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Benthic assemblages on artificial reefs in the northwestern Adriatic Sea: Does structure type and age matter?

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A B S T R A C T

The use of artificial reefs is on the rise worldwide. While their fish aggregating effects are well known, the epibenthic assemblages have been poorly investigated. Two types of artificial reefs (pyramids of concrete slabs and bundles of concrete tubes) have been deployed out of the Po River Delta in 2006 and 2010. The epibenthic assemblages were investigated in 2009 and 2012. Benthic assemblages on both structure typologies were dominated by species tolerating high sedimentation rates. Dissimilarities were found among assemblages with different ages, and, in less extend, between reef typologies. Colonisation by *Mytilus galloprovincialis* and other major space occupiers did not follow a clear succession pattern and was not affected by reef typology. Species colonisation was likely driven by variability in environmental conditions and recruitment processes rather than by reef typology. This study suggests that environmental features of the deployment sites should be carefully considered in planning and designing artificial reefs, especially in eutrophic and turbid coastal waters, exposed to high river loads.

1. Introduction

Artificial reefs (ARs) are manmade structures deployed on sea bottoms with the primary purpose of protecting coastal habitats and increasing biotic resources by aggregating marine species and preventing trawling (Baine, 2001). ARs support sessile filter feeders, providing nourishment and refuges for motile species, and attracting bentho-nectonic fishes (Bohnsack and Sutherland, 1985; Baine, 2001). Since the mid-1800s, ARs were deployed in many regions of the world, including tropical and temperate areas, starting with the United States of America and Japan (Bohnsack and Sutherland, 1985). The materials used in their construction include natural rocks, concrete blocks and several discarded supplies, like tires, pipes, shells, barges, bundled solid waste, coal ash, vehicles, etc. (Feary et al., 2011). The first ARs along European coasts were installed in the 1960s, most structures have been located in the Mediterranean Sea. Since this time more than 70 AR complexes, made by different materials, have been deployed along Italian coasts (Fabi et al., 2011). Traditionally, in the oligotrophic waters of the western Mediterranean Sea, the goals of ARs were to protect *Posidonia oceanica* meadows from illegal trawling, to increase habitat complexity and promote higher species diversity (Relini et al., 1994; Riggio et al., 2000; Gonzalez-Correa et al., 2005). Conversely, in the eutrophic waters of the central and northern Adriatic Sea, the main purpose was to increase fishery yields (Bombace et al., 1994; Ardizzone et al., 1996; Bombace et al., 1997).

Regardless of the potential benefits of ARs, their increasing frequency worldwide has given rise to concerns regarding their possible negative impacts, especially the dumping of waste and the use of unsuitable materials. In response to these threats as well as international conventions addressing the issue, some regulations, guidelines and protocols have been drawn up (e.g. London Convention and Protocol/UNEP, 2009; for an overview see Fabi et al., 2011). As a result, most recently deployed subtidal artificial habitats have been designed for specific purposes. Concrete is the

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most common material, because it is cheap, versatile, allowing the realization of structures with different shapes and sizes, and may ensure long life, being resistant to the chemical and physical marine actions (Fabi et al., 2011). Physical properties of the concrete vary according to the reinforcements and additives included in the cement mixture. Several natural and synthetic admixtures are used as hardening accelerators and retarders, corrosion inhibitors, etc. Besides improving concrete properties, the choice of additives is dictated by economic and environmental considerations, including the reduction of greenhouse gas emissions and recycling of wastes. Unfortunately, manufacturers often do not make available the compositions and properties of the concrete products or the possible interactions with living organisms (e.g. patents: EP0134855 B1, EP1193348 B1, WO2014125493 A1).

The choice of the type of artificial structures and their placement should always take into account the expected, as well as possible undesired effects on coastal habitats. While fish aggregating effects of ARs are well known and the effectiveness of different structure typologies in this respect are well documented (Santos et al., 1997), much less attention has been dedicated to the benthic assemblages colonising the structures, despite the impact they may have on costal habitats, and the possible implications on ecosystem functioning, e.g. changes in species composition, species interactions and food webs (Ambrose and Anderson, 1990; Bertasi et al., 2007; Gallaway et al., 2009), alteration of population connectivity and genetic diversity (Cowen and Sponaugle, 2009; Fauvelot et al., 2009), facilitation of the spread of non-indigenous species (Airoldi et al., 2005; Bulleri and Airoldi, 2005; Glasby et al., 2007). Vagile and sessile species colonise ARs according to complex ecological processes affected by seasonal larval supply, water circulation, turbidity and nutrients, depths, orientation and physical–chemical features of the substrata (Anderson and Underwood, 1994; Relini et al., 1994; Riggio et al., 2000; Turner and Todd, 1993). Moreover, the interaction of abiotic and biotic factors may operate at different temporal and spatial scales (Glasby, 1998; Rodriguez et al., 1993). Water quality (e.g.: oligotrophic *vs.* eutrophic, clear *vs.* turbid) is considered a relevant factor in structuring benthic assemblages, as resulted by comparing ARs deployed in different locations at similar depths (Maughan, 2001; Relini et al., 1994; Riggio et al., 2000). Whereas within the same site and/or in very similar environmental conditions, materials (Anderson and Underwood, 1994; Glasby, 2000; Reyes and Yap, 2001), shapes (Bourget et al., 1994), orientation (Baynes, 1999; Genzano et al., 2011; Glasby and Connell, 2001; Ponti et al., 2002), shading and proximity to the seafloor (Glasby, 1999) are the main factors affecting the structure of benthic assemblages.

