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Bioerosive and bioprotective role of barnacles on rocky shores

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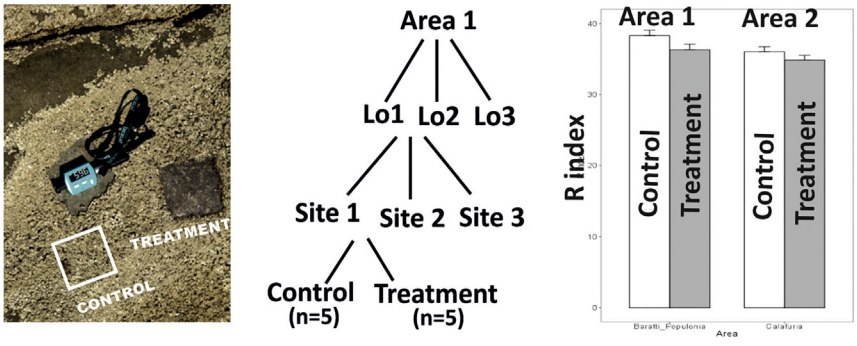
HIGHLIGHTS

- Previous works suggest the possible complex and spatially variable role of barnacles as bio-remodelers on rocky shores.
- The role of barnacles as bio-remodelers was investigated at different spatial scales along the rocky coast of NW Italy.
- An *in situ* manipulative experiment was carried out, based on a hierarchical spatial design and on rock hardness testing.
- Barnacles play a bioprotective role at sub-surficial level, consistent across different spatial scales.
- Barnacles can simultaneously act as bioeroders at surface level, likely fostering the dissolution of the carbonate rock.

GRAPHICAL ABSTRACT



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ABSTRACT

Bioerosion and bioprotection (bio-remodeling) is the action exerted by biota colonizing rocky shores. It represents an important component among processes responsible for shaping coastal landforms, and a clear evidence of interaction between the biosphere and the solid earth. Barnacles extensively colonize the midlittoral belt of rocky shores in the Mediterranean Basin. Previous research, mostly based on laboratory evidence, suggests that barnacles are bioprotectors, in that they protect the rock surface from different types of physical and chemical weathering. In this paper, we present the results of a field experiment carried out at different spatial scales at two study areas along the moderately energetic and microtidal coast of NW Italy. Barnacles were removed from the sandstone bedrock in replicated plots (manipulated plots) arranged according to a hierarchical spatial design. After four months rock hardness was tested on each plot with both Schmidt hammer and Equotip Piccolo devices, as well as on a corresponding number of control plots. Data were processed by means of a multifactorial analysis of variance (ANOVA). In control plots, rock hardness tested with Schmidt hammer exceeded that measured in previously manipulated plots. Testing with Equotip yielded the opposite results. This experimental evidence confirmed that barnacles play a bio-protective role in the midlittoral at sub-surficial level, while adding the key aspect that this effect is generalizable to spatial scales ranging from a few centimeters up to tens of kilometers. In addition, our results showed, for the first time, that at surface level they can simultaneously act as bioeroders, likely causing corrosion of the rock surface by fostering dissolution of the sandstone carbonate matrix.

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1. Introduction

Rocky shores evolve under different geomorphic processes that are driven both by marine and subaerial agents (Stephenson et al., 2013; Kennedy et al., 2014). A huge amount of work has been done in order to assess, rank and quantify the effect of such processes (Trenhaile, 1987; Sunamura, 1992; Naylor et al., 2010; Moses and Robinson, 2011; Naylor et al., 2014) and to relate their relative efficiency to the development of specific coastal landforms (Gomez-Pujol et al., 2006; Moura et al., 2006; Stephenson and Kirk, 2000a, 2000b; Kennedy et al., 2011; Ogawa et al., 2011; Feal-Perez and Blanco-Chao, 2013; Dickson et al., 2013; Trenhaile, 2015).

Among the most relevant processes acting on coastal rock surfaces are also those operated by the biota colonizing rocky shores (Spencer, 1992; Radtke et al., 1997; Viles, 1988; Kázmér and Taboroši, 2012; Naylor et al., 2012). We refer to bio-remodeling to indicate those actions exerted by marine and terrestrial biota on rocky shores (Pappalardo et al., 2016), and different from the contribution of physical and chemical weathering in shaping the coastline. Bio-remodeling includes bioerosion (Viles, 1988), i.e. the action of biological agents directly removing inorganic particles from the rock surface or weakening it, or indirectly fostering weathering processes, and bioprotection (Carter and Viles, 2005), i.e. the sheltering of rock surfaces directly exerted by biota and effective in preventing or retarding weathering processes.

