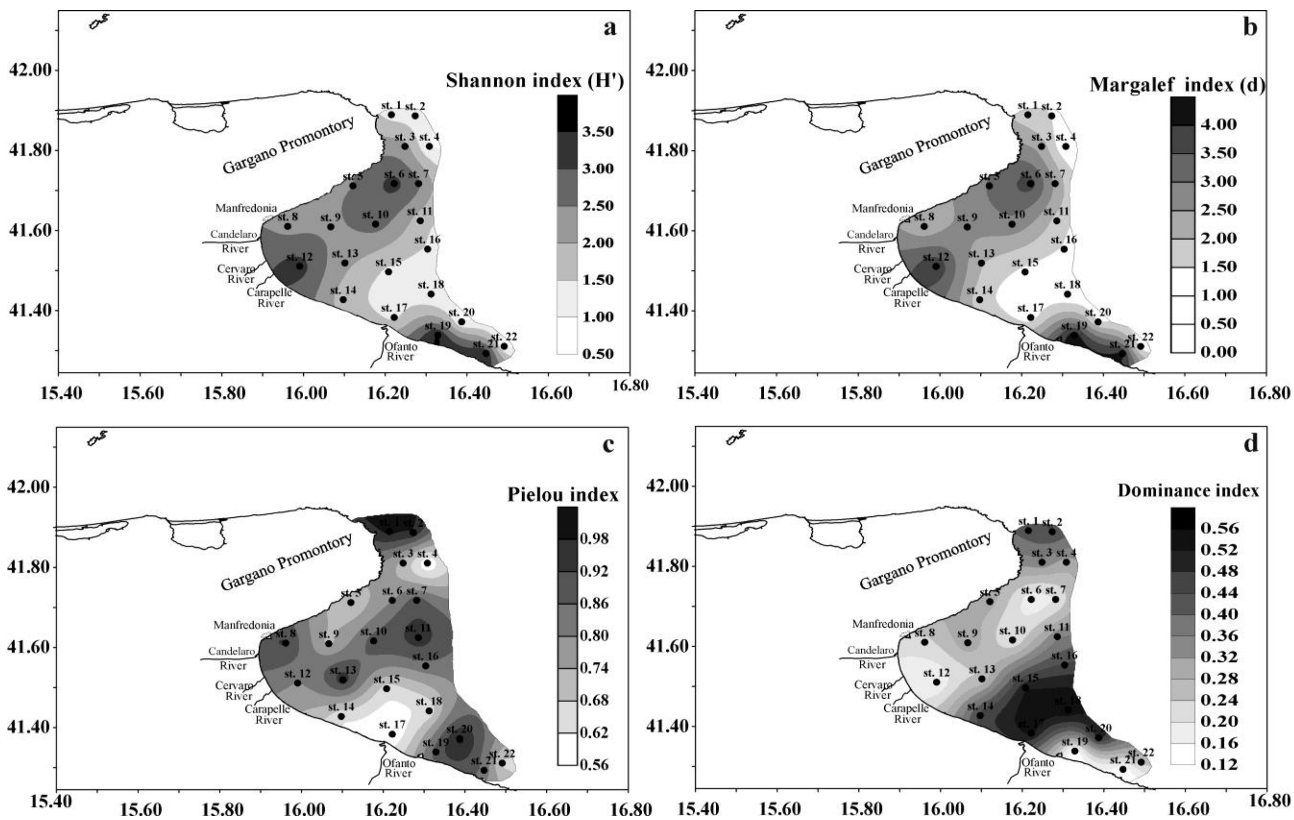

Figure 5. Spatial distribution of the structural Indices of the macrozoobenthic community recorded in each station. Areas were contoured using kriging interpolation method.

maximum of 4.34±1.29 at the station 19. The Pielou index (J) varied from a minimum of 0.56±0.50 detected at the station 4, to a maximum of 1±0.00 recorded at the stations 1 and 20. The Dominance index (D) varied from a minimum of 0.12±0.05 detected at the station 19, to a maximum of 0.55±0.39 recorded at the station 18. The spatial distribution of the diversity index of the macrozoobenthic community calculated in each sampling station are shown in Figure 5a, b, c and d. Correlations (Spearman rank) between the biotic (abundance, Margalef, Pielou, Shannon, Dominance index, Indicator species) and abiotic (% LOI, silt %, clay % sand %) variables are shown in Table 3. The abundance was positively correlated with % sand, while it was negatively

