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EVALUATION ON THE ECOLOGICAL STATUS OF THE MACROZOOBENTHIC COMMUNITIES IN THE MARANO AND GRADO LAGOON (NORTHERN ADRIATIC SEA)

Nicola BETTOSO, Ida Floriana ALEFFI, Lisa FARESI, Pietro ROSSIN & Giorgio MATTASSI
ARPA-FVG Osservatorio Alto Adriatico, I-33057 Palmanova (UD), via Cairoli 14, Italy
E-mail: nicola.bettoso@arpa.fvg.it

Patrizia CRIVELLARO
Dipartimento di Scienze della Vita, Università degli studi di Trieste, I-34100 Trieste, via Valerio 28/A, Italy

ABSTRACT

The status of the macrozoobenthic community in the Marano and Grado Lagoon was evaluated, according to the application of the Water Framework Directive for the transitional waters. Benthos samplings were carried out in 2008. At forty-two sampled stations 14,522 organisms from 163 taxa were identified. The number of taxa and diversity indexes decreased from inlets towards the inner bank of the lagoon, as a function of a salinity gradient identified with three water types. Multivariate analysis and analysis of benthic biocenoses revealed the existence of three distinct macrozoobenthic communities related to the closeness and/or the proximity of sea. Dominant species resulted to be typical resident of lagoonal environment, accompanied with opportunistic species able to tolerate large variations of chemical and physical parameters in the transitional environments. M-AMBI index assigned the ecological quality status in relation to biodiversity degree.

Key words: macrozoobenthos, Lagoon of Marano and Grado, ecological status, Water Framework Directive, northern Adriatic Sea

VALUTAZIONE DELLO STATO ECOLOGICO DELLE COMUNITA' MACROZOOBENTONICHE NELLA LAGUNA DI MARANO E GRADO (ADRIATICO SETTENTRIONALE)

SINTESI

Lo stato ecologico delle comunità macrozoobentoniche della Laguna di Marano e Grado è stato esaminato in applicazione della Direttiva Comunitaria sulle acque superficiali per gli ambienti di transizione. Il macrozoobenthos è stato campionato nel 2008 su 42 stazioni e sono stati identificati 14.522 individui per un totale di 163 taxa. Il numero di taxa e gli indici di diversità hanno presentato valori decrescenti dalle bocche lagunari verso le aree interne della laguna, in funzione del gradiente di salinità identificato nei tre tipi idrici. L'analisi multivariata e l'analisi biocenotica hanno rilevato la presenza di tre distinte comunità bentoniche in relazione alla vicinanza e/o lontananza dal mare. Le specie dominanti sono risultate quelle tipiche degli ambienti lagunari, accompagnate da specie opportuniste capaci di tollerare l'elevata variabilità ambientale degli ambienti di transizione. L'indice M-AMBI ha evidenziato come lo stato di qualità ecologica venga attribuito in funzione del grado di biodiversità.

Parole chiave: macrozoobenthos, Laguna di Marano e Grado, stato ecologico, Direttiva Quadro sulle Acque, Adriatico Settentrionale

INTRODUCTION

Lagoons are classified as transitional waters sited between marine and continental domains. These systems are brackish or hyperhaline water bodies, separated from sea by barrier islands, formed in transgressional regime due to the presence of abundant terrigenous supplies and significant coastal transports (Brambati, 1988). Until 1950's lagoons, and generally all transitional waters, were classified according to salinity, but the tools employed were quite different. Finally in 1958 the "Venice system" was proposed as a water classification system according to fixed salinity values.

The Water Framework Directive (WFD 2000/60/CE) defines transitional waters as *"all the surface water bodies in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by fresh water flows"*. According to this definition, transitional waters are all ecotones situated between terrestrial, freshwater and marine ecosystems, characterized by high spatial heterogeneity and temporal variability (Basset *et al.*, 2006a). On this basis, transitional waters include fjords, river mouths, deltas, rias, lagoons, coastal ponds and estuaries (McLusky & Elliott, 2007). Transitional waters are heterogeneous and dynamic ecosystems (Gomez *et al.*, 1998; Benedetti-Cecchi *et al.*, 2001) which morphology and hydrology change quickly under the influence of high sedimentation rates, natural coastal dynamics and frequent human activities (Ver *et al.*, 1999; Pastres *et al.*, 2004). These habitats often show high trophic fluxes, broad ranges of chemical and physical parameters with fast biogeochemical cycles (Herbert, 1999; Petihakis *et al.*, 1999; De Wit *et al.*, 2001). In addition, due to their shallow depth and scarce renewal of waters, most of the transitional ecosystems are very vulnerable to eutrophication and chemical pollution (Barnes, 1999), leading to rapid and often unpredictable changes in communities' composition and functioning (Herbert, 1999; Sfriso *et al.*, 2001; Mistri *et al.*, 2002a). The conservation and management of transitional waters requires monitoring activity, integrating chemical and physical evaluation with biological assessment (Gibson *et al.*, 2000; Logan & Furse, 2002).

In shallow water systems, such as lagoons, benthic compartment plays a crucial role controlling the main ecological processes; therefore changes in its structure could affect the whole ecosystem (Snelgrove *et al.*, 1997; Weslawski *et al.*, 2004; Tenore *et al.*, 2006). Due to this, it is possible to estimate the effects of different ecological drivers on the ecosystems' functioning, by analyzing modifications of lagoon benthic communities over time (Pranovi *et al.*, 2008).

The Marano and Grado Lagoon is a part of the lagoon system of the northern Adriatic Sea, stretching between the mouths of the Po and Isonzo rivers (Brambati, 1988). The lagoon, which is located among the Isonzo river to the East and the Tagliamento river to the West, has a total surface area of 160 km^2, and extends parallel to the coastline along 32 km (Falace *et al.*, 2009).

