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Impact of an open-sea suspended mussel culture on macrobenthic community (Western Adriatic Sea)

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ABSTRACT

The potential impact of a suspended mussel farm on the coastal macrobenthic communities of the Western Adriatic Sea was seasonally evaluated through a multi-control sampling strategy over 1 year. Both univariate biological indices and multivariate analysis indicated that the variations of benthic macrofauna were mainly due to seasonality rather than location of the sampling sites in respect to the farm, and that the main species contributors were common to most sites and seasons. Most of these species are known as indicators of organic enrichment and/or pioneer species in recolonization of defaunated bottoms and commonly occur in the macrobenthic populations inhabiting the seabed of the North-Central Adriatic Sea between 12 and 15 m depth. Only the different abundances of filter- and deposit-feeders gave some evidence of a limited, spatial influence on the culture in the surroundings. The external sites showed a significant difference compared to the reference sites (ANOSIM: $R=0.395$, $P=0.5$). The overall results suggest that open-sea mussel culture has minimal detrimental effects on the zoobenthic communities of the Western Adriatic Sea that are usually in an immature stage due to subsequent environmental and anthropogenic disturbances. Although one-year study might not be sufficient to evaluate the effects of mussel culture, the results of this work represent a useful tool for the monitoring of the potential environmental impact of mussel farms to ensure the sustainable development of shellfish culture in the Italian shallow coastal waters.

1. Introduction

In Italy commercial farming of shellfish has always played the most important role in marine and brackish water aquaculture from the viewpoint of productivity, areal exploitation and number of farms. Mussel farming (*Mytilus galloprovincialis*) represents the most important activity and it noticeably increased in the last 15 years. The most recent Italian census points out that in 2005 there were 263 mussel cultures (Prioli, 2008), while the annual production amounted to around 63,500 t corresponding nearly to 50% of the national shellfish culture production (FAO FISHSTAT, 2005). In the past, most of these cultures consisted of floating or bottom systems localized in sheltered areas (bays, gulfs, lagoons) but recently a lot of new long-line farms have been established in the open sea, mainly along the Italian coast of the Northern and Central Adriatic Sea, where the high hydrodynamism enhances mussel growth (Maffei et al., 1996) and minimizes the possible environmental impacts inducing a greater dilution of faecal and pseudo-faecal material (Midlen and Redding, 1998; Muir, 2001; Hartstein and Rowden, 2004).

Intensive shellfish farming, in fact, involves large amounts of organic material accumulation on the bottom below the cultures causing strong changes in the physical and chemical characteristics of sediments (Dahlback and Gunnarsson, 1981; Kaspar et al., 1985; Gilbert et al., 1997; Nizzoli et al., 2006). A variety of levels of effect of suspended mussel culture on the benthic marine environment are reported in literature (Tenore et al., 1982; Kaspar et al., 1985; Baudinet et al., 1990; Hargrave, 1994). Heavy sedimentation of organic material directly below mussel farms leads to localised enrichment inducing oxygen depletion and sulphate reduction in areas with poor water exchange (Dahlback and Gunnarsson, 1981; Kaspar et al., 1985; Dowd, 2005; Giles et al., 2006) altering bacteria and benthic environments (Castel et al., 1989; Dinet et al., 1990; Grenz et al., 1990; Duplisea and Hargrave, 1996). Macrofaunal abundance is commonly reduced (Tenore et al., 1982; Mattsson and Lindén, 1983; Grant et al., 1995; Beadman et al., 2004; Smith and Shackley, 2004; da Costa and Nalesso, 2006) and differences in the composition of the infauna population are observed with a larger diversity at the reference sites (Kaspar et al., 1985), while opportunistic deposit-feeders dominate the benthic infauna of the mussel-farm sediment (Dahlback and Gunnarsson, 1981; Mattsson and Lindén, 1983; Smaal, 1991; Munday et al., 1992; Grant et al., 1995). Similar but weaker effects have also been observed in some of the few studies carried out in this field in the Mediterranean Sea, i.e. in the Gulf of Trieste and in the Gulf of Gaeta (Brizzi et al., 1995; Mirto et al., 2000).

The long-term sustainability of shellfish farming depends on the maintenance of the health of the natural ecosystem and evaluating the

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effects of suspended mussel cultures on the underlying marine environment; the benthic community is a primary factor in determining the sustainable environmental management of aquaculture (Gibbs, 2007). Systematic monitoring of marine ecosystem is extremely important to detect physical, chemical and biological changes in the water column, sediments and above all in the benthic community that can include highly sensitive species to ecological alteration caused by mussel bioturbation (Mirto et al., 2000). Indicator species usually tolerate adverse sediment conditions and may be represented by a wide variety of taxa (Pearson et al., 1983; Smith et al., 2001). Therefore, while microbial communities have been suggested as bioindicators for their important role in the biogeochemical processes occurring in mussel farm sediments (La Rosa et al., 2001), meio and macrofauna have been proposed as new environmental bioindicators of mussel farm impacted areas due to their ability to sensitively respond to any ecological alteration caused by organic enrichment (Mazzola et al., 1999, Mirto et al., 1999, da Costa and Nalesso, 2006).

