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Soft-bottom macrozoobenthos of the southern part of the Gulf of Trieste: faunistic, biocoenotic and ecological survey

Borut MAVRIČ[1], Martina ORLANDO-BONACA[1], Nicola BETTOSO[2] and Lovrenc LIPEJ[1*]

[1]Marine Biology Station, National Institute of Biology, Fornače 41, 6330 Piran, Slovenia

[2]Osservatorio Alto Adriatico - ARPA FVG, Via La Marmora 13, 34100 Trieste, Italy

Corresponding author, e-mail: lipej@mbss.org

A faunistic, biocoenotic and ecological survey of soft-bottom macrozoobenthic communities was carried out for the southern part of the Gulf of Trieste on the basis of samplings in 2005 and 2006. At 28 sampled stations a total of 14595 specimens belonging to 306 animal taxa were identified. The most abundant species were Capitella capitata, Lumbrineris gracilis, Heteromastus filiformis, Corbula gibba *and* Tellina distorta*. The highest relative species abundance in all water bodies was close to 15%. The dominant species confirmed that the environment of the Gulf of Trieste is unstable. This environmental instability could also explain the rather high values of AMBI. The MDS analysis and other applied indices indicated that there were no statistically significant differences between water bodies. The values for Shannon-Wiener diversity index (H') and Pielou's index (J') were among the highest ever recorded for the soft-bottom assemblages of the Gulf of Trieste. The analysis of benthic biocoenoses revealed that the sampling area is a boundary between infra- and circalittoral belts, which could explain the very high species richness.*

Key words: Macrozoobenthos, soft-bottom, biocoenoses, ecological aspects, Gulf of Trieste

INTRODUCTION

Despite the centennial tradition in biological oceanography research in the Adriatic Sea, especially in its northernmost part, *i.e.* the Gulf of Trieste, surprisingly there are still gaps in basic knowledge. Many published works, describing different macrozoobenthic communities, are available for the area though the great majority of them were performed in the northern part of the Gulf which is rather different from the southern part. Later, certain studies on macrozoobenthic community were carried out in the seventies and eighties of the last century, dealing mainly with pollution, anoxia and some with the distribution of usually specific taxonomic groups (e.g. polychaets and echinoderms) (AVČIN *et al.*, 1973, 1979; AVČIN & VRIŠER, 1983; STACHOWITSCH & FUSCHS, 1995). However, knowledge on the macrobenthic fauna of the area is still far from being satisfactory.

The Gulf of Trieste is characterized by different environmental and anthropogenic pressures, which are affecting soft-bottom communities, such as periodic events of the "mare sporco" phenomena (mucilage aggregations), episodes of hypoxia and anoxia, substantial riverine inflow, intensive maritime transport, intensive fishery, mariculture and others (STACHOWITSCH & FUSCHS, 1995). These pressures could inflict certain changes in the soft bottom animal communities, at least in terms of succession.

The assessment of the ecological status (ES) of coastal waters plays an important role in coastal zone management, particularly as it is required by the European Water Framework Directive (WFD) (EC, 2000). In order to achieve and maintain a »good« status of water bodies by 2015, the WFD document offered general guidelines on how to evaluate this status based on innovative ecological approaches. A great role in these approaches was given to 'Biological Quality Elements' (BQEs) which need to be studied and their status evaluated with appropriate scientific tools. One of the BQEs to be considered when assessing the ES of coastal waters is soft bottom benthic invertebrates (EC, 2000). Several indices based on benthic invertebrates were developed in recent years (AMBI (AZTI's Marine Biotic Index) and M-AMBI (Multivariate AMBI) (BORJA *et al.*, 2000; BORJA & MUXIKA, 2005; MUXIKA *et al.*, 2007); Bentix (SIMBOURA & ZENETOS, 2002); Medocc index (GIG, 2008); BQI (ROSENBERG *et al.*, 2004), DKI, IQI, NQI (BORJA *et al.*, 2007; GIG, 2008)) and were incorporated in the national ES assessment methodologies. For Slovenian coastal sea assessment a methodology was developed in 2007 based on M-AMBI (LIPEJ *et al.*, 2007) which was successfully intercalibrated within MedGIG (GIG, 2008).

After many years of discontinuity in soft bottom macrozoobenthic research in the Slovenian coastal sea, a new focus was placed on this field in 2005 and 2006 with the sampling for the development of the national ES assessment methodology. The aim of this paper is to evaluate the structure and diversity of shallow soft-bottom macrozoobenthos based on these new data and to evaluate them from the biocoenotic and ecological aspects.