Aristocle Vatova has provided most of the main studies and notions dealing with structure of benthic communities in the northern Adriatic lagoons. Since 1930 he studied hydrology, benthic flora and fauna in the Venice Lagoon (Vatova, 1940, 1949), subsequently benthic fauna and productivity of the Marano and Grado Lagoon (Vatova, 1964a, 1964b, 1965). Vatova (1964a) described the general features of the Marano and Grado lagoons, focusing on differences between the two basins. In particular the author measured a lower mean salinity in the Marano Lagoon (21‰) than the Grado Lagoon (26‰) and this difference allowed distinguishing the basins and the related distribution of benthic communities. Benthic fauna of the Marano was in fact poorer than that of Grado, both in term of species and abundance, due to higher freshwater inputs. On the other hand, it was more productive in term of biomass.

The most recent and exhaustive study on macrozoobenthos in the Marano and Grado Lagoon was carried out during a three-year study, from 1993 to 1995 (Orel *et al.*, 2001; Zamboni, 2008). Authors substantially confirmed the observations pointed out by Vatova (1964a): a decreasing gradient of biodiversity was observed moving from the Grado to the Marano, as well as from inlets to inner areas of the lagoon. Orel *et al.* (2001) and Zamboni (2008) identified the zonation of benthos on the basis of confinement degree in the paralic environments as proposed by Guelorgèt & Perthuisot (1983), who defined paralic environments the aquatic ecosystems which have, or had, relation with the sea.

In 1986 the Manila clam (*Tapes philippinarum*) was introduced in the Marano Lagoon for aquaculture purposes. In the time its irrational harvesting with mechanical dredges out of farming areas impacted the benthic community (Orel *et al.*, 2002, 2005). Since 2006 the uncontrolled use of dredges was stopped and manual harvesting is permitted beyond the farming areas.

The aim of the paper was to evaluate the ecological status of the macrozoobenthic community in the Marano and Grado Lagoon, as required by the application in the WFD.

MATERIAL AND METHODS

The Marano and Grado Lagoon is defined as a coastal microtidal lagoon with large dimensions (Italian Ministry of Environment Decree n.131/08) and the related water types were established as a function of salinity values. In detail, we can discriminate between the mesohaline lagoon (5–20 psu), polyhaline lagoon (20–30 psu) and euhaline lagoon (30–40 psu). Forty-two

Fig. 1: Study area and sampling stations.
Sl. 1: Obravnavano območje in vzorčevalne postaje.

sampling sites were selected both on the basis of water types, surface and potential gradient of confinement from sea inlets to inner areas (Fig. 1).

Benthic samples were collected with a 0.047 m^2 van Veen grab in May 2008. At each station four grabs were taken. The sediment was sieved on a 1 mm mesh and fixed in 4% buffered formaldehyde solution stained with Bengal Rose, and then the fauna was separated and identified to the lowest possible taxonomical level.

Uni- and multivariate techniques were employed to analyze the communities' structure including: abundance, number of taxa, diversity indexes (Shannon-Wiener diversity index (H') on $\log_2$ basis (Shannon & Weaver, 1949), Margalef's index (d) (Margalef, 1958) and Pielou's evenness index (J) (Pielou, 1966). The Bray-Curtis similarity coefficient was calculated on square-root transformed data, using complete linkage; subsequently, one-way ANOSIM, K-dominance curves and SIMPER analysis were applied to evaluate similarity and/or differences among groups (PRIMER software package developed at the Plymouth Marine Laboratory).

Bionomic percentage affinity (A%) was calculated by considering characteristic species according to Pérès & Picard (1964). The correction coefficient *C* was first calculated as a percentage of characteristic species of biocenosis *j* respect to the ones of other biocenosis. Then, the absolute affinity of each station was calculated as:

$A_j = n_j\ (100\text{-}C_j)$

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

A% was calculated for each biocenosis found in the lagoon: Euryhaline and Eurythermal Lagoon biocenosis (LEE French acronym for biocoenose Lagunaire Euryhaline et Eurytherme), fine well-sorted sand biocenosis (SFBC biocoenose des Sables Fins Bien Calibres), superficial muddy sand in sheltered areas biocenosis (SVMC biocoenose des Sables Vaseux Superficiels en Mode Calme), coastal terrigenous muds biocenosis (VTC biocoenose des Vases Terrigenes Cotieres), *Posidonia oceanic*a meadow biocenosis (HP biocoenose de l'Herbier de Posidonies), fine superficial sand biocenosis (SFS biocoenose des Sables Fins Superficiels) and coastal detritical bottoms biocenosis (DC biocoenose des fonds Detritiques Cotiers).

The Bray-Curtis similarity coefficient was calculated on not transformed A% data, using complete linkage. Furthermore RELATE procedure was used to compare clusters derived from abundance and A% data.

Tab. 1: Average values of number of taxa, abundance, H', d, J and summary of Kruskal-Wallis one-way analysis of variance applied to the water types.
Tab. 1: Povprečne vrednosti števila taksonov, števil čnosti, H', d, J in povzetek Kruskal-Wallisove enosmerne analize variance na tipih voda.

	No. taxa	Abundance (ind./m^2)	H'	d	J
Euhaline	38±14	1,775±1,773	3.79±0.68	6.46±2.00	0.74±0.10
Polyhaline	26±8	1,937±1,698	3.01±0.81	4.37±1.19	0.65±0.15
Mesohaline	13±4	1,711±892	2.13±0.50	2.06±0.70	0.59±0.09
Kruskal-Wallis (H)	18.49	0.026	16	20.2	5.23
p-value	≤0.0001	≤0.99	≤0.0003	≤0.0001	≤0.073
df	2	2	2	2	2

AMBI and Biotic Index (BI) were applied (Borja *et al.*, 2000) using the AMBI program (AZTI Marine Biotic Index) (www.azti.es). These indexes are based on the classification of the benthic species in five (I-V) ecological groups (EG), according to their tolerance to pollution (from EG-I = species very sensitive to organic enrichment, intolerant to pollution, EG-II = species indifferent to enrichment, EG-III = species tolerant to enrichment, slightly unbalanced environments, EG-IV = second-order opportunistic species, slight to pronounced unbalanced environments, to EG-V = first-order opportunistic species, pronounced unbalanced environment), then applying an algorithm to calculate the AMBI on a scale of increasing pollution (from 1 to 6) and obtaining the corresponding BI (from 0-1 = unpolluted sites, 2 = slightly polluted, 3 = moderately polluted, 4–5 = moderately to heavily polluted, 6 = heavily polluted to 7 = extremely polluted, azoic state). M-AMBI (Multivariate AMBI) was calculated to assess the ecological quality status (EcoQS): High, Good, Moderate, Poor and Bad according to WFD. This index includes the species richness, Shannon-Wiener diversity and AMBI at the very same time (Muxika *et al.*, 2007). EcoQS was evaluated on the basis of the reference conditions proposed for Italian transitional waters (ISPRA, 2010).