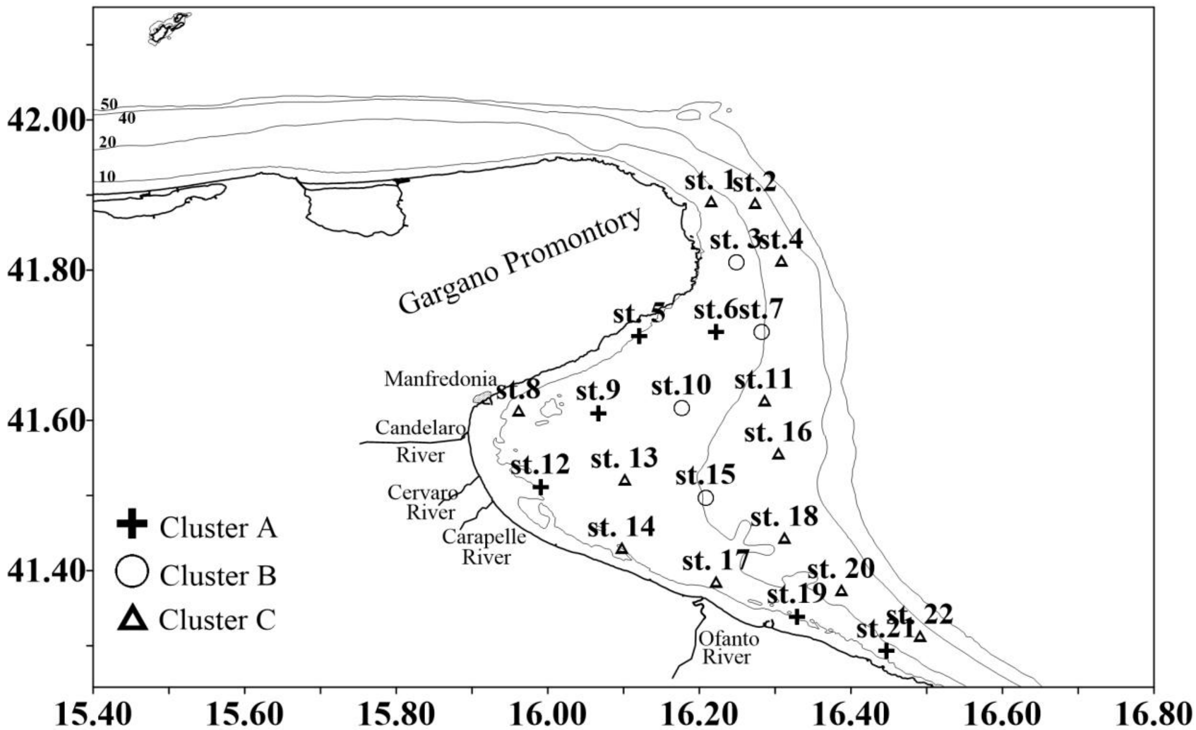

Figure 6. Manfredonia Gulf, location map of the sampling stations of each cluster.

Table 3. Spearman rank order correlations between all abiotic variables and structural indices of the macrozoobenthos communities.

	% Sand	**% Silt**	**% Clay**	**% LOI**	**Ind. m^{-2}**	**d**	**J'**	**H**	**D**	***C. gibba***	***S. scutata***	***A. latreillii***
% Sand		-0.57**	-0.85***	-0.38	0.54**	0.51**	-0.20	0.48*	-0.31	-0.02	-0.45*	0.21
% Silt			0.25	0.02	-0.18	-0.20	0.19	-0.21	0.09	0.17	0.30	0.16
% Clay				0.50*	-0.63**	-0.67***	0.04	-0.64***	0.51*	-0.03	0.36	-0.34
% LOI					-0.54**	-0.61**	-0.16	-0.53**	-0.54***	-0.23	0.19	-0.53*
Ind m^{-2}						0.81***	-0.22	0.88***	-0.57**	0.07	-0.38	0.68***
d							0.28	0.96***	-0.78***	-0.04	-0.43*	0.52*
J'								0.13	-0.23	0.01	-0.01	-0.15
H									-0.76***	-0.04	-0.38	0.52
D										0.10	0.26	-0.23
C. gibba											-0.24	0.05
S. scutata												-0.08

Abundance, Ind. m^{-2}; **d,** Margalef index; **J,** Pielou index; **H',** Sannon index; **D,** Dominance index; ***,** P<0.05; ****,** P<0.01; *****,** P<0.001

correlated with % clay and % LOI. The Margalef index was negatively correlated with % clay, and % LOI, while it was positively correlated with abundance. The Shannon-Wiener index was negatively correlated with % clay and % LOI. Among the indicator species taken into consideration, only the Polychaete *S. scutata* showed a negative correlation with the % sand, while the Crustacea *A. latreilleii* showed a negative correlation with the % LOI.

