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Scuba diving damage on coralligenous builders: Bryozoan species as an indicator of stress

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ABSTRACT

The effects of scuba diving activities on coralligenous concretions builders in the Mediterranean Sea are reported for a non-marine protected area (non-MPA). Five erect bryozoan species, which are particularly vulnerable due to their fragile structure, were investigated: *Adeonella calveti*, *Myriapora truncata*, *Pentapora fascialis*, *Reteporella grimaldii*, and *Smittina cervicornis*. These species were sampled at frequently and rarely visited diving sites to the maximum depths reachable with the most common recreational diving certifications (i.e., 40 m). To do this, a non-destructive photographic sampling technique was used to minimize any impact on the benthic communities. For each sample, the number of colonies, their width, coverage, type of injury and degree of exposure were quantified using image analysis software. The number of species differed between the frequently and rarely visited diving sites, and frequently visited sites had significantly lower number of colonies and reduced colony width. Species-specific response to stress was associated with colony morphology and skeleton rigidity. Both the type of injury and colony position within the coralligenous habitat were affected by the presence of scuba divers. A linear model was proposed to analyse the response of bryozoans to scuba diving pressure. The results reported here suggest that *P. fascialis* and *R. grimaldii* could serve as robust species indicators of diving stress.

1. Introduction

Coralligenous reef formations are considered, in terms of biodiversity, as the second benthic habitat in the Mediterranean Sea after the *Posidonia oceanica* meadows (Boudouresque, 2004). The coralligenous frame is produced primarily by the accumulation of calcareous algae growing in dim light conditions, and secondarily by bio-constructor animals that help develop and consolidate the framework created by the calcareous algae. Several bryozoans, polychaetes (serpulids), corals, and sponges characterize this category (Ballesteros, 2006). Bryozoans in particular are very abundant on coralligenous assemblages where they constitute the most important group among secondary builders. The accretion of their skeleton parts (both of encrusting and erect species) contributes to the growth of the coralligenous framework (Novosel et al., 2004; Ballesteros, 2006).

Being both beautiful and colourful, the coralligenous habitat is among the most attractive seascapes, which coupled to its slow dynamics and longevity make it one of the habitats most exposed to human impacts (Ballesteros, 2006). Coralligenous habitat is included in the 'reefs' category by the Habitat Directive (HD, 92/43/EEC), and is therefore also automatically part of the Natura 2000 network (Council European Communities, 1992). As such, coralligenous habitat shall be monitored and assessed by the descriptors of Good Environmental Status (GES) following the Marine Strategy Framework Directive (MSFD, Directive 2008/56/EC). Under the Barcelona Convention for the conservation of Mediterranean biodiversity (1995), coralligenous reefs are among those habitats in urgent need of rigorous protection; however, the 'Action plan for the conservation of the coralligenous and other calcareous concretions in the Mediterranean Sea' (UNEP-MAP-RAC/SPA, 2008) was adopted 13 years later. Unfortunately, as underscored by Cànovas-Molina et al. (2016), the fragmented and uncoordinated geopolitics of the Mediterranean basin undermine the attainment of full knowledge and the development of common conservation measures for the threatened coralligenous habitat.

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Tourism has, since the last decade of the past century, become the main sector of the service industry in Italy where it has undergone a non-linear trend in growth. In particular, the majority of European travellers are attracted by coastal destinations, where more individual leisure time and prosperity together with the rising interest in the environment and wildlife (e.g., birds, whales and coral reefs) has fostered the development of several recreational activities, such as swimming, surfing, snorkelling, scuba diving and yachting (Davenport and Davenport, 2006). At the same time, largely out of concern, the scientific community has tried to assess if and how the tourism sector is sustainable (Buckley, 2012).

Among all the aforementioned activities, scuba diving is one of the most popular and fastest-growing pastimes in the world, with an increase of ca. 1 million of recreational diving licenses issued every year (Davis and Tisdell, 1995; Davenport and Davenport, 2006). Scuba divers, however, can influence both benthic assemblages and fish behaviour mainly via direct contact, sediment re-suspension and the emission of air bubbles (Kulbicki, 1998; Milazzo et al., 2002; Hasler and Ott, 2008). Studies investigating the effects of scuba diver activities have been carried out in various locations worldwide: the Red Sea (Zakai and Chadwick-Furman, 2002), the Caribbean Sea (Barker and Roberts, 2004), South Africa coasts (Walters and Samways, 2001), Australian coasts (Rouphael and Inglis, 2001; Rouphael and Inglis, 2002) and the Mediterranean Sea (Milazzo et al., 2002).

In the Mediterranean Sea the effects of scuba diving activities have been assessed mainly in Marine Protected Areas (MPA). In particular, Di Franco et al. (2009) recognized marine caves and coralligenous bottoms as habitats most frequented by scuba divers, and therefore as those also most vulnerable to impact and degradation. Focusing on coralligenous habitat, studies have reported diving impacts on reef builders or fragile organisms, such as gorgonians (Coma et al., 2004; Linares et al., 2010), bryozoans (Sala et al., 1996; Garrabou et al., 1998; Nuez-Hernández et al., 2014) and ascidians (Luna-Pérez et al., 2010).

