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Impact of a harbour construction on the benthic community of two shallow marine caves

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ABSTRACT

Marine caves are unique and vulnerable habitats, threatened by multiple global and local disturbances. Whilst the effects of climate change on marine caves have already been investigated, no information exists about the effects of local human impacts, such as coastal development, on these habitats. This study investigated the impact of the construction of a touristic harbour on two shallow underwater marine caves in the Ligurian Sea (NW Mediterranean). As a standard methodology for monitoring marine caves does not exist yet, changes over time on the benthic community were assessed adopting two different non-taxonomic descriptors: trophic guilds and growth forms. Harbour construction caused an increase of sediment load within the caves, with a consequent decline of filter feeder organisms. Abundance of small organisms, such as encrusting and flattened sponges, was greatly reduced in comparison to organisms with larger and erect growth forms, such as domed mounds and pedunculated sponges. Our study indicated that growth forms and trophic guilds are effective descriptors for evaluating changes over time in marine caves, and could be easily standardised and applied in monitoring plans. In addition, as the harbour construction impacted differently according to the cave topography, the use of a systematic sampling in different zones of an underwater cave is recommended.

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1. Introduction

Marine caves are unique and vulnerable ecosystems (Sarà, 1976) listed in the EU Habitat Directive 92/43/EEC (habitat type 8330) and in the Barcelona Convention (UNEP-MAP-RAC/SPA, 2008; Giakoumi et al., 2013). However, marine caves are not included in the list of those priority habitats needing special conservation efforts. The importance of marine caves is linked to their role in maintaining a high biodiversity along coastal zones (Todaro et al., 2006; Bussotti and Guidetti, 2009; Fraschetti et al., 2009), due to their ecological connection (both trophic and at the population level) with other communities of coastal habitats, such as coralligenous and rocky reefs, seagrass beds and sandy bottoms (Harmelin et al., 2003). They also exhibit a connection with the pelagic system, due to water movement, which brings food and propagules into caves (Rastorgueff et al., 2015). Marine caves constitute a naturally fragmented habitat, which can act as a refuge or ecological island (Rastorgueff et al., 2015, and reference therein) and often possess an astonishing ecological and faunal affinity with the deep sea (Boury-Esnault et al., 1993; Bianchi et al., 1996; Janssen et al., 2013). Submerged or semi-submerged marine caves are widely distributed along coastal areas (Rastorgueff et al., 2015), and about 66% of the Mediterranean marine protected areas include marine caves (Abdulla et al., 2008).

Several motile organisms, such as crustaceans, molluscs and coastal fishes, can be found inside marine caves (Harmelin et al., 1985; Bussotti and Guidetti, 2009; Bussotti et al., 2015), but the most peculiar resident community is represented by benthic sessile invertebrates such as sponges, ascidians, bryozoans, cnidarians, serpulids and brachiopods (Bianchi, 2003). Distribution of these sessile invertebrates within marine caves is dictated by gradients of light and water movement, and vary in terms of species composition, dominance and abundance according to the cave topography (Riedl, 1966; Morri and Bianchi, 2003; Gerovasileiou and Voultsiadou, 2015). For instance, in a blind-end (cul-de-sac) cave with linear topography, the gradients develop regularly along the exterior–interior axis, conforming to the classical zonation scheme: the first zone, at the cave entrance, is dominated by encrusting algae; inside the cave, a second zone is characterized by passive filter feeders; finally, in the terminal zones of the cave only active filter feeders remain (Balduzzi et al., 1989; Morri and Bianchi, 2003). In tunnel-shaped caves or in cavities showing different topographies the zonation of communities becomes more complex and may be influenced also by other factors (Parravicini et al., 2010).

Coastal ecosystems are changing under the pressure of global impacts, such as climate warming and ocean acidification (Bianchi et al., 2014; Rodrigues et al., 2015, and references therein). Global impacts may act in a simultaneous way (at the same time) or in an additive

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way (one after the other) with local impacts such as urbanization, coastal development and overfishing (Airoldi et al., 2005; Rossi, 2013; Piggott et al., 2015). Different studies showed the effects of climate change on marine caves (Chevaldonné and Lejeusne, 2003; Parravicini et al., 2010; Gerovasileiou and Voultsiadou, 2012). However, available information about the effects of local impacts on marine caves only focused on unregulated underwater activities (Di Franco et al., 2010; Guarnieri et al., 2012), whilst no information exist on the effects of coastal constructions on these habitats. This lack of information may represent a serious problem in the view of a correct environmental management (Price et al., 2014). Coastal constructions may cause increase of sediment loads and water turbidity (Davenport and Davenport, 2006; Anfuso et al., 2011), which are likely to cause a decline in filter feeders organisms (e.g. sponges), whose filter-feeding apparatus may get clogged by sediments (Bell et al., 2015). Additionally, a coastal construction may alter the hydrodynamic regime and local currents of an area (Anfuso et al., 2011; Ferrari et al., 2014). Variations in the regime of marine currents may change the natural gradients of light penetration and water movement in an underwater cave, i.e. of the two most important factors responsible for the particular environment and for the biological zonation inside the caves (Bianchi and Morri, 1994; Corriero et al., 2000; Martì et al., 2004).

