



# Meiofaunal assemblages associated with native and non-indigenous macroalgae



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## ABSTRACT

Meiofauna is a useful tool to detect effects of different disturbances; however, its relevance in the frame of biological invasions has been almost fully neglected. Meiofaunal assemblages associated with the invasive macroalga *Sargassum muticum* were studied and compared with those associated with two native macroalgae (*Bifurcaria bifurcata* and *Chondrus crispus*). We used a linear mixed model to determine the influence of habitat size (i.e. macroalgal biomass) in shaping meiofaunal assemblages. Results showed that habitat size (i.e. macroalgal biomass) shaped meiofaunal assemblages influencing its abundance, richness and structure. However, the identity of macroalga (i.e. species) appears also to play a significant role, particularly the differences of complexity among the studied species may shape their meiofaunal assemblages. Finally, the invasive macroalga appears to influence positively species richness. Our results highlight the need of including different faunal components to achieve a comprehensive knowledge on effects of invasive macroalgae and that meiofaunal assemblages may be a valuable tool to examine them.

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## 1. Introduction

Meiofauna is a ubiquitous component of benthic assemblages from the supralittoral to the deepest bottoms of the ocean (Giere, 2009). Moreover, meiofauna plays a key role in the function of ecosystems (Piot et al., 2013). Meiofauna is always more abundant than macrofauna, whereas macrofauna generally surpasses meiofauna in terms of biomass (Gibbons and Griffiths, 1986). Nevertheless, the faster turnover rates of meiofauna suggests that it can be as important as the macrofauna in terms of secondary production (Koop and Griffiths, 1982). Meiofauna also represents an important food resource for many fish species and invertebrates (Huff and Jarett, 2007; Giere, 2009). Additionally, meiofauna is essential for maintaining the bacteria in a continued state of growth by means of its grazing activity and nutrient cycling (Gibbons and Griffiths, 1986), making detritus available to macroconsumers either through its enhancement of microbial activity or by ingestion of the meiofauna themselves (Coull, 1988; Huff and Jarett, 2007).

In rocky shores, meiofauna density exceeds that of macrofauna

and it represents up to 25% of total secondary production (Gibbons and Griffiths, 1986). Despite its ecological relevance, meiofauna has been understudied, particularly in intertidal rocky shores (Frame et al., 2007). Meiofauna in rocky shores is found in a variety of habitats such as bare rock, rock crevices or sessile macrofauna but it has been more commonly reported in association with macroalgae (Gibbons, 1988, 1991; Norderhaug et al., 2007). The high abundance of meiofauna harboured by rocky macroalgal belts has been frequently reported (Danovaro and Fraschetti, 2002; Frame et al., 2007). For instance, phytal meiofauna may reach a million individuals per m<sup>2</sup> of macroalga, which in terms of biomass may correspond to 10% of the macrofauna (Giere, 2009).

Although some species of phytal meiofauna show very distinct habitat preferences (Hicks, 1977; Trotter and Webster, 1984), most of them are distributed over a wide range of macroalgae (Frame et al., 2007). However, abundance and diversity of meiofaunal assemblages differs among macroalgae. The macroalgal complexity has been identified as the most powerful parameter that shapes meiofaunal assemblages (Gibbons, 1988; Gee and Warwick, 1994a, 1994b) that in turn, is modified by a set of biotic and abiotic conditions, such as water depth or wave exposure (Gibbons, 1988; Giere, 2009). Macroalgae with a more complex morphology usually offer a large number of habitats for colonisation of meiofauna (Gibbons, 1991). Moreover, complex macroalgae provide a higher variety of food resources (Hicks, 1980) and a better

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protection from predators (Coull and Wells, 1983), desiccation and wave action (Gibbons, 1988; Hull, 1997; Hooper and Davenport, 2006; Norderhaug et al., 2014); facilitating the trapping of sediment and detritus which adhere to the exudations and the biofilms of the macroalgae (Giere, 2009). Therefore, meiofauna associated with complex macroalgae usually shows higher abundance and diversity than the associated with those less complex (e.g. Hicks, 1980; Gee and Warwick, 1994a, 1994b; Hooper and Davenport, 2006; Frame et al., 2007). Experiments using artificial substrates have also confirmed the positive relationship between complexity and meiofaunal density (Atilla et al., 2005). However, complexity includes two main components of habitat: the morphology and the size (Gee and Warwick, 1994a, 1994b; Veiga et al., 2014). Regarding the effect of macroalgal size, some studies found that larger macroalgae offer a large surface area for the attachment of meiofaunal individuals (Gunnill, 1982a, 1982b). Nevertheless, Arroyo et al. (2006) reported that the relationship between macroalgal size (i.e. biomass) and the meiofaunal abundance and diversity on *Laminaria ochroleuca* was dependent on the considered part of the macroalga (i.e. frond versus holdfast) and Norderhaug et al. (2007) showed that habitat size influenced the abundance of macrofauna associated with *Laminaria hyperborea* but not that of meiofauna. More recently, Richardson and Stephens (2014) found that correlation between biomass and meiofaunal abundance differ among macroalgal species. Therefore, the role of macroalgal size in shaping meiofaunal assemblages is not yet clear and different works have provided contradictory results.