RESULTS

14,522 organisms from 163 taxa (142 species determined) were identified. Polychaetes were by far the dominant group with 72 species followed by the molluscs (36 species), crustaceans (25 species), echinoderms (6 species) and "other". This latter usually represents scarce groups such as ascidians, anthozoans, sipunculids, nemertines, phoronids, turbellarians and larvae of insects. Taking into consideration the three water types, 147 taxa were recorded in the euhaline water type (16 sampling stations) for a total of 5,339 individuals; 106 taxa were collected in the polyhaline water type (20 sampling stations), for a total of 7,283 individuals and finally 36 taxa in the mesohaline water type (6 sampling stations), for a total of 1,930 individuals.

The percentage abundance of groups was quite proportional in each water type, but the disappearance of echinoderms in the mesohaline lagoon was notable (Fig. 2). Table 1 shows mean values in each water type of the number of taxa, abundance, H', d and J. A clear decreasing gradient from euhaline lagoon to mesohaline basin was significative for taxa, H' and d (Tab. 1); mean abundance did not show any gradient from inlet to inner areas, whereas mean J was decreasing but not in a significative manner.

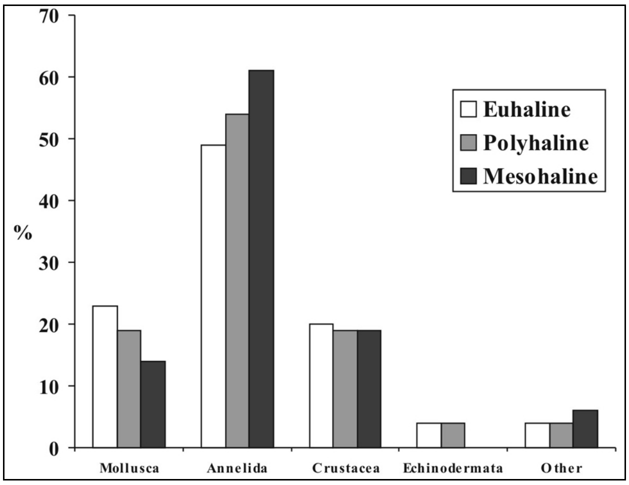

Fig. 2: Percentage of taxa for different animal phyla detected in euhaline, polyhaline and mesohaline water types.
Sl. 2: Delež taksonov za različna živalska debla v evhalinem, polihalinem in mezohalinem tipu vode.

The dendrogram resulting from the Bray-Curtis similarity matrix showed three different groups tested with one-way ANOSIM (R=0.578; p<0.001): stations close to inlets (group 1), stations among inlets and the inner bank (group 2) and stations closed to the inner bank (group 3) (Fig. 3).

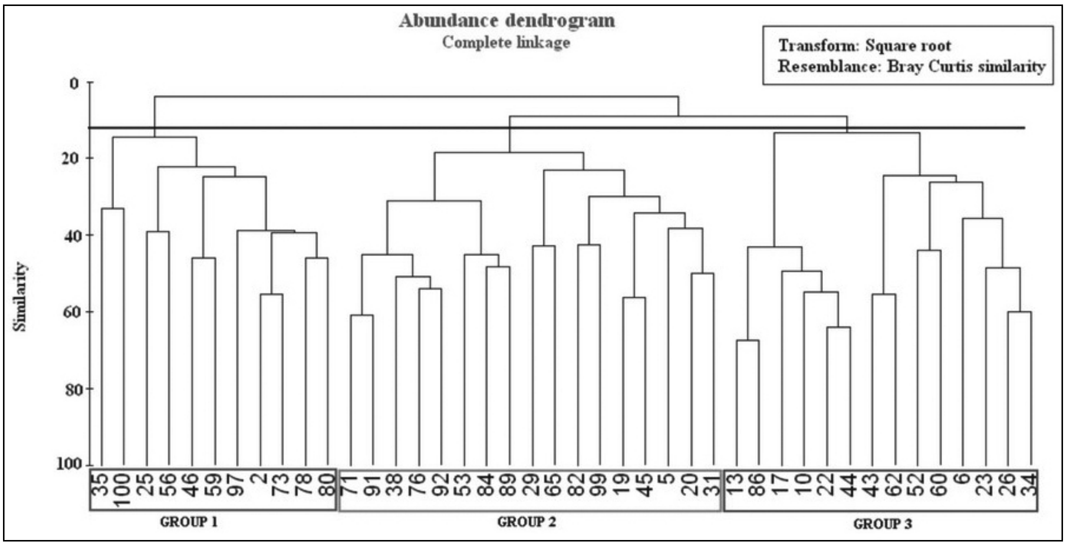

Fig. 3: Dendrogram obtained by taxa abundance values.
Sl. 3: Dendrogram številčnosti taksonov.

Tab. 2: Cumulative percentage of dominant taxa in each group revealed by SIMPER analysis.
Tab. 2: Kumulativni odstotek dominantnih taksonov v vsaki skupini, ugotovljen s SIMPER analizo.

