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Baseline

Microphytobenthic response to mussel farm biodeposition in coastal sediments of the northern Adriatic Sea

Annalisa Franzo[a,b,*], Tamara Cibic[a], Paola Del Negro[a], Cosimo Solidoro[c]

[a] Sezione Oceanografia, OGS (Istituto Nazionale di Oceanografia e Geofisica Sperimentale), Via. A. Piccard 54, I-34151 Trieste, Italy
[b] Department of Life Sciences, Università di Trieste, v. Valerio 28/A, I-34127 Trieste, Italy
[c] OGS (Istituto Nazionale di Oceanografia e Geofisica Sperimentale) Borgo Grotta Gigante 42/c Sgonico, Italy

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ABSTRACT

The effects of long-line mussel farming on microphytobenthos were investigated in a coastal area of the Gulf of Trieste. Sediment grain-size, organic matter content, microalgal abundance and community structure were analysed in September 2008 and March 2009. Four areas were sampled: a twenty-year farm, a four-year farm, a disused farm and a reference site. Principal component analysis (PCA) highlighted a decreasing gradient of organic matter content from the twenty-year farm to the control. Mussel farming seemed to influence microphytobenthic abundance with higher densities in the oldest farm. Three genera were dominant; *Navicula* and *Gyrosigma* seemed to be stimulated by the organic load under the active farms while we infer that *Nitzschia* proliferation was limited by shade caused by mussel ropes. In the PCA, samplings of the disused farm were placed in-between the still active farms and the control, indicating the partial recovery occurred in this site.

The growth of mussel production throughout the world (FAO, 1997) has induced an increased interest in the evaluation of mussel farm impact. Several studies have focused on the environmental effects of shellfish farming worldwide, showing different impact levels on sediment composition which range from low (Danovaro et al., 2004) to significant (Newell, 2004), and include the development of anoxic sediment (Christensen et al., 2003), changes in the structure of benthic communities (Chamberlain et al., 2001; Mirto et al., 2000) and modifications of nutrient fluxes (Newell, 2004). Farmed bivalve populations filter out suspended particulate matter from the water column, use a small proportion of this for growth, respiration and reproduction, and excrete the remainder either in dissolved form or as particulate matter (faeces and pseudofaeces, collectively called biodeposits) that sink to the seafloor (Gibbs, 2007 and references therein). The sedimentation rate of organic matter under a culture has been estimated to be up to three times higher than at a control site, involving carbon and nitrogen accumulation in the sediment (Hall et al., 1992 and references therein). Changes in the sediment chemical composition are reflected in the structural alterations of benthic microbial, meiofaunal (Mirto et al., 2000) and macrozoobenthic communities (Chamberlain et al., 2001). Mussel culture may also influence seagrass and algae, but there are few examples of such effects reported in the literature and the causative mechanisms are rarely clear (McKindsey et al., 2011). Although microphytobenthos (MPB) play a key role in benthic ecosystem functioning by influencing oxygen production and nutrient cycles (Barranguet, 1997; Newell, 2004 and references therein), studies focused on the response of these benthic assemblages to the impact of mussel farming are still very rare. In particular, microphytobenthic dominant fraction, i.e. benthic diatoms, could be useful in evaluating the impact since these organisms have been proven to be excellent bioindicators and suitable tools for marine biological monitoring (Cibic et al., 2008). In fact, because of their short generation times, they rapidly respond to environmental changes and provide early warnings of both increased pollution and successful habitat restoration. Diatoms are sensitive to changes in nutrient concentrations and each taxon has a specific optimum and tolerance for nutrients. The resulting composition of species, replacements, eliminations, diversity or abundance changes can give a proper idea of the recent history of environmental events affecting an area (Cibic and Blasutto, 2011 and references therein).

The aim of the present study is to answer the following questions: (1) Does mussel farming quantitatively and/or qualitatively affect the MPB? (2) Is there a relation between the age of the mussel farm and the degree of the impact on MPB? (3) Is there a shift in

Abbreviations: %PAR, percentage of measured irradiance at the bottom with respect to surface irradiance; BPC, Biopolymeric Carbon; MPB, microphytobenthos; TN, total nitrogen; TOC, total organic carbon; RA, relative abundance.

* Corresponding author at: Sezione Oceanografia, OGS (Istituto Nazionale di Oceanografia e Geofisica Sperimentale), Via. A. Piccard 54, I-34151 Trieste, Italy. Tel.: +39 0402249740; fax: +39 0402248770.

E-mail address: afranzo@ogs.trieste.it (A. Franzo).

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the composition of the microalgal community in the disused mussel farm compared to the still active farms? (4) To what extent does suspended mussel farming impact a semi-enclosed shallow basin such as the Gulf of Trieste?

The Gulf of Trieste, located in the north-western end of the Adriatic Sea, is a shallow basin with an average depth of 17 m (Celio et al., 2002). The geographical and hydrological features have been exhaustively presented by Lipizer et al. (2012). The area is characterised by intense and historically long and continuous man-induced stress factors. Chief among them is extensive mussel farming, which currently covers a 15 km long × 100 m wide area along the coastline. The blue mussel *Mytilus galloprovincialis* (Lamarck 1819) is cultivated using the long-line system: mussel larvae settle on ropes hanging down from long, horizontal anchored lines, suspended by buoys (Sdrigotti and Fonda Umani, 2002). This economic activity currently represents a very important economic asset for the local fishery industry.