MATERIAL AND METHODS

Study area

The Slovenian coastal sea is the southern part of the Gulf of Trieste, the latter representing the northernmost part of both the Adriatic and the Mediterranean Sea. The Gulf of Trieste is a shallow semi-enclosed gulf, characterized by the largest tidal differences (semidiurnal amplitudes approach 30 cm) and the lowest winter temperatures (below 10°C) in the Mediterranean Sea (BOICOURT *et al.*, 1999), by high temperature and salinity variations, and important stratification of the water column (STRAVISI, 1983). The hydrodynamism of the Gulf of Trieste is linked mainly to the ascending eastern current coming from the Istrian coast. The general circulation pattern is predominantly counter-clockwise in the lower layer and clockwise in the surface layer. This circulation, especially in the surface layer can be modulated by prevailing winds such as the Bora (STRAVISI, 1983).

The Slovenian coastline is approximately 46.7 km long and is almost entirely made of Flysch, which is the major source of detrital material. The coastline is composed of two major bays, the Bay of Koper and the Bay of Piran, which are wide submerged valleys of the small rivers Rižana and Dragonja, respectively. Mainly cliffs of Flysch comprise the rest of the coastline. The Slovenian coastal sea is, according to these characteristics and water typology definitions proposed by the WFD, split into four water bodies (Fig. 1). The coastline is under high anthropogenic influence and currently only around 18% of it remains in its natural state (TURK, 1999). Slovenian coastal waters are affected by freshwater inflows, bottom deposit re-suspension, pollution and other anthropogenic impacts (heavy metals, Port of Koper, untreated or partially treated sewage outfalls, intensive farming, overfishing and mariculture) (KOVAČ *et al.*, 2006; FAGANELI *et al.*, 2009; GREGO *et al.*, 2009).

RANKE (1976) was the first that studied the sediments of the Bay of Piran. His findings showed that surface sediments are distinctly zoned in terms of lithological and biological features, with a westward increase of the median grain size. Sediments close to the Flysch coast were dominated by silt, with 30-35% of clay and less than 1% of the coarser sand fraction (more than 63 μm). From the mouth of the Dragonja River to the middle of the Bay of Piran, with extension toward Piran, there was an increase in the clay fraction (35-50%) with almost no sand. Toward deeper waters of the bay there was an

