

On the distribution of the allochthonous bivalves  
*Anadara inaequivalvis* (Bruguière, 1789),  
*Anadara demiri* (Piani, 1981) and  
*Musculista senhousia* (Benson in Cantor, 1842)  
in the Adriatic Sea, Italy

ELISABETTA MORELLO, CRISTIANO SOLUSTRI, BRUNO ANTOLINI,  
CARLO FROGLIA  
ISMAR - C.N.R., Sezione Pesca Marittima, Largo Fiera della Pesca,  
60125 Ancona (Italy)

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## SUMMARY

The distribution patterns in the Adriatic Sea of three bivalves of Indo-Pacific origin, *Anadara inaequivalvis*, *Anadara demiri* and *Musculista senhousia*, were investigated. Analysis of a population of *A. inaequivalvis* in the central Adriatic confirmed the occurrence of years of conspicuous recruitment followed by years of intense growth and poor recruitment events. Extensive sampling of northern and central Adriatic inshore waters revealed the presence of *A. demiri* from Jesolo to Vasto, whilst *M. senhousia*, previously found in brackish waters and enclosed bays only, was found to have successfully colonised open sea areas between Porto Garibaldi and S. Benedetto del Tronto.

## INTRODUCTION

The number of species of Indo-Pacific origin which have made their appearance in the Mediterranean Sea has increased dramatically in the past decade. Their entrance into the basin can be attributed to both anthropogenic activities (e.g., aquaculture, shipping, fisheries, etc.) and natural phenomena (lessepsian migration). In the case of several species, favourable environmental conditions have induced considerable population booms. Significant examples are given by the Manila clam, *Tapes philippinarum* (Adams and Reeve, 1850), which was introduced in Chioggia lagoon in 1983 for aquaculture (Cesari and Pellizzato, 1985) and the mussel, *Brachidontes pharaonis* (Fischer, 1870), a true lessepsian migrant first recorded in the Mediterranean Sea only after the opening of the Suez canal and reported at Port Said in the early 1900s (Pallary, 1912).

This contribution concerns three bivalve species that have successfully established themselves in the Adriatic Sea: the ark shells *Anadara inaequivalvis* (Bruguière, 1789) (Fig. 1) and *Anadara demiri* (Piani, 1981) (Fig. 2), and the Asian date mussel *Musculista senhousia* (Benson in Cantor, 1842) (Fig. 3).

*Anadara inaequivalvis* was introduced accidentally into the Mediterranean probably in ballast waters. It was first reported in the Adriatic Sea, off Ravenna, thirty years ago (Rinaldi, 1972; Ghisotti, 1973) and since then it has extended its distribution across the entire western Adriatic Sea, from the Gulf of Trieste (pers. obs.) and Venice (Cesari and Pellizzato, 1985; Mizzan, 1999) to Trani (D'Introno, 1980). Its introduction into the Adriatic coincided with the advent of intense eutrophication events and extraordinary algal blooms that resulted, locally, in temporary hypoxia conditions and release of sulphides in the sediment (Marasovic, 1989). It is the presence of such adverse conditions that appears to have favoured the establishment and spreading of *A. inaequivalvis*, giving it a competitive advantage with respect to native species and causing their demise (de Zwaan et al., 1991). The reasons for its success are that, in contrast to native bivalve species, the haemolymph of *A. inaequivalvis* contains nucleated erythrocytes packed with both haemoglobin, which enables the binding of oxygen in oxygen-deficient conditions (de Zwaan et al., 1991; Holden et al., 1994), and haematin, which is responsible for the removal of sulphides (de Zwaan et al., 1995). In the central Adriatic Sea it has successfully colonised the