Group	Taxa	Cum. %
Paralic group	*Abra segmentum*	34.7
	Hediste diversicolor	55.05
	Streblospio shrubsolii	66.94
Mixed group	*Chaetozone* sp.	17.75
	Abra segmentum	34.76
	Heteromastus filiformis	44.91
	Streblospio shrubsolii	53.34
	Oligochaeta indet.	61.48
Marine group	*Minuspio cirrifera*	12.02
	Mediomastus capensis	21.97
	Heteromastus filiformis	30.16
	Abra segmentum	37.55
	Pseudoleiocapitella fauveli	44.59
	Capitella capitata	51.12
	Oligochaeta indet.	56.84
	Myriochele oculata	62.1

Trend of k-dominance curves identified the community structure in each of the identified groups: group 1, or marine group, with the highest number of species and a quite regular and homogeneous trend; group 3, or paralic group, with higher slope and the lowest number of species; group 2, or mixed group, with an intermediate shape (Fig. 4).

SIMPER analysis identified the mostly involved species in the three groups (Tab. 2). The paralic group was mainly represented by the bivalve *Abra segmentum*, the nereid polychaet *Hediste diversicolor* and the spionid *Streblospio shrubsolii*. The mixed group was characterized by the abundance of the capitellid *Heteromastus filiformis*, the cirratulid *Chaetozone* sp. and oligochaets, in addition to *A. segmentum* and *S. shrubsolii*. The Marine group, in addition to *A. segmentum*, *H. filiformis* and oligochaets, recorded the abundance of the capitellids *Mediomastus capensis*, *Pseudoleiocapitella fauveli*, *Capitella capitata*, the spionid *Minuspio cirrifera* and the owenid *Myriochele oculata*.

Overall, 26 exclusive and preferential species for 7 biocenoses were found (Tab. 3). The dendrogram obtained from the Bray-Curtis similarity matrix applied on A% data, highlighted three groups of stations on the basis of the different A% values for Eurythermal and Euryhaline biocoenosis (LEE) (Fig. 5): the Paralic group having $A\%_{LEE}$ >65%, the Marine group with $A\%_{LEE}$ <30% and Mixed group 30%< $A\%_{LEE}$ <65%. The RELATE procedure revealed a similarity of the groups identified by two dendrograms (Rho=0.546; p<0.0001).

Tab. 3: Characteristic species and biocenoses detected in the study area: Euryhaline and Eurythermal Lagoon biocenosis (LEE), fine well-sorted sand biocenosis (SFBC), superficial muddy sand in sheltered areas biocenosis (SVMC), coastal terrigenous muds biocenosis (VTC), *Posidonia oceanica* ***meadow biocenosis (HP), coastal detritical bottoms biocenosis (DC) and fine superficial sand biocenosis (SFS).***
Tab. 3: Značilne vrste in biocenonoze v obravnavanem območju: biocenoza evrihaline in evritermne lagune (LEE), biocenoza na finem sortiranem pesku (SFBC), biocenoza zamuljenih peskov v zaščitenih predelih (SVMC), biocenoza obalnega terigenega mulja (VTC), biocenoza podvodnih travnikov *Posidonia oceanica* ***(HP), biocenoza obalnega detritičnega dna (DC) in biocenoza finega površinskega peska (SFS).***

Characteristic species	Biocenosis
Gibbula adriatica	LEE
Cerastoderma glaucum	
Abra segmentum	
Tapes philippinarum	
Hediste diversicolor	
Streblospio shrubsolii	
Carcinus mediterraneus	
Nephtys hombergi	SFBC
Owenia fusiformis	
Prionospio caspersi	
Diogenes pugilator	
Tellimya ferruginosa	
Thracia papyracea	
Euclymene oerstedi	
Upogebia pusilla	SVMC
Loripes lacteus	
Tapes decussates	
Paphia aurea	
Petaloproctus terricolus	
Sternaspis scutata	VTC
Ampharete acutifrons	
Laonice cirrata	
Venus verrucosa	HP
Euclymene lumbricoides	
Abra prismatica	DC
Glycera tridactyla	SFS

The EcoQS assigned with M-AMBI, was Good for 44% of euhaline stations, Moderate for 38%, Poor for 12% (st. 76 and 100) and Bad for 6% (st. 99) (Fig. 6). In polyhaline type the stations with High status corresponded to 20%, Good to 50%, Moderate to 25% and Poor to 5% (st. 86) (Fig. 6). In the mesohaline type one station (st. 43) was Good, three stations were assessed as Moderate (50%) and two were Poor (st. 13 and 17) (Fig. 6).

The summarizing Table 4 reports M-AMBI as EcoQS, AMBI as disturbance classification and the groups (Marine, Mixed, Paralic) assigned with clusters. The mean number of taxa and average Shannon-Wiener index (H′) were calculated for each EcoQS of the water types.

Within the euhaline type (salinity 30-40 psu) all stations with Good ecological quality status possessed Marine characteristics, with 50 identified taxa and H′ >4. Stations with Moderate EcoQS possessed normally Mixed characteristics, on average 29 taxa and mean H′=3.5. Stations having Poor EcoQS possessed 33 taxa and H′=2.9: st. 100 had Marine characteristics but a Poor status was assigned probably because of high dominance of oligochaetes, indicating strongly unbalanced conditions. Bad EcoQS was assigned to st. 99, which was very poor in term of taxa. In the polyhaline type (salinity 20-30 psu) only two stations have Marine characteristics (st. 25 and 35), but normally stations showed Mixed or sometimes Paralic conditions. Stations with High EcoQS possessed on average 38 taxa and H′=4. Stations with Good EcoQS had 24 taxa and H′>3. In mesohaline type (salinity 5-20 psu), stations have Paralic conditions, except for st. 43 which is Mixed-Paralic with Good EcoQS (17 taxa, H′=2.5). Disturbance classification detected with AMBI varied from slightly disturbed to moderately disturbed and it seems not linked to water type and cluster groups.

DISCUSSION

The aim of this study was to characterize the macrozoobenthos living in the Marano and Grado Lagoon, 15 years after the studies carried out in 1993–1995 (Drioli, 1995/1996; Zamboni, 1995/1996; Orel *et al.*, 2001; Zamboni, 2008), and to provide a preliminary application of the WFD 2000/60/CE in this lagoon.