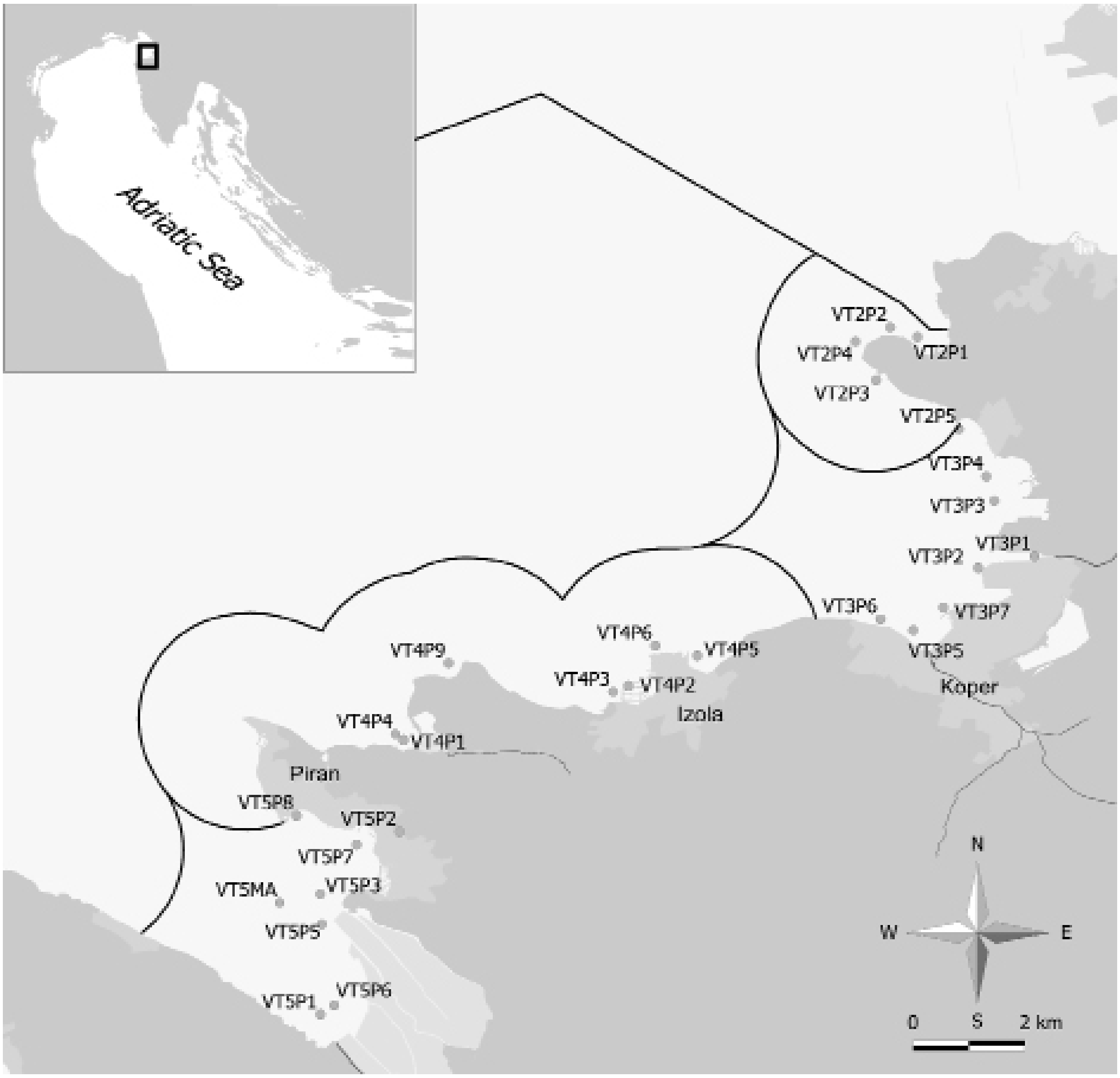

Fig. 1. Soft-bottom invertebrate sampling stations in the Slovenian coastal sea
Legend: VT – water body; P - station

evident increase, first in the silt and then in the sand fractions, with a clay fraction less than 5%.

With the same accuracy OGORELEC *et al.* (1987) studied the sediments in the Bay of Koper. They underlined that sediments near the coast (a narrow strip at depths not greater than 5 m) are mainly silty, with up to 15% of clay and up to 40% of sand (mainly detritus of Flysch, limestone and mollusc shells). In deeper waters sediments are more homogenous, again mainly silty, but with 20-40% of clay and only up to 3% of sand. In open waters, there is an increase in the sand fraction (about 20%) and a decrease of the clay fraction (about 25%).

Almost all the grains that form the sediment of the inner part of the Bay of Koper have a detritic origin and came into the bay by the erosion of the Flysch coast. Because of the high clay fraction and because of the periodic artificially induced turbulence (deepening of the sea bottom for the widening of the Port of Koper), the sediment of the inner part of Koper bay has a relatively poor consistency, much lower than the sediment of the open part of the bay (FAGANELI *et al.*, 1984).

A gradual increase in the grain size towards the open part of the Gulf of Trieste is also clearly evident from a successive work of OGORELEC *et al.* (1991). Their results again showed how the sediments of Koper and Piran bays are mainly composed of silty clay (with about 60% of clay), while in the central part of the Gulf the sand fraction prevails, consisting of about 80% of biogenic detritus.

Fieldwork

Samples were taken at 28 stations scattered along the entire Slovenian coast (Fig. 1) in the period from 2005-2006. They were obtained with Van Veen grab (0.1 m^2) at depths between 7-10 m on a mainly clayey silt sediment bottom (40% clay, less than 5% sand, mean grain size 3-10 µm, carbonate content 30-40% (OGORELEC *et al.*, 1991)). Sea-grass covered seabed was avoided. All stations were less than 1 mile distant from the coast, as required by WFD standards. At each station three replicates were taken. For the purpose of this study, replicates were treated as separate samples during preparation, identification and part of the analysis.

After sampling, all benthic samples were immediately sieved through a 3 mm and 1 mm mesh-size sieve. The retained material was fixed with 80% ethanol-sea water solution. In the laboratory benthic invertebrates were sorted with care into main taxonomic groups, identified to the lowest possible taxonomic level and counted. After sorting both fractions 3 mm and 1 mm were treated together. The nomenclature was checked following the European Register of Marine Species (COSTELLO *et al.*, 2001).

Data analysis

Communities were elucidated through cluster analysis of sampling stations based on the macrozoobenthic composition (abundance square-root transformed data, Bray-Curtis similarity, MDS). This analysis was carried out using the PRIMER® computer software. Taxa richness (S), density of individuals per m^2, Shannon-Wiener diversity index on a $\log_2$ basis (H´), Pielou's evenness index (J'), AZTI Marine Biotic Index (AMBI) and Multimetric AMBI (M-AMBI) were calculated for each sampling station. These values were averaged for each water body. AMBI and M-AMBI were calculated according to each methodology following recommended guidelines: for AMBI according to BORJA *et al.* (2000) and for M-AMBI according to MUXIKA *et al.* (2007). Bionomic percentage affinity (A%) was calculated according to PÉRÈS & PICARD (1964) considering characteristic exclusive species. The correction coefficient C was first calculated as percentage of characteristic species of biocoenosis j with respect to those of other biocoenosis. Then the absolute affinity of each station was calculated as:

$$A_j = n_j \ (100 - C_j)$$

where n_j is the number of characteristic species of biocoenosis j for the station considered. Finally, using a simple proportion, this parameter was expressed as percentage affinity (A%).

