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Response of macroalgae and macroinvertebrates to anthropogenic disturbance gradients in rocky shores

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ABSTRACT

The compliance of macroalgal and macroinvertebrate assemblages to anthropogenic disturbance gradients (e.g., nutrient enrichment) was investigated at intertidal rocky shores. Macroalgae and macroinvertebrates presented parallel behavior, both showing shifts in the communities' structural variation along the gradients, in which an higher number of opportunistic species (and higher abundances) were found in more stressful sites (close to the disturbance source), in contrast to less disturbed sites (far from the disturbance source), which showed higher presence of more sensitive species (and higher abundance of several of them).

The macroinvertebrate abundance and taxonomic composition, which are parameters required by the Water Framework Directive (WFD) to be included in tools for the ecological quality status assessment, responded to the disturbance gradient. Results suggest that the macroinvertebrate biological element might be considered an indicator of disturbance in intertidal rocky shores as good as the macroalgae, and therefore the development of a specific methodology based solely on benthic macroinvertebrates of rocky shores, presently a gap in the ecological quality status assessment for the WFD, seems feasible.

1. Introduction

Rocky shores, similarly to many coastal systems, have been historically exposed to human pressures (e.g., wastewater discharges) (Mearns et al., 2014). Despite that, rocky shores are considered of great importance in marine ecosystems, providing valuable ecosystem services in terms of biological diversity, contribution to primary productivity, fisheries and tourism (Seitz et al., 2013).

In the last decade, the interest on coastal marine biological communities has increased, mainly concerning the classification of water bodies' quality status, which is an essential requirement in terms of the implementation of directives such as the Water Framework Directive (WFD, Directive 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC) in Europe, or the Clean Water Act (CWA, 2002) in the United States, among others (Borja et al., 2008). The use of benthic communities in marine pollution assessments is based on the concept that they reflect not only conditions at the time of sampling but also conditions to which the community was previously exposed (Reish, 1987). Due to their permanence over seasonal time scales, benthic communities may integrate the effects of long-term exposure to natural and anthropogenic disturbances (Borowitzka, 1972). Moreover, there is extensive literature about their taxonomy, ecology and distribution, and about responses to disturbance (e.g., Boaventura et al., 2002; Schiel, 2004; O'Hara et al., 2010; O'Connor, 2013; Cabral-Oliveira et al., 2014a,b).

In coastal waters (CW), where are included the rocky shores, the macroinvertebrates and macroalgae are some of the biological elements encompassed in such quality assessments. However, despite of the readiness of information on rocky shore intertidal communities, the use of both elements in assessment studies is many times hampered by the different methodologies usually applied to each element (e.g., sampling technique, data processing). Consequently, many studies have generally been based in visual census, or have been focused on relations between particular groups of macroinvertebrates and/or macroalgae (e.g., Bishop et al., 2002; Terlizzi et al., 2005; Pereira et al., 2006; De-la-Ossa-Carretero et al., 2010; Atalah and Crowe, 2012), and not using quantitative data and encompassing entire communities, as in the present work. Furthermore, despite the many historical papers analysing such communities (e.g., Littler and Murray, 1975; López Gappa et al., 1993; Archambault et al., 2001), studies on the structural variation

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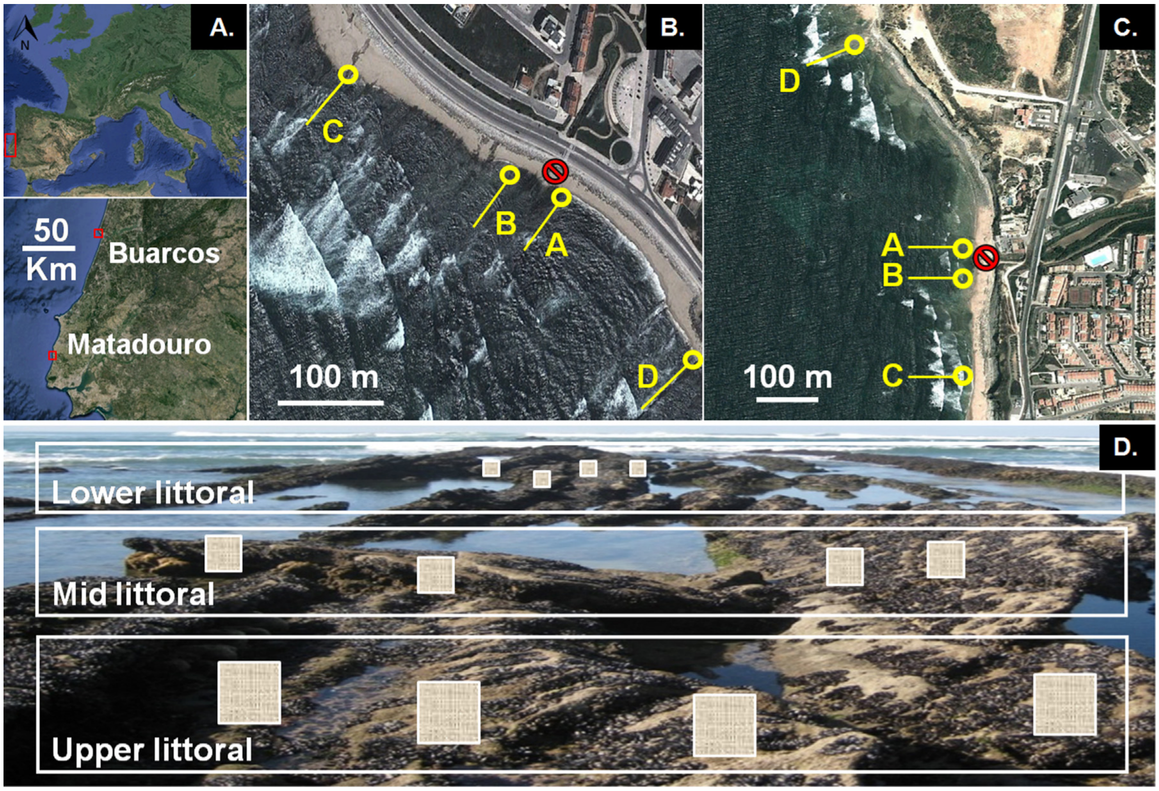