However, most of the available literature refers to intensive mussel cultures in estuaries and inshore coastal waters, while very little is known about the offshore farms. Therefore, the present study was developed to provide baseline biological information on the effects of open-sea suspended cultures of *M. galloprovincialis* on the macrobenthic communities of the North-Central Adriatic Sea, in order to evaluate its seasonal impact.

2. Methods

2.1. Sample sites

A mussel culture located at about 2.5 km offshore the Western Adriatic coast at a mean depth of 11 m on a sandy-mud seabed, was investigated from June 2001 to February 2002 (Fig. 1). The farm was built in 1995 and production started in 1996. It takes up an area of 2 km^2 with 27 horizontal long-lines from 900 to 1600 m of length placed at 40–50 m from each other. The 2.5–3 m vertical long strings holding the mussels and bounded to the horizontal long-lines are 3–5 m above the bottom. The production is about 1000 t yr^{-1}. The long-lines are Southeast oriented, running parallel to the shoreline and to the predominant Southeast current that has a mean speed of 10 cm s^{-1} and maximum speed of 30 cm s^{-1}. Detailed studies on water circulation in the area were carried out by Artegiani et al. (1997) and Gačić and Artegiani (2001). The sandy-mud sediments of the mussel culture area were described by Danovaro et al. (2004). They reported seasonal variations in grain size composition with an increment of the sand/mud fraction in spring and fall. Redox potential discontinuity depth also varied widely between the seasons, ranging from 0.7 cm in summer to 6.5 cm in winter, while the total organic matter showed values between 1.2±0.1 (summer) and 6.1±3.3% (winter) of sediment dried weight.

2.2. Data collection

A preliminary survey was carried out in April 2001 and nine sites were selected for benthic sampling within and surrounding the mussel farm (Fig. 1). Two sites, I1 and I2 were inside the farm boundary and two sites were established as controls 600 m to the Northwest and West (C1 and C2). To study the possible effects of the farm over a linear gradient, sites E0, E1, E2, E3, and E4 were located along a Southeast axis parallel to the main current direction, extending 0, 30, 60, 120, and 300 m from the farm, respectively.

Four monitoring surveys were carried out with consideration of selected environmental and farming factors: the first one was

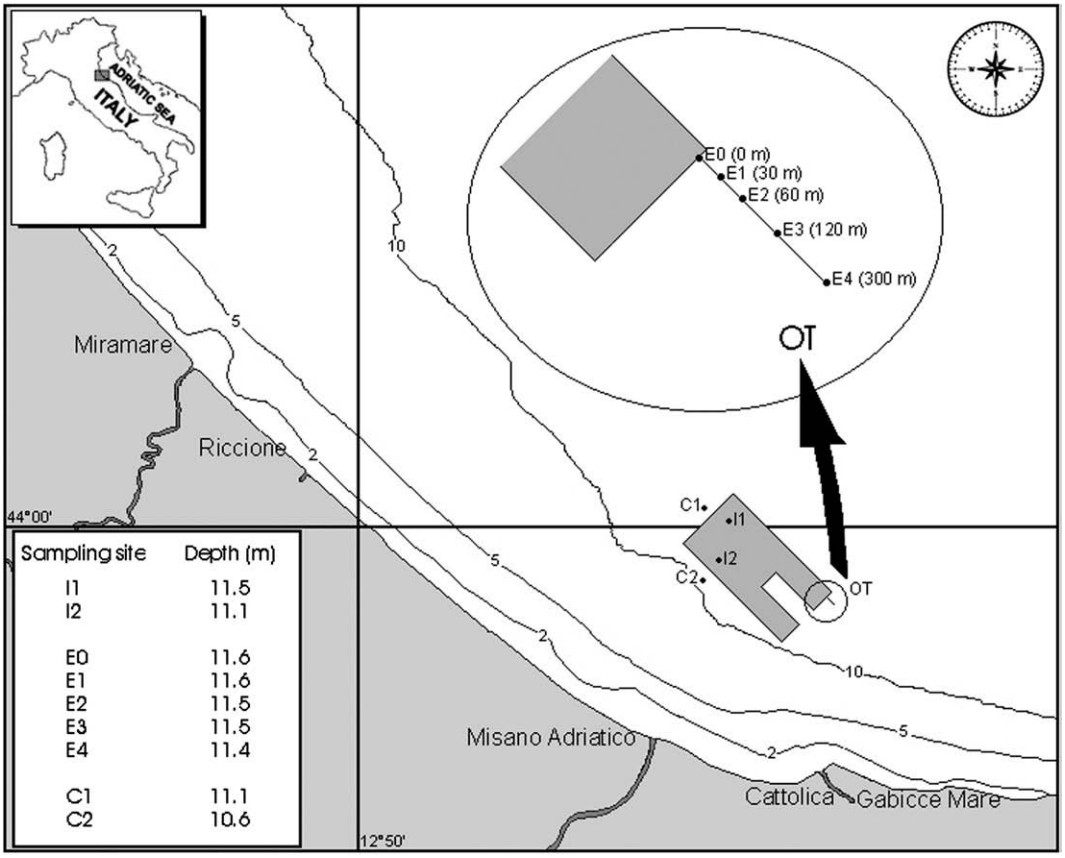

Fig. 1. Location of the mussel farm along the Western Adriatic coast and sampling scheme. C1 and C2: control sites; I1 and I2: inside farm sites; OT: outside transect; E0, E1, E2, E3 and E4: outside transect sites.