Multivariate analysis of macrozoobenthos community

The position of the sampling stations of the three clusters in the Manfredonia Gulf it is shown in Figure 6. The Figure 7a and b shows the cluster analysis (a) and the MDS (b) conducted on the data of abundance (N° ind m^{-2}) of macrozoobenthic community and sediments characteristics (% sand, % silt, % clay and % LOI) detected at

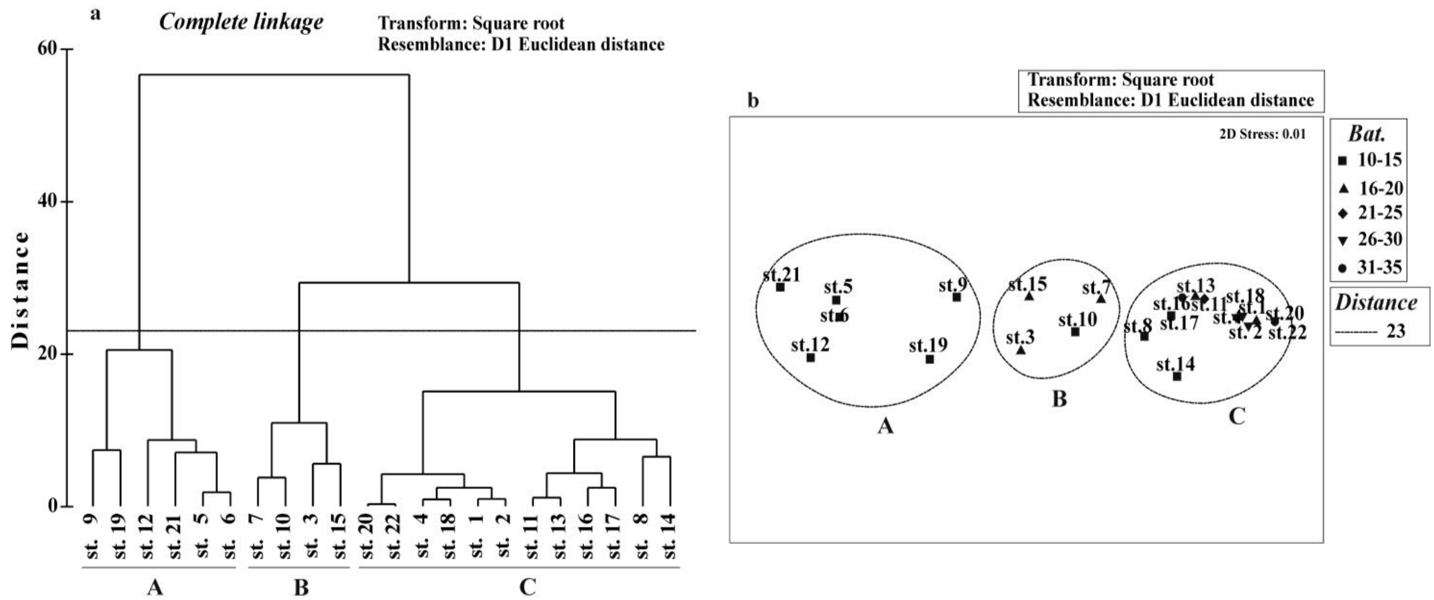

Figure 7. Hierarchical cluster analysis results (at) and MDS diagrams (b).

