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Mollusc diversity associated with the non-indigenous macroalga *Asparagopsis armata* Harvey, 1855 along the Atlantic coast of the Iberian Peninsula

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ABSTRACT

The aims of this study were to explore mollusc assemblages associated with the non-indigenous macroalga *Asparagopsis armata*, to compare them with those on other macroalgae at the study region and to explore potential differences on mollusc assemblages between two regions in the Atlantic coast of the Iberian Peninsula, where *A. armata* is present. To achieve this, at each region, four intertidal shores were sampled. Twenty-nine mollusc species were reported and thus, *A. armata* harboured similar or higher diversity than other annual macroalgae in this area. When compared with perennial macroalgae, results depend on the species and studied area. Moreover, significant differences in structure of mollusc assemblages between the two studied regions were found. However, these were due to differences in the relative abundance of species rather than the presence of exclusive species at each region.

1. Introduction

In marine environment many organisms provide habitat and harbour diverse assemblages (e.g. mussels, corals, seagrasses, macroalgae, Gestoso et al., 2013; Cerrano et al., 2010; Currás et al., 1993, Veiga et al., 2014, 2016). These organisms are known as ecosystem engineers because they increase habitat complexity, buffering the negative effects of abiotic factors (e.g. desiccation, changes in temperature), biotic (e.g. predation, grazing) and increase the amount of food and resources for the organisms inhabiting them (Jones et al., 1994). Marine macroalgae are widespread organisms along rocky shores worldwide and many are considered as ecosystem engineers (Milazzo et al., 2000; Miranda et al., 2013). However, the ability of macroalgae to modify environment and diversity of associated assemblages differs among species. Regarding invertebrate assemblages (i.e. phytal fauna), it has been shown that the morphological complexity and size of macroalgae play a significant role in shaping structure and faunal diversity (Hicks, 1980; Gee and Warwick, 1994; Veiga et al., 2014; Torres et al., 2015).

On the last decades, the introduction of different macroalgal species out of their natural range of distribution has increased as consequence of human activities (Williams and Smith, 2007). The introduction of these non-indigenous species (NIS) and the study of their positive/negative effects on native invertebrate assemblages is a challenging topic in marine ecology. The effect of a NIS macroalga on phytal fauna will depend on its morphological complexity when compared with that of the native macroalgae, if the latter is displaced by the NIS (Veiga et al., 2014, 2016). Therefore, the ability of a NIS to maintain biodiversity at human-altered environments will depend on its identity (Zwerschke et al., 2016). Unfortunately, most of the studies that have evaluated the impact of NIS macroalgae on native invertebrates are focused in a few taxa (e.g. *Sargassum muticum* (Yendo) Fensholt, 1955, *Caulerpa* spp., Viejo, 1999; Sánchez-Moyano et al., 2007; Byers et al., 2010; Gestoso et al., 2010; Cevik et al., 2012; Engelen et al., 2013). However, effects of the majority of NIS remain unexplored or poorly studied. The Rhodophyte macroalga *Asparagopsis armata* Harvey, 1855 is a good example of a NIS that has received little attention by marine ecologists. This species was detected in the Iberian Peninsula on the first half of the last century (Miranda, 1934). Nowadays, *A. armata* is present at the Mediterranean coasts (Soler-Hurtado and Guerra-García, 2011) and shows a discontinuous distribution along the north and north-west Atlantic coast of the Iberian Peninsula (Fig. 1). In the North of Portugal, it is very rare close to the River Minho mouth (Araújo et al., 2009) and completely absent along the rest of the North Portuguese coast till San Martinho do Porto (Fig. 1), where it becomes again very

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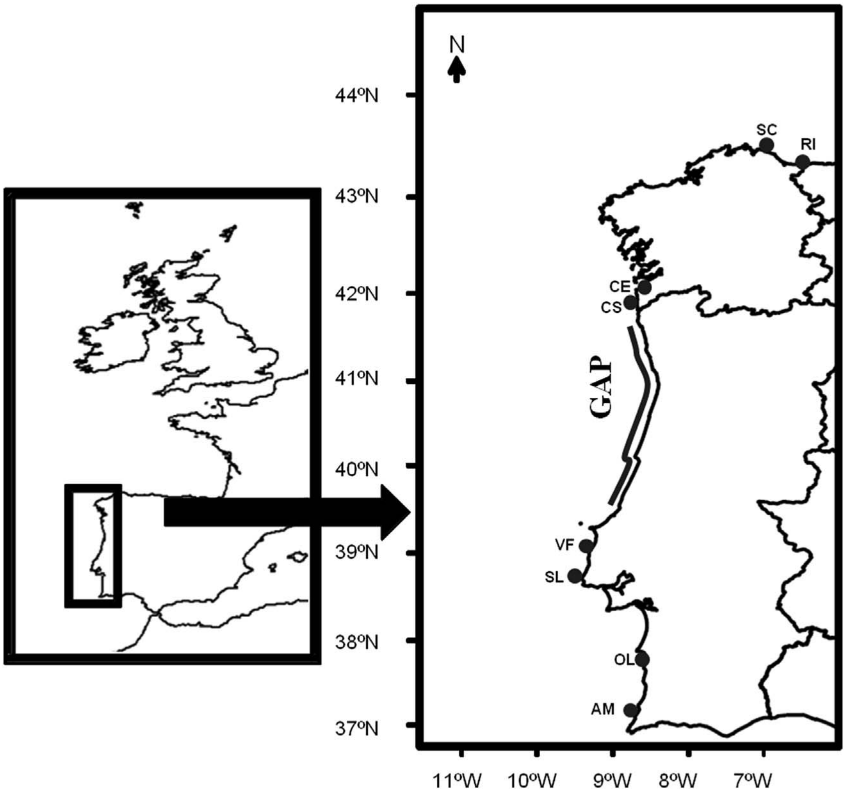

