Original scientific article
Received: 2006-10-11

UDC 639.42:574.5(262.3 Tržaški zaliv)

EFFECTS OF SUSPENDED MUSSEL CULTURE ON THE MACROZOOBENTHOS IN THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA, ITALY)

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ABSTRACT

This paper presents the results of a study of benthic community and sediments beneath a mussel culture and at a control site. The study was conducted on a monthly basis from May 1998 to April 1999 in the Gulf of Trieste (northern Adriatic Sea). The two sites had comparable sediment texture, while organic carbon and nitrogen content was higher beneath the mussel farm. Number of species, abundance and diversity indexes were similar at the two sites, while the biomass was, on average, twice as large beneath the farm. In general, the impact on the benthos did not appear to be very strong.

Key words: mussel cultures, macrozoobenthos, disturbance assessment, Adriatic Sea

EFFETTI DELLE MITILICOLTURE SUL MACROZOOBENTHOS DEL GOLFO DI TRIESTE (ALTO ADRIATICO, ITALIA)

SINTESI

L'impatto sul macrozoobenthos delle mitilicolture nel Golfo di Trieste è stato valutato analizzando le modificazioni della struttura della comunità macrobentonica ed i parametri abiotici maggiormente significativi. I campionamenti sono stati eseguiti a cadenza mensile, tra maggio 1998 ed aprile 1999, sotto ad una mitilicoltura ed in una stazione di riferimento. Le due stazioni hanno la stessa tessitura (30% silt, 70% argilla), mentre le percentuali di carbonio organico e di azoto totale sono, rispettivamente, il 30% e 25% più elevate sotto la mitilicoltura. Il numero di specie, l'abbondanza e gli indici di diversità presentano valori simili, mentre la biomassa è il doppio sotto la mitilicoltura. La classificazione e l'ordinamento nMDS (non-metric multidimensional scaling) separano chiaramente le due stazioni, inoltre le curve ABC (Comparazione Abbondanza-Biomassa) evidenziano un disturbo leggero sotto la mitilicoltura. Il debole impatto sul macrozoobenthos può essere dovuto alla riduzione, negli ultimi anni, della produzione della mitilicoltura in esame, ma soprattutto, alle caratteristiche idrodinamiche dell'area che sembrano avere un ruolo importante nella dispersione dei biodepositi.

Parole chiave: mitilicolture, macrozoobenthos, valutazione del disturbo, Mar Adriatico

INTRODUCTION

The farming of the blue mussel *Mytilus galloprovincialis* on hanging longlines is the main mariculture activity in the Gulf of Trieste, where it has been carried out traditionally for several hundred years and industrially for more than 40 years. Mussel farms nowadays cover an area 15 km long and 100 m wide, along the NE coast of the Gulf. At the end of the 1980's, about 8,500 tons year^{-1} was produced. Then, toxic algal blooms and occasional mucus aggregates during the summer, coupled with a general crisis of the fisheries activity, caused a drastic production fall reaching 2,000 tons in 1996 (Franzosini, 1998). Recovery has begun since, and production reached 4,000 tons year^{-1} in 2000 (Orel & Zamboni, 2004). In spite of the slow recovery, mussel farms currently represent a very important economic asset for the local fishery industry.

Mussel cultures produce large amounts of biodeposits (faeces and pseudofaeces) that cause increased deposition of organic material in the benthos beneath them (Kautsky & Evans, 1987; Hatcher *et al.*, 1994). Dahlbäck & Gunnarsson (1981) estimated the sedimentation rate of organic matter under a culture to be up to three times higher than at a control site, involving carbon and nitrogen accumulation in the sediment (Hall *et al.*, 1990, 1992). The enrichment in organic matter causes changes in the sediment composition (Mirto *et al.*, 2000) as well as an increase in oxygen consumption, causing bottom hypoxia or anoxia (Mattson & Lindén, 1983). In turn, these conditions influence the structure of the macrobenthic communities (Brizzi *et al.*, 1995; Chamberlain *et al.*, 2001), leading to the dominance of opportunistic polychaetes and to macrofaunal biomass drops (Hargrave *et al.*, 1993). The smaller benthic components, such as meiofaunal and microbial communities, are deeply influenced too (Mirto *et al.*, 2000; La Rosa *et al.*, 2001). The impact can vary considerably among locations, both in extent and degree, depending on the environmental characteristics of the area (Grant *et al.*, 1995; Svane & Setyobudiandi, 1996).

The aim of this study was to evaluate the effects of suspended mussel cultures on the underlying macrobenthic fauna, by analysing the changes in the community structure during one year. The most significant features of the sediment (redox potential, organic carbon and nitrogen) were also analysed to assess the differences between the area underneath the cultures and a control site.

MATERIALS AND METHODS

The Gulf of Trieste is a shallow bay (maximum depth 26 m), characterized by wide temperature changes between winter and summer (e.g. from surface layer minimum of about 7 °C to maximum ≥26 °C). Thermal stratification in the summertime and winter mixing, as well as high sedimentation rates of river sediment outputs are also typical of the area.