each station, in order to evaluate the best MDS configuration, a stress value of 0.01 was imposed. Both analyses showed three clusters (A, B, C) (Figure 7a). A cluster (A) with 6 stations (9, 19, 12, 21, 5 and 6) all located along the bathymetric between 10-15 meters, characterized by grain-size: silt (31.05%), clay (26.45%) sand (35.16%) and LOI (2.84%). In this grouping, a total of 953 individuals were counted. The mean abundance was 3483±1611 ind m^{-2}. The dominant organisms were the Crustacea *A. latreillii* (23%), the Polychaeta Capitellidae (13%) and Maldanidae (10%) and Bivalve *C. gibba* (3%) detected only at the station 6 (548±423 ind m^{-2}). The structural index of the macrozoobenthic community was: 2.11±0.37 (H), 3.62±0.88 (d), 0.79±0.10 (J) and 0.82±0.09 (D), greater than the other two clusters. A second cluster (B) that grouped four stations, of which three (7, 3 and 15) located between 16-20 meters deep and one (station 10) located at 10-15 meters deep, was characterized by high content of silt (49.36%), clay (37.52%) and LOI (3.28%). In this grouping, 243 individuals were counted. The mean abundance was of 1332±798 ind. m^{-2}. The dominant species were the Crustacean *A. latreillii* (24%) and the Bivalve *C. gibba* (17%), followed by the Polychaeta Capitellidae (13%) and Maldanidae (10%). The structural index of the macrozoobenthic community was: 1.53±0.47 (H), 2.22±0.78 (d), 0.79±0.14 (J) and 0.73±0.17 (D). The third cluster (C) grouped 12 stations, of which seven (2, 4, 11, 16, 18, 20 and 22) located between 21-35 meters deep and five station (1, 8, 13, 14 and 17) between 10-20 meters deep, characterized by silt (41.90%), clay (44.66%) and LOI (4.77%). A total of 185 individuals were counted in this group. These stations had the lowest abundance values (338±267 ind m^{-2} and structural indexes of the macrozoobenthos community: H (1.01±0.58), d (1.51±0.79), J (0.81±0.34) and D (0.76±0.19). The dominant groups were the Polychaeta: Lumbrineridae (16%) followed by the Capitellidae (14%), and the specie was the *S. scutata* (14%). The ANOSIM test found highly significant differences ($p<0.001$) of the abundance, Pielou, Magalef and Shannon Index among the three groups, while very significant differences ($p<0.01$) was found instead for the Dominance index. The values (W) of the ABC index measured for each station are shown in Table 2. The data of the ABC index, measured for each sampling station, indicate that the Manfredonia Gulf is moderately disturbed (W=0.317±0.259) (Table 2). In particular, the stations 9 and 21, located along the bathymetric between 10-15 m were grossly disturbed with negative values of W respectively: -0.03 for station 9 and -0.05 for the station 21 (Figure 8). The inshore stations, grouped in the cluster A, were more disturbed (W=0.108±0.129) than the offshore stations in the clusters B (W=0.135±0.060) and C (W=0.481±0.232) Table 4.

DISCUSSION

The sediments of the Manfredonia Gulf showed a typical spatial distribution of the Mediterranean coastal areas.

Coarser sediments (sand >30%) was dominant near-shore at shallow depths in one restricted area, that is parallel to the coastline of the Carapelle River mouths. In

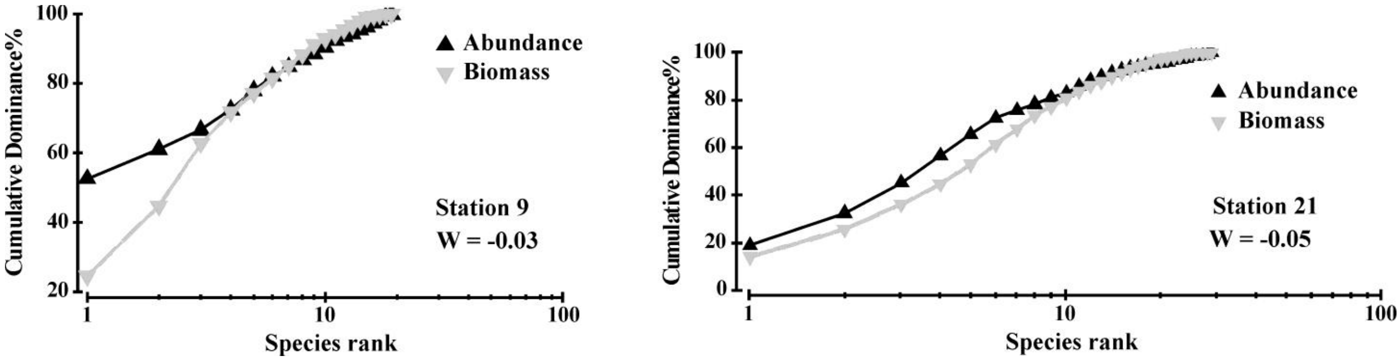

Figure 8. Curves ABC-plotter Index of the station 9 and 21.

Table 4. The values of the ABC index of each cluster.

	Cluster A	**Cluster B**	**Cluster C**
W value	0.108±0.129	0.135±0.060	0.481±0.232

