Marine Environmental Research 122 (2016) 113–125

Contents lists available at ScienceDirect

Marine Environmental Research

journal homepage: www.elsevier.com/locate/marenvrev

Spatial variability of soft-bottom macrobenthic communities in northern Sicily (Western Mediterranean): Contrasting trawled *vs.* untrawled areas

C. Romano [a, b], E. Fanelli [c, *], G. D'Anna [d], C. Pipitone [d], S. Vizzini [e], A. Mazzola [e], F. Badalamenti [d]

[a] Centre d'Estudis Avançats de Blanes (CEAB-CSIC) Carrer d'acces a la Cala Sant Francesc 14, 17300, Blanes (Girona), Catalunya, Spain
[b] Marine Invertebrate Phylogenetics Lab., Scripps Institution of Oceanography, 8750 Biological Grade Hubbs Hall, La Jolla, CA, 92037, USA
[c] Marine Environment Research Centre ENEA - Santa Teresa Pozzuolo di Lerici, 19100, SP, Italy
[d] CNR-IAMC, Sede di Castellammare del Golfo, via Giovanni da Verrazzano 17, 91014 Castellammare del Golfo, Italy
[e] Dipartimento di Scienze della Terra e del Mare, CoNISMa, Via Archirafi 18, 90123 Palermo, Italy

ARTICLE INFO

Article history:
Received 25 July 2016
Received in revised form
6 October 2016
Accepted 9 October 2016
Available online 11 October 2016

Keywords:
Benthic communities
Continental shelf
Trawling impact
Fishery exclusion zones
Spatial closures
Stable isotope analysis

ABSTRACT

This study examines the impact of bottom trawl fishing on the macrobenthic communities inhabiting the coastal terrigenous mud off the northern coast of Sicily (Western Mediterranean). Two intensely trawled gulfs were compared with two gulfs from which trawling has been excluded for 15 years. The results show a significant effect of trawling on the faunal assemblage and when comparing the mean biomass and the whole isotopic composition of the benthic communities. A similar pattern, although not significant, was found for total abundance, biomass, production/biomass ratio and diversity. Higher abundance and lower biomass were found in the untrawled areas, attributable to the presence of more numerous yet smaller individuals, possibly a consequence of more abundant larger predators that are not removed by trawling, and consequent higher predatory pressure on the benthic macrofauna. The SIMPER analysis evidenced a dominance of burrowing deposit feeding worms (Paraonidae and Cossuridae) in trawled areas, as a result of increased mechanical alteration and hence more organic matter available as food. In contrast, the response to trawling as drawn by the use of trophic markers (i.e., stable isotopes) was less clear. While $\delta^{15}N$ of benthic taxa did not vary significantly between untrawled and trawled areas, $\delta^{13}C$ was higher in trawled areas possibly due to high sediment resuspension and consequent intense microbial activity. Mixing models confirmed higher reliance to a detritus-based food web for benthic organisms in the trawled areas. Standard Ellipse Areas (SEAc) as a measure of community niche width were slightly larger in trawled areas, likely due to higher generalism triggered by alteration/removal of the original benthic community.

1. Introduction

Macrobenthos responds rapidly to anthropic and natural stress and integrates long-term changes in environmental conditions (Gray et al., 2006 and references cited therein; Jennings et al., 2001; Pearson and Rosenberg, 1978). For this reason benthic assemblages, widely recognized as effective bioindicators of marine environment condition, are commonly used as a powerful tool to measure the impacts of contaminants, nutrient enrichment (e.g. in case of eutrophication) and other anthropogenic sources of disturbance (Abebe et al., 2004; Blanchard and Feder, 2003; Borja et al., 2000; Guidetti et al., 2000). Within European Union countries, the Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC) have promoted the monitoring of soft-bottom benthic fauna (Aguirrezabalaga and Ceberio, 2006; De Juan and Demestre, 2012; Todaro, 2002) in the frame of ecosystem-based fisheries management for the sustainable use of marine ecosystems (Muntadas et al., 2014).

Although progresses have been made, many challenges remain to be addressed in order to understand how the macrobenthic fauna responds to various human pressures and to develop reliable

* Corresponding author.
E-mail address: emanuela.fanelli@enea.it (E. Fanelli).

http://dx.doi.org/10.1016/j.marenvres.2016.10.002
0141-1136/

methods to assess impacts at sea. This is the case of bottom-towed fishing gears, which cause direct and indirect impacts on benthic ecosystems (Jennings and Kaiser, 1998; Kaiser et al., 2006). Among such gears, bottom trawls mechanically disturb and alter the benthic habitats, remove, injure, or kill a wide range of benthic organisms, and reduce benthic production, thereby leading to a substantial effects on the structure and functioning of benthic ecosystems (de Groot, 1984; De Juan et al., 2011; Jennings et al., 2001; Kaiser et al., 2006; Muntadas et al., 2014). Indeed, trawling may have profound effects not only on the abundance and spatial distribution of benthic communities, but also on their trophic structure and function (Jennings et al., 2001).

Trawl exclusions have been widely used as fisheries management tools over soft bottoms, with significant effects on the biomass of demersal fish populations inside marine managed areas (Goñi et al., 2011). Their effect on commercial fisheries in adjacent fishing grounds (presumably through spillover and/or larval export) is much less clear though, although it has sometimes been observed especially in temperate seas (Goñi et al., 2011; Murawski et al., 2005). In the Mediterranean trawling bans have proved successful in fish stock rebuilding initiatives and as a resolution tool in disputes between conflicting fishery segments (Pipitone et al., 2014; Whitmarsh et al., 2003). Trawl exclusion zones provide also physical protection to benthic communities and habitats from the impact of fishing. Although they proved to have restorative effects on the trophic functioning of benthic communities (Mumby et al., 2006), our knowledge of their effects remains limited, especially with respect to ecosystems (De Juan and Demestre, 2012; Mangano et al., 2014a).