Sampling was performed monthly from May 1998 to April 1999 at a mussel farm located along the NE coast of the Gulf (Fig. 1). This farm is operative since 1976, with an annual production of about 100 tons, with a reduction of about 40% in the years preceding the study, like at many farms of the Gulf. In this area the surface currents, as shown by Martinčić *et al.* (1998), range from 0 to 28 cm s^{-1} (mean value of 8 cm s^{-1}) due to the tidal influence, but first of all to the effect of the winds.

Two stations were analysed: 1) station M, located inside the farm, on muddy sediments (30% silt, 70% clay) almost completely covered by a "mussel-carpet", constituted of living and dead mussels falling from the ropes, and by plastic nets used as culture ropes, at a depth of 13 m; 2) station B, as the control site, located about 100 m away from the culture, not impacted by the mussel culture, with similar depth (14 m) and sediment texture (29% silt, 71% clay). Temperature (T) (°C), salinity (S) (psu) and dissolved oxygen (D.O.) (% saturation) were measured on vertical profiles using a CTD Idronaut mod. 401 probe.

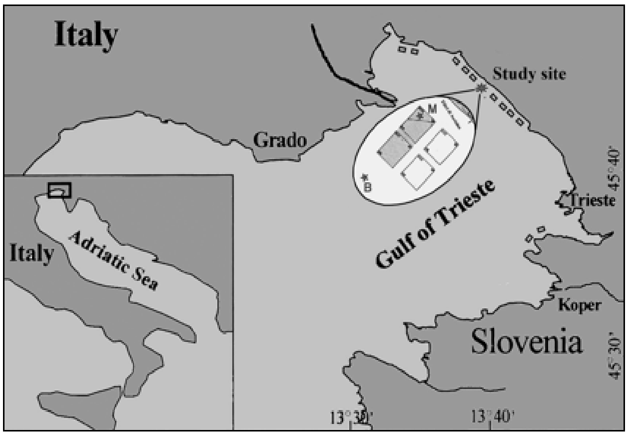

Fig. 1: Map of the study area and sampling stations.
Sl. 1: Zemljevid preučevanega območja in vzorčišč.

Three core samples for redox potential measurements, organic matter and sediment particle size analyses were collected every month by SCUBA-divers by hand-coring. The redox potential (Eh) of the sediment was immediately measured at 1.5 cm intervals down to 10.5 cm, using a redox probe, standardized in Zobell's solution, in inert medium (Standard Methods, 1992). The surface layers of the samples were freeze-dried, homogenized and sieved through a 300 μm mesh sieve, after acidification (Hedges & Stern, 1984) to remove the carbonates. Analyses of organic carbon and total nitrogen were performed on three replicates, using a Perkin Elmer 2400 CHNS/O analyzer calibrated with acetanilide at a combustion temperature of 1050 °C. The textural composition of the sediment samples was defined by dry sieving (sandy fraction) and by using the Micrometrics Sedigraph 5000 ET Particle Size Analyzer for silt and clay composition, following procedures reported by Covelli & Fontolan (1997).

At each station, three replicate samples were collected with a 0.1 m^2 van Veen grab and sieved on a 0.5 mm mesh sieve. The retained fauna was preserved in 4% buffered formaldehyde solution, sorted and identified to the highest possible taxonomical level. Biomass was determined as ash-free dry weight (AFDW). The species were grouped into five feeding guilds: carnivores/omnivores, suspension feeders, surface deposit feeders, sub-surface deposit feeders and herbivores (grazers) (Fauchald & Jumars, 1979; Bachelet, 1981).

Species richness, abundance, Shannon-Wiener diversity index ($\log_e$) and evenness index were used to analyse the community structure. The cluster analysis and the non-metric multidimensional scaling (MDS) were carried out on square root-transformed abundance data using the Bray-Curtis similarity measure. The SIMPER procedure was applied to determine the good discriminating species for dissimilarity between the affected area and the control station. To detect disturbances on the benthic community, the Abundance Biomass Comparison (ABC) method (Warwick, 1986) and W-statistics (Clarke & Warwick, 2001) were applied:

$$W = \sum_{i=1}^{S} (Bi - Ai) / [50(S-1)]$$

Bi and Ai are the biomass and abundance values for each rank (i) in an ABC curve, and S is the number of species. W takes values in the range from –1 (severely disturbed) to +1 (undisturbed), so the community should have a negative W value if it has been disturbed. Univariate and multivariate analyses were performed using PRIMER 5 software (Clarke & Warwick, 2001).

RESULTS

Abiotic factors

The two stations were characterized by very similar hydrological features. Annual mean temperatures at the bottom were slightly higher at station M (14.8±5.3 °C) than at station B (14.4±5.0 °C), ranging from a minimum of 8.1 °C to a maximum of 21.8 °C at the farm site, and from 7.9 °C to 21.1 °C at the control site. Salinity varied from 35.87 psu to 37.85 psu at the farm site, and from 35.87 psu to 37.88 psu at the control site. The surface layer showed low values at both stations in October and April, in coincidence with larger river inputs during the rainiest periods. Dissolved oxygen values at the bottom ranged from 70.07% to 101.22% at station M and from 73.54% to 101.86% at station B. The lowest values were registered at both stations in September.

