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EFFECTS OF AN INTENSIVE CAGE FARM ON THE MACROBENTHOS IN THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA)

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ABSTRACT

Macrobenthos changes beneath a cage farm were investigated during October 2000 in the Gulf of Trieste (northern Adriatic Sea). The floating cage farm became operational in 1990, with an annual gross production of sea bream and sea bass of around 300 ton yr^{-1}. Eight stations were sampled: four beneath the cages, three at about 100 m from the cages and one at 250 m. The number of species ranged from a minimum of 21 under the cages to a maximum of 49 in the outside zone, while abundance was higher under the cages (1890 ind. m^{-2}) than outside (933 ind. m^{-2}). The dominant species were the opportunistic polychaetes Neanthes caudata *and the mollusc* Mytilus galloprovincialis. *Despite the huge gross cage production, the impacts were not as severe as those described under similar organic enrichment conditions elsewhere; they did, however, show a decrease in species richness, a replacement of the typical muddy community with more tolerant and opportunistic species, and an increase of abundance values.*

Key words: mariculture, sea bream, sea bass, impact, Gulf of Trieste

EFFETTI DELLA PESCICOLTURA INTENSIVA IN GABBIE SUL MACROBENTHOS DEL GOLFO DI TRIESTE (NORD ADRIATICO)

SINTESI

Nel Golfo di Trieste, ad ottobre 2000, sono state analizzate le modificazioni del macrobenthos dovute alla presenza di un impianto di pescicoltura in gabbie. L'impianto ha iniziato ad essere operativo nel 1990 ed ha una produzione lorda annuale di circa 300 tonnellate di orate e branzini. Sono state campionate otto stazioni: quattro al di sotto delle gabbie, tre a circa 100 m ed una a 250 m. Il numero di specie varia da un minimo di 21 sotto alle gabbie e 49 nella zona esterna, mentre i valori di abbondanza sono più elevati sotto alle gabbie (1890 ind. m^{-2}) rispetto alle stazioni esterne (933 ind. m^{-2}). Le specie dominanti sono il polichete opportunista Neanthes caudata *ed il mollusco* Mytilus galloprovincialis. *Malgrado l'elevata produzione dell'impianto, la comunità bentonica non sembra aver subito il forte impatto descritto in simili condizioni di arricchimento organico, si nota, però, una riduzione nel numero di specie, una sostituzione delle specie caratteristiche dei fondi fangosi con specie più tolleranti ed opportuniste, ed un aumento dei valori di abbondanza.*

Parole chiave: pescicoltura, orate, branzini, impatto, Golfo di Trieste

INTRODUCTION

Marine aquaculture has shown a huge increase in production in several Mediterranean countries over the past few decades. Mariculture expansion, mainly based on floating cage farms in sheltered areas, has led to concerns regarding the effects on the environment. Fish farming produces organic waste primarily composed of uneaten feed and fecal material (Iwama, 1991), which partially settles on the seabed, leading to changes in sediment quality (Karakassis *et al.*, 1998; McGhie *et al.*, 2000; Kovač *et al.*, 2001) and benthic communities (Ritz *et al.*, 1989; Weston, 1990). The macrofauna is a good indicator for monitoring the impact of aquaculture on the marine environment considering that the community structure can be related to the stage of degradation. Changes in benthic communities related to organic enrichment were exhaustively described by Pearson & Rosenberg (1978).

The macrobenthos beneath a cage farm and in the surrounding area was investigated in the Gulf of Trieste (northern Adriatic Sea) in order to evaluate the degree of disturbance directly related to the cages. The floating cage farm, covering some 25,000 m^2 and located close to about thirty years old mussel farms, began to operate in 1990. The annual gross production of sea bream *(Sparus aurata)* and sea bass *(Dicentrarchus labrax)* was around 300 ton yr^{-1} in the last five years. The farm operates from April to November, for during this period the water temperature in the Gulf of Trieste is above 14 °C (Celio *et al., in press)* and the fish are fed. In contrast, during the winter, when temperature falls below 10 °C, fish are fed at a very low percentage of body weight, with a strong reduction in the amount of organic matter reaching the bottom.