Fig. 1. Study sites location: A. Europe and Portugal; B. Buarcos; C. Matadouro; D. Sampling design. In both Buarcos and Matadouro sites (A–D) are placed gradually away from the source of pollution (SOP; ⃠ sign), with site D positioned as control.

of intertidal rocky shore macroalgae and macroinvertebrate communities, simultaneously, and inside the same disturbance gradient are not common.

The present work aimed to analyze the shifts shown by macroalgal and macroinvertebrate communities exposed to the same anthropogenic disturbance gradient (e.g., small nutrient enriched water discharges). More specifically: (a) to verify if the structural variation of macroinvertebrate and macroalgal communities follows similar patterns, and (b) to check if the variation in structure of each biological element is related to the disturbance level affecting the study areas.

2. Materials and methods

2.1. Study area

Two rocky shores located in the western Portuguese coast, Buarcos and Matadouro (Fig. 1A), were studied in this work. They are included in the Exposed (Buarcos) and Moderately Exposed (Matadouro) Atlantic Coast typologies (TICOR project, Bettencourt et al., 2004; available at http://www.ecowin.org/ticor/). Along this coast the prevailing current direction is from West-Northwest (Portuguese Coastal Current) with occurrences from Southwest (Portuguese Coastal Counter-Current) (Bettencourt et al., 2004). In Buarcos area, the Boa Viagem hill may lead to a current turnover from North-South to South-North orientation (Pais-Costa, 2011; personal observation). The most frequent wave period and wave height are in the range of 8–12 s and of 1–3 m, respectively. Tide is semidiurnal and the extreme spring tide ranges from 3.5 to 4 m (Boaventura et al., 2002; Bettencourt et al., 2004). Surface sea temperature ranges between 13 and 15 °C during winter and 20 and 22 °C during summer, and surface salinity varies between 35 and 36 (Boaventura et al., 2002).

Both rocky shores are situated in narrow sandy shores and limited landward by urban infrastructures, namely coastline protection adjacent to seaside avenues. Buarcos is approximately 150 km north to Matadouro and is more exposed to the Atlantic influence. There, the rocky surface is composed of slightly sloped shelving platforms. In Matadouro, wave energy is more attenuated, and the rocky surface is less irregular and more horizontal along the platforms.

The sampling areas at both shores were selected due to the presence of a point source of pollution (SOP) discharging almost directly on the upper intertidal zone (Fig. 1B and C). At each shore, although with a very low run-off, the discharge is continuous throughout the year, crossing urban centers (Buarcos – Figueira da Foz, and Matadouro – Mafra, with 62,125 and 76,685 residing inhabitants in 2011, respectively) and agricultural land before reaching the shore.

2.2. Sampling design

Four sites were selected at Buarcos and Matadouro to characterize the disturbance gradients, sites A, B and C distancing gradually from the SOP (about 30–40, 50–60 and 250–300 m, respectively), and site D situated opposite to the prevailing coastal current direction, used as control (300–500 m, respectively) (Fig. 1B and C). At each site three horizontal zones were selected, naturally defined by tides – upper littoral (submersed for ~25% of the tide period, ~6 h/day), mid littoral (submersed for ~50% of the tide period, ~12 h/day) and lower littoral (submersed for ~75% of the tide period, ~18 h/day). At each zone four random replicates ($12 \times 12\ cm^2$) were sampled (Fig. 1D). Sampling was done twice in summer (August and September 2011), during low-water of spring tides, and pools and crevices were avoided. The samples (96 from each shore) were immediately preserved after sampling