fact, the stations located at shallow depths (10-15 m) had higher % sand content and a lower content of % silt, % clay and % LOI. Instead, the stations located offshore in deep waters (20-40 m) were characterized by fine sediment and a high content of % LOI, % silt and % clay. The distribution of sediments and the macrozoobenthic community in the Manfredonia Gulf reflected the interaction between river discharge, oceanographic circulation and morphological features of the area. These environmental factors promote the deposition of coarse-grained sediments near-shore and force the deposition of fine-grained sediments to deeper areas external to the Manfredonia Gulf (Spagnoli et al., 2004, 2008). The structural diversity of the macrozoobenthic community of the Manfredonia Gulf was on average lower than in the northern and central Adriatic Sea (Occhipinti-Ambrogi et al., 2005; Bacci et al., 2009; Simonini et al., 2009; Frontalini et al., 2011), and Naples Bay (Fasciglione et. al., 2016). The dominant species belong to most part of limivorous and superficial detritivores. In the Manfredonia Gulf, the high spatial variability of the abundance of the macrozoobenthic community was already observed previously by Scirocco et al. (2006, 2014). This spatial variability could be attributed to several different environmental (freshwater inputs, urban wastewaters, drainage watercourses, agricultural drainage watercourses) and oceanographic aspect and to fishing activities carried out in the area. The macrozoobenthic composition at the study area was characterized by the presence of a few dominant, highly abundant and for the most part opportunist species (*C. gibba*, *A. latreillii,* and *S. scutata*). The results of this survey are in agreement with what was previously reported by Scirocco et al. (2006, 2014). The most frequent and abundant groups were the Capitellidae family and the Crustacean *A. latreillii*, the Polychaeta *S. scutata* and the Mollusca *C. gibba*; all opportunistic species typical of environments rich in organic matter and subject to environmental disturbances. The presence, also if limited to a few stations, of the bivalve *C. gibba*, indicates that the sampling area is characterized by the sediment instability, organic enrichment and anoxic conditions (Crema et al., 1991; Tomassetti et al., 1997; Cavallini et al., 2005). *C. gibba* is widely distributed throughout the estuaries of northern Europe and the Mediterranean Sea; it is considered an indicator of sediment instability (Perès and Picard, 1964), organic enrichment and anoxic conditions (Hrs-Brenko, 1981; Jensen, 1990; Diaz and Rosenberg, 1995). *C. gibba* is well adapted to live in unstable environments as constantly polluted zone and in coastal and offshore areas exposed to seasonal or occasional environmental disturbances (Žerjav Meixner, 2000; Hrs-Brenko et al., 1994; Hrs-Brenko, 2006) as well as in areas that have low species diversity (Borja et al., 2000; Pruvot et al., 2000; Solis-Weiss et al., 2004). The population dynamics of these species are characterized by a very rapid response to environmental variability, early recolonization, explosive increases in the population during the faunal recovery process and a rapid decline in the density of the population after the subsequent recolonization of the environment by other fauna or the occurrence of an environmental disturbance (Pearson and Rosenberg, 1978; Gray, 1981; Tsutsumi and Kikuchi, 1983).

Conclusion

Our results indicate that the surface sediments of Manfredonia Gulf are dominated by silt-clay and clayey-silt, with limited sandy areas. The Gulf, being protected by the direct effect of the western Adriatic current (WAC), due to the presence of the Gargano Promontory, is subject to the establishment of hydrodynamic conditions that facilitated sedimentation. This condition could be favored by the poorly marked bathymetric profile of the Gulf area. The dominant species belong for the most part to the limivorous and superficial detritivores, in terms of composition and structure, to those that Salen-Picard (1985) defines as "*decanting facies*", as indicators of stress to excessive sedimentation. The conditions moderately disturbed of the area detected by the ABC curves are probably to be traced back to more of natural factors, such as sedimentary and circulatory dynamics, than to anthropic impacts. However, the disturbance condition detected if it lasts over the years could compromise the important role of nursery area for the small pelagics of the Adriatic Sea. This study represents an initial exploration of the area. The Manfredonia Gulf represents an interesting ecological area which needs to be monitored carefully also in the framework of the present global climate change.

ACKNOWLEDGEMENTS

This study is a contribution to the “SSD-Pesca” project on fisheries in Southern Italy (see http://mezzogiorno.cnr.it/), funded by the Italian Ministry of Finance and Economy, and to a pilot project funded by Puglia Regional Administration within the European Fisheries Fund (2007 e 2013).

REFERENCES

Alberelli G., Covazzi-Harriague A., Danovaro R., Fabiano M. & Fraschetti S. (1999). Differential responses of bacteria, meiofauna and macrofauna in a shelf area (Ligurian Sea, NW Mediterranean): Role of food availability. J. Sea Res. 42:11-26.

Ayari R. & Afli A. (2003). Bionomie benthique du petit golfe de Tunis. Bulletin de l’Institut National des Sciences et Technologies de la Mer de Salammbo ̂, Tunisia. 30: 79-90.

Bacci T., Trabucco B., Marusso V., Vani D., Lomiri S., Gabellini M. & Virno Lamberti C. (2009). Caratterizzazione biocenotica di un’area dell’Alto Adriatico: risultati preliminari di uno studio sulla comunita` macrozoobentonica marina di fondo mobile. Atti del congresso congiunto AIOL-SitE- Ancona 2007.

Basatnia N., Hosseini S. A. & Muniz P. (2015). Performance comparison of biotic indices measuring the ecological status base on soft-bottom macroinvertebrates: a study along the shallow Gomishan lagoon (Southeast Caspian Sea). Braz. J. Oceanogr. 63(4):363-378.