Since 2001, thanks to regional and European funds, experimental concrete AR complexes have been deployed on sandy and muddy bottoms along the western Adriatic coasts (Spagnolo et al., 2014). The aim of the present study was to analyse variability of macrobenthic assemblages in relation to the typology and age of ARs deployed off the Po River Delta (northern Adriatic Sea). Benthic assemblages on two types of artificial reefs, pyramids of slabs (Tecnoreef®, hereafter TR) and bundles of tubes (hereafter BT), differing in shape, concrete chemical composition, and age, were compared.

2. Materials and methods

2.1. Artificial reefs typologies and study site

Two types of ARs have been investigated (Fig. 1): pyramids made of concrete slabs (TR – declared "sea-friendly" by the producer, Tecnoreef®, manufactured using only natural components, without synthetic additives; pH ~9; 1.8 and 2.4 m height); and bundles of common concrete tubes, BT, assembled in cubes laid on a concrete slab and retained by an iron cage (pH ~12; 1.8 m height). Despite similar size and surface rugosity, the two reef typologies differed in shape, surface inclination and material (e.g. type of concrete and pH). The ARs were deployed in 2 times: November 2006 (hereafter AR1) and March 2010 (hereafter AR2), 2 nautical miles offshore of the Po River Delta (northwestern Adriatic Sea, 44° 54′ N 12° 33′ E), at 13–14 m depth and close to a longline mussel farm (Fig. 2). In AR1, TR pyramids and BT structures were arranged in two adjacent areas (100 × 200 m and 100 × 120 m) separated by 50 m. AR2 has a nucleus (100 × 200 m) of TR pyramids surrounded by BT structures deployed along the perimeter. TR pyramids deployed in AR2 differed from AR1 only by the smaller holes, strengthening the structures, which in AR1 was already damaged after two years.

ARs have been deployed on a muddy bottom (silt > 75%) in an area affected by high freshwater and sediment inputs from the Po River, which has a mean flow of 1500 $m^3\ s^{-1}$ (period 1918–2006), with higher values in spring and autumn (Fig. 3). The combination of the thermohaline circulation and tide (up to 1 m) often results in strong currents. Frequently, water turbidity (mean Secchi disk 1.5 m) reduces penetration of solar radiation, while the superficial halocline and seasonal thermocline cause sharp stratification of the water column (Table 1). Moreover, effluents from the Po River are rich in nutrients, favouring growth of plankton (Aubry et al., 2012).

2.2. Sampling design and laboratory analyses

With the aim to test for differences in benthic communities related to reef typology (TR *vs.* BT) and age (AR1 *vs.* AR2), macrobenthic assemblages were investigated in June 2009 on AR1 (~2.6 yrs after deployment; Fig. 3) and June 2012, both on AR1 and

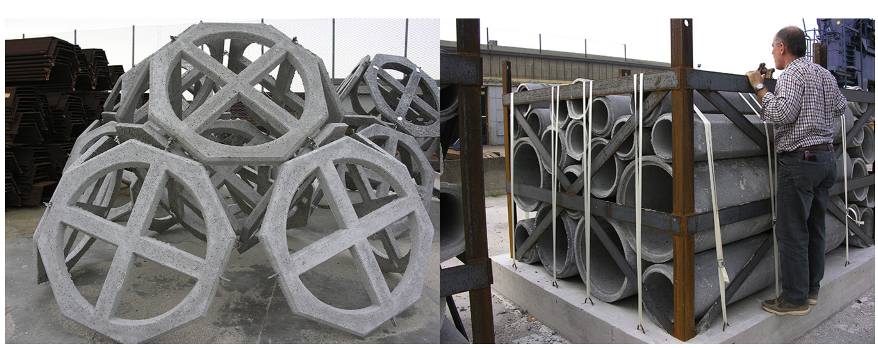

Fig. 1. Example of ARs structures deployed: pyramids of slabs (2 floors, 1.8 m height), assembled with slabs of 'sea-friendly' concrete (Tecnoreef®), on the left and bundles of tubes, made by common concrete, laid on a concrete slab and retained by an iron cage (1.8 m height, on the right).