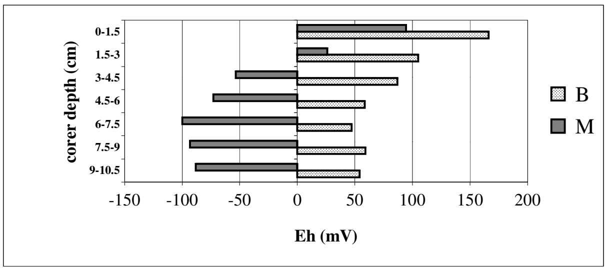

Fig. 2: Mean values of the redox potential of the sediment of the mussel farm (M) and of control station (B).
Sl. 2: Srednja vrednost redox potenciala v sedimentu pod gojiščen školjk (M) in na kontrolni postaji (B).

Eh mean values were higher at station B in all sediment levels (Fig. 2), but the monthly profiles were very variable. At the surface layer (0-1.5 cm), values ranged from –52 mV to 239 mV at station M, and from –37 mV to 422 mV at station B. Considering the mean values of Eh in the different layers, station M showed positive values down to 3 cm depth, while mean values at station B were always positive (Fig. 2).

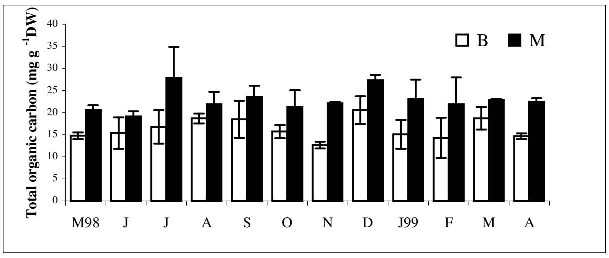

Fig. 3: Temporal variation of the total organic carbon.
Sl. 3: Časovno variiranje skupnega organskega ogljika.

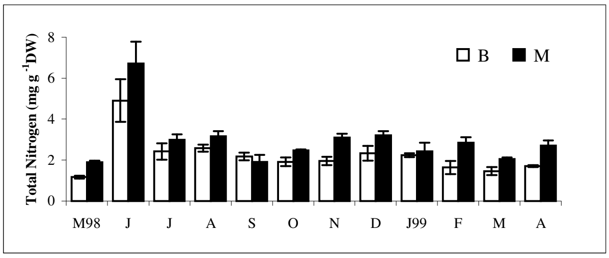

Fig. 4: Temporal variation of the total nitrogen.
Sl. 4: Časovno variiranje skupnega dušika.

Elemental analysis of the surface sediment showed organic carbon and total nitrogen values (as mg g^{-1} dry sediment) always higher beneath the mussel farm (Figs. 3, 4), but the t-test demonstrated significant differences between the two stations only for organic carbon ($p < 0.05$). The organic carbon content at station M ranged from 19.17 (±1.83) mg g^{-1} (June) to 27.83 (±7.02) mg g^{-1} (July). At station B, the highest value measured was 20.53 (±3.2) mg g^{-1} in December and the lowest 12.62 (±0.78) mg g^{-1} in November. The total nitrogen concentration was always higher at station M than at station B, except for September; values varied from 1.90 (±0.36) mg g^{-1} to 6.72 (±1.07) mg g^{-1} at station M, and from 1.16 (±0.07) mg g^{-1} to 4.91 (±1.05) mg g^{-1} at station B. The C/N ratios at both stations were generally lower than 12, with highest values in September at station M (14.47±3.01) and in March at station B (15.00±0.2), while the lowest values were found in June at both stations (Fig. 5).

Faunal composition

A total of 163 taxa were identified at station M and 170 at station B, among which 140 were mutual taxa between the two stations. Polychaetes were always the richest group, followed by molluscs, crustaceans and echinoderms (Tab. 1). The monthly pattern of the number of taxa was similar under the mussel farm and at the control site. In May we observed the highest number at both stations, with 85 species at station M and 108 at station B, whereas the lowest values were found in winter, with 41 taxa at station M (February) and 50 taxa at station B (March) respectively (Fig. 6).

The total abundance was not significantly different between the stations. At each site, the highest values were found in May, due to the dominance of two polychaetes: *Prionospio cirrifera* representing 58% of all individuals at station M, and *Lumbrineris gracilis* representing 23% at station B. Low values were recorded in winter (Fig. 7).

Tab. 1: Number of taxa in the main macrobenthic groups at the two stations.
Tab. 1: Število taksonov v glavnih makrobentoških skupinah na obeh postajah.

Number of taxa	Station M	Station B
Polychaetes	78	85
Molluscs	41	45
Crustaceans	23	19
Echinoderms	10	11
Others	11	10
Total	**163**	**170**

The analysis of abundance of the main taxonomic groups (polychaetes, molluscs, crustaceans, echinoderms) showed that polychaetes were always dominant at both stations (on average 85% at station B and 72% at station M) and in all samples. Crustaceans, molluscs and echinoderms were on average more abundant at station M than at station B, with 15%, 9%, 4% and 6%, 6%, 3% respectively.