Bell J. D. & Pollard D. A. (1989). Ecology of fish assemblages and fisheries associated with seagrasses. In: Larkum, A.W.D., Mc-Comb, A.J., Shepherd, S.A. (Eds.), Biology of Seagrasses. Elsevier, Amsterdam. Pp. 536-564.

Bello G., Marano G. & Vaccarella R. (1982). Molluschi di "matte" morta di Posidonia oceanica Delile del litorale barese. Quad. Ist. Idrobiol. Acquacolt. Brunelli. 2(3):23-25.

Bianchi C. N. & Zurlini G. (1984). Criteri e prospettive di una classificazione ecotipologica dei sistemi marini costieri italiani. Acqua aria. 8:785-796.

Bilyard G. R. (1987). The value of Benthic infauna in marine pollution monitoring studies. Mar. Pollut. Bull. 18:581-585.

Borja A., Franco J. & V. Perez (2000). A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. Mar. Pollut. Bull. 40(12):1100-1114.

Borme D., Tirelli V. & Palomera I. (2013). Feeding habits of European pilchard late larvae in a nursery area in the Adriatic Sea. J. Sea Res. 78:8-17.

Byers S. C., Mills E. L. & Stewart P. L. (1978). A comparison of methods of determining organic carbon in marine sediments, with suggestions for a standard method. Hydrobiologia. 58:43-47.

Cavallini F., Iotti M. & Simonini R. (2005). Evoluzione dei popolamenti macrozoobentonici dell’Adriatico Settentrionale. I. Analisi dei dati storici di Aristocle Vatova (1934-1936). Atti della Società dei Naturalisti e Matematici Modena. 135:145-154.

Chiaudani G., Gaggino G. F., Marchetti R. & Vighi M. (1982). Caratteristiche trofiche delle acque costiere Adriatiche: Campagna di rilevamento 1978-1979. Ser. Monog. Progetto Finalizzato Promozione Qualità Ambiente CNR, Roma, AQ/2/14. 170p.

Clarke K., R. (1990). Comparison of dominance curve. J. Exp. Marine Biol. Ecol. 138(1-2):143-157.

Crema R., Bonvicini Pagliai A. M., Cognetti Varriale A. M., Morselli I. & Zunarelli Vandini R. (1983). Role of communities in macrozzobentoniche biological monitoring coastal marine environment, in: Eutrofizzazione dell’Adriatico. Ricerche e Linee d’intervento. Regione Emilia Romagna. Pp. 379-384.

Crema R., Castelli A. & Prevedelli D. (1991). Long term eutrophication effects on macrofaunal communities in northern Adriatic Sea. Mar. Pollut. Bull. 22(10):503-508.

Damiani V., Bianchi C. N., Ferretti O., Bedulli D., Morri C., Viel M. & Zurlino G. (1988). Risultati di una ricerca ecologica sul sistema marino costiero pugliese. Thalassia Salentina. 18:153-169.

Danovaro R., Gambi C., Manini E. & Fabiano M. (2000). Meiofauna response to a dynamic river plume front. Mar. Biol. 137:359-370.

Deegan L. A., Day J. W., Gosselink Jr J. G., Yánez-Arancibia A., Chávez G. S. & Sánchez-Gil P. (1986). Relationships among physical characteristics, vegetation distribution and fisheries yield in Gulf of Mexico estuaries. In: A. Wolfe (Ed.), Estuarine variability. New York: Academic Press. Pp. 83-100.

Den Hartog C. (1970). The seagrasses of the world. Elsevier, Amsterdam, London.

Diaz R. J. & Rosenberg R. (1995). Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr. Mar. Biol. Ann. Rev. 33:245-303.

Fasciglione P., Barra M., Santucci A., Ciancimino S., Mazzola S. & Passaro S. (2016). Macrobenthic community status in highly polluted area: a case study from Bagnoli, Naples Bay, Italy. Rend. Fis. Acc. Lincei (2016) 27:229-239. DOI 10.1007/s12210-015-0467-5.

Fiesoletti F., Specchiulli A., Spagnoli F. & Zappalà G. (2005). A new near time monitoring network in the Gulf of Manfredonia-Southern Adriatic Sea. In: European operational oceanography: Present and future, June 2005, pp 788-792. Paper presented at the Fourth International Conference on EuroGOOS, Brest-France.

Frontalini F., Semprucci F., Coccioni R., Balsamo M., Bittoni P. & Covazzi-Harriague A. (2011). On the quantitative distribution and community structure of the meio and macrofaunal communities in the coastal area of the Central Adriatic Sea (Italy). Environ. Monit. Assess. 180:325-344.

