Estuarine, Coastal and Shelf Science 143 (2014) 12–19

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Influence of the invasive Asian clam *Corbicula fluminea* (Bivalvia: Corbiculidae) on estuarine epibenthic assemblages

M.I. Ilarri [a,b,*], A.T. Souza [a], C. Antunes [a,c,d], L. Guilhermino [a,b], R. Sousa [a,e]

[a] Interdisciplinary Centre of Marine and Environmental Research (CIIMAR/CIMAR), University of Porto, Rua dos Bragas 289, P 4050-123 Porto, Portugal
[b] ICBAS – Instituto de Ciências Biomédicas de Abel Salazar, Universidade do Porto, Rua de Jorge Viterbo Ferreira, 228, 4050-313 Porto, Portugal
[c] Aquamuseu do Rio Minho, Parque do Castelinho, 4920-290 Vila Nova de Cerveira, Portugal
[d] University School Gallaecia, Largo das Oliveiras, 4920 Vila Nova de Cerveira, Portugal
[e] CBMA – Centre of Molecular and Environmental Biology, Department of Biology, University of Minho, Campos de Gualtar, 4710-057 Braga, Portugal

ARTICLE INFO

Article history:
Received 8 August 2013
Accepted 15 March 2014
Available online 24 March 2014

Keywords:
Carcinus maenas
Crangon crangon
Pomatoschistus microps
invasive alien species
Minho estuary
predation

ABSTRACT

One of the most widespread invasive alien species (IAS) in aquatic ecosystems is the Asian clam *Corbicula fluminea*. Several studies have shown that *C. fluminea* can cause large-scale changes in macrozoobenthic assemblages; however, very few attempted to investigate the effects of this IAS on mobile epibenthic species, such as fishes and crustaceans. In this context, the influence of *C. fluminea* on epibenthic species was investigated during one year by comparing the associated epibenthic fauna in three nearby sites of the Minho estuary (NW of the Iberian Peninsula), wherein the abiotic conditions are similar but the density of the Asian clam is highly different. From a total of 13 species, six were significantly influenced by *C. fluminea*; five responded positively, namely the brown shrimp *Crangon crangon*, the European eel *Anguilla anguilla*, the common goby *Pomatoschistus microps*, the brown trout *Salmo trutta fario* and the great pipefish *Syngnathus acus*, whereas the shore crab *Carcinus maenas* was negatively influenced. However, stomach contents analysis revealed that fish and crustacean species do not feed on *C. fluminea*, suggesting that this IAS is still not a large component of the diet of higher trophic levels in this estuarine ecosystem. Our results suggest that the structure provided by *C. fluminea* shells is likely to be one of the main factors responsible for the differences observed. *C. fluminea* physical structure seems to influence the epibenthic associated fauna, when found in densities higher than 1000 ind./m^2, with sedentary small-bodied crustaceans and fishes being mainly attracted by the increasing in habitat complexity and consequent enhancement of heterogeneity and shelter availability.

1. Introduction

Invasive alien species (IAS) are one of the most significant threats affecting the integrity of aquatic ecosystems (Richter et al., 1997; Grosholz, 2002). In recent years, aquatic ecosystems have been subjected to numerous introductions which contributed for significant changes in structure and functioning of the invaded systems (Byrnes et al., 2007; Strayer, 2010). Via physico-chemical (e.g. light availability, nutrient levels, heat transfer, habitat complexity and physical transport of materials) and biological (e.g. diversity, spatial distribution, biotic interactions affecting the density and biomass of other species) changes, IAS can be responsible for impacts ranging from the individual to the ecosystem level (Sousa et al., 2011; Simberloff et al., 2013). However, due to the high context dependency, it is difficult to predict the potential impacts of IAS in a new environment. The potential impacts of IAS, in part, can be related to the complex organism–organism and organism–habitat interactions, as well as the impacts of a particular species which can vary across different geographic locations (Mayer et al., 2000; Ricciardi and Atkinson, 2004; Ward and Ricciardi, 2007).

The structural complexity created by some IAS can directly or indirectly modify communities and ecosystems, given that invasive species have the capacity to modulate the availability of resources to other species, by physically creating, modifying and maintaining habitats (i.e. physical ecosystem engineering; Crooks, 2002). Bivalves are one of the most invasive faunal groups in aquatic ecosystems and their engineering attributes can markedly affect biological communities, ecosystem processes and functions (Sousa et al., 2009, in press). The hardness of their shells plays an

* Corresponding author. ICBAS – Instituto de Ciências Biomédicas de Abel Salazar, Universidade do Porto, Rua de Jorge Viterbo Ferreira, 228, 4050-313 Porto, Portugal.
E-mail address: martinailarri@gmail.com (M.I. Ilarri).

http://dx.doi.org/10.1016/j.ecss.2014.03.017
0272-7714/

important role in bivalve ecological success, once it can preclude the access of predators (Wright et al., 2012). Indeed, it can also contribute to important physical modifications (i.e. provision of substrata for attachment, provision of shelter from predators, physical and/or physiological stress, affecting also the transport of particles and solutes in the benthic environment; Gutiérrez et al., 2003) that can greatly influence the associated fauna (Werner and Rothhaupt, 2007; Zaiko et al., 2009; Ilarri et al., 2012).