The study was carried out in September 2008 and March 2009 in a coastal area of the Gulf of Trieste. Four sites, characterised by similar biogeochemical and geomorphological features, were chosen because subjected to a different degree of potential impact due to mussel farming (Fig. 1): a twenty-year farm (45° 45.14′ N, 13° 38.59′ E); a four-year farm (45° 45.06′ N, 13° 38.66′ E); a farm disused for more than 12 years (45° 44.93′ N, 13° 39.09′E) and a control site located 250 m ca. away from the farms (45° 44.82′ N, 13° 39.06′ E). In each site, sediment samples were collected at 5 stations (A, B, C, D, and E) located along the direction of the dominant current flux. The distance among stations was 6 m ca. At each station, 3 points (e.g. A1, A2, and A3), 1.5 m away from each other, were sampled. For logistical reasons, sediment samples from the 60 sampling points (4 sites × 5 stations × 3 points) were collected within few weeks. Seawater temperatures along the water column were measured using a Seabird 19 Plus Seacat probe. A PNF-300 Profiling Natural Fluorometer and a Li-Cor mod. Li-193SA Spherical Quantum Sensor were used to measure the Photosynthetic Available Radiation (PAR) at the central St. C of each area. PAR was converted to %PAR, which is the benthic PAR expressed as the percentage of surface irradiance.

At each point, scuba divers collected 3 virtually undisturbed sediment cores using polycarbonate sample tubes (12.7 cm I.D) with a sample area of 127 cm^2. Once in the laboratory, all sediment cores were partially extruded and the oxic sediment layer (0–1 cm ca) was collected and homogenised. The analyses of the sediment grain size, Total Organic Carbon (TOC) and Total Nitrogen (TN), Biopolymeric Carbon (BPC), Chl *a* and phaeopigments were performed on subsampled aliquots of oxic sediment as described by Cibic and co-authors (2012b) and references therein.

For the microphytobenthic analyses, aliquots of 2 cm^3 of homogenised sediment were withdrawn using a syringe and directly fixed with 10 ml of formaldehyde (4% final concentration) buffered solution $CaMg(CO_3)_2$, in pre-filtered bottom seawater (0.2 μm filters). After manual stirring, 20 μL aliquots of the sediment suspension were drawn off from the slurries and placed in a counting chamber. Only cells containing pigments and not empty frustules were counted under a Leitz inverted light microscope (Leica Microsystems AG) using a 32X objective (320X final magnification) (Utermöhl, 1958). The microalgal taxonomy was based on Round et al. (1992) and the AlgaeBase website (http://www.algaebase.org/). The qualitative identification of microphytobenthic assemblages was carried out to the genus and, when possible, to the species level using floras listed in Cibic et al. (2007a).

Descriptive statistics was performed on the entire microphytobenthic community in order to calculate the Relative Abundance (RA) for the main groups of organisms (i.e. Bacillariophyta, undetermined Phytoflagellates, undetermined Cysts, undetermined Spores, Cryptophytes and Coccolithophors). Focusing solely on diatoms, the RA of all genera and species were calculated. Both the tube dwelling diatom species (*Navicula corymbosa*, *Navicula mollis*

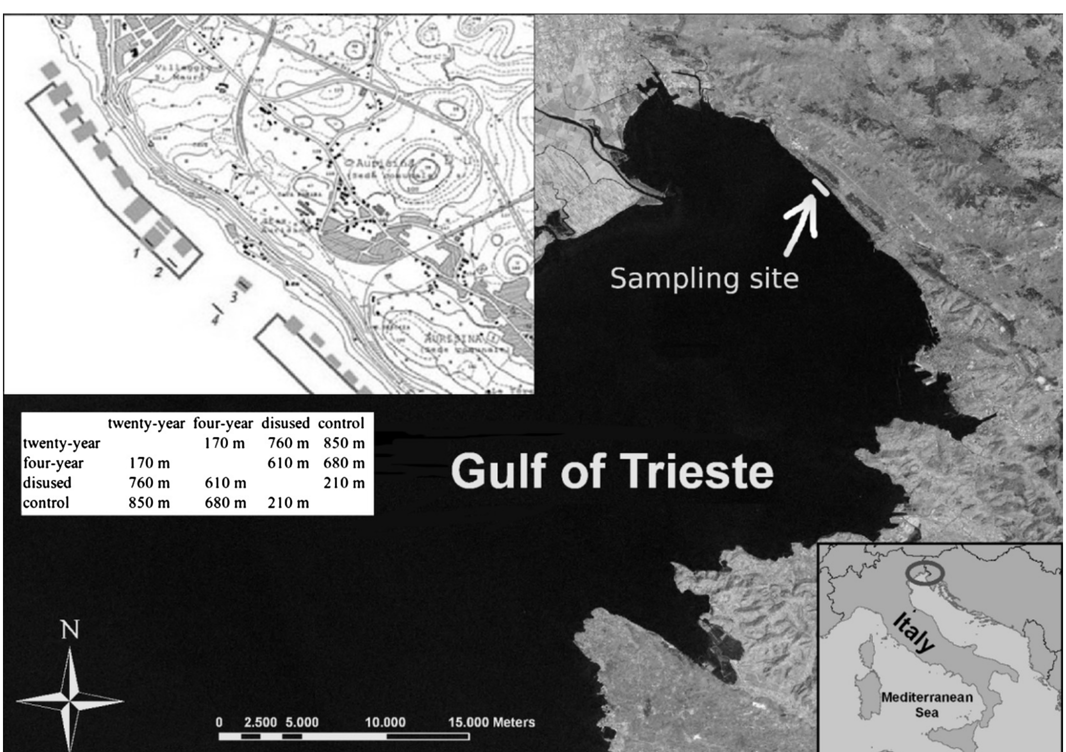

Fig. 1. Location of the 4 investigated areas in the Gulf of Trieste. Area 1 = twenty-year working farm; area 2 = four year working farm; area 3 = disused farm; and area 4 = control site.