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INVASION NOTE

Southern limit of distribution of the soft-shell clam *Mya arenaria* on the Atlantic East Coast

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Abstract The invasive soft-shell clam *Mya arenaria* was recorded for the first time in the Tagus estuary, central Portugal. Propagules of the soft-shell clam were probably unintentionally introduced into the Tagus estuary through ballast water. *Mya arenaria* was observed in muddy sands in the upper intertidal zone. The assemblage in which the soft-shell clam was observed was composed of typical estuarine species such as the gastropod *Hydrobia ulvae*, the bivalve *Scrobicularia plana* and several polychaete species. The population density of Mya *arenaria* in the finding area was 40 ind m^{-2} with a fresh biomass of 163.5 g FW m^{-2}.

Keywords *Mya arenaria* · Tagus estuary · Ballast water

Introduction

The bivalve *Mya arenaria* can be found in all European seas (Gollasch 2006) and is widely distributed along European coasts (Strasser 1999). However there is no evidence of the presence of the soft-shell clam on the coast of the Iberian Peninsula, except for one report. Guimarães and Galhano (1988) described *Mya arenaria* as a part of the fauna found in the Lima Estuary, northern Portugal; since then, however, the soft-shell clam has not been reported in the same location (Sousa et al. 2006), and this has been interpreted as reflecting extinction of the population, if it ever existed.

The purpose of the present short research note is to report the occurrence of *M. arenaria* in the Tagus estuary, the southernmost distribution limit ever recorded for this species on the Atlantic East coast.

Materials and methods

The Tagus estuary is located on the central western coast of the Iberian Peninsula and it has extensive intertidal mudflats, mostly on the southern bank (Fig. 1).

The occurrence of *Mya arenaria* was first registered in June 2007 when some bivalves were caught for a laboratory aquarium. Sampling to characterize the population of *Mya arenaria* and the assemblage in which it was described was carried out during low tide in the upper intertidal area of the Coina salt marsh, on September 12th 2007. The location of the find and sampling site are coincidental and are shown in Fig. 1.

Temperature, salinity, dissolved oxygen, redox potential and pH were measured in the interstitial

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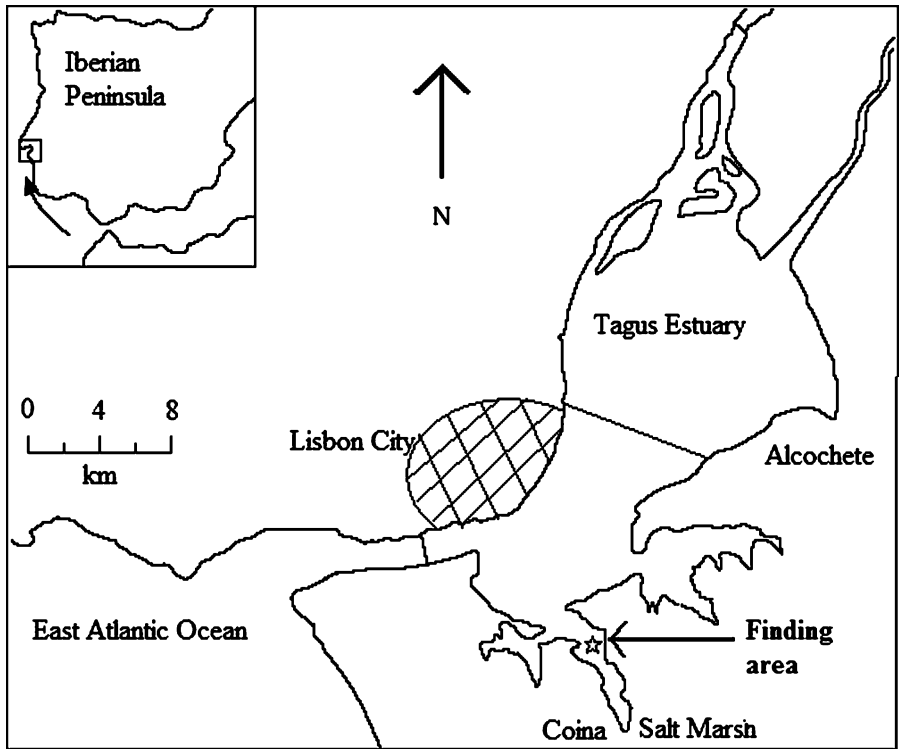

Fig. 1 Area where the population of *Mya arenaria* was found in the Coina salt marsh, Tagus estuary. The sampling site and the area where the specimens were discovered are the same

water with a standard field probe. Sediment was analyzed by the sieving method. The organic matter content was also determined, by the method described by Buchanan (1984).

A core of 9.5 cm inner diameter was used to sample infaunal organisms over a total sampling area of 0.05 m^2 (seven replicates). The material was sieved through a 1 mm sieve. Benthic animals were then sorted, counted and identified under a dissecting microscope and preserved in 70% ethanol; biomass was estimated as fresh weight (FW). The Shannon–Wiener's species diversity index and Pielou's index for evenness were calculated.

Results

The mean values of temperature, salinity, oxygen, redox potential and pH were 21.9°C, 32.05 psu, 0.98 mg l^{-1}, −58 mV and 7.34 respectively. Medium and fine sand represented more than 75% of the sediment composition and 1.2% of the organic matter content.

