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Associated macrozoobenthos with the invasive Asian clam *Corbicula fluminea*

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ABSTRACT

The Asian clam *Corbicula fluminea* is one of the most invasive species in brackish and freshwater ecosystems. In the Minho estuary (NW of the Iberian Peninsula) this invasive species can reach densities up to 4000 ind m^{-2}, occurring over large areas. *C. fluminea* can significantly alter the physical structure of the benthic environment, and the structure and functioning of this estuarine community. In this context, this work aimed to evaluate the correlation of different densities of *C. fluminea* on the macrozoobenthos across five sites in the Minho estuary during three distinct periods of 2009 (winter, spring and summer). The comparative analysis indicate that macrozoobenthic density, biomass and diversity positively respond to increasing density of *C. fluminea*, with abiotic conditions also playing an important role in the observed patterns, both in brackish and freshwater settings. Crustacea, Insecta and Gastropoda are the main faunal groups responding positively to *C. fluminea* increasing density. The mechanisms responsible for these positive trends still needs to be established although engineering activities and the increase in waste products may play essential roles. Nevertheless, despite such positive effects, earlier studies have showed that the density, biomass and spatial distribution of some species, especially native bivalves dramatically decreased after *C. fluminea* introduction.

1. Introduction

Non-indigenous invasive species (NIS) are altering terrestrial and aquatic ecosystems at unprecedented rates representing a serious threat to native biodiversity (Carlton and Geller, 1993; Cox, 2004; Davis, 2009; Lodge et al., 1998).

Freshwater bivalve invasions can dramatically change the ecological characteristics of the invaded ecosystems (Sousa et al., 2009). Bivalves can create, modify and maintain habitats through physical modifications of the environment (i.e. physical ecosystem engineering; Jones et al., 1994, 1997) with particularly important impacts in shallow-water areas (Gutiérrez et al., 2003; Sousa et al., 2009). Bivalves have a series of engineering attributes (e.g. shell production, sediments reworking, filter feeding) which, depending on species density and activity rates, may cause significant modifications of the benthic environment (Erwin, 2008; Gutiérrez et al., 2003; Ruesink et al., 2005; Sousa et al., 2009). These organisms can be also responsible for the increase in nutrients, released at the form of feces and pseudofaeces, which may be also responsible for significant alterations of the benthic environment (Dame, 1996).

Currently the Asian clam *Corbicula fluminea* is one of the most widespread species in aquatic ecosystems being listed as one of the 100 worst invasive species in Europe (DAISIE). Native from Southeast Asia, *C. fluminea* has been dispersing worldwide over the last 80 years, being well recognized by its invasive behavior and high economic and ecological impacts (Darrigran, 2002; McMahon, 2002). Its broad geographic dispersal in the last decades is partially explained by its rapid growth, early sexual maturity, short lifespan, high fecundity and association with human activities (Sousa et al., 2008b). *C. fluminea* was reported for the first time in Europe in the late 1970s (Mouthon, 1981), being nowadays widespread in this continent (e.g. Iberian Peninsula, central Europe and part of the South-eastern Europe; Araujo et al., 1993; Ciutti and Cappelletti, 2009; Kinzelbach, 1991; Sousa et al., 2008b; Swinnen et al., 1998). In North, Central and South America, this species has also a wide geographic dispersal and has been reported in several countries ranging from Argentina to southern Canada (Darrigran, 2002; Strayer, 1999).

Corbicula species can modify the environment influencing biological communities and ecosystem functioning (Sousa et al., 2009). On a smaller scale, the dominance of *C. fluminea* can be related to the reduction of other bivalve species (Sousa et al., 2008c,d); however it is possible that the *C. fluminea* increases overall density and diversity of benthic species, once it can provide changes related to, the availability of a structural complex substratum suitable to colonization

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by infaunal and epifaunal species, and also to the abiotic conditions resulting from sediment reworking, filtration and high levels of feces and pseudofeces produced (Hakenkamp and Palmer, 1999; Vaughn and Hakenkamp, 2001).

In this study, the null hypotheses of similar density, species richness and biomass of the macrozoobenthic assemblages under different densities of *C. fluminea* were tested. First the correlation of different densities of *C. fluminea* on the macrozoobenthic assemblages, when subject to brackish and freshwater conditions was evaluated. Then, we investigated the temporal changes in the assemblages' characteristics, and also the faunal groups mostly influenced by *C. fluminea* increasing density.

2. Material and methods

2.1. Study area

This study was conducted in the River Minho estuary (NW of the Iberian Peninsula). *C. fluminea* was first recorded in this ecosystem in 1989 and nowadays dominates the density, biomass (e.g. some sites with density and biomass higher than 4000 ind m^{-2} and 550 g AFDW m^{-2}, respectively) and secondary production of the benthic compartment (Sousa et al., 2007; Sousa et al., 2008a,d,e). The River Minho originates in the Serra de Meira, Spain, with 95% of its hydrological basin located in this country and 5% in Portugal. It extends across 300 km, flowing NNE–SSW into the Atlantic Ocean. The influence of spring tides extends approximately 40 km upstream, covering a total area of 23 km^2. This estuary can reach a maximum width of 2 km and its waters are partially mixed most of the time. However, salt wedge conditions can develop when major floods occur. This estuarine area has been described in more detail in previous studies (see Sousa et al., 2005, 2008a,c) and the characterization of the macrozoobenthic assemblages along the estuarine gradient can be found in Sousa et al. (2008e).