Differences between water bodies were tested using non-parametric Kruskal-Wallis one-way analysis of variance.

RESULTS

At 28 sampled stations a total of 14595 specimens belonging to 306 animal taxa were identified. Among them, 277 taxa with 14167 specimens altogether were identified to the species level. The most represented taxonomic group were polychaets (112 species with 10794 specimens), molluscs (77 species with 2192 specimens), crustaceans (74 species with 718 specimens) and echinoderms (12 species with 453 specimens). Other groups such as anthozoans, sipunculids and tunicates were present only with a few taxa.

The comparison of the relative abundance of different taxonomic groups (Table 1) showed a similar pattern in all water bodies. The highest dominance in all water bodies was observed for polychaets. It ranged from 65 to 84% (Table 1). The highest dominance was found at VT3, which also includes the station VT3P1, showing a greater than 99% dominance of polychaets. Molluscs were the second most dominant group, ranging from 11 to 21% of the total abundance, followed by crustaceans ranging from 3 to 10% of the total abundance. The most abundant spe-

Table 1. Percentage of pooled macroinvertebrate abundances of different taxonomic groups in water bodies (VT). The values for water body 3 (VT3) are presented with complete data and data without station VT3P1

	VT2	VT3	VT3 (P1 omitted)	VT3P1	VT4	VT5
Polychaeta	76.45	84.18	63.56	99.35	66.31	64.90
Mollusca	13.99	10.66	23.72	0.43	20.78	19.29
Crustacea	6.39	3.42	7.41	0.23	10.25	6.26
Echinodermata	2.33	1.41	4.20	0.00	1.84	8.28

cies was the polychaet *Capitella capitata* with 3987 individuals, the great majority of which was however recorded only at one single station, VT3P1 (13157 ind.m^{-2}). The second and the third most abundant species were *Lumbrineris gracilis* and *Heteromastus filiformis*, respectively. The k-dominance curves showed the same pattern in all studied water bodies, with an initial dominance close to 15%. Only the already mentioned station VT3P1 was distinguished by a different pattern, with an enormous dominance (more than 98%) of a single species (Fig. 2).

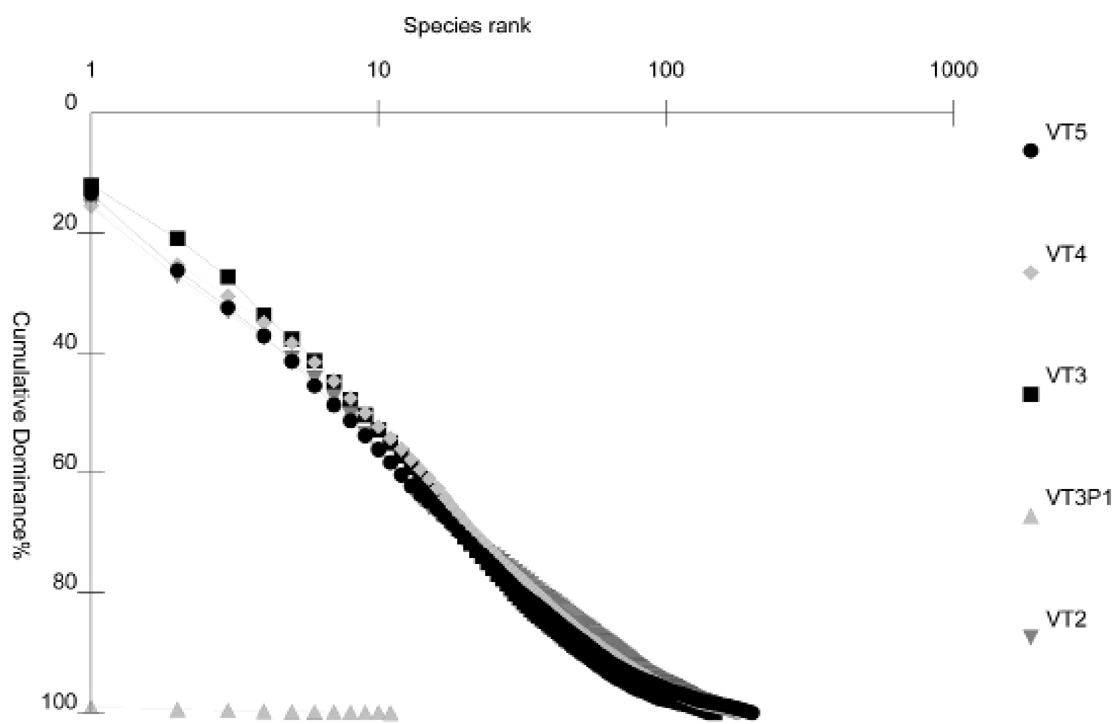

Fig 2. K-dominance curve of each water body (VT2, VT3, VT4, VT5) and separated station VT3P1

The most frequently occurring species in all water bodies were *Lumbrineris latreilli* (86.7%), *L. gracilis* (85.6%) and *H. filiformis* (84.4%) among polychaets, *Tellina distorta* (85.6%) and *Corbula gibba* (83.3%) among molluscs and *Amphiura chiajei* (52.2%) among echinoderms.