Previously, several authors classified lagoons and coastal ponds as a function of salinity values (Redeke, 1922, 1933; Brunelli, 1933; D'Ancona, 1959). The salinity is a key parameter affecting the biological organization and the expression of biodiversity in Italian lagoons (Basset *et al.*, 2006b) and Greek brackish environments (Reizopoulou & Nicolaidou, 2004). Three water types were identified and analyzed in Marano and Grado according to the actual Italian legislations.

Tab. 4: Summarizing table.
Tab. 4: Pregledna tabela.

sampling station	water type	EcoQS (M-AMBI)	No. taxa (mean values)	H' (mean values)	groups cluster A%	groups cluster abundance	AMBI disturbance classification
46	EU	GOOD	50	4.4	Marine	Marine	Slightly
56	EU	GOOD	50	4.4	Marine	Marine	Slightly
59	EU	GOOD	50	4.4	Marine	Marine	Slightly
73	EU	GOOD	50	4.4	Marine	Marine	Moderately
78	EU	GOOD	50	4.4	Mixed	Marine	Moderately
80	EU	GOOD	50	4.4	Marine	Marine	Moderately
84	EU	GOOD	50	4.4	Marine	Mixed	Slightly
29	EU	MODERATE	29	3.5	Mixed	Mixed	Slightly
38	EU	MODERATE	29	3.5	Mixed	Mixed	Moderately
52	EU	MODERATE	29	3.5	Marine	Paralic	Slightly
89	EU	MODERATE	29	3.5	Mixed	Mixed	Moderately
92	EU	MODERATE	29	3.5	Mixed	Mixed	Moderately
97	EU	MODERATE	29	3.5	Mixed	Marine	Slightly
76	EU	POOR	33	2.9	Mixed	Mixed	Moderately
100	EU	POOR	33	2.9	Marine	Marine	Moderately
99	EU	BAD	14	3	Mixed	Mixed	Moderately
2	POLY	HIGH	38	4	Paralic	Marine	Moderately
23	POLY	HIGH	38	4	Paralic	Paralic	Slightly
31	POLY	HIGH	38	4	Mixed	Mixed	Slightly
53	POLY	HIGH	38	4	Paralic	Mixed	Slightly
5	POLY	GOOD	24	3.2	Mixed	Mixed	Slightly
19	POLY	GOOD	24	3.2	Mixed	Mixed	Moderately
20	POLY	GOOD	24	3.2	Mixed	Mixed	Moderately
26	POLY	GOOD	24	3.2	Paralic	Paralic	Moderately
34	POLY	GOOD	24	3.2	Mixed	Paralic	Slightly
45	POLY	GOOD	24	3.2	Mixed	Mixed	Moderately
60	POLY	GOOD	24	3.2	Paralic	Paralic	Slightly
62	POLY	GOOD	24	3.2	Mixed	Paralic	Slightly
65	POLY	GOOD	24	3.2	Mixed	Mixed	Moderately
71	POLY	GOOD	24	3.2	Mixed	Mixed	Moderately
6	POLY	MODERATE	22	2.2	Paralic	Paralic	Moderately
25	POLY	MODERATE	22	2.2	Marine	Marine	Slightly
35	POLY	MODERATE	22	2.2	Marine	Marine	Moderately
82	POLY	MODERATE	22	2.2	Paralic	Mixed	Moderately
91	POLY	MODERATE	22	2.2	Mixed	Mixed	Moderately
86	POLY	POOR	10	1.6	Paralic	Paralic	Slightly
43	MESO	GOOD	17	2.5	Mixed	Paralic	Slightly
10	MESO	MODERATE	14	2.4	Paralic	Paralic	Slightly
22	MESO	MODERATE	14	2.4	Paralic	Paralic	Slightly
44	MESO	MODERATE	14	2.4	Paralic	Paralic	Moderately
13	MESO	POOR	9	1.6	Paralic	Paralic	Slightly
17	MESO	POOR	9	1.6	Paralic	Paralic	Slightly

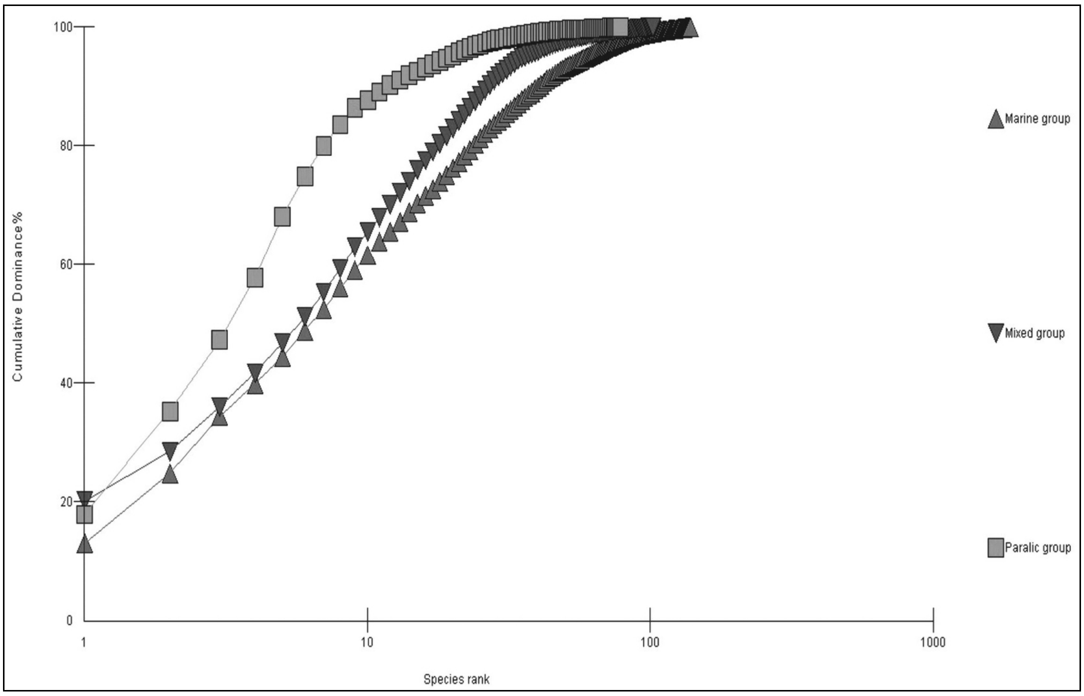

Fig. 4: K-dominance curves relative to three different groups detected by dendrogram.
Sl. 4: Krivulje K-dominance za tri različne skupine, ugotovljene z dendrogramom.