Gray J. S. (1981). The ecology of marine sediments. Cambridge University Press, Cambridge. 185p.

Hrs-Brenko M. (1981). Population studies of *Corbula gibba* (Olivi), Bivalvia, Corbulidae, in the Northern Adriatic Sea. J. Mollus. Stud. 47(1):17-24.

Hrs-Brenko M. (2006). The basket shell, *Corbula gibba* Olivi, 1972

(Bivalve Mollusks) as a species resistant to environmental disturbances. A review. Acta Adriat. 47(1):49-64.

Hrs-Brenko M., Medakovic D., Labura Ž. & Zahtila E. (1994). Bivalve recovery after a mass mortality in the autumn of 1989 in the Northern Adriatic Sea. Period. Biol. 96(4):455-459.

Ingole B., Sivadas S., Goltekar R., Clemente S., Nanajkar M., Sawant R., D'Silva C., Sarkar A. & Ansari Z. (2006). Ecotoxicological effect of grounded MV River Princess on the intertidal benthic organisms off Goa. Environ. Int. 32(2):284-291.

Jensen J. N. (1990). Increased abundance and growth of the suspension-feeding bivalve *Corbula gibba* in a shallow part of the eutrophic limfjord, Denmark. Neth. J. Sea Res. 27(1):101-108.

Mancinelli G. & Vizzini S. (2015). Assessing anthropogenic pressures on coastal marine ecosystems using stable CNS isotopes: State of the art, knowledge gaps, and community-scale perspectives. Estuar. Coast. Shelf Sci. 156:195-204.

Montagna P. A. & Yoon W. B. (1991). The effect of freshwater inflow on meiofaunal consumption of sediment bacteria and microphytobenthos in San Antonio Bay, Texas, USA. Estuarine, Coastal and Shelf Science. 33:529-547.

Montagna P. A., Kalke R. D. & Ritter C. (2002). Effect of restored freshwater inflow on macrofauna and meiofauna in upper Rincon Bayou, Texas, USA. Estuaries. 25:1436-1447.

Moodley L., Heip C. H. R. & Middelburg J. J. (1998). Benthic activity in sediments of the northwestern Adriatic Sea: Sediment oxygen consumption, macro and meiofauna dynamics. J. Sea Res. 40:263-280.

Nelson B. W. (1972). Mineralogical differentiation of sediments dispersal from the Po Delta. In: Stanley, D.J. (Ed.), The Mediterranean Sea: A Natural Sedimentation Laboratory. Dowden, Hutchinson & Ross, Stroudsburg. Pp. 441-453.

Nixon S. A., Oviatt C. A., Frithsen J. & Sullivan B. (1986). Nutrients and the productivity of estuarine and coastal marine ecosystems. J. Limnol. Soc. South Afr. 12:43-71.

Occhipinti-Ambrogi A., Savini D. & Forni G. (2005). Macrobenthos community structural changes off Cesenatico coast (Emilia Romagna, Northern Adriatic), a six-year monitoring programme. Sci. Total Environ. 353:317-328.

Panfili M. (2012). Ecology of early life stages of small pelagic fishes *Engraulis encrasicolus* and *Sardina pilchardus* in the Adriatic Sea. Ph.D Thesis. Università Politecnica delle Marche, Dipartimento di Scienze del Mare. 130p.

Pearson T. H. & Rosenberg R. (1978). Macrobentic succession in relation to organic enrichment and pollution of the marine environment. Oceanogr. Mar. Biol. Ann. Rev. 16:229-311.

Perès J. M. & Picard J. (1964). Nouveau manuel de Bionomie bentique de la mer Mediterranee. Recueil des Travaux de la Station Marine d'Endoume. 47(31):3-137.

Pollard D. A. (1984). A review of ecological studies on seagrass-fish communities with particular reference to recent studies in Australia. Aquat. Bot. 18:3-42.

Pruvot C., Empis A. & Dhainaut-Courtois N. (2000). Presence du mollusque Bivalve C*orbula gibba* (Olivi, 1792) dans les sediments meubles du port est de Dunkerque (Mer du Nord) = New record of the mollusk *Corbula gibba* (Olivi, 1792) in the muddy sands of Dunkirk harbour (Nord Sea). B. Soc. Zool. Fr. 125:75-82.

Red List IUCN of Threatened Species (2010). e.T153535A4516419. http://dx.doi.org/10.2305/IUCN.UK.2010-3.RLTS.T153535A4516419.en

Red List IUCN of Threatened Species (2015). e.T133142A75872554. http://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T133142A75872554.en

Rodolfo-Metalpa R., Bianchi C. N., Peirano A. & Morri C. (2000). Coral mortality in NW Mediterranean. Coral Reefs. 19(1):24.