Nowadays, invasive species are considered one of the greatest threats to biodiversity and ecosystem functioning (Pejchar and Mooney, 2009; Salvaterra et al., 2013). It is estimated that the ecological impacts of only about 6% of exotic seaweeds have yet been studied, with most studies concentrated on a small list of notorious species (Smith et al., 2014), including *Sargassum muticum* (Yendo) Fensholt. This macroalga was introduced in Europe in the early 1970s and nowadays it is distributed from Norway to Morocco as well as in the Mediterranean Sea (Sabour et al., 2013).

Meiofaunal assemblages have been widely used as tool to detect effects of pollution (Austen et al., 1994; Rubal et al., 2009; Veiga et al., 2009, 2010; Baguley et al., 2015), even at higher taxonomic levels (Herman and Heip, 1988). However, few studies have yet explored potential effects of invasive macroalgae on the structure of meiofaunal assemblages. Moreover, most of them have focused on the effects of *Caulerpa* spp. in meiofauna from sedimentary environments showing that the invasive increases the abundance of meiofauna but decreases the diversity of some meiobenthic taxa (Carriglio et al., 2003; Sandulli et al., 2004; Travizi and Zavodnik, 2004). Up to the moment, only two studies have explored the effects of invasive macroalgae on meiofauna from rocky shores (i.e. Smith et al., 2014; Richardson and Stephens, 2014). For instance, Richardson and Stephens (2014) showed that *S. muticum* harbours a different meiofaunal assemblage to that of the studied native species and that meiofaunal abundance is poorly correlated with biomass of *S. muticum*. On the contrary, Smith et al. (2014) pointed that the invasive turf *Caulacanthus ustulatus* (Mertens ex Turner) Kützing seems to facilitate a more diverse meiofaunal assemblage.

Most of the studies about meiofauna associated with macroalgae have been focused on specific taxa such as harpacticoid copepods (e.g. Hicks, 1980; Steinarsdóttir et al., 2003; Arroyo et al., 2006; Song et al., 2010), nematodes (e.g. Trotter and Webster, 1984; Da Rocha et al., 2006), turbellarians (Boaden, 1996) and ostracods (Hull, 1997; Frame et al., 2007). However, quantitative ecological data of the whole meiobenthic assemblage are still scarce (but see Arroyo et al. (2004)). In this context, the present study aims to investigate the meiofaunal assemblages associated with the invasive macroalga *S. muticum* in intertidal rock pools;

such assemblage will be compared with those harboured by the native species *Bifurcaria bifurcata* R. Ross and *Chondrus crispus* Stackhouse present in the same habitat. We hypothesized that: i) habitat size provided by macroalgae will play a significant role shaping the abundance, taxon richness and structure of meiofaunal assemblages; ii) the structure of meiofaunal assemblages will differ among macroalgae of different complexity even when these provide an equal habitat size, and iii) the abundance, richness and structure of meiofaunal assemblages associated with the invasive macroalga will differ from those associated with native ones.

## 2. Material and methods

### 2.1. Sampling and sample processing

This study was carried out between February and November 2012 at two rocky shores in the North of Portugal, located along about 2.5 km of coast north of Viana do Castelo (between 41°43' 0.3"N and 41°41'36.36"N; 8°51'10.52"W) and Âncora (between 41°48'58.64"N and 41°50'33.44"N; 8°52'28.67"W) (Fig. 1). A more detailed description of the study area can be found in Veiga et al. (2014).

Macroalgae in the study area experience spatial and temporal variability (Rubal et al., 2011; Veiga et al., 2013). Samples of the three target species (i.e. *C. crispus*, *B. bifurcata* and the invasive *S. muticum*) were collected on four dates (February, May, August and November 2012) at two rocky shores to identify and quantify their meiofauna. Submerged macroalgae in tidal pools were collected during low tide at midshore. To ensure the independence of the samples, at each date, different areas of the shores were sampled and each replicate was collected from different pools. In all, 64 individuals of each macroalga (i.e. 8 replicates per macroalga at each date and shore), haphazardly selected, were collected. Each



Fig. 1. Map of the Portuguese coast indicating the location of the 2 sampled shores.

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