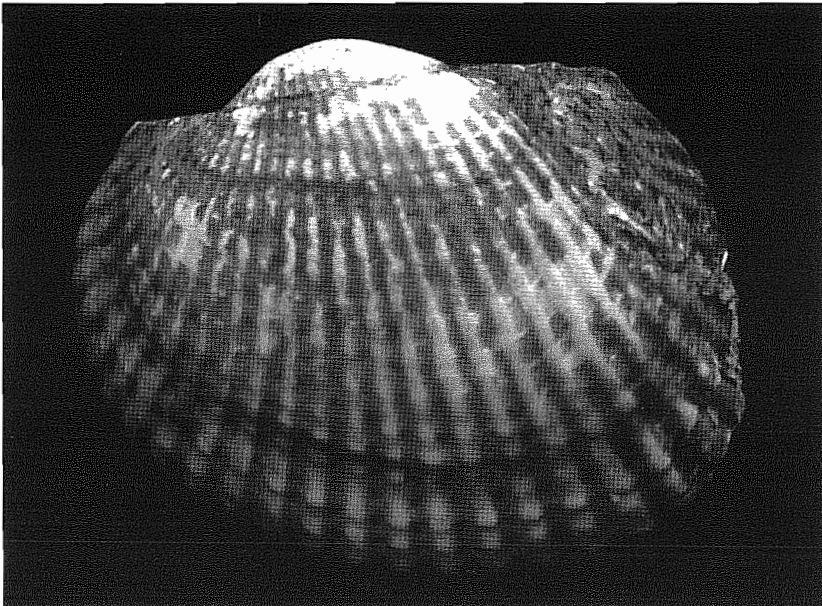


Fig. 1 - *Anadara inaequivalvis* (L = 17.3 mm)

silty sand sediments down to depths of at least 15 m (Frogia et al., 1998) placing native bivalves, amongst which *Chamelea gallina* (Linnaeus, 1758), under considerable ecological stress (Casali and Colafranceschi, 1986).

Since 2000 a new competitor has made its appearance in the same habitat: *A. demiri* (Morello and Solustri, 2001). The species was probably introduced into the Mediterranean Sea through the Suez Canal, either as planktonic larvae carried in the ballast waters of ships or in the benthic stages attached by means of the byssus to the fouling of ships. It was first reported in the Mediterranean in the bay of Izmir (Turkey) in the late 1970s (Demir, 1977) and, twenty years later, in the Gulf of Thermaikos and the bay of Thessaloniki (Aegean Sea) (Zenetos, 1994). At present, very little is known on the biology and ecology of this species, but, similarly to *A. inaequivalvis*, it appears to contain respiratory pigments with high oxygen affinity which could, under hypoxic conditions, confers it a competitive advantage with respect to autochthonous bivalves. Zenetos (1994), in fact, hypothesised a correlation between the greatest densities of *A. demiri* in the bay of Thessaloniki and conditions of intense environmental pollution. A further advantage in spreading could be conferred to *A. demiri* by its ability, retained into adult life, of attaching, by means of a byssus thread, to all kinds of hard substrates, from plastic materials to other living bivalves (*C. gallina*) and gastropods (*Bolinus brandaris*, (Linnaeus, 1758)) (Solustri et al., in press).

The Asian date mussel *Musculista senhousia* is native of Asia with a natural distribution which extends from Siberia to Singapore, Thailand and the Red Sea (Barash and Danin, 1971; Kulikova, 1978; Crooks, 1992). Since the 1920s this species has invaded the brackish waters and enclosed bays of many countries,

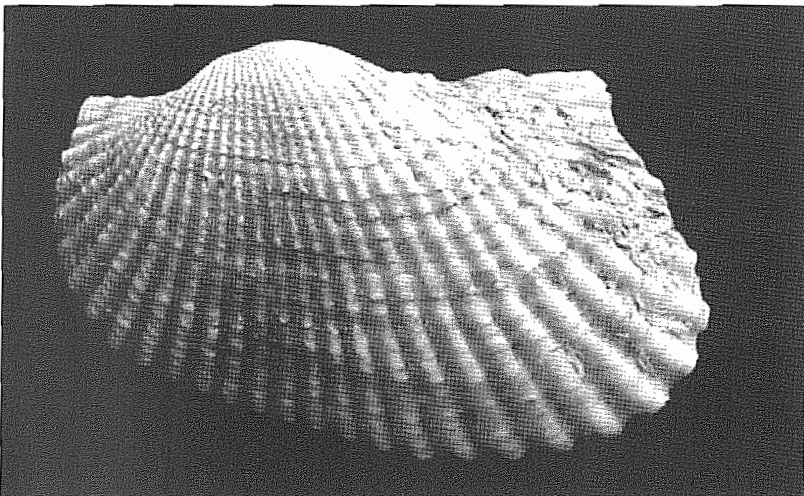


Fig. 2 - *Anadara demiri* (L = 18.6 mm)