The ten most abundant taxa at each station are listed in Table 2. Species composition at station M was dominated by the polychaetes *P. cirrifera* and *L. gracilis*. The former was very abundant only in May (3239 ind m^{-2}), whereas the latter was abundant every month. The dominant species at station B were the polychaetes *L. gracilis*, *Aricidea* spp. and *Maldane glebifex*. Some species were exclusively present at one station. *Haliotis lamellosa tuberculata* and *Paracentrotus lividus* were found only at station M, whereas three polychaete species, *M. glebifex*, *Lumbrineris tetraura* and *Sthenolepis yhleni*, were recorded only at station B. The mollusc *Nucula nucleus* and the crustaceans *Pisidia longimana* and *Athanas nitescens* were significantly more abundant at station M than B, on average 98 vs 20 ind m^{-2}, 108 vs 32 ind m^{-2} and 57 vs 8 ind m^{-2} respectively.

Tab. 2: Top ten ranked taxa, mean density and percentage at the two stations.
Tab. 2: Prvih deset najpomembnejših taksonov, njihova srednja gostota in deleži na obeh postajah.

Station M			Station B		
Taxa	**Ind. m^{-2}**	**%**	**Taxa**	**Ind. m^{-2}**	**%**
Prionospio cirrifera	350	17.84	*Lumbrineris gracilis*	492	25.61
Lumbrineris gracilis	195	9.95	*Aricidea* sp.p.	251	13.05
Aricidea sp.p.	168	8.56	*Maldane glebifex*	121	6.32
Pisidia longimana	108	5.48	*Eunice vittata*	103	5.37
Nucula nucleus	98	5.01	*Pomatoceros triqueter*	84	4.37
Pomatoceros triqueter	86	4.37	*Lumbrineris latreilli*	61	3.17
Eunice vittata	65	3.30	*Levinsenia gracilis*	57	2.95
Lumbrineris latreilli	61	3.13	Syllidae indet.	45	2.33
Athanas nitescens	57	2.89	*Prionospio cirrifera*	42	2.18
Gammaridae indet.	51	2.58	Gammaridae indet.	40	2.07
		63.10			67.41

The Shannon-Wiener diversity index and evenness index did not show significant differences between the stations. Shannon-Wiener average was 2.99 (±0.37) at station M and 3.04 (±0.24) at station B, and evenness average was 0.76 (±0.09) at station M and 0.74 (±0.05) at station B.

In order to evaluate the percentage of sensitive/tolerant species, the species found at the two sites were assigned to the ecological groups reported by Simboura & Zenetos (2002). Only half of the species identified could be assigned, therefore the number of sensitive/tolerant species was reported, without the percentage values. The results should be considered with care, as only half of the community is represented. At station M, 22 sensitive and 56 tolerant species were found, while at station B, 32 sensitive and 59 tolerant species were recorded.

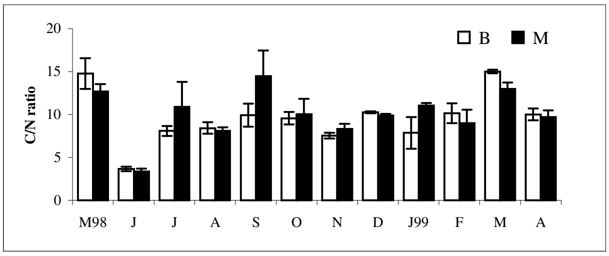

Fig. 5: Temporal variation of C/N ratio.
Sl. 5: Časovno variiranje C/N razmerja.

Biomass (not considering *M. galloprovincialis* fallen from the ropes) was higher beneath the mussel culture with a mean value of 41.65 (±30.73) g AFDW m^{-2} compared to a value of 22.73 (±15.20) g AFDW m^{-2} at the control site. At station M, the highest value was recorded in August (114.05 g AFDW m^{-2}) and the lowest in December (3.03 g AFDW m^{-2}) (Fig. 8), while at station B, the highest value of biomass was 60.57 g AFDW m^{-2} in December and the lowest in March (4.52 g AFDW m^{-2}). At both stations, on average 68% of the biomass was composed by epifauna, above all anthozoa and ascidiacea, and 32% of infaunal organisms.

Beneath the mussel farm, in addition to anthozoa and ascidiacea (Tab. 3), the most representative species, in terms of biomass, were the polychaete *Marphysa sanguinea* and the molluscs *Hexaplex trunculus* and *Lima exilis,* while at the control site the polychaetes *M. sanguinea* and *Chaetopterus variopedatus* were the most important.

Considering the feeding guilds, suspension feeders (anthozoa*,* ascidiacea*, L. exilis, Cucumaria planci)* dominated by biomass at station M, representing 51% of the total biomass (Tab. 4), while carnivores represented 34% in biomass, mostly due to the polychaete *M. sanguinea* and the mollusc *H. trunculus*. Similarly, at station B, suspension feeders dominated (68%), followed by carnivores (21%). Regarding the other trophic groups, grazers and surface deposit feeders were more important as biomass beneath the mussel farm, whereas surface deposit feeders and sub-surface deposit feeders played a more important role at the control site.

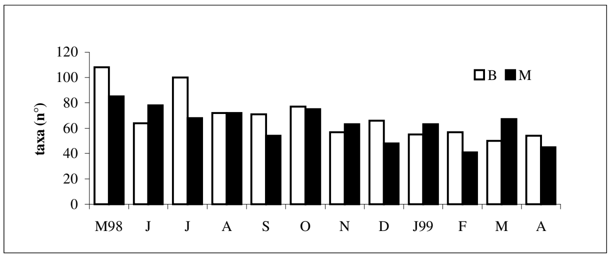

Fig. 6: Number of taxa of the macrobenthic fauna at station M and station B.
Sl. 6: Število taksonov makrobentoške favne na postaji M in postaji B.