The Marano Lagoon is embedded in the inland, coupled to a less marine water exchange and very abundant freshwater inputs from Stella, Corno and Aussa rivers (Fig. 1); on the contrary the Grado Lagoon is characterized by scarce freshwater inputs and a wider exchange of marine water. The subdivision of the whole basin into three water types reflects quite well the previous observations of Vatova (1964a, 1964b, 1965) and more recently those of Orel *et al*. (2001) and Zamboni (2008). During 2008 taxa richness, diversity and evenness indices showed high values particularly in nearby inlets. In these areas Shannon-Wiener index (H') was >4, which can be considered a very high value for soft bottom macrozoobenthic communities (Gray, 2000). Therefore high indices values and relevant number of species recorded in 2008 (163 taxa) compared to the 90's, (85 taxa in the three years; Zamboni, 2008), could indicate the increasing richness of taxa in the Marano and Grado Lagoon during the last 15 years. The number of taxa decreased moving from the inlets towards the inner bank of the lagoon, as described also in previous studies. On the contrary, abundance did not show any distribution gradient. On the whole, the partition of benthos into three salinity bands was confirmed by a decreasing diversity from the inlets towards the inner bank. Due to this, a monitoring program based on water types is fully supported by observations carried out in the first studies (Vatova, 1964a, 1965; Orel *et al.*, 2001; Zamboni, 2008) and the 2008 survey.

Guelorgèt & Perthuisot (1982, 1983, 1992) referred on the existence of peculiar euryhaline species. This feature was previously emphasized by Pérès & Picard (1964), who defined the Euryhaline and Eurythermal Lagoon biocenosis. This biocenosis is typical of unstable environments where higher or lower salinity and/or wider salinity and temperature variations occur during the year. This peculiarity is mainly due to river floods, rainfalls and high summer rate of evaporation. Moreover, living communities are able to recover rather quickly their original structures when environmental disturbances and/or dystrophic crisis occur. Due to this great resilience, rather than stability of the communities, paralic environments prevail. The previously mentioned peculiar characteristics of the communities led Guelorgèt & Perthuisot (1982, 1983, 1992) to divide the paralic domain into two subsets. The first one as near paralic, close to the inlets and with chemical-physical parameters similar to sea, whereas the second one as far paralic, farther from sea with chemical-physical parameters deeply different to marine domain. As previously discussed, the salinity is considered a key parameter determining a transition gradient from a typical marine community to a freshwater one. In fact, the fresh/marine waters exchange and circulation play an important role in the dynamics of a lagoon. In this way, hydrology is the fundamental factor conditioning any lagoon environment. In the same context Guelorgèt & Perthuisot (1992) defined the confinement as the time of renewal of

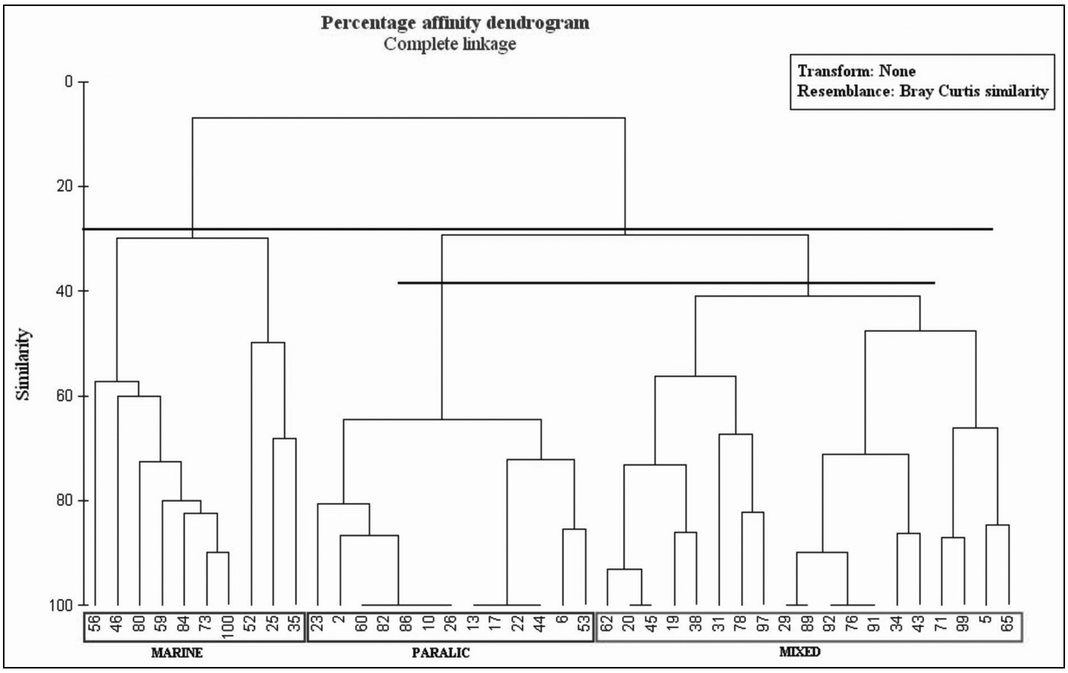

Fig. 5: Dendrogram obtained by percentage affinity values.
Sl. 5: Dendrogram, narejen na podlagi afinitetnih vrednosti (v %).

marine elements in relation to the extension of paralic domain. However, this definition should be considered on a larger scale since it is dependent on many other parameters such as tidal range, width inlets, freshwaters inputs, wind regime, depth, trophic conditions, transparency, oxygen content and so on.