The MDS diagram underlined an evident discrimination between station VT3P1 and all the other stations (Fig. 3a). Excluding the above-mentioned station from the analysis, the sampled stations did not show any significant differences in terms of spatial distribution (Fig. 3b).

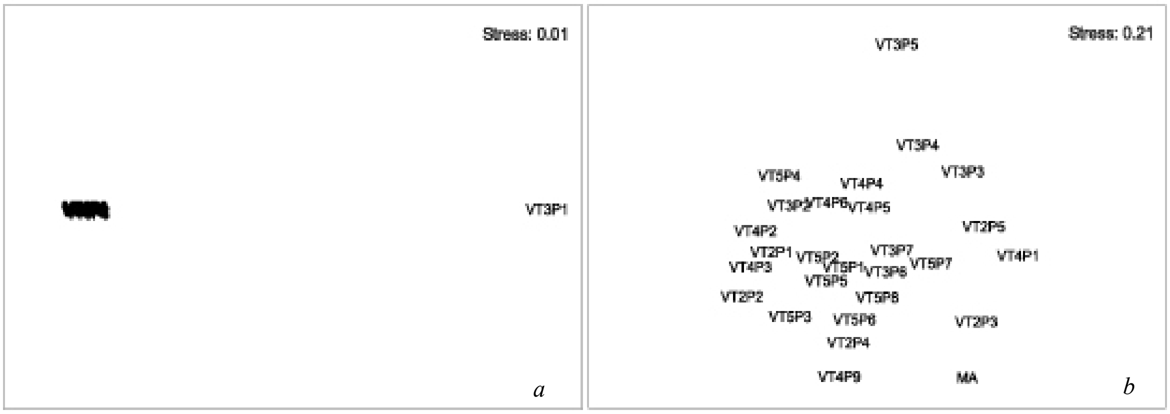

Fig 3. a - MDS based on Bray-Curtis similarity computed on square root transformed data using all stations; b – MDS based on Bray-Curtis similarity computed on square root transformed data with station VT3P1 omitted from the analysis
Legend: VT – water body; P - station

The taxa richness varied from 11 to 106 species per station (Table 2). The lowest number of species, and at the same time the highest abundance, was recorded at station VT3P1 where *C. capitata* dominated with 98.87% of the total number of individuals. Also, all other calculated indices reached their negative extremes at this station. The highest number of species was recorded at VT2P1 and VT2P2 with 105 and 106 identified taxa, respectively. The two stations were also characterized by high values of Shannon-Wiener diversity index (5.22, 5.27) although the highest value (5.39) was found at VT5P4. The lowest value was found at station VT3P1 (0.10). The Pielou's evenness values ranged from 0.74 to 0.92, with the exception of station VT3P1 with 0.03. The AMBI values varied from 1.54 to 2.75. An exception was again noted for station VT3P1 with a value 5.96. The highest M-AMBI values were evaluated at VT2P1 and VT2P2 (0.86, 0.88) and the lowest value of 0.57 at VT2P3. Outside this range was VT3P1 with a M-AMBI of 0.04. The Kruskal-Wallis one-way analysis of variance showed no statistically significant differences between water bodies for any of the averaged values ($p>0.05$).

The total share of indicator species was above 50% of total abundance for all water bodies (Table 3). All water bodies were characterized by a rather high share of indicators of environmental (sedimentary) instability, which ranged from 7.9% to 9.8% of the total abundance. They were more or less represented by the two dominant species, *i.e. T. distorta* and *C. gibba.* Indicators of heavy pollution, such as *C. capitata,* were present more or less only at VT3, with 3.4% of the total abundance. At the separated station VT3P1, such indicators represented as much as 99% of the total abundance. Widely distributed species were present in all four water bodies, with a percentage ranging from 16 to 28% of the total abundance. *Lumbrineris gracilis* and *L. latreilli* together constituted approximately 80% of widely distributed species abundance. Relative abundance of characteristic species exclusive for biocoenosis ranged from 18.8 to 29.2%.

Overall, 33 exclusive species for 7 biocoenoses were found (Table 4). Three biocoenoses were exclusive for the infralittoral, three for the circalittoral and one biocoenosis was not related to a specific belt. The polychaets *H. filiformis*, exclusive for the biocoenosis of superficial muddy sands in sheltered areas (SVMC), and *Laonice cirrata*, exclusive for the biocoenosis of coastal terrigenous muds (VTC), were contributing more than 65% of the total abundance of exclusive species in each water body. The proportion of biocoenotic affinities to infralittoral and circalittoral biocoenosis was almost the same for all water bodies.