Salen-Picard C. (1985). Indicateus biologiques et sedimentation en milieu circalittoral méditerranéen. Rapports de la Commission Internationale pour l'Exploration de la Mer Méditerranéene. 29:211-212.

Scirocco T., Casolino G., Fabbrocini A. & D'Adamo R. (2006). I popolamenti bentonici litorali dei fondi mobili in un sito ad elevato impatto antropico: il Golfo di Manfredonia, Italia. Biol. Mar. Mediterr. 13(1):643-646.

Scirocco T., Specchiulli A., Cilenti L. & D'Adamo R. (2014). Assessment of macrozoobenthic distribution in the Manfredonia Gulf (Eastern Mediterranean). Biol. Mar. Mediterr. 21(1):265-266.

Semprucci F., Boi P., Manti A., Covazzi Harriague A., Rocchi M., Colantoni P., Papa S. & Balsamo M. (2010). Benthic communities along a littoral of the Central Adriatic Sea (Italy). Helgoland Marine Research. 64(2):101-115.

Serhat A., Husamettin B., Argyro Z., Kurun A. & Kubanc C. (2006). Ecological quality status of coastal benthic ecosystems in the Sea of Marmara. Mar. Pollut. Bull. 52(7):790-799.

Shepard F. P. (1954). Nomenclature based on sand-silt-clay ratios. J. Sediment. Petrol. 24:151-158.

Sigl W. (1973). Der Golf von Manfredonia (Su¨ dliche Adria). I. Die fazielle Differenzierung der Sedimente. Senckenbergiana Maritima. 5: 3-49.

Simeoni U. (1992). I litorali tra Manfredonia e Barletta (Basso Adriatico): dissesti, sedimenti, problematiche ambientali. Bollettino della Societa` Geologica Italiana. 111:367-398.

Simonini R., Grandi V., Massamba-N'Siala G., Lotti M., Montanari G. & Prevedelli D. (2009). Assessing the ecological status of the North-western Adriatic Sea within the European Water Framework Directive: a comparison of Bentix, AMBI and M-AMBI methods. Mar. Ecol. 30:241-254.

Solis-Weiss V., Aleffi F., Bettoso N., Rossin P., Orel G. & Fonda-Umani S. (2004). Effects of industrial and urban pollution on the benthic macrofauna in the Bay of Muggia (industrial port of Trieste, Italy). Sci. Total. Environ. 328(1-3): 247-263.

Spagnoli F., Bartholini G., Dinelli E. & Giordano P. (2008). Geochemistry and particle size of surface sediments of Gulf of Manfredonia (Southern Adriatic sea). Estuarine, Coastal and Shelf Science. 80:21-30.

Spagnoli F., Bartholini G., Marini M. & Giordano P. (2004). Biogeochemical processes in sediments of the Manfredonia Gulf (Southern Adriatic Sea): early diagenesis of carbon and nutrient and benthic exchange. Biogeosciences Discussions. 1:803-823. www.biogeosciences.net/bgd/1/803/. SRef-ID: 1810-6285/bgd/2004-1-803. European Geosciences Union 2004.

Thomson B. W., Riddle M. J. & Stark J. S. (2003). Cost-efficient methods for marine pollution monitoring at Casey station, East Antarctica. Mar. Pollut. Bull. 46:232-243.

Tomassetti P., Tosti M. & De Santis A. (1997). Distribution of *Corbula gibba* (Olivi) (Mollusca, Bivalvia) in two areas of the northern Adriatic Sea related to some physical-chemical parameters. Biol. Mar. Mediterr. 4(1):452-455.

Tsutsumi H. & Kikuchi T. (1983). Benthic ecology of a small cove with seasonal oxygen depletion caused by organic pollution. Publs Amakusa mar. blol. Lab. 7:17-40.

Vaccarella R., Paparella P., Bello G. & Marano G. (1998). The smooth scallop, *Chlamys glabra*, fishery in the Gulf of Manfredonia (South-Western Adriatic Sea). Rapp. Comm. int. Mer Medit. 35:500-501.

Warwick R. M. (1986). A new method for detecting pollution effects on marine microbenthic communities. Mar. Biol. 92:557-562.

Zaouali J. (1993). Les peuplements benthiques de la petite Syrte, Golfe de Gabès-Tunisie. 5 Résultats de la campagne de prospection du mois de juillet 1990. Marine Life. 3:47-60.

Žerjav Meixner V. (2000). Potrošnja kisika i ponašanje školjkaša *Corbula gibba* (Olivi, 1792) u eksperimentalnim uvjetima [Oxygen consumption and the behaviour of shellfish *Corbula gibba* (Olivi, 1792) in the experimental conditions]. Thesis, University of Zagreb. 98p.