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Ecological assessment of a heavily human-stressed area in the Gulf of Milazzo, Central Mediterranean Sea: an integrated study of biological, physical and chemical indicators

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ABSTRACT

Marine environmental disturbance can be assessed directly from physical and chemical parameters, or indirectly by the study of indicator species. In this study, an integrated approach to monitor the Gulf of Milazzo, labeled as a highly contaminated site, is presented. A total of 83 samples were collected from hard and soft bottoms in 2010. In sum, 2739 specimens belonging to 246 taxa, two first records for the Tyrrhenian Sea (*Micronephthys stammeri* and *Nicomache lumbricalis*) and three nonindigenous species (*Brachidontes pharaonis*, *Crassostrea gigas* and *Notomastus aberans*) were recorded. Biodiversity and biotic indices and their relationship with sediment parameters and the level of pollutants were assessed to describe faunal assemblage and evaluate environmental quality. Pearson tests evidenced significant negative correlation between polychlorinated biphenyls (PCBs) and specific richness ($p < 0.10$). A comparison of the standard and recorded biotic values showed that M-AMBI seems to be the index more representative of ecological quality status (EcoQ) in the Gulf of Milazzo. No evident signs were highlighted on the complex.

1. Introduction

Coastal waters are sensitive habitats that support high levels of biodiversity and provide many marine raw materials and services (Costanza et al., 1998; de Groot et al., 2002; Beaumont et al., 2008). Excessive human use of marine ecosystems (Mason, 2002; Matthiessen and Law, 2002) has led to local different degrees of environmental disturbance such as loss of habitat, change of nutrient status and cycling, loss of food supplies, erosion, reduced sediment supply, change of sea level and consequent inundations, and increased exposures to natural disturbances (Lotze et al., 2005; Worm et al., 2006; McCauley et al., 2015).

Other focal threats to ecological health are represented by bioinvasions of nonindigenous species that, by different vectors such as marine traffic (hull fouling or ballast water), aquaculture and interoceanic canals, are able to colonize new locations, causing loss of biodiversity of autochthon species (Vitousek et al., 1996; Ojaveer et al., 2014; D'Alessandro et al., 2015). Nonindigenous species, because of lack of natural prey, tend to supply autochthon species, causing loss of biodiversity (Bax et al., 2003; Occhipinti-Ambrogi, 2007).

Environmental disturbance, caused by natural or human causes, can be assessed directly from physical and chemical parameters (Daskalakis and O'Connor, 1995) or indirectly by the study of indicators as macrozoobenthic species (Pearson and Rosenberg, 1987; Borja et al., 2000; Lindegarth and Hoskin, 2001). The latter method is found on the paradigm of Pearson and Rosenberg (1987), which showed that macrobenthic organisms change their community structure according to natural conditions and anthropogenic environmental impacts in three progressive steps: abundance increases, species diversity increases and dominant species change from pollution-tolerant to pollution-sensitive ones (Grigg, 1994; Pearson and Rosenberg, 1987; Otway, 1995; Borja et al., 2000). On the basis of this assumption, by the study of benthic community, it is possible to establish an ecological quality status (EcoQ) of studied areas (Borja et al., 2000; Cruz-Motta and Collins, 2004; Currie and Isaacs, 2005).

The implementation of the European Water Framework Directive 2000/60/EC and 2008/56/CE has developed several biotic indices based on the classification of species (or groups of species) in several ecological groups representing specific sensitivity levels to disturbance. In this study, the applicability of BOPA (benthic opportunistic

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polychaetes amphipods) index, AMBI (AZTI marine biotic index) and M-AMBI (multivariate AMBI) for monitoring the impact of pollution on soft-bottom macrobenthic communities of the Gulf of Milazzo was tested. The first index is easier to use than the other two indices. However, it needs the maximum taxonomic effort. For using BOPA index, it is necessary to recognize amphipods, distinguishing the opportunistic genera of amphipods *Jassa* from others and a reduced list of opportunistic polychaetes. M-AMBI is a multimetric index based on benthic macroinvertebrates, which integrates AMBI values with values of diversity and richness. Aims of this study are to assess the ecological status of the highly polluted Milazzo shelf through a multidisciplinary study, including chemical, physical and biological features, to examine relationships between biotic and abiotic compounds (seafloor features and contaminant distribution) and investigate the presence of nonindigenous species.