Table 2. Comparison of different stations and water bodies (average values) in term of taxonomic richness, density per m², Shannon-Wiener diversity index (H,) Pielou's evenness index (J'), AMBI and M-AMBI. The data for VT3P1 are presented separately
Legend: WB – water body (VT2, VT3, VT4, VT5); P – station; av - average

WB	station	S	av. S	N	av. N	J'	av. J'	H'	av. H'	AMBI	av. AMBI	M -AMBI	av. M-AMBI
VT2	VT2P1	105	68	2270	1429	0.78	0.80	5.22	4.70	2.02	1.91	0.86	0.74
	VT2P2	106		2250		0.78		5.27		1.94		0.88	
	VT2P3	28		643		0.77		3.73		1.88		0.57	
	VT2P4	64		1507		0.76		4.58		1.92		0.72	
	VT2P5	38		477		0.90		4.71		1.78		0.67	
VT3	VT3P1	11		13287		0.03		0.10		5.96		0.04	
VT3	VT3P2	81	49	1457	991	0.80	0.79	5.08	4.41	2.75	2.01	0.75	0.70
	VT3P3	43		1110		0.79		4.26		1.94		0.66	
	VT3P4	51		1507		0.74		4.22		2.13		0.65	
	VT3P5	47		467		0.92		5.13		1.56		0.73	
	VT3P6	49		1253		0.79		4.44		2.10		0.66	
	VT3P7	57		867		0.79		4.62		1.56		0.73	
VT4	VT4P1	43	64	520	1320	0.85	0.81	4.64	4.84	1.73	1.93	0.68	0.74
	VT4P2	79		1880		0.81		5.11		2.49		0.76	
	VT4P3	77		2157		0.79		4.96		2.00		0.78	
	VT4P4	57		630		0.86		5.00		1.76		0.74	
	VT4P5	57		1327		0.74		4.30		1.74		0.70	
	VT4P6	76		1297		0.82		5.14		2.10		0.78	
	VT4P9	63		1430		0.80		4.77		1.68		0.75	
VT5	VT5P1	69	62	1423	1224	0.81	0.81	4.94	4.77	2.04	2.07	0.75	0.72
	VT5P2	75		1480		0.79		4.91		2.50		0.74	
	VT5P3	73		1540		0.81		5.00		1.97		0.77	
	VT5P4	75		960		0.87		5.39		2.00		0.80	
	VT5P5	78		1400		0.81		5.11		2.04		0.79	
	VT5P6	58		1600		0.76		4.47		1.80		0.71	
	VT5P7	40		590		0.84		4.49		2.34		0.63	
	VT5P8	57		1450		0.78		4.54		2.37		0.67	
	VT5MA	35		583		0.80		4.09		1.54		0.64	

Table 3. Comparison of different water bodies (VT) in term of the percentage of different indicator species present in samples (sensu PÉRÈS & PICARD, 1964)

Indicator species	VT2	VT3	VT4	VT5	VT3P1
Indicators of the environmental instability	8.30	7.90	9.80	8.70	0.00
Indicators of pollution	0.10	3.40	0.00	0.10	99.00
Widely distributed species	28.30	16.20	23.70	22.60	0.10
Characteristic species exclusive for biocoenosis	20.50	29.20	18.80	20.80	0.10
Total share of indicator species	57.20	56.70	52.30	52.20	99.20

Table 4. Comparison of different water bodies (VT) in terms of percentage of biocoenotic affinities (sensu PÉRÈS & PICARD, 1964). Legend: SVMC - biocoenosis of the superficial muddy sands in sheltered areas, SFBC - biocoenosis of fine well-sorted sands, HP - biocoenosis of Posidonia meadows, VTC - biocoenosis of terrigenous mud, DC - biocoenosis of the coastal detritic, DE - biocoenosis of the muddy detritic bottoms and SGCF - biocoenosis of the coarse sands and fine gravels under bottom currents

		VT2	VT3	VT4	VT5
Infralitoral biocoenosis	SVMC	28.90	35.20	26.90	19.10
	SFBC	13.10	14.90	24.20	13.70
	HP	5.30	2.30	6.60	5.20
Circalittoral biocoenosis	VTC	34.20	37.40	26.10	36.50
	DE	16.80	8.10	12.80	17.50
	DC	1.80	2.10	3.30	6.80
Biocoenosis not related to specific belt	SGCF	0.00	0.00	0.00	1.10
	VTC+SVMC	63.00	72.60	53.00	55.60
	Total infralittoral biocoenosis	47.20	52.30	57.70	38.10
	Total circalittoral biocoenosis	52.80	47.70	42.30	60.80

DISCUSSION

The analysis of the soft-bottom macrozoobenthos in the coastal part of the Gulf of Trieste revealed that the area boasts high taxa richness. The 277 species determined at 28 sampled stations can be considered a rather high value in comparison to the cumulative number of 640 species identified at 177 sampling stations in the northern part of the Gulf of Trieste, in the period from 1966 to 2004 in the depth range from 3.5 to 24 m (ROSSIN, 2005). Real evaluation and comparison with historical data from this area is unfortunately impossible. This is due to the fact that many different sampling techniques were used, that different size ranges of organisms were used, that taxonomy was insufficient, and that sometimes only presence and absence were noted and not the abundances.