MATERIAL AND METHODS

The study area is located in the northernmost part of the Gulf of Trieste, Italy. The shallow bay (maximum depth 25 m) is characterized by high hydrological variability due to a wide thermal differences between winter and summer, to major freshwater inputs, and to the action of tide and winds. Annual variations in temperature and salinity cover the range 6.5–28 °C and 22–38, respectively (Bussani *et al.*, 2003). The tidal current amplitude is on the order of 10 cm s^{-1} (Malačič & Viezzoli, 1998), while the drift current can reach 50 cm s^{-1} with ENE winds (Mosetti & Purga, 1990).

In the area where the cages are situated, the complexity of the hydrological features of the Gulf is increased by the shallow depth (10 m), by the influence of the Isonzo and Timavo Rivers, and by the artificial confinement of the farm caused by the screen effect of the surrounding mussel long-lines.

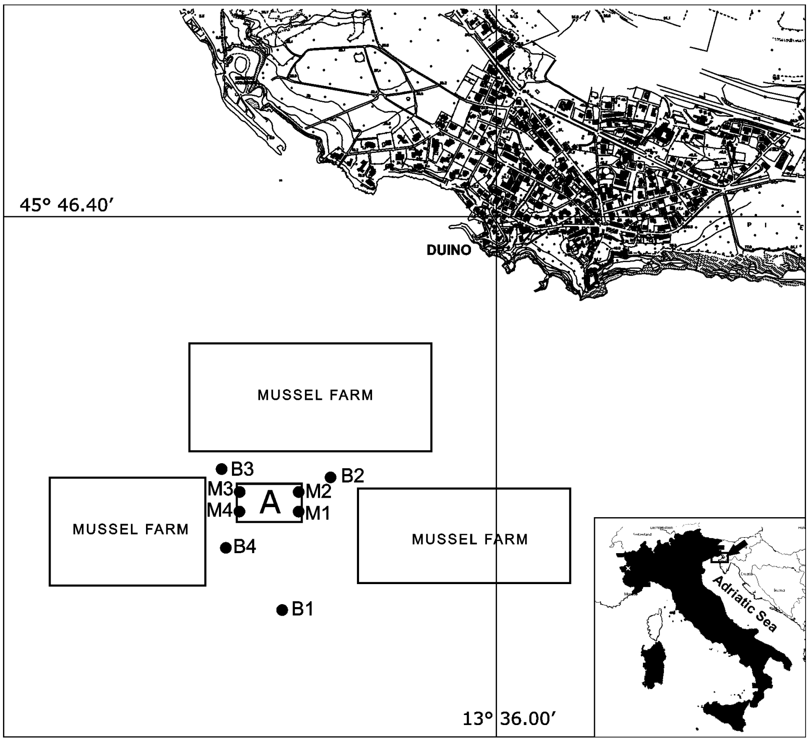

Fig. 1: Map showing location of sampling stations; (A) denotes fish farm area.
Sl. 1: Zemljevid z lokacijami vzorčnih mest; (A) ponazarja območje gojenja rib v kletkah.

Direct observations by scuba-divers were carried out in order to identify the potential presence and visible spatial extent of the impact *(e.g.* blackened sediment) and the presence of bacterial mats. In October 2000, eight stations were sampled: four along the edge of the cages (M1, M2, M3, M4), three (B2, B3, B4) at 100 m from the cages and from the mussel farm, and one – considered as a control station (B1) – at about 250 m from both (Fig. 1). The stations are situated at an average depth of 10 m on muddy sediment. At each station, four replicates were collected with a 0.1 m^2 van Veen grab, sieved through a 1 mm mesh and preserved in 4% buffered formalin.

The structure of benthic community was analysed as species composition, abundance, Shannon-Wiener diversity index (H') on $\log_e$ basis (Shannon & Weaver, 1949), evenness (J) (Pielou, 1966), and k-dominance curves. Non-metric multi-dimensional scaling (MDS) ordination was performed according to the Bray-Curtis similarity index on square-root transformed abundance data.

RESULTS

Diver's observations beneath the cages revealed no black mud or bacterial mats at the sediment surface. Mussel clumps and debris (net parts and ropes) coming from cages and mooring system were evident on the bottom.