Fig. 3 - *Musculista senhousia* (L = 20.0 mm)

probably transported in ballast waters or in shipments of other bivalves object of aquaculture. In the 1920s it was collected for the first time in western U.S.A. (Kincaid, 1947 in Crooks, 1992); in the 1970s in New Zealand (Willan, 1985) and the eastern Mediterranean (Barash and Danin, 1972); in the 1980s in Australia (Slack-Smith and Brearley, 1987) and the western Mediterranean (Hoenselaar and

Hoenselaar, 1989); and in the 1990s in the Adriatic Sea (Bucci, 1994; Lazzari and Rinaldi, 1994) and Sardinia (Savarino and Turolla). *M. senhousia* seems to prefer sandy or sandy-silty substrata within which it forms extensive byssus mats which can alter the hydrodynamic, sedimentological and topographical characteristics of the sea floor (Mistri, 2002).

#### MATERIALS AND METHODS

The population of *A. inaequalvis* in the coastal waters between Civitanova Marche and Pedaso was sampled from 1997 to 2001 by means of an experimental hydraulic dredge while it was used for the assessment of clam stocks, *C. gallina* and *Paphia aurea*, in the Maritime District of S. Benedetto del Tronto, at depths between 3 and 16 m.

The Adriatic distribution of *A. demiri* and *M. senhousia* was assessed within the framework of various projects carried out in the northern and central Adriatic Sea by sampling with hydraulic dredges, charcot dredges, rapido trawls, Van Veen grabs, box-corers and suction samplers.

The high number of records in the Ancona and S. Benedetto del Tronto Maritime Districts was, thus, due to the greater sampling intensity in these areas.

#### RESULTS AND CONCLUSIONS

The trend in population structure of *A. inaequalvis* shown in Fig. 4 reflects temporal stability in growth patterns coupled with great variability in recruitment events. The progression of modes in the frequency distributions of the length classes enabled the Authors to see the growth, in subsequent years, of the substantial cohort recruited in 1997, and see that it was characterised by very low recruitments. These results are in agreement with previous observations by Froggia et al. (1998) in the same area whereabout, between 1984 and 1996, the *A. inaequalvis* population underwent years of very strong recruitment, followed by inconspicuous recruitment, until substantial reduction of the strong year class.

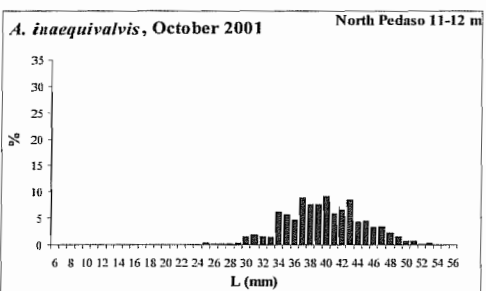
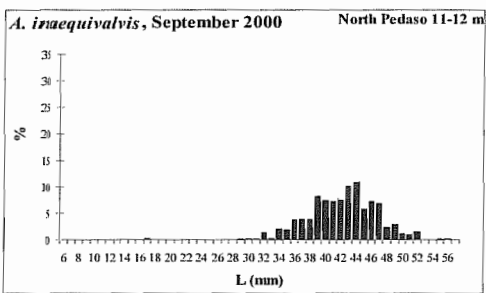
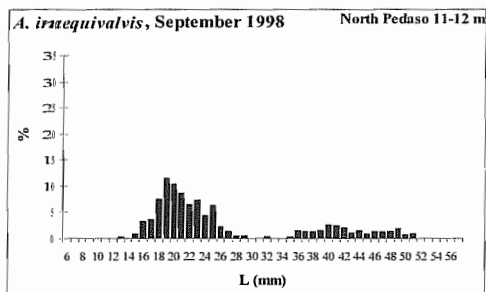