Multivariate analysis in 2008 defined three different areas as a function of closeness to inlets and freshwaters inputs. The group of stations close to inlets could be defined as a lagoon community having marine characteristics; stations nearby the inner bank as a strictly paralic community; finally stations showing a combination of marine and paralic properties as a mixed community. This kind of partition was confirmed and validated by ANOSIM analysis; moreover k-dominance curves focused a basic community structure in each group. In the same way SIMPER analysis punctually identified the mostly involved species of the mentioned groups.

Three characteristic species of paralic environments and LEE biocenosis represent at least 60% of relative abundance in the Paralic group and dominate in inner zones where marine species cannot survive: *Abra segmentum*, *Hediste diversicolor* and *Streblospio shrubsolii*. *A. segmentum* is typically euryhaline, frequent in oligo-hyperhaline waters, tolerates a wide range of salinities, from 3 to 41 psu (Marazanof, 1969; Kevrekidis, 2004). It is common and frequently abundant in the Mediterranean coastal lagoons, where it plays a dominant role, both in terms of number and biomass, in the infauna of these habitats and represents an important food for fish (Kevrekidis & Kasapis, 2009). *H. diversicolor* preferentially lives in muddy sediments. It is a typical inhabitant of European brackish water habitats and shows a high level of tolerance towards different types and concentrations of contaminants (Volpi *et al.*, 1999). *H. diversicolor* tolerates a wide salinity range, preferring, in any case, areas characterized by low salinity values (Guerzoni & Tagliapietra, 2006) and it is largely distributed in Mediterranean lagoons (Bazaïri *et al.*, 2003; Nicolaidou *et al.*, 2005). *S. shrubsolii* is a typical lagoon species widely distributed also in other Mediterranean lagoons (Mistri *et al.*, 2002b; Rossi & Lardicci, 2002; Bazaïri *et al.*, 2003; Dauer *et al.*, 2003). Furthermore, Mixed and Marine groups were characterized by the dominance of polychaetes belonging to Capitellidae and Spionidae families represented by small size species capable to settle in habitats having a strong variability, such as transitional environments (Holte & Oug, 1996; Mistri *et al.*, 2002b) and adapted to colonize habitats with organic enrichment (Mistri *et al.*, 2001; Thouzeau *et al.*, 2007). Oligochaets, indicating desalinized water (Nicolaidou *et al.*, 2005), were abundant, too. In addition, the owenid *Myriochele oculata*, a sandy species especially diffused nearby inlets, contributed to define the Marine group.

The bionomic analysis (Pérès & Picard, 1964) revealed the existence of seven biocenoses. The main were LEE and SFBC, this latter is typical of marine domain and largely diffused in Mediterranean Sea as a soft bottom infralittoral biocenosis. The second dendrogram obtained by A% values was comparable to abundance

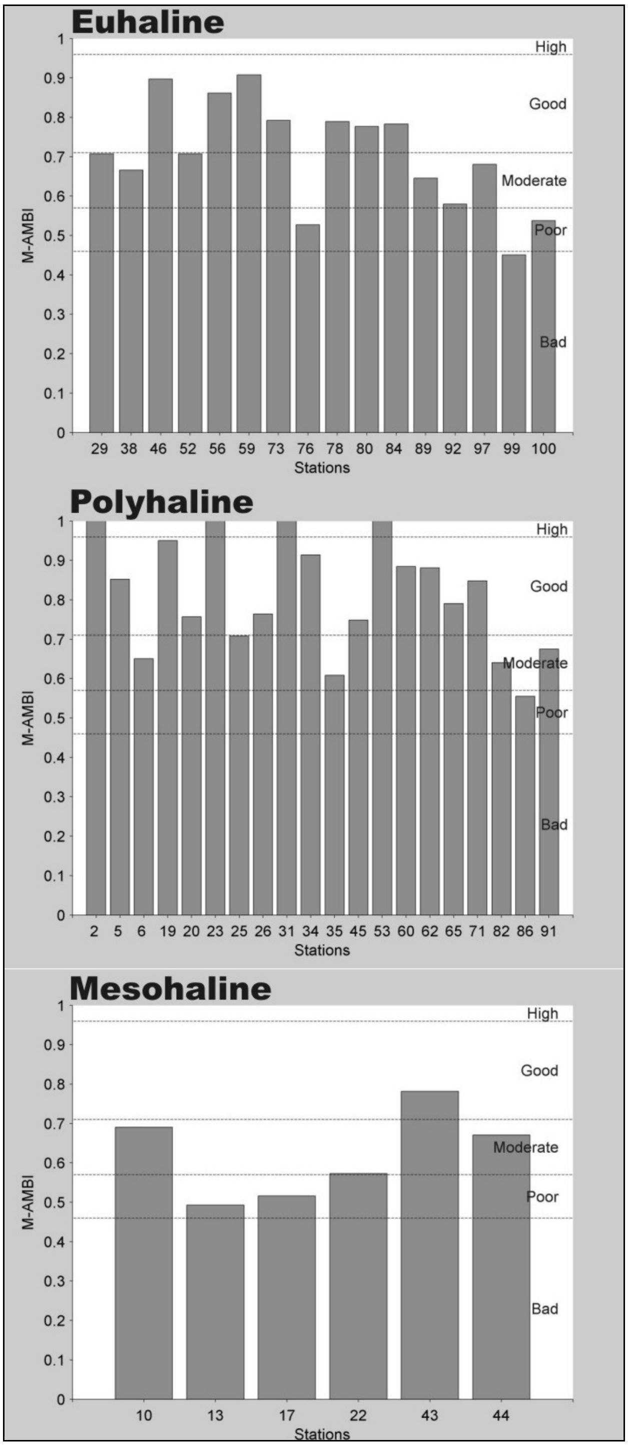

Fig. 6: EcoQS of euhaline, polyhaline and mesohaline stations according to M-AMBI index.
Sl. 6: Ekološko stanje kakovosti (EcoQS) za evhaline, polihaline in mezohaline postaje na podlagi izračuna indeksa M-AMBI.

cluster as revealed by RELATE procedure. In this way stations having Marine affinities are mostly represented by SFBC, whereas LEE is meanly <30%. LEE affinity in Paralic stations exceeds 65%, and LEE affinity in Mixed group ranges between 30 and 65%.