The 145 taxa found for the dominant taxonomic group, polychaets, can be considered a high value compared to the 884 species, *i.e.* the total polychaete fauna, of the Mediterranean Sea (ARVANITIDIS *et al.*, 2002). The most dominant polychaet species were *Capitella capitata, Lumbrineris latreilli, Lumbrineris gracilis* and *Heteromastus filiformis.*

The polychaets *L. gracilis* and *L. latreilli* are considered widely distributed species (PÉRÈS & PICARD, 1964), widespread in all types of soft bottom communities of the northern Adriatic. *Lumbrineris gracilis* is among the most important species both in term of abundance and frequency of occurrence (ALEFFI *et al.*, 2003), while *L. latreilli* is particularly abundant on the pelitic sands of the area (ALEFFI & BETTOSO, 2001). Both species are considered indicators of semi-polluted or transitional zones of the Mediterranean Sea when they form high-density populations (PEARSON & ROSENBERG, 1978; SIMBOURA *et al.*, 1998). BORJA *et al.* (2000) considered both of them as representatives of the second ecological group

Capitella capitata was present in immense abundance at station VT3P1. This high abundance is the reason for the high distinctness of VT3P1 from the rest of the stations shown with the multivariate analysis MDS. The distinctness is also evident from other analyses (see Table 2). *Capitella capitata* is indicative of heavy pollution and typically increases in abundance as a result of hydrocarbons and organic input (BELLAN, 1967; HISCOCK *et al.*, 2005; SOLIS-WEISS *et al.*, 2007). PÉRÈS & PICARD (1964) considered the dominance of this species as characteristic for biocoenosis of heavily polluted areas. In our study, station VT3P1 is located at the mouth of the Rižana River which also carries sewage discharges from the town of Koper. At the same time this area is also a part of the industrial port of the town of Koper. At other stations of the same water body (VT3), the percentage of species indicators of pollution was rather low, whereas in the other water bodies they were more or less absent. *Capitella capitata* was placed by BORJA *et al.* (2000) in the group of opportunistic species of the second grade.

Heteromastus filiformis inhabits the bathyal, infralittoral and circalittoral of the gulfs and estuary. It has a clear preference for fine sediments. The species occurs more frequently as the mud content increases (PEARSON & ROSENBERG, 1978; BADALAMENTI & CASTELLI, 1993). *Heteromastus filiformis* is an opportunistic species, tolerant to a wide range of environmental conditions (REIZOPOULOU *et al.*, 1996). It shows a broad tolerance for salinity (YSEBAERT *et al.*, 2002). Moreover, it is also tolerant or increases abundance in relation to heavy metals or organic input including nutrients, it is resistant to severe hypoxia (HISCOCK *et al.*, 2005) and it is among the first colonizers of areas disturbed by dredging or dumping activities (GOSNER, 1978). BORJA *et al.* (2000) considered this polychaete as an opportunistic species of the first grade.

Maldane glebifex is reported as one of the most abundant polychaets in the Gulf of Trieste, with densities as high as 1673 ind.m^{-2} (SOLIS-WEISS *et al.*, 2007). During our study the species was found with a maximum density of only 23.33 ind.m^{-2}. This low value could be explained by the fact that our samplings were performed in a depth range mostly from 6 to 12 m, while this species is characteristic for muddy bottoms and can be found in deeper waters (SOLIS-WEISS *et al.*, 2007). BORJA *et al.* (2000) considered this polychaete as a sensitive species from the first ecological group.

Another of the most dominant elements was also bivalve *Corbula gibba*. The species is considered as an indicator of sedimentary instability (SOLIS-WEISS *et al.*, 2004a). It is linked to a high sedimentation rate (COSENTINO & GIACOBBE, 2006). It is particularly abundant during hypoxic, and after anoxic, crises (HRS-BRENKO *et al.*, 1994). HISCOCK *et al.* (2005) defined this bivalve even as a species resistant to severe hypoxia. According to BORJA *et al.* (2000) this species is placed in the group of opportunistic species of the first order. During the present study, this pioneer species was recorded with maximum densities of 120 ind.m^{-2}. These values are similar to densities obtained by ALEFFI & BETTOSO (2000) for the Italian part of the Gulf of Trieste, but much lower than in other parts of the northern Adriatic Sea. At several sites in the Gulf of Trieste influenced by outfalls of the underwater sewage discharges and industrial pollution, *C. gibba* dominated the macrobenthic community with at least 35% in the total abundance (SOLIS-WEISS *et al.*, 2004b, 2007). One of these sites is the Bay of Muggia (SOLIS-WEISS *et al.*, 2004b) where the maximum density of 1500 ind.m^{-2} was recorded (ROSSIN, 2005). With the exception of the Bay of Muggia, the highest densities of *C. gibba* were recorded in the deeper part of the Gulf of Trieste which is facing frequent episodes of hypoxia and the almost continuous impact of trawling.