Tab. 3: Biomass and relative percentage of the most representative species.
Tab. 3: Biomasa in deleži najbolj reprezenativnih vrst.

Station M			Station B		
Taxa	**g AFDW m^{-2}**	**(%)**	**Taxa**	**g AFDW m^{-2}**	**(%)**
Anthozoa indet.	6.75	16.2	Ascidiacea indet.	8.16	35.9
Marphysa sanguinea	5.60	13.4	Anthozoa indet.	3.78	16.6
Ascidiacea indet.	4.83	11.6	*Marphysa sanguinea*	2.38	10.5
Hexaplex trunculus	4.75	11.4	*Chaetopterus variopedatus*	1.30	5.7
Lima exilis	3.11	7.5	*Hexaplex trunculus*	0.94	4.1
Cucumaria planci	2.46	5.9	*Ophiothrix quinquemaculata*	0.58	2.5
Paracentrotus lividus	2.16	5.2	Nemertea indet.	0.55	2.4
Nucula nucleus	1.99	4.8	*Dasybranchus caducus*	0.51	2.2
		76			80

In term of abundance, surface deposit feeders (46%) dominated under the mussel farm due to some small-sized polychaetes, such as *Prionospio cirrifera* and *Aricidea* spp., followed by carnivores (39%). At station B, carnivores (47%) dominated, followed by surface deposit feeders (32%), while sub-surface deposit feeders were found almost exclusively at the control site.

Tab. 4: Feeding guilds: percentage of biomass and abundance. SF: Suspension feeders; C/O: Carnivores/Omnivores; SDF: Surface Deposit Feeders; SSDF: Sub-Surface Deposit Feeders; G: Grazers (herbivores).
Tab. 4: Prehranjevalni cehi: delež biomase in številčnosti. SF: suspenziofagi; C/O: karnivori/omnivori; SDF: površinski detritofagi; SSDF: podpovršinski detritofagi; G: rastlinojedci.

	Biomass (%)		Abundance (%)	
	Station M	**Station B**	**Station M**	**Station B**
SF	51.0	68.0	14.0	12.0
C/O	33.7	21.0	38.8	47.0
SDF	6.9	4.8	45.7	32.0
SSDF	0.1	3.7	0.6	8.7
G	8.3	2.5	0.9	0.3

Cluster analysis and MDS provided a clear separation between the two sites, with the only exception of the May sample under the farm, which is in the dendrogram included in the control site group (Figs. 9a, 9b). The ABC curves, generated from the combination of monthly data, indicate a slight disturbance in the mussel site (Fig. 10): the curves lie somewhat close together and cross each other. W values, calculated for each station and month, were positive for both stations, except for station M in May, which showed a slightly negative value (Tab. 5). The values ranged from –0.008 to 0.314 at station M, with a mean of 0.195 (±0.093); at station B, they ranged from 0.128 to 0.355, with a mean of 0.209 (±0.058).

Table 6 shows the results of breaking down the dissimilarities between the two sites into species contributions: the dissimilarity between the two sites was mainly due to *M. glebifex*, *N. nucleus* and *L. gracilis*, which were the species with higher Diss./SD ratio. Nearly 50% of the contribution to dissimilarity was accounted for by the first eight species listed.

Tab. 5: W-statistic values corresponding to the monthly ABC curves of the two stations.
Tab. 5: W – statistične vrednosti, ki ustrezajo mesečnim krivuljam ABC obeh postaj.

	station M	**station B**
M '98	-0.008	0.128
J	0.232	0.24
J	0.215	0.21
A	0.304	0.177
S	0.31	0.199
O	0.139	0.228
N	0.218	0.182
D	0.125	0.355
J99	0.15	0.247
F	0.314	0.193
M	0.176	0.145
A	0.162	0.209
Average	**0.195**	**0.209**
SD	0.093	0.058

Tab. 6: Breakdown of average dissimilarity between the two stations into contributions from each species.
Tab. 6: Razčlemba povprečne različnosti med dvema postajama na prispevke vsake vrste.

	B	**M**	**Av. diss**	**Diss/SD**	**Contrib %**	**Cum. %**
	Av. abund	**Av. abund**				
Lumbrineris gracilis	491.67	195.28	7.61	1.42	12.71	12.71
Prionospio cirrifera	41.94	350.28	5.70	0.48	9.51	22.22
Aricidea sp.p.	250.56	168.06	4.43	0.88	7.39	29.61
Maldane glebifex	121.39	1.39	3.34	1.92	5.57	35.18
Decapoda	32.78	109.72	2.64	1.11	4.40	39.58
Pisidia longimana	31.67	107.50	2.61	1.01	4.36	43.94
Pomatoceros triqueter	83.89	93.33	2.33	1.23	3.89	47.83
Nucula nucleus	20.28	98.33	2.20	1.69	3.67	51.50
Average dissimilarity between stations = 59.90						

DISCUSSION AND CONCLUSIONS

The abiotic factors (T, S, D.O.) measured in the water column were similar for both stations. The D.O. lowest values were registered in September, when D.O. usually decreases in most of the bottom layers of the Gulf of Trieste. This is due to the summer thermal stratification of the water column (5–6 m at the beginning of spring until about 15 m at the end of summer) (Cardin & Celio, 1997).