In this present work we analysed the impact of scuba diving frequency on five erect bryozoans species that are very common in coralligenous habitat: *Adeonella calveti* (Canu and Bassler, 1930), *Myriapora truncata* (Pallas, 1766), *Pentapora fascialis* (Pallas, 1766), *Reteporella grimaldii* (Jullien, 1903) and *Smittina cervicornis* (Pallas, 1766). These species are recognized as threatened by human pressures due to their fragile structure (Rosso et al., 2010; Chimenz Gusso et al., 2014). Furthermore, these bryozoans were taken into account in the formulation of indices for coralligenous ecological status (Deter et al., 2012; Gatti et al., 2015). The aim of this work was to assess the sensitivity of bryozoans to impact from scuba diving. To do this, we quantified colony number, width, and percentage of injury, and degree of exposure of the five bryozoan species on coralligenous habitat using non-destructive sampling methods.

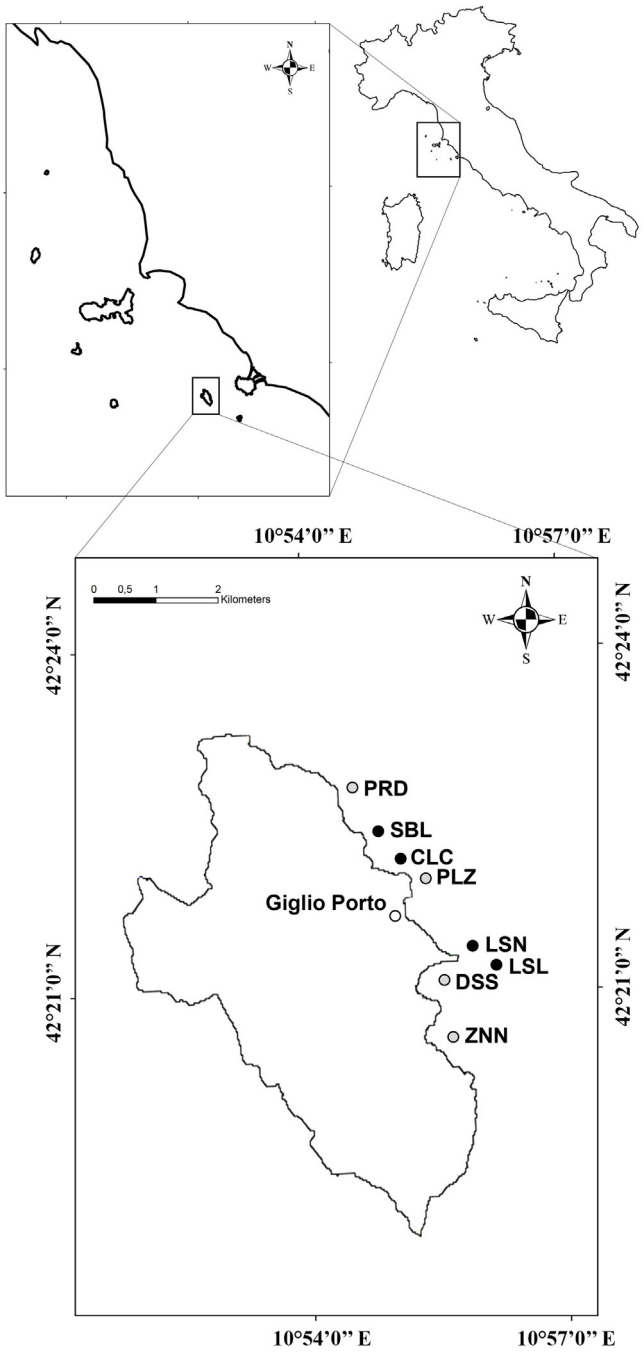

Fig. 1. The study area with the 8 sampling stations. DSS = Dissalatore; PLZ = Punta Lazzaretto; PRD = Punta Radice; ZNN = Zannea; CLC = Cala Cupa; SBL = Secca dei Subielli; LSS = Le Scole Sud; LSN = Le Scole Nord. Light grey dots indicate R (rare diving) stations, whereas black dots indicate F (frequent diving) stations.

2. Material and methods

2.1. Study area and data collection

This field study was carried out along the East coast of Giglio Island (Tuscany Archipelago, central Thyrrenian Sea) (Fig. 1). Although within the Tuscan Archipelago National Park (DPR 22/07/1996), the marine area surrounding Giglio Island is currently not under national environment protection. Due to its notable landscape and natural interest, Giglio Island is one of the most famous and frequented scuba diving spots of the central Italian peninsula. In terms of recreational diving activities, the eastern coast of Giglio Island is used much more than its western part; the former has a greater number of diving centres located in the town of Giglio Porto (four diving centres for ca. 1500 residents), and because it is closer to continental coasts, other diving operators, mostly from Tuscany and Latium, can visit Giglio's eastern coast using their private vessels.

To investigate the effects of scuba diving frequency on bryozoan populations, two depth zones were considered: 14–25 m (Shallow stations = "S") vs. 28.5–38.5 (Deep stations = "D").

We established a total of eight sampling stations in the study area, which were evenly split between two diving-use categories, defined as follows (Fig. 1; summarized in Table 1):

'Frequent' diving (F): diving sites used by local and non-local diving centres several times per week, amounting to >100 divers