A total of 110 species and 8,046 individuals were collected at the eight stations. The number of species ranged from 21 at station M3 to 49 at B3, while total abundance ranged from 383 ind. m^{-2} at B1 to 1890 ind. m^{-2} at M1 (Tab. 1). The highest diversity and evenness values were found at station B3 (3.24) and at station B1 (0.86), the lowest at station M3 for both indices (H' = 1.49 and J = 0.49). In all samples, the dominant taxon, both for species richness and abundance, were polychaetes, as already shown for the muddy sediments of the Gulf of Trieste (Brizzi *et al.*, 1995; Aleffi *et al.*, 1996).

The dominant species beneath the cages was *Neanthes caudata*, whose density was 650 ind. m^{-2} at M1 and 630 at M3, while its density reached 188 and 128 ind. m^{-2} at stations M2 and M4, respectively (Fig. 2). *Mytilus galloprovincialis* and Decapoda were also more abundant under the cages.

In order to test community stress at any station, the k-dominance curves were used, in which species are ranked in order of abundance on the x-axis with percentage dominance on the y-axis (cumulative scale) (Fig. 3). The curves were clearly more elevated at stations M1–M4, indicating an increase in species dominance beneath the cages. The elevation of the curve for M3 resulted from the high abundance of the polychaete *N. caudata* (630 ind. m^{-2}). Station B4 represented an intermediate state, while B1, B2 and B3 had lower partially overlapping curves.

Figure 4 shows the MDS configuration plot, with superimposed cluster groupings at a similarity level of 40%. There was a clear separation of B1 and B3 (group 1) from the other stations (group 2). In group 2, station M3 was separated from the others, according to the representation of the relationship among samples given by the MDS plot.

Tab. 1: Number of species (S), abundance (N), Shannon-Wiener diversity index (H'), and evenness (J) at each station.
Tab. 1: Število vrst (S), številčnost (N), Shannon-Wienerjev diverzitetni indeks (H') in indeks enakomernosti porazdelitve (J) na vsakem vzorčnem mestu.

	Stations under the cages				Stations outside the cages			
	M1	M2	M3	M4	B1	B2	B3	B4
S	44	44	21	36	37	47	49	48
N (ind. m^{-2})	1890	1078	1058	1285	383	643	803	933
H'	2.38	2.31	1.49	2.09	3.1	3.11	3.24	2.65
J	0.63	0.61	0.49	0.58	0.86	0.81	0.83	0.68

DISCUSSION

The number of species at station M3 (beneath the cages) was considerably lower compared to the values found at the other stations, which showed richness close to other areas of the Gulf of Trieste (Solis-Weiss *et al.*, 2001). The total abundance recovered in samples collected on muddy bottoms in the Gulf is on average around 1000 ind. m^{-2} (Aleffi *et al.*, 1995). In the study area, abundance was comparable to the muddy sediments of the Gulf, with an increase beneath the cages (Tab. 1).

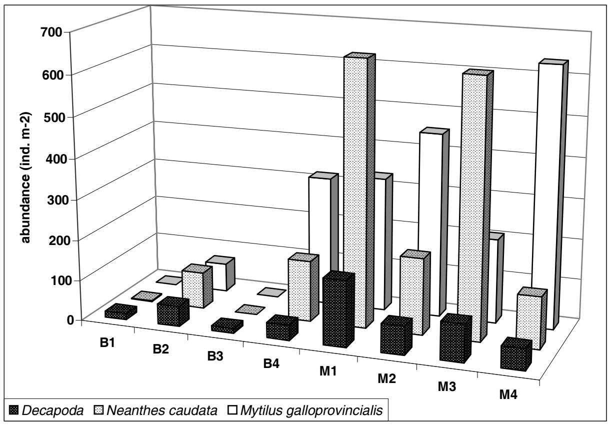

Fig. 2: Abundance of the dominant species and taxa at sampling stations.
Sl. 2: Številčnost prevladujočih vrst in taksonov na vzorčnih mestih.

The dominant species beneath the cages was *N. caudata*, an opportunistic species (Bellan, 1967). This may be related to the appearance of the "opportunistic peak" reported in Pearson & Rosenberg (1978) under the effect of organic load. K-dominance curves provided evidence of disturbance at the stations under the cages, especially at M3. Station B4 showed a high dominance of *M. galloprovincialis* and *N. caudata*, being at an intermediate community stress level: together, these two species made up 50% of the total abundance at the station.