Tellina distorta is the second dominant mollusc element. It is an infaunal deposit feeder whose presence is favoured by increments in organic content of the sediment (RUEDA & SALAS, 2008). It is a sedimentary instability indicator (NODOT *et al.*, 1984) that is also tied to a high sedimentation rate (COSENTINO & GIACOBBE, 2006). BORJA *et al.* (2000) considered this bivalve as a sensitive species from the first ecological group.

Few alien species were found in samples, such as the bivalves *Scapharca (Anadara) inaequivalvis* and *Musculista senhousia,* and a cirriped *Balanus trigonus*.

The multivariate analysis MDS of all the stations, with the exception of VT3P1, showed no significant groupings. Also, all indices used showed very similar values for all four water bodies. The reasons might be related to the similar conditions along the Slovenian coast and in the proximity of all the stations and consequently their interrelatedness. Structural indices such as Shannon-Wiener diversity index (H') and Pielou's index (J) showed very high values. They are even among the highest ever recorded for the soft-bottom assemblages of the Gulf of Trieste (SOLIS-WEISS *et al.*, 2001, 2004a; ROSSIN, 2005). AMBI values for all stations were above 1.5, with an average value of 1.99. This is slightly higher than that (1.81) assessed by ROSSIN (2005). The unstable environment of the entire Gulf of Trieste could explain the rather high values of AMBI. This can also be confirmed based on the above-mentioned dominant species. According to all of the results, benthic fauna in all water bodies are very similar and no statistically significant differences were observed.

The analysis of benthic biocoenoses revealed that the sampling area is a boundary area between infra- and circalittoral belts. The Slovenian part of the Gulf of Trieste is relatively well protected from southern winds and partially also from the northern one, called Bora. Consequently, this boundary area is characterized by low hydrodynamic activity and muddy sediments, but also by the lower limit of seagrass distribution. The most widespread seagrass in the Gulf of Trieste is *Cymodocea nodosa* which inhabits sandy and muddy infralittoral bottoms down to 12-14 m depth, depending on water transparency (OREL, 1988). Seagrasses tend to attenuate hydrodynamic action and trap fine sediments and organic matter in their shoots. The passage from infralittoral biocoenosis to the circalittoral one is characterized by very high species richness as well.

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Makrozoobentos mekanih dna južnog dijelg tršćanskog zaljeva: faunistička, biocenozna i ekološka istraživanja

Borut MAVRIČ[1], Martina ORLANDO-BONACA[1], Nicola BETTOSO[2] i Lovrenc LIPEJ[1*]

[1]*Morska biološka postaja, Nacionalni institut za biologiju, Fornače 41, 6330 Piran, Slovenija*

[2]*Opservatorij Alto Adriatico - ARPA FVG, Via La Marmora 13, 34100 Trst, Italija*

**Kontakt adresa, e-mail: lipej@mbss.org*

SAŽETAK

Obavljen je faunistički, biocenozni i ekološki pregled zajednica makrozoobentosa mekih dna južnog dijela tršćanskog zaljeva na temelju uzorkovanja u 2005. i 2006. godini. Uzorci su prikupljani na 28 postaja, a ukupno je sakupljeno 14 595 primjeraka organizama odnosno određeno je 306 životinjskih svojti. Najbrojnije vrste su *Capitella capitata*, *Lumbrineris gracilis*, *Heteromastus filiformis*, *Corbula gibba* i *Tellina distorta*. Najveća relativna brojnost vrsta u svim vodenim tijelima iznosila je blizu 15%. Dominantna vrsta je potvrdila da je okruženje u tršćanskom zaljevu nestabilno. Ova nestabilnost okoliša također može objasniti prilično visoke AMBI vrijednosti. MDS analize i druge primjene indeksa ukazuju da nema statistički značajne razlike između vodenih tijela. Vrijednosti za Shannon-Wiener indeks raznolikosti (H') i Pielou indeks (J') bile su prema sastavu među najvišim ikada zabilježenim za mekana dna u tršćanskom zaljevu. Analiza bentoske biocenoze je otkrila da je područje uzimanja uzoraka granica između infra-i cirkalitoralnog pojasa, što bi moglo objasniti izuzetno bogatstvo vrsta.

Ključne riječi: makrozoobentos, mekano dno, biocenoze, ekološki aspekti, tršćanski zaljev