The Marine, Mixed and Paralic groups could correspond to zones II, III and IV-V respectively, as defined by Guelorgèt & Perthuisot's benthic zonation (Guelorgèt & Perthuisot, 1982, 1983, 1992). In fact, Marine group resembles the zone II, as a corresponding entrance into lagoon domain with the presence of most tolerant marine species belonging to SFBC and Fine Superficial Sands (SFS) biocenosis. Mixed group was similar to zone III with a remarkable scarcity or even disappearance of echinoderms. Vatova (1964a, 1965) noticed that the holothurioid *Trachythyone elongata* is the only capable to withstand sudden salinity changes and, in fact, only 7 specimens of 4 echinoderms species were found in the polyhaline water types *(T. elongata, Asterina gibbosa, Amphiura chiajei* and *Amphipholis squamata).* Finally, Paralic group resembled zone IV, because of the total disappearance of most tolerant marine species, such as echinoderms, and an absolute dominance of strictly paralic species such as *A. segmentum, Cerastoderma glaucum* and *H. diversicolor.* In some limited areas Paralic group resembled also zone V because of the appearance of chironomids larvae.

No specimens of the characteristic lagoon bivalve *Scrobicularia plana* were found in 2008. This species already recorded in the Marano and Grado Lagoon by Vatova (1964a, 1964b, 1965) and considered as particularly sensitive to river floods, was scarcely present in the 70's because of pollution phenomena (Battaglia *et al.*, 1972) and now it results to be absent since the 90's (Zamboni, 2008).

Macrozoobenthos in 2008 embraced a distribution comparable to the three years study 1993-1995 (Orel *et al.*, 2001; Zamboni, 2008). In the lagoon the salinity constitutes a sort of barrier to strictly marine species, leading to the selection of more tolerant organisms. In the inner part of the lagoon there is a clear dominance of LEE species accompanied by strongly opportunistic annelids.

The final goal was the application of indices proposed by WFD, in order to define the ecological quality status in each sampling station. M-AMBI showed a significant Good-Moderate quality status in euhaline stations. However, some sites located within heavily modified water bodies showed a Poor or Bad status. In polyhaline type 70% of stations showed Good to High EcoQS. Mesohaline type, the inner part of the Marano Lagoon, showed almost a Moderate status, due to natural selectivity of paralic habitats, characterized by low biodiversity. As suggested by Dauvin *et al.* (2009), the main issue in the application of indexes for the classification is that in order to determine anthropogenic stress, they account to relative abundances of stress-tolerant species. However, these latter may also be tolerant to natural stressors. Moreover, due to the high variability of both physical and chemical parameters, transitional environments are generally characterized by low benthic diversity if compared to the marine environment with several opportunistic and tolerant organisms, withstanding these conditions. AMBI provides ecological group assignments based on expert opinion for a lot of taxa. Moreover the ecological behaviour of several species is quite different when they have to adapt to lagoonal conditions (Cognetti & Maltagliati, 2008) or to different geographical areas. The reference conditions for the final EcoQS are established by the legislation. Actually, in Italy, a draft document proposed by Italian Environmental Ministry provides the same reference condition for oligo-, meso- and polyhaline waters. As aforementioned the Marano and Grado Lagoon shows a quite different benthic community in the mesohaline waters compared to polyhaline waters. Hence the application of a single reference condition for these different types causes to classify mesohaline waters with Moderate or Poor quality. In this situation, in order to achieve at least the Good EcoQS in the whole Marano and Grado Lagoon, macrozoobenthic community should reach a number of species comparable to a typical soft bottom community of marine environments, thus loosing the characteristics and ecological functions of paralic environments.

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OCENA EKOLOŠKEGA STATUSA ZDRUŽB VODNIH NEVRETENČARJEV V MARANSKI IN GRADEŠKI LAGUNI (SEVERNI JADRAN)

Nicola BETTOSO, Ida Floriana ALEFFI, Lisa FARESI, Pietro ROSSIN & Giorgio MATTASSI

ARPA-FVG Osservatorio Alto Adriatico, I-33057 Palmanova (UD), via Cairoli 14, Italy

E-mail: nicola.bettoso@arpa.fvg.it

Patrizia CRIVELLARO

Dipartimento di Scienze della Vita, Università degli studi di Trieste, I-34100 Trieste, via Valerio 28/A, Italy

POVZETEK

Ocenjenjen je bil status združb vodnih nevretenčarjev v Maranski in Gradeški laguni, v skladu z aplikacijo Okvirne direktive o vodah za somornice. Vzorčenja bentosa so bila izvedena leta 2008. Na 42 vzorčevalnih postajah je bilo identificiranih 14.522 organizmov, pripadajočih 163 taksonom. Število taksonov in indeksi pestrosti so se zmanševali od mesta dotokov proti notranjemu bregu lagune, in sicer kot funkcija gradienta slanosti treh tipov vode. Multivariatna analiza in analiza bentoških biocenoz sta razkrili obstoj treh združb vodnih nevretenčarjev, vezanih na bližino/oddaljenost od morja. Dominantne vrste so tipični prebivalci lagunskega okolja, spremljajo pa jih oportunistične vrste, ki lahko tolerirajo velike variacije kemičnih in fizikalnih parametrov v somornicah. Indeks M-AMBI opredeljuje ekološko stanje glede na biotsko raznolikost.

Ključne besede: vodni nevretenčarji, Maranska in Gradeška laguna, ekološki status, Okvirna direktiva o vodah, severni Jadran

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