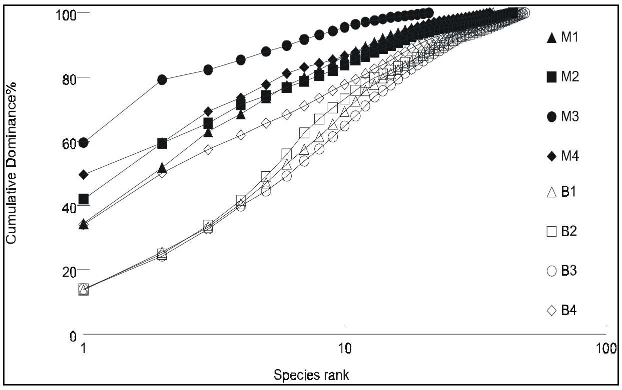

Fig. 3: K-dominance curves for abundance at sampling stations under (closed symbols) and outside (open symbols) the cages.
Sl. 3: Krivulje dominance K za številčnost na vzorčnih mestih pod kletkami (zaprti simboli) in zunaj njih (odprti simboli).

Analysing the species composition of the two main groups derived from the dendrogram, group 1 (stations B1 and B3) was distinguished by the presence of the polychaetes *Maldane glebifex* and *Laonice cirrata*, characteristic of the biocoenoses of the terrigenous mud (VTC) as described by Pérès (1967), and by *Terbellides stroemi* and *Melinna palmata*, commonly found on muddy bottoms. Among molluscs, the dominant in group 1 was *Dentalium inaequicostatum*. The second group of stations was pooled based on the presence and abundance of the molluscs *M. galloprovincialis* and *Nucula nucleus,* the polychaetes *N. caudata* and *Marphysa sanguinea,* and the crustaceans *Processa* spp., *Pisidia longimana* and *Brachynotus sexdentatus*. Among these species, *M. galloprovincialis* had fallen directly from the upper floating cages and ropes, while Decapoda were associated with secondary hard substrata formed by ropes, nets and mussel shells: they were also the dominant epibenthic invertebrates beneath the mussel farm in the Ria de Arousa (Freire *et al.*, 1996). Some species commonly indicating organic enrichment (Bellan, 1967; Pearson & Rosenberg, 1978), such as *N. caudata* (ranging from 90 ind. m^{-2} to 650 ind. m^{-2}) and few specimens of the polychaetes *Malacoceros fuliginosus* and *Capitella capitata,* were present. *C. capitata* is rarely found in the Gulf of Trieste, even in heavily polluted areas (Bellan & Pérès, 1972; Orel *et al.*, 1987), and has never been recorded at high density. In contrast, it was frequently found under fish cages in many other geographical areas (Pocklington *et al.*, 1994; Karakassis *et al.*, 1999). Note also the absence of *M. glebifex*, which is widely distributed in the muddy bottoms of the Gulf (Solis-Weiss *et al.*, 2001); this is probably related to anthropogenic modifications that alter the natural density of the sediment, as noted in previous studies under the mussel long-lines of the Gulf of Trieste (Brizzi *et al.*, 1995).

The MDS plot outlined a gradient of increasing disturbance moving from station B1 - B3 to M3. Stations B2 and B4, although positioned outside the cages, occupied an intermediate position, and were close to M2 and M4 owing to the abundance of *N. caudata* and *M. galloprovincialis*. The farm's disturbance and impact on the benthic community seemed to be more intense in a restricted area comprising the cages' perimeter and station B4. The reference station (B1) was unaffected in consideration of the presence of species characteristic of the muddy bottom of the Gulf and the lack of indicator species of organic enrichment. The outer stations were slightly disturbed at the most, possibly a combined effect due to the proximity of the cages and the mussel farms, even if, generally, the impact of shellfish lines is not as deleterious as that of the fish farms (Pocklington *et al.*, 1994), as the latter involves a net addition of organic matter in the form of fish feed to the environment. The effects at stations B2 and B4 were thus most probably related to the fish farm.