A number of papers have examined the effect of grazing organisms, such as *Gastropoda* (limpets) and *Echinoidea* (sea urchins) (McLean, 1967; Torunski, 1979; Schneider and Torunski, 1987; Trudgill, 1987; Trudgill et al., 1987; Abensperg-Traun et al., 1990; Andrews and Williams, 2000; Gomez-Pujol et al., 2006; Fornòs et al., 2006; Naylor et al., 2012; Vidal et al., 2013), as well as the role of seaweeds (Morrison et al., 2009; Coombes et al., 2013a) and, in the mid and supra-littoral, biofilm (Coombes et al., 2011; Coombes and Naylor, 2012; Mayaud et al., 2014). Also the role of lichens has been investigated (Moses and Smith, 1993; Chen et al., 2000;Carter and Viles, 2003, 2004), but only in specific coastal areas (Gomez-Pujol et al., 2007; Pappalardo et al., 2016). Among the most controversial is the role of barnacles as bio-remodelers. These organisms have been traditionally considered bioprotectors, as they form physically protective crusts on the rock surface (Laborel and LaborelDeguen, 1996; Spencer and Viles, 2002; De Waele and Furlani, 2013). Their effect has been recently investigated through studies carried out along oceanic coasts (Naylor et al., 2012), as well as in the Mediterranean Sea, characterized by different wave, climate and tidal regimes (Pappalardo et al., 2016). Laboratory simulations have proved barnacles to play a bioprotective effect, as they reduce sub-surface temperatures in the rock (Coombes and Naylor, 2012; Coombes et al., 2017). However, preliminary field experiments showed a moderate, mostly indirect, bioerosive or neutral role of barnacle cover over coastal rocks (Pappalardo et al., 2016). The apparent contrasting effects observed under laboratory or field conditions emphasize the possible complex and spatially variable role of barnacles as bio-remodelers on rocky shores. Presence and abundance of barnacles, in fact, are influenced by the topography of the bedrock and

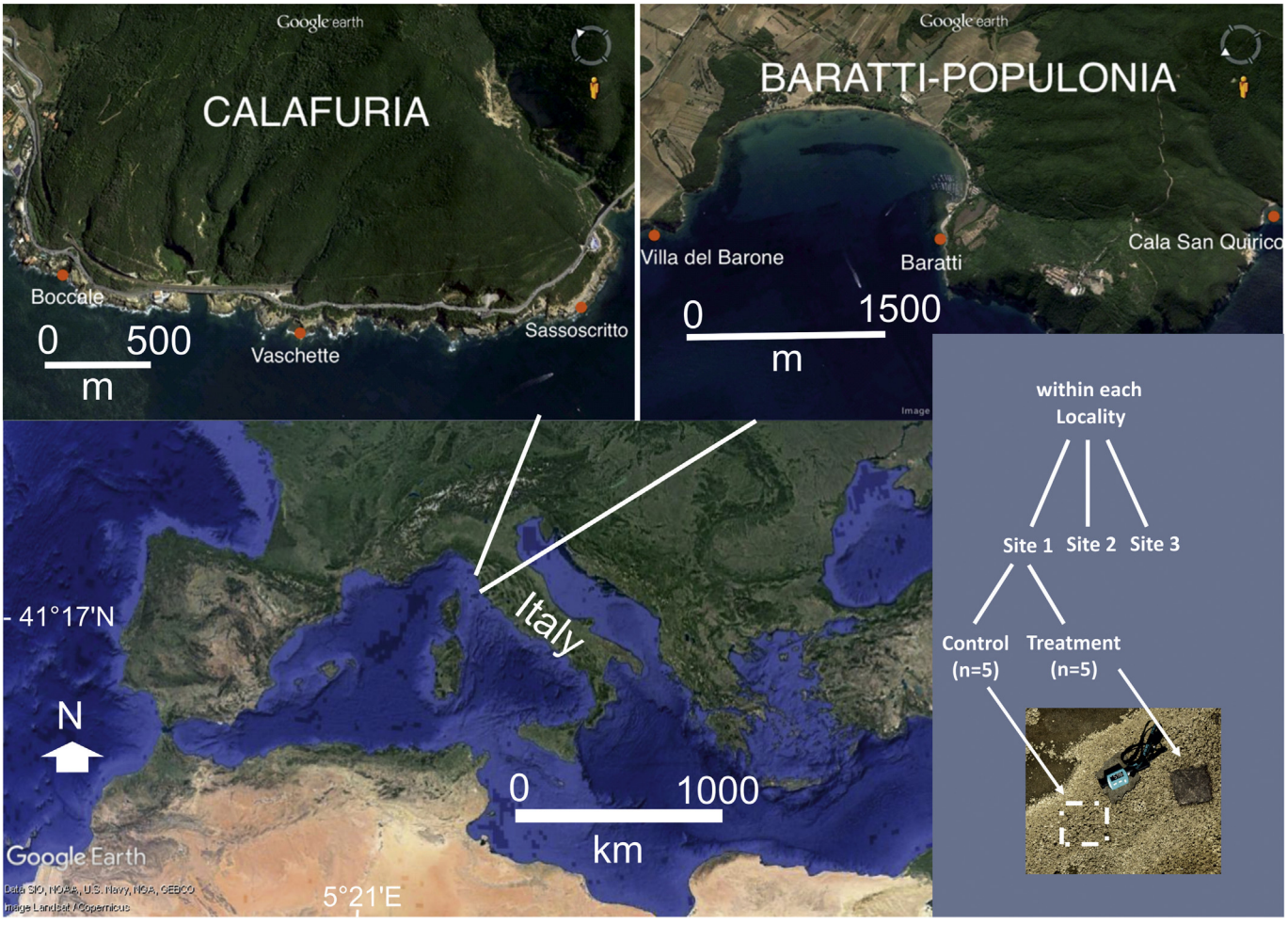

Fig. 1. Sketch map showing the location of the two study areas (Calafuria and Baratti-Populonia) along the NW coast of Italy, and of the three Localities identified within each area. In the frame, the experimental design applied within each Locality is shown, including three random Sites within each locality, in each of which five Treatment plots and five Control plots were included.