Currently, one of the most widespread IAS in aquatic ecosystems is the Asian clam *Corbicula fluminea* (Sousa et al., 2008d). It was first recorded in Europe at least in the early 1980s (Mouthon, 1981), and now it occurs in almost all European countries (Ilarri and Sousa, 2012). In Portugal, *C. fluminea* was firstly reported in the early 1980's (Mouthon, 1981), presently occurs in most Portuguese hydrological basins, including many estuarine systems (Sousa et al., 2007a). Since 2004, studies focusing on *C. fluminea* ecology were intensified in the Minho River (NW of the Iberian Peninsula). Most of these studies further confirmed the high invasive potential of the species, showing that *C. fluminea* dominates the infauna community in terms of density, biomass, and secondary production in the last 70 km of the Minho River (Sousa et al., 2007b, 2008a,b,c). Also, *C. fluminea* can influence the habitat heterogeneity, by modifying the diversity of the macrozoobenthic assemblages favoring sessile crustaceans, gastropods and insects and negatively affecting other bivalve species (Ilarri et al., 2012). However, nothing is known about the influence of *C. fluminea* on mobile epibenthic species. In this context, our aims were threefold: (a) to examine whether different densities of *C. fluminea* influence the epibenthic assemblages, (b) to investigate possible seasonal changes in the epibenthic assemblages responding to different *C. fluminea* densities, and (c) to examine through stomach content analysis whether the epibenthic species prey on *C. fluminea*.

2. Materials and methods

2.1. Study area and sampling campaign

The Minho estuary (NW Iberian Peninsula) has a maximum length of 40 km and covers an area of approx. 23 km^2 (Sousa et al., 2007b). Detailed description of the macrozoobenthic assemblages and main abiotic characteristics of this area can be found in previous studies (Sousa et al., 2005, 2008c). The present study was performed in three selected sites at the lower estuary (situated about 8 km from the river mouth) (Fig. 1). The selected sites are near to each other, with the site 1 (S1) located about 400 m away from site 2 (S2) and about 800 m away from site 3 (S3). The selected study area presents an annual average depth that ranged between 2.0 and 2.5 m and the Minho estuary is classified as a mesotidal and partially mixed system (Ferreira et al., 2003), although during periods of high river discharge, it tends towards a salt wedge estuary (Sousa et al., 2005). The water current varied from moderate to strong and these variations are due to the tidal influence or to upstream river discharge (Ferreira et al., 2003). The substratum is composed mainly by sandy sediments, debris, leaf litter and *Corbicula fluminea* shells (live and dead).

In order to characterized the epibenthic assemblages, tows were performed and fyke-nets were placed during an annual cycle (four seasons), from January to November. Four replicate tows per site in each of the four seasons (total of 48 samples) were performed always during the day at high tide using a beam trawl (5 mm mesh size) towed at constant speed (2 km h^{-1}) for 90 s, corresponding to a total distance of 50 m (Freitas et al., 2009). Whereas, for the fyke-nets (10 mm mesh, 0.7 m diameter mouth, 7 m long, 3.5 m central wing) six replicates per site in each of the four seasons were collected (total of 72 samples). Fyke-nets remained underwater for 24 h. All individuals caught for both tows and fyke-nets were counted and measured to the nearest 0.1 mm.

At each site, during low tides, environmental variables (water temperature, salinity, pH, dissolved oxygen (DO) and redox potential (ORP)) were also measured with a multiparameter probe YSI 6820.

Gut contents of the fishes and crustaceans sampled by fyke-nets, in the three selected sites, were analyzed using a stereomicroscope, in order to check whether these species had parts and/or traces of *Corbicula fluminea* in their digestive tracts.

2.2. Data analysis

Analysis of similarities (ANOSIM) was performed to explore the abiotic data patterns over space and time. Initially, all variables

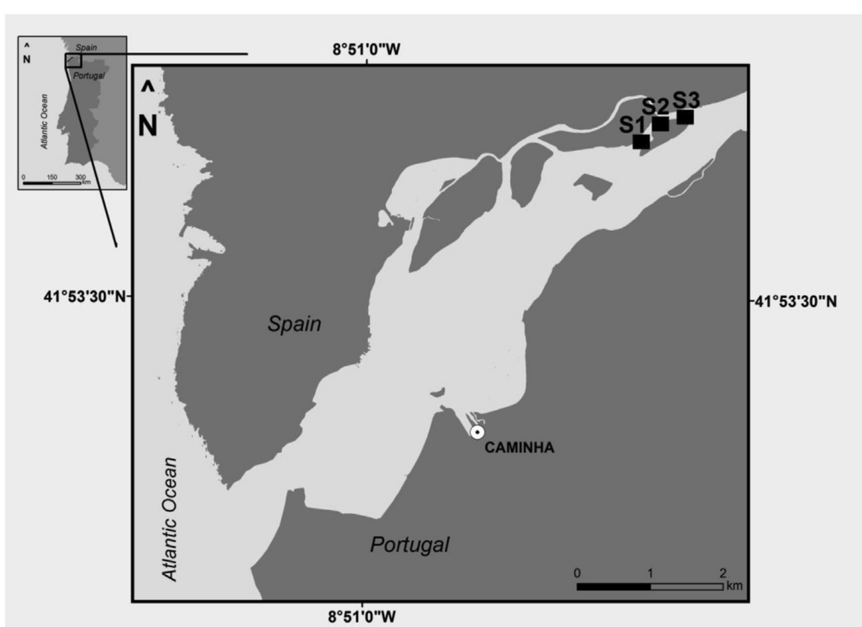

Fig. 1. Map of the study area showing the three selected sites at the lower Minho estuary, NW Iberian Peninsula.