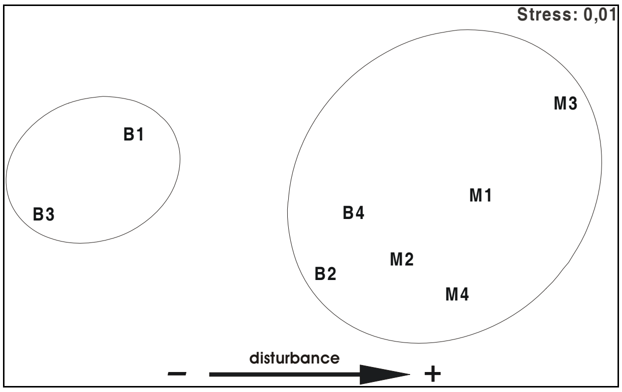

Fig. 4: Multidimensional scaling (MDS) for each station with cluster superimposed.
Sl. 4: Večdimenzionalno skaliranje (MDS) za vsako vzorčno mesto z označenimi klasterji.

Other authors have observed bottom effects limited to the immediate vicinity of fish cages, generally depending on the water circulation pattern (Weston, 1990; Johnsen *et al.*, 1993). The huge production level of the farm did not lead to a disturbance comparable to the impact described elsewhere for similar production levels (Angel *et al.*, 1995), even if, generally, fish farming above fine sediments, such as present in this study, has the potential for severe environmental impact (Lauren-Maatta *et al.*, 1991). The relatively low impact level may be due to the short feeding period of the fish during the year (8 months) and to the strong dilution of feed and fecal wastes by the intense tidal and inertial streams. The average water current velocity of about 8 cm s^{-1} in the coastal area (Martinčić *et al.*, 1998) may have been enough to reduce the effects of organic enrichment, limiting biodeposition on the bottom. An average current of about 6 cm s^{-1}, for example, was sufficient to disperse solid wastes of a cage farm at Gran Canaria Island, as noted by Molina Domínguez *et al.* (2001).

The macrobenthic communities in the Gulf of Trieste receive high sedimentary loads due to the proximity of the Isonzo and Timavo river mouths and to an organic load from the heavily populated coast. The Gulf is characterized by high environmental instability, both natural (*i.e.* hypoxic and anoxic events, aperiodic mucilage production) and anthropogenic (*i.e.* urban development, sewage ducts discharges, intensive sea traffic and trawl fisheries, tourist activities) that has led to selective pressure on the community towards a more resilient state (Solis-Weiss *et al.*, 2001). So, in consideration of the overall situation, fish cages represent only one, and localized, problem for the Gulf.

CONCLUSIONS

Our study revealed that although the gross cage production is huge, the bottom was not azoic as described under similar organic enrichment conditions elsewhere. Nevertheless, we observed clear modification of the benthic community that can be summarized by: a) a weak decrease in species richness, except for in a restricted area in which the decrease was stronger, b) a substitution of the typical muddy community with certain more tolerant and opportunistic species, c) a considerable increase in abundance values.

UČINKI INTENZIVNEGA GOJENJA RIB V KLETKAH NA MAKROBENTOS V TRŽAŠKEM ZALIVU (SEVERNI JADRAN)

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POVZETEK

V oktobru 2000 so avtorji prispevka preučevali spremembe v makrobentosu pod kletkami za gojenje rib v Tržaškem zalivu (severni Jadran). V plavajočih kletkah se je gojenje rib začelo leta 1990, z letno bruto pridelavo orad in brancinov v višini približno 300 ton. Avtorji so vzorce jemali na osmih postajah: na štirih pod kletkami, na treh kakih 100 m od njih, medtem ko je bila zadnja od kletk oddaljena 250 m. Število vrst se je sukalo od najmanj 21 pod kletkami do največ 49 v zunanjem pasu, medtem ko je bila številčnost večja pod kletkami (1890 osebkov/m^2) kot zunaj (933 osebkov/m^2). Prevladujoče vrste so bile oportunistični mnogoščetinci Neanthes caudata *in mehkužci* Mytilus galloprovincialis. *Kljub izjemno visokemu bruto prirastku rib v kletkah pa vplivi niso bili tako veliki kot tisti, opisani v podobnih razmerah organskega bogatenja drugod. Zato pa so zagotovo povzročili, da se je zmanjšalo bogastvo vrst, da so značilne skupnosti na blatnem dnu nadomestile bolj tolerantne in oportunistične vrste in da se je povečala številčnost vrst.*

Ključne besede: marikultura, orada, brancin, vplivi, Tržaški zaliv

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