According to many authors (Kaspar *et al.*, 1985; Hatcher *et al.*, 1994; Stenton-Dozey *et al.*, 2001), there is an increase of organic carbon and nitrogen under mussel cultures: in our study, the organic carbon and the total nitrogen concentrations were 30% and 25% higher beneath the mussel farm than in the control site respectively. The C/N ratio showed average values ≤ 12, indicating the marine origin of the organic material in the sediments (Wassmann, 1984). The low C/N ratio values in June, at both stations, could indicate the prevalence of protein-rich organisms with high nitrogen content and/or microbial activity. High C/N values (May and March) may highlight the prevalence of degradation processes of organic nitrogen in the water-sediment interface and the presence of allochthonous organic matter (Faganeli *et al.*, 1988). In turn, the higher C/N ratio values under the harvesting area in July, September and January could indicate accumulation of refractory organic material, derived mainly from faeces and decaying mussels and foulers (Stenton-Dozey *et al.*, 2001).

At station M, anoxic conditions were observed in the sediment, but only in the layers underlying the first 3 cm. From scuba-diving direct observations, no bacterial mats or black muds were detected. The sediment beneath the mussel farm was almost completely covered by a "mussel-carpet", constituted of living and dead mussels falling from the ropes, and by plastic nets used as culture ropes. A large number of mussels fall down from the overlying ropes, particularly during the first stages of development or in summer, before their harvesting, when the byssus threads break. The mussels commonly survive on the seabed for a few months, although three-year-old specimens have occasionally been collected (Brizzi *et al.*, 1995). In this way, the mussel cultures transfer to the benthic system large amounts of organic matter available for predators and scavengers, as well as faeces and pseudofaeces for deposit feeders (Frankenberg & Smith, 1967; Tenore *et al.*, 1973; Stuart *et al.*, 1982; Rosenberg & Loo, 1983).

Polychaetes represented the dominant group at both stations, which was expected considering that they normally constitute about 80% of abundance on muddy sediments (Somaschini *et al.*, 1996).

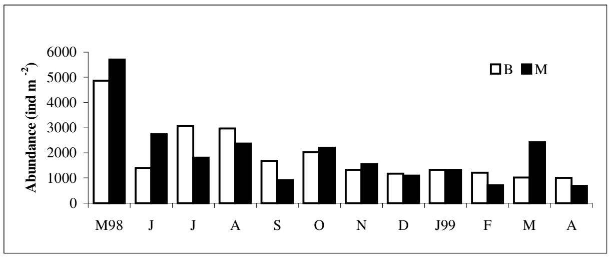

Fig. 7: Abundance of the macrobenthic fauna at station M and station B.
Sl. 7: Številčnost makrobentoške favne na postaji M in postaji B.

The analysis of the presence of sensitive and tolerant/opportunistic species highlighted at both stations a high number of tolerant species, which were the same as found commonly in all the muddy sediments of the Gulf of Trieste (Solis-Weiss *et al.*, 2001; Aleffi *et al.*, 2005). Moreover, it is to underline that on muddy bottoms (as found at the two stations) the fauna is generally dominated by tolerant species.

The percentage abundances of the main taxa were similar at both stations, except for the crustaceans that appeared to be more abundant under the mussel farm, especially the decapod *Pisidia longimana*. Another species of the same genus *Pisidia longicornis* has been found as dominant in the epifauna of the culture ropes in the Rìa de Arousa (Spain) (Román & Pérez, 1982) and as the main component in the diet of the predator crustaceans living there (González-Gurriarán *et al.*, 1995). According to Freire (1996), culture ropes could be considered an additional substratum for the development of epifaunal and macroalgal communities. In this case, the "mussel carpet" under the farm represents an ideal habitat and food supply for crustaceans and for some herbivores like the abalone *Haliotis lamellosa tuberculata* and the sea urchin *Paracentrotus lividus*, exclusively present at station M, but very frequent on the secondary hardground-community in the Gulf of Trieste (Zuschin & Pervesler, 1996).

The high abundance at station M of *Nucula nucleus*, a deposit feeder bivalve, should be noted, partly because it is one of the species that provided the greatest contribution to dissimilarity between affected area and control station. Another species of the same genus, *Nucula nitidosa,* was reported by Mattsson & Lindén (1983) as dominant at the start of mussel harvesting. *N. nucleus* is considered a species that spreads towards organic effluents (Elias, 1992). Grant *et al.* (1995) recorded another nuculoid, *Nuculana tenuisulcata,* as dominant under the ropes, due to an increased supply of sedimentary organic matter beneath the farm area.

The analyses of species richness, abundance and the Shannon-Wiener index did not reveal significant differences between the two sampling sites, and the diversity values were high compared to other areas of the Gulf of Trieste (Solis-Weiss *et al.*, 2001). Moreover, the high percentage (83%) of mutual species between the stations outlined the similarity also in species composition.