2. Materials and methods

2.1. Study area and sampling activity

Sampling was carried out along the narrow continental shelf of the Gulf of Milazzo, north-eastern coast of Sicily, Central Mediterranean Sea (Fig. 1). The Gulf is exposed to high anthropogenic pressure because of the presence of an international harbor, oil refineries, thermal power plant and shipbuilding industry. According to a census on the marine traffic associated with refinery activities (ISPRA, 2009), it was estimated that approximately 3256 vessels (66% chemical/oil product tanker; 15.86% crude oil tanker; 12.56% LGT tanker and 5.48% oil product tanker) have transited between 2006 and 2010 through the Gulf of Milazzo. The area is also subject to marine traffic associated with fishing and tourism (recreational ships, cruise ships and hydrofoils daily to the Aeolian Islands). In 2005, the industrial area of Milazzo was included in the list of Contaminated Sites of National Interest (Directive 23 December 2005 n. 266, art. 1 com. 561, national law in Italian language). The study area is characterized by low water circulation, mainly driven by NW winds. The surface water circulation is defined by a branch of Modified Atlantic Water (MAW), which, flowing eastward, forms a near-coast anticyclonic gyre and generates an accumulation area in the northern part of the Gulf (Sitran et al., 2009). This area is also subject to the influence of three small rivers with irregular flows (Corriolo, Niceto, Muto and Saya Archi/Rio Cucugliata Streams).

Undisturbed soft-bottom samples were collected during the summer of 2010 by a 0.1-m^2 *van Veen* grab in 16 sampling sites, two of which, at a distance of about 10 km from the refinery, were chosen as control.

Sampling sites were located along two bathymetries, at depths of 20 and 50 m (Table 1). Four replicates were collected for each sampling site, for 64 samples, of which three were used for macrofaunal analysis and one for grain size and chemical analyses.

Sampling from hard bottom was carried out by scuba diving, scraping a surface of 400 cm^2 from three pillars of refinery, of which two were functional (P1 and P2) and one was disused (P3). Three samples were collected from each station at three different depths (0.5, 6.0 and 15.0 m), for a total of 35 samples (Table 1).

Benthic samples from soft and hard bottoms were sieved on board through a 0.5-mm mesh, and the retained material was fixed with 4% buffered formalin. After 48 h, the samples were transferred for a long-term storage to 70% ethanol.

2.2. Laboratory analyses

Grain size analysis was performed according to Buchanan and Kain (1971), the fraction above 63 μm was examined by American Society for Testing Materials (ASTM) series sieves with an interval of 1 Φ ($\Phi = -\log_2 Ø$, mm), while the fraction below 63 μm (silt and clay) was analyzed by column dispersion method. Sediment types were classified according to the ternary Wentworth scale (Wentworth, 1922).

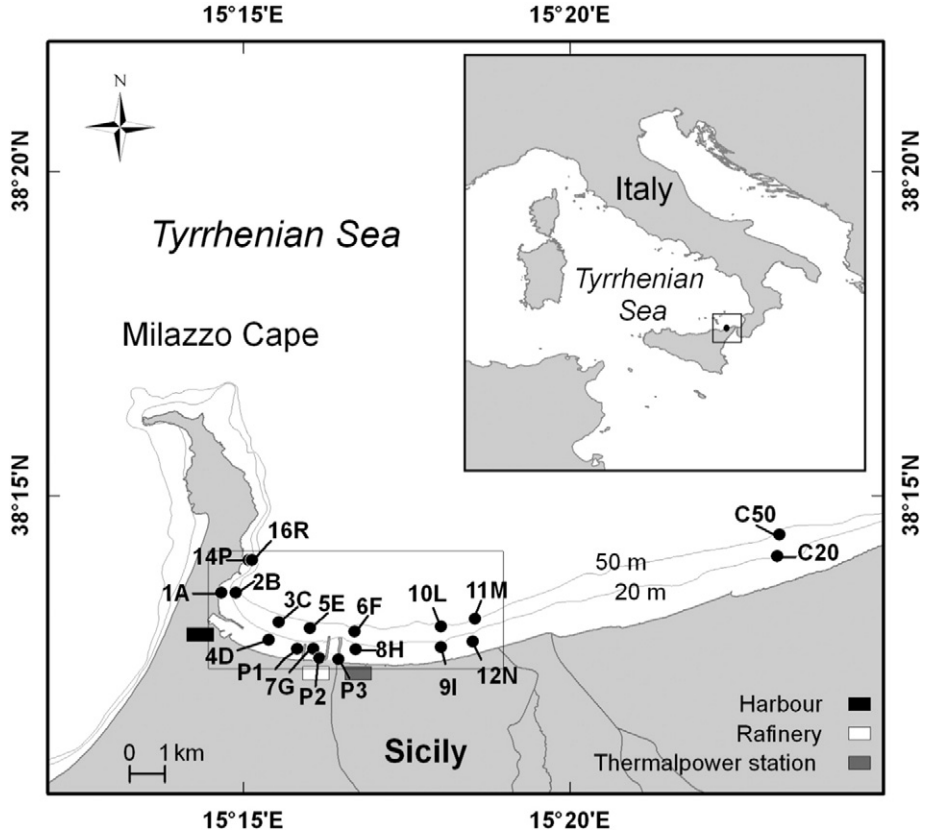

Fig. 1. Area of sampling, with sampling stations represented by black points and SIN zone by the selected area.