In 1990 two no-trawl areas were established in the gulfs of Castellammare and Patti (northern Sicily, Western Mediterranean) in order to rebuild the locally depleted demersal fish stocks (Pipitone et al., 2000). A huge fish stock rebuilding process has been recorded in the former gulf (Pipitone et al., 2014) and, less strongly also in the latter (Potoschi et al., 1995; Rinelli et al., 2004). These no-trawl areas provided an opportunity to study and analyze the benthic assemblages released from the impacts of trawling and consequently exposed to higher predatory pressure from increased fish density.

The aim of this paper is to quantify the effect of different fishing regimes on the assemblage and food web structure of soft-bottom benthic communities off the coast of northern Sicily fifteen years after a trawl ban implementation. For this purpose, the no-trawl gulfs of Castellammare and Patti were contrasted against two trawled areas located along the same coast (the gulfs of Termini Imerese and of Sant'Agata) where trawl fishing is intensely practiced. Thus, two untrawled and two trawled areas have been considered in an attempt to avoid confounding conclusions due to patterns of variability observed e.g. in experiments where a single protected area is compared to one adjacent unprotected area (Lindegarth et al., 2000). Further, considering that Mangano et al. (2014b) found different trawl fishing effort within the same gulfs based on Vessel Monitoring System (VMS) data analysis, three equal-surface sectors (two lateral and one central) for each location were also considered. This assumption is furthermore justified by the similar morphology of the four gulfs with soft bottoms in their central part and steeper rocky bottoms at the outer ends.

The specific objective of this study was to assess the effect of trawling on soft-bottom macrobenthic taxa using different variables. Specifically we tested the hypothesis that 1) abundance, biomass and P/B ratio; 2) assemblage structure and α- and β-diversity; 3) trophic level and source of carbon and 4) community metrics and isotopic (interpreted as trophic) niche, would differ between trawled and untrawled gulfs. For each of these variables we made specific predictions, in particular we expect:

1) higher macrobenthic abundance and biomass in trawled areas because, although physically impacted by trawling, these areas face a lower predation rate due to lower fish biomass;
2) a more homogeneous and complex assemblage structure (Lindegarth et al., 2000) in untrawled areas with lower α- and higher β-diversity in trawled areas because of habitat simplification (α-diversity), and because the variability among benthic samples (β-diversity) is generally higher in more impacted areas (Warwick and Clarke, 1993);
3) lower trophic level of the benthic community in trawled areas because species at lower trophic levels are less impacted by trawling (Jennings et al., 2001) and higher $\delta^{13}C$ in the trawled areas, due to larger sediment resuspension and cycling of more refractory organic matter (Fanelli et al., 2011a; Pusceddu et al., 2014);
4) a wider isotopic niche in trawled areas due to greater generalism (Fanelli et al., 2010) caused by alteration/removal of the original benthic communities and higher dependence of benthic organisms on the detritus-based food web.

2. Materials and methods

2.1. Study area

The study was carried out in four areas off the coast of northern Sicily, two untrawled (Gulf of Castellammare, GCAST, 38°04′N, 12°56′E; Gulf of Patti, GPATT, 38°10′N, 15°06′E), and two trawled (Gulf of Termini Imerese, GTERM, 38°02′N, 13°46′E; Gulf of Sant'Agata, GSANT, 38°04′N, 14°20′E) (Fig. 1). GCAST and GPATT are fishery exclusion zones where trawling has been banned since 1990 on the continental shelf and the upper slope under Regional Act 25/1990 (200 and 242 km^2 no-trawl area, respectively). The fishing activity inside these gulfs is restricted to artisanal fishing that extends over the continental shelf and upper slope and includes mainly static gears and small purse seines.

GTERM and GSANT are characterized by a medium-large trawling fleet resulting in an intensive multispecies demersal fishery (target species: Mediterranean hake, red mullet, anglerfishes, red and pink shrimps, cephalopods), and by an artisanal fleet (Mangano et al., 2014a). In these two gulfs trawl fishing is allowed at >50 m depth. Since VMS data were not available at the time of sampling we have used an index of fishing intensity in 2009 based on the number of times each 1 km^2 cell is fished each year (Mangano et al., 2014a) as a proxy of fishing intensity in 2005. This index varied between 0.032 and 0.367 in GSANT and corresponded to a low fishing intensity, while GTERM exhibited a higher trawling effort, with average values ranging between 0.136 and 0.691 (Mangano et al., 2014b).

All the gulfs are characterized by soft bottoms in their central part and by steep rocky shores and bottoms - excluded from the studied area - at the outer ends, presenting similar environmental characteristics at the time of sampling (Fanelli et al., 2011a). Sediment grain size (Table 1) was homogeneous and did not show significant differences among areas (ANOVA tests for all variables, $p > 0.05$). Further, chlorophyll *a* concentration at surface, used as a proxy of primary production and several variables measured in the particulate organic matter in sediments (i.e., chlorophyll *a*, phaeopigments, lipids, carbohydrates, proteins equivalent carbon, the proteins/total carbohydrates and the biopolymeric fraction of sedimentary carbon) all used as indicators of the quality and bioavailability of organic matter, were similar among gulfs (Fanelli et al., 2011a).