Fig. 1. Location of the eight studied shores along the Atlantic coast of the Iberian Peninsula: Ribadeo (RI), San Ciprián (SC), Cabo Estai (CE) and Cabo Silleiro (CS) in the north region and Vale dos Frades (VF), São Lourenço (SL), Oliveirinha (OL) and Amado (AM) in the south region. The black solid line shows the distribution gap of *A. armata* along the Atlantic coast of the Iberian Peninsula.

abundant and frequent (Fig. 1). Despite its wide distribution and its presence for about a century at the Iberian Peninsula, its effect on the diversity and structure of phytal assemblages has been only recently explored, mostly on Peracarid crustaceans (e.g. Pacios et al., 2011; Guerra-García et al., 2012), while the diversity of other relevant taxa such as polychaetes or molluscs still remains unexplored.

Molluscs are an abundant and diverse component of the phytal assemblages (e.g. Milazzo et al., 2000; Sánchez-Moyano et al., 2000). They play a relevant ecological role because grazing molluscs control the proliferation of epiphytes on the host macroalga. In this way, a reduction in grazers may lead to overgrowth by epiphytic algae and cause severe effects on the habitat-forming macroalgae (e.g. Moksnes et al., 2008). Moreover, molluscs serve as an important source of food for many juvenile fishes (e.g. Ruitton et al., 2000). Therefore, it is important to fill the gap of knowledge about the diversity and structure of molluscan fauna associated with *A. armata*. This information would be necessary to properly evaluate the potential negative impacts of this NIS on the studied area, such as reductions or modifications of assemblages' diversity and/or available resource for juvenile fishes.

The present study aimed: (i) to describe the diversity and structure of the mollusc assemblages associated with *A. armata* along the western Atlantic coast of the Iberian Peninsula; ii) to compare the mollusc diversity harboured by *A. armata* with that of other native and NIS macroalgae at the studied region; iii) to explore potential differences on the mollusc diversity and assemblage structure between the two regions of the Atlantic coast of the Iberian Peninsula (North and South) where this species is present.

2. Material and methods

2.1. Study area

The study area encompassed approximately 885 km between latitudes 37º31′22.45″N and 43º40′37.55″ N, from Galicia (NW Spain) in the North to the Alentejo in the South (Portuguese continental coast), with the exception of northern Portugal, where *A. armata* is not present (Fig. 1). This wide area is under a semidiurnal tidal regime, with the largest spring tides about 3.5–4.0 m. The wave regime is dominated by swell from the NW and most storms occur during winter-autumn. There are several latitudinal environmental gradients along the Atlantic coast of the Iberian Peninsula that can result in different diversity and assemblage structure of phytal fauna harboured by *A. armata* from North to South. Therefore two sampling regions, where this macroalga is present, were considered: a) North region, from northeast to southwest Galicia, and b) South region, from central to south Portugal. The most relevant oceanographic gradients across this area are: (1) sea surface temperature (SST) that shows an increase of values from north to south (Gómez-Gesteira et al., 2008); (2) surface phytoplankton pigment concentration that shows a general decrease from north to south (Peliz and Fiúza, 1999); (3) seasonal upwelling events that affect the Atlantic coast, reducing the SST and increasing the nutriment input, differ in intensity and distance from the shore along this coast (Prego and Bao, 1997; Ospina-Alvarez et al., 2010); (4) there is a greater input of freshwater to the sea at the north region due to the presence of many rivers and the intense rain regime during autumn-winter that can reduce the salinity. Moreover, the morphology and geological composition of the shores differs between the studied regions; rocky shores in Galicia show a significant slope corresponding mainly to granites whereas along central and south Portugal they are more gently sloped and composed mainly of sandstone or calcareous rock. All these environmental gradients modify invertebrate traits and attributes (e.g. Rubal et al., 2015), the identity of available species to colonise NIS macroalgae (e.g. Pereira et al., 2006) and can shape the effect of ecological drivers such as grazing (Franco et al., 2015). These regional variations in biotic variables and interactions can result on differences on assemblages harboured by *A. armata* at these two regions.

2.2. Sampling and sample processing

Gametophytes of *A. armata* were sampled at the aforementioned