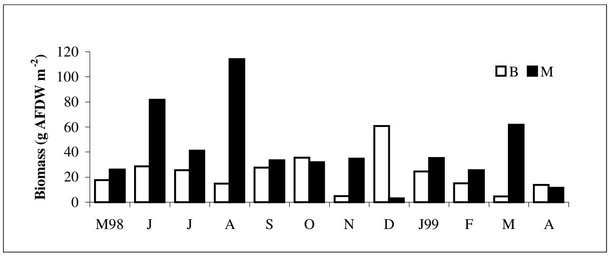

Fig. 8: Biomass of the macrobenthic fauna at station M and station B.
Sl. 8: Biomasa makrobentoške favne na postaji M in postaji B.

The biomass, on average, was twice as large at station M. This corresponds well with Hatcher *et al.* (1994) and Grant *et al.* (1995) results, since they have reported biomass values generally higher under mussel sites than at the control sites.

Suspension feeders and carnivores were dominant in biomass at both stations. However, in abundance, surface deposit feeders dominated under the farm and carnivores at the control site, in contrast to the study of Stenton-Dozey *et al.* (1999), who reported a dominance of deposit feeders, both in biomass and abundance, followed by carnivores beneath mussel cultures.

At each station, suspension feeders were represented by specimens with relatively high biomass, such as the ascidians (mostly *Microcosmus sp.*), the brittle star *Ophiothrix quinquemaculata* and, almost exclusively at station M, the holothurian *Cucumaria planci* and the bivalve *Lima exilis*. These species belong to one of the most widespread epibenthic communities in the Gulf of Trieste, known as *Ophiothrix-Reniera-Microcosmus* community (O-R-M) after the name of the three dominant genera (Fedra *et al.*, 1976). The O-R-M community is characterised by mobile and sessile suspension feeders, which are aggregates in the form of multi-species clumps (Stachowitsch & Fuchs, 1995). Ott & Fedra (1977) and Ott (1981) assumed that this community plays an important role in stabilizing the entire ecosystem by removing suspended material from the water column and storing it in the form of benthic biomass. Beneath mussel cultures, this epifaunal community had a higher biomass, because the "mussel carpet" and the plastic ropes lying on the bottom form an ideal substratum for attachment.

Carnivores, both predators and scavengers, were generally attracted by mussels falling from the culture ropes, as already noted in many studies (Tenore *et al.*, 1982; Kaspar *et al.*, 1985; Grant *et al.*, 1995; Crawford *et al.*, 2003) including Brizzi *et al.* (1995) in the Gulf of Trieste.

Remarkably, sub-surface deposit feeders were present exclusively at the control site, and mainly represented by the polychaete *Maldane glebifex*. This species highly contributed to the dissimilarity between the two stations: it was almost absent beneath the mussel farm, as already found under other mussel cultures in the Gulf of Trieste, probably because the mussel biodeposition alters the compactness of the sediment, preventing the building of its tube (Brizzi *et al.*, 1995). Moreover, the negative mean Eh values of the sediment underlying 3 cm at the station M could have contributed to the small percentage of sub-surface deposit feeders.

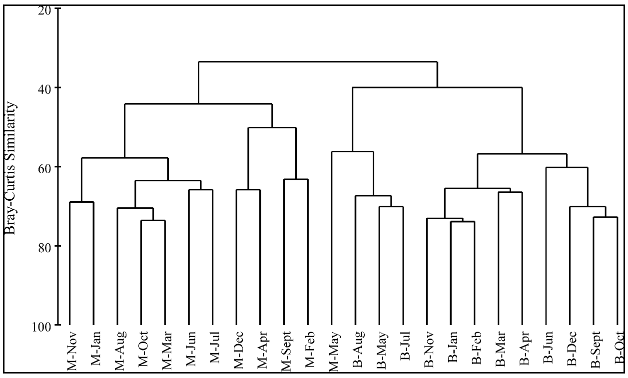

Fig. 9a: Dendrogram of hierarchical clustering of the monthly samples at the two stations.
Sl. 9a: Dendrogram hierahičnega grozdičenja mesečnih vzorcev na obeh postajah.

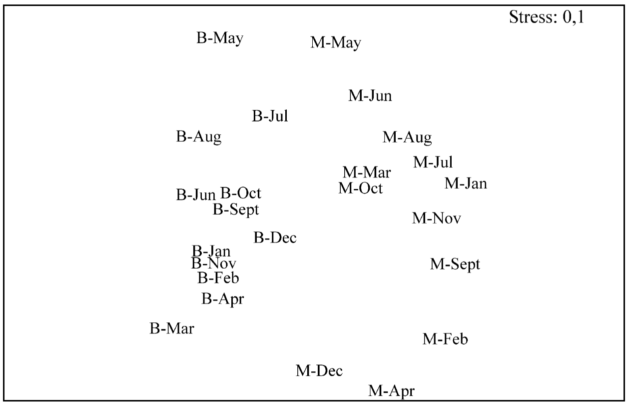

Fig. 9b: MDS plot for macrobenthic abundance at the two stations.
Sl. 9b: Večdimenzionalno skaliranje (MDS) številčnosti makrobentosa na obeh postajah.

