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The onset of fish colonization in a coastal defence structure (Chioggia, Northern Adriatic Sea)

M. Pizzolon, E. Cenci, C. Mazzoldi*

Department of Biology, University of Padova, Via U. Bassi 58/B, 35131 Padova, Italy

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Abstract

Coastal defence structures constitute the most extensive hard substrates of the Northwestern Adriatic Sea and are known to sustain rich benthic and nektonic communities. To appreciate the pattern of colonization, we studied the fish assemblage of a recently deployed breakwater. We compared observations from two years, the different sides (landward and seaward) of the barrier, and the two fringes, characterized by timing of work completion. The results indicate that colonization, still in process, follows different patterns among species. Benthic and necto-benthic species presented a striking increase in abundance and richness in the second year of colonization, while more mobile species did not evince any variation between years. Differences in mobility among species suggest that the latter group may have reached the breakwater from nearby artificial substrates, whereas the former colonized the new structure as recruits. In addition, fish assemblages differed between the two sides, likely due to variation in the environmental characteristics, and according to depth, reflecting species preferences.
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1. Introduction

Coastal erosion causing flooding and the retreat of cliffs, beaches and dunes, is one of the major factors affecting the integrity of littoral areas (National Institute for Coastal and Marine Management of the Netherlands, 2004; Airoldi et al., 2005a). To provide protection against erosion, an increasing number of defence structures have been built along coastlines in recent years, especially in Europe (National Institute for Coastal and Marine Management of the Netherlands, 2004). These structures, deployed at varying distances from the coast and from other offshore barriers, consist of hard substrates, completely submerged or presenting a more or less pronounced emergent crest, and are often deployed in a composite system of breakwaters, that are constructed usually at some distance from the coast, and groynes, that run perpendicular to the shoreline (Lamberti et al., 2005). The structural characteristics of these defence systems may have an effect on both the morphology of the adjacent native seabed (Martin et al., 2005; Zyserman et al., 2005) and the communities inhabiting the area (Martin et al., 2005; Airoldi et al., 2005a; Pérez-Ruzafa et al., 2006). However, the ecological implications of artificial structure deployment are just beginning to be investigated (Bulleri and Airoldi, 2005; Martin et al., 2005; Moschella et al., 2005; Airoldi et al., 2005a; Pérez-Ruzafa et al., 2006), and have been mainly focused on their benthic communities (Bacchiocchi and Airoldi, 2003; Moschella et al., 2005; Airoldi et al., 2005a,b), whereas information on their fish communities remains limited (Pérez-Ruzafa et al., 2006; Santin and Willis, 2007). Nevertheless, processes occurring along defence structures, built specifically for coastal defence, are similar from those occurring on other well studied artificial substrates, from pier pilings, pontoons, seawalls, to offshore structures, such as pilings of oil and gas platform, to the artificial reefs specifically deployed for scientific investigations or for conservation purposes (i.e. Connell and Glasby, 1999; Fabi et al., 2002; Atilla et al., 2003; Love et al., 2006; Perkol-Finkel et al., 2006; Rule and Smith,

* Corresponding author.
E-mail addresses: matteo.pizzolon@unipd.it (M. Pizzolon), elisacenci@hotmail.it (E. Cenci), carlotta.mazzoldi@unipd.it (C. Mazzoldi).

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2007). Considering the ichthyofauna, fish assemblages have been studied in relation to habitat complexity and characteristics (Brotto and Arauj, 2001; Charbonnel et al., 2002; Sherman et al., 2002; Zalmon et al., 2002; Jan et al., 2003; Lingo and Szedlmayer, 2006), isolation (Belmaker et al., 2005; Santos et al., 2005), algal and epibenthic cover (Ruitton et al., 2000; Coleman and Connell, 2001), and in relation to the type of substrate (Carr and Hixon, 1997; Overholtzer-McLeod, 2004; Thanner et al., 2006). In general, artificial reefs, usually deployed for conservation purposes (Jensen, 2002; Miller, 2002), seem to have positive effects in attracting and/or producing fish, and also limit the damage caused by bottom trawling, physically impeding this fishing activity in specific areas (Carr and Hixon, 1997; Pondella et al., 2002; Stephens and Pondella, 2002; Powers et al., 2003). Similar to artificial reefs, the structures deployed for coastal defence, often constituting the only hard substrate in an area, offer a colonization opportunity for an otherwise absent hard-bottom species (Airoldi et al., 2005a), and provide both refuge and food, which may attract individuals of different species from nearby substrates and predators (Herrera et al., 2002), increasing the number of local species (Coll et al., 1998; Powers et al., 2003). In addition, these structures might function as producers if some species use them for recruitment, growth and/or reproduction (Coll et al., 1998; Powers et al., 2003), and if the presence of the new substrate actually increases the total rate of these processes in the area (Carr and Hixon, 1997; Stephens and Pondella, 2002).