2.2. Sampling strategy and laboratory analysis

Samples were collected during three distinct periods in 2009 (winter, spring and summer) in five sites along the Minho estuary (Fig. 1). The temporal scale of sampling covered the pre- and post-recruitment periods of most benthic invertebrates and encompassed seasonal climatic variation. All the sites were located in subtidal soft bottoms and were selected based on the following criteria: (i) three sites were chosen in the lower estuarine area to evaluate the influence of *C. fluminea* on the brackish macrozoobenthic assemblage (S1, S2 and S3); (ii) two sites were chosen in the upper estuarine area to evaluate the possible effect of *C. fluminea* on the freshwater macrozoobenthic assemblage (S4 and S5); Sites within each salinity regime (i.e. brackish or freshwater) were chosen based on their similar abiotic conditions (e.g. depth, salinity and sediment characteristics) and their variation in *C. fluminea* density. In the case of the brackish sites, *C. fluminea* density was the highest in S3, intermediary in S2 and the lowest in S1. In sites located in the upper estuary the higher density was higher in S5 than in S4. Due to the extensive spread of this NIS in the estuary, it was impossible to find out control sites without live *C. fluminea* in both estuarine areas. The three sites located downstream

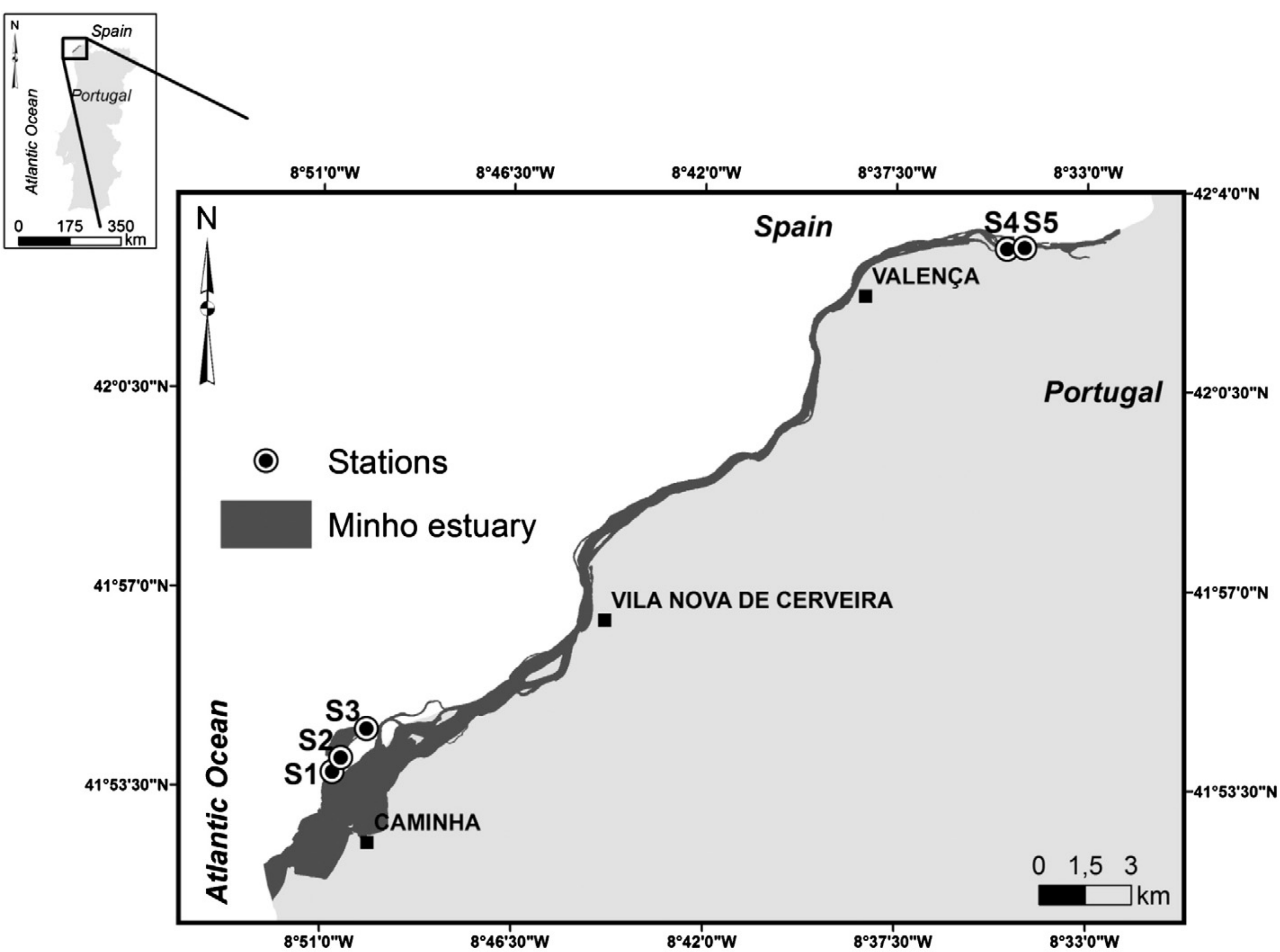

Fig. 1. Map of Minho estuary showing the brackish (S1, S2 and S3) and freshwater sites (S4 and S5). Insets show the location of the study estuary in the Portuguese coast.