Both cluster analysis and MDS provided a clear separation between the sites, likely due to the abovementioned differences of species composition and abundance. The ABC method indicated a very slight impact of the mussel culture on the benthos, because the effects of mussel biodeposition did not drive the community to an early succession stage, to which the ABC method is more sensitive. Considering the W values, calculated monthly, only one sample (May-station M) showed a slightly negative value probably due to the higher presence and abundance of species with small body size.

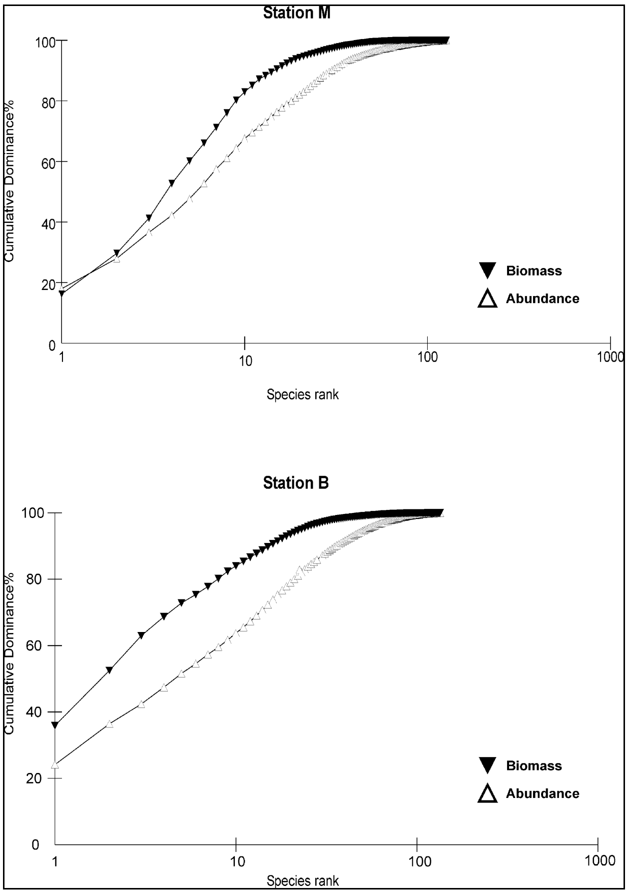

Fig. 10: ABC plots based on the monthly data for the two stations.
Sl. 10: ABC diagrama na osnovi mesečnih podatkov za obe postaji.

The presence of suspended cultures have induced some modifications on the bottom sediments, but as discussed in other studies (Baudinet *et al.*, 1990; Grant *et al.*, 1995; Crawford *et al.*, 2003; McKinnon *et al.*, 2003), the macrobenthic community does not appear to be under intense stress. The typical conditions of the communities exposed to a strong organic enrichment, as described by Pearson & Rosenberg (1978), are not present. The limited impact detected could be due to the decrease of production of this mussel farm in the previous years, but above all, to the presence, in the study area, of currents with mean values of 8 cm s^{-1} (maximum value 28 cm s^{-1}) (Martinčić *et al.*, 1998). Hydrodynamics sustained an efficient water circulation and, consequently, a limited biodeposition on the bottom. Anyway, the macrobenthic communities show some differences in biomass and species composition between the two sites. The degree and extent of the effects have been related, in many studies, to different factors such as the age of the farm, the densities of the organisms on the ropes or the hydrological characteristic of the area (Chamberlain *et al.*, 2001). In our study, hydrodynamics seem to play an important role in the dispersion of the biodeposits and in the consequent low level of impact found.

ACKNOWLEDGEMENTS

The research was funded by the Regione Friuli Venezia Giulia. Our thanks are due to Prof. Serena Fonda-Umani from the University of Trieste for her helpful comments on the ms.

UČINKI GOJENJA KLAPAVIC NA MAKROZOOBENTOS V TRŽAŠKEM ZALIVU (SEVERNI JADRAN, ITALIJA)

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POVZETEK

Avtorji prispevka so preučevali učinke gojenja školjk na makrozoobentos v Tržaškem zalivu (severni Jadran), in sicer z analiziranjem sprememb v strukturi združbe in ob upoštevanju najpomembnejših abiotskih parametrov. Študija je potekala od maja 1998 do aprila 1999 z mesečno frekvenco pod gojiščem klapavic in na kontrolni postaji kakih 100 m od gojišča. Tekstura morskega dna na preučevanih lokalitetah je bila enaka (30% mulja, 70% ilovice), medtem ko so bile koncentracije organskega ogljika in dušika za 30% oz. 25% večje pod gojiščem školjk. Po številu vrst in diverzitetnem indeksu ni bilo opaznejših razlik na preučevanih lokalitetah, medtem ko je bila biomasa v povprečju dvakrat večja pod gojiščem. Grozdičasta analiza in nemetrično večdimenzionalno skaliranje (nMDS) sta pokazala očitno razliko med lokalitetama, krivulji ABC (primerjava med številčnostjo in biomaso) pa manjše motnje na gojišču školjk. Rahli učinek gojenja školjk na makrozoobentos bi lahko bil posledica zmanjšanega obsega gojenja klapavic v zadnjih letih, predvsem pa hidrodinamičnih značilnosti območja, za katere se zdi, da igrajo pomembno vlogo v disperziji biousedlin.

Ključne besede: gojenje školjk, makrozoobentos, ocena motenj, Jadransko morje

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