The period immediately following the deployment of a new structure constitutes a unique opportunity to follow colonization processes, monitoring changes in the composition of fish assemblages. This study aimed to highlight the temporal and spatial colonization pattern of a breakwater recently deployed close to other artificial structures. With this goal, we compared fish assemblages: (a) between two consecutive years (the years immediately following deployment of the structure); (b) between the two sides of the breakwater (seaward and landward), presenting different distances from other artificial reefs nearby; and, only in the second year (c) between two different positions (the northern and southern fringes) within the breakwater; and (d) among three different depths (shallow: 1.5–2 m deep, intermediate: 4.5–5 m deep, and deep: 8–10 m deep). The first comparison aimed to assess if the colonization process was still in progress and which species were presenting variations in abundance between years. The aim of the comparison between sides was to detail the colonization pattern. Indeed, if colonization involves individuals coming from nearby artificial reefs, we would expect to find greater abundance/richness on the side closer to those reefs. Northern and southern positions within the breakwater were compared because building works lasted longer on the southern end (including throughout the first year of observations), so we expected to find differences in fish assemblages between the two positions due to a delay in the colonization process and/or disturbance related to the works on the southern fringe. Differences in terms of depth were analysed, in the second year, to provide a more comprehensive overview of fish assemblage.

2. Materials and methods

2.1. Study site

The study site is a breakwater located approximately 400 m off the southern jetty of the southern channel connecting the Venetian Lagoon to the Adriatic Sea (Fig. 1). This structure is a complementary component of the project known as Mo.S.E. (Modulo Sperimentale Elettromeccanico), a system of mobile gates aimed at reducing the acqua alta phenomena in the Venetian Lagoon. In particular, this breakwater was designed to increase friction, thereby abating the intensity of the tidal current at inlets and attenuating the levels of the highest tides. It was built between September 2003 and March 2006, is crescent shaped and 522 m long. Its crest is 2.5 m above the mean water level. This breakwater reaches its maximum depth of 11 m on its eastern (seaward) side and 8.5 m on the western (landward) one. From its crest to a depth of 3 m below the surface, the barrier consists of artificial cement acropods. Natural stone blocks, larger than 1 m in diameter, complete the bottom part of the breakwater. The combination of these two components, differing in both shape and material, gives rise to a habitat presenting large sheltered caves over its entire depth range, and small holes, very common in the deeper stone blocks. The muddy–sandy seabed, typical of the Northwestern Adriatic Sea, surrounds the breakwater on the bottom. Three large natural waterways, the Brenta, Adige and Po rivers, flow into the sea from the southern end of the Venetian Lagoon and the breakwater with the jetty of Sottomarina constitute the first barrier encountered by their waters.

2.2. Sampling design and timing

Fish surveys were carried out between 7 July and 13 October 2005 and between 29 June and 30 August 2006. As few individuals/species are visible at low water temperatures, because they hide in holes or crevices, and/or migrate to deeper, warmer waters, depending on mobility (Sayer et al., 1994; Guidetti et al., 2005), we chose to undertake observations during these warmer months. The experimental design included four factors (Fig. 1C): (1) year, with two levels: (a) 2005; and (b) 2006; (2) position, with two levels: (a) north, and (b) south; (3) side, with two levels: (a) seaward (eastern side of the breakwater); and (b) landward (western side of the breakwater); and (4) depth, with three levels: (a) shallow (about 1.5–2 m deep), (b) intermediate (4.5–5 m deep), and (c) deep (8–10 m deep, corresponding to the deepest section of the breakwater, close to the soft bottom). All factors were fixed and orthogonal (Underwood, 1997): year: the two years correspond to the first and second years immediately following deployment; position: the breakwater presents only two positions; side: the breakwater presents only two sides; and depth: three discrete depth ranges were selected. Position was included as a factor only in 2006, when the building works on the southern fringe were completed. Only the northern positions were surveyed in 2005. Four replicates per side and depth were performed in 2005, and four replicates per side, depth and position were performed in 2006, for a total of 72 transects.

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