This paper represents the first attempt to investigate the effects of a tourist harbour construction on two underwater marine caves. In order to assess changes over time of the benthic community, two different non-taxonomic descriptors were used, i.e. trophic guilds and growth forms (Parravicini et al., 2010). The former provide information about trophic organization (which depends on light penetration and particulate matter availability), the latter on the degree of ecological confinement (an expression of water exchange and cave topography).

2. Materials and methods

2.1. Study area

The two marine caves are located near Ventimiglia, a town in Western Liguria, Italy (Fig. 1a). The largest cave is named Grotta Grande (Fig. 1b): it is a semi-submerged marine cave, facing NE, with the entrance at 4 m depth and the terminal part of the cavity at 2.5 m depth with respect to the mean sea level. The cave topography shows an internal subdivision in two sectors after a linear distance of 15 m from the entrance: the western sector continues for about 15 m within the coastal conglomerate, whilst the eastern sector terminates after about 6 m. The zone of the cave near the entrance has a pebble bottom, whereas,

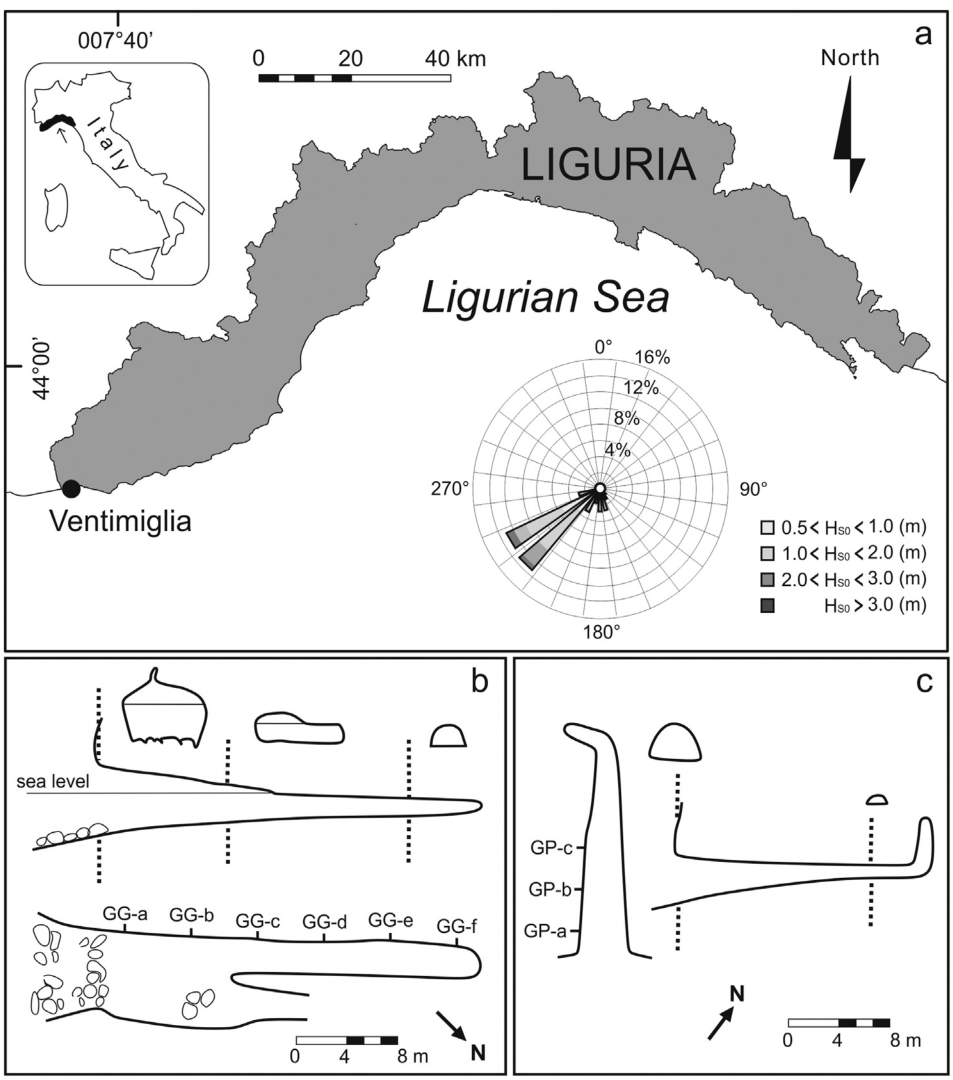

Fig. 1. Geographic location of the study area with the relative annual wave climate (data from Corsini et al., 2006, modified). H_{S0} is the mean annual significant offshore wave height (m) recorded by the La Spezia buoy (43°55′41.99″N; 09°49′36.01″E) (a); topography of the Grotta Grande (b) and of the Grotta Piccola (c), redrawn from "Catasto delle Grotte della Liguria DSL/SSI" and with the position of the sampling stations (GG-a to GG-f in the Grotta Grande, GP-a to GP-c in the Grotta Piccola).

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