The population of Mya *arenaria* found in the Coina salt marsh is part of an assemblage composed by 14 species (Table 1) mainly dominated by the gastropod *Hydrobia ulvae*, the most abundant species, which represented 92.4% of the total abundance. The second most abundant species was the bivalve *Scrobicularia plana* (1,040 ind m^{-2}). The polychaetes *Capitella capitata* (440 ind m^{-2}), *Hediste diversicolor* (280 ind m^{-2}), *Alkmaria romijni* (220 ind m^{-2}) and *Streblospio shrubsolii* (160 ind m^{-2}) were one order of magnitude less abundant than *S. plana*, although they were still important in terms of numbers. They also belonged to a taxonomic group that represented half of the total species richness of the assemblage. The bivalves *Scrobicularia plana* and *Mya arenaria* were the dominant species in terms of biomass, accounting for 181.84 g FW m^{-2} (40.6%) and 163.42 g FW m^{-2} (36.5%), respectively. The last two species together with the gastropod *Hydrobia ulvae* represented more than 96.5% of the total biomass of the assemblage (Table 1).

The diversity and evenness of the assemblage were 0.60 and 0.23 respectively. The values of the indexes were low because of the large numbers of the gastropod *Hydrobia ulvae*; low values for diversity and evenness were also previously described by Calvário (2001) for the Tagus estuary.

Table 1 Taxonomic group, density and biomass of the observed species in the Coina salt marsh

Species	Taxonomic group	Density (ind m^{-2})	Biomass (g FW m^{-2})	Density (%)	Biomass (%)
Hydrobia ulvae (Pennant, 1777)	Gastropoda	29,320	87.62	92.43	19.55
Scrobicularia plana (da Costa, 1778)	Bivalvia	1,040	181.84	3.28	40.58
Capitella capitata (Fabricius, 1780)	Polychaeta	440	0.13	1.39	0.03
Hediste diversicolor (O·F. Müller, 1776)	Polychaeta	280	13.08	0.88	2.92
Alkmaria romijni Horst,1919	Polychaeta	220	0.06	0.69	0.01
Streblospio shrubsolii (Buchanan, 1890)	Polychaeta	160	0.02	0.5	0.004
Diptera larvae unid.	Others	80	0.20	0.25	0.05
Mya arenaria (Linnaeus 1758)	Bivalvia	40	163.41	0.13	36.47
Glycera tridactyla (Schmarda, 1861)	Polychaeta	40	1.41	0.13	0.32
Mysta picta (Quatrefages, 1865)	Polychaeta	20	0.19	0.06	0.04
Cyathura carinata (Krøyer, 1847)	Isopoda	20	0.09	0.06	0.02
Polydora ciliata (Johnston, 1838)	Polychaeta	20	0.0020	0.06	0.00040
Tubificidae unid.	Others	20	0.0002	0.06	0.00004
Ampithoe valida Smith, 1873	Amphipoda	20	0.0002	0.06	0.00004
Totals		31,720	448.05	100	100

Discussion

Ballast water has been reported to be the main cause of species introduction into European waters (Gollasch 2006), and the occurrence of *M. arenaria* in the Tagus estuary is probably the result of an unintentional introduction through ballast.

The presence of *M. arenaria* in the Coina salt marsh is the result of successful settlement of its pelagic larvae. High densities of adult *M. arenaria* in high or mid intertidal zones have been described in previous studies elsewhere (Powers et al. 2006), although this cannot be considered a general trend. Because the specimens of *M. arenaria* caught were of the same size, direct settlement may be the most likely scenario to explain the occurrence of the clams in the high intertidal zone, rather than post-settlement migration. Predation is a relevant factor that would explain the very low density of *M. arenaria* in the intertidal region. The green crab *Carcinus maenas* and the shrimp *Crangon crangon* are amongst the most common predators that inhabit the Tagus Estuary (Calvário 2001; Rodrigues et al. 2006), apart from fishes and birds that feed in the intertidal area. In this sense, Beal et al. (2001) concluded that predation was the main factor that explained the observed intertidal distribution of *M. arenaria* in Maine, on the eastern coast of North America.

The assemblage in which *M. arenaria* was found is similar to others described for the same estuarine system (Calvário 2001; Rodrigues et al. 2006) and even in northern Europe (Ysebaert et al. 1998). As described for the Ems and Schedel estuaries (Ysebaert et al. 1998), *M. arenaria*, *Scrobicularia plana* and *Hediste diversicolor* constitute part of a mud community of sheltered areas of variable salinity in addition to some species that characterize communities of normal salinity. According to the same authors, *M. arenaria* was observed in the polyhaline (18–30 psu) and mesohaline (5–18 psu) zones of the studied estuaries. Therefore, considering the physiological plasticity of the soft-shell clam, as well as the estuarine circulation of the Tagus estuary, which provides water masses from its central area to the surrounding salt marshes (Braunschweig et al. 2003), *M. arenaria* may be expected to spread seawards to the limit at which marine communities prevail, and upstream to an area of a certain permanent influence of fresh water, always assuming that the clam population is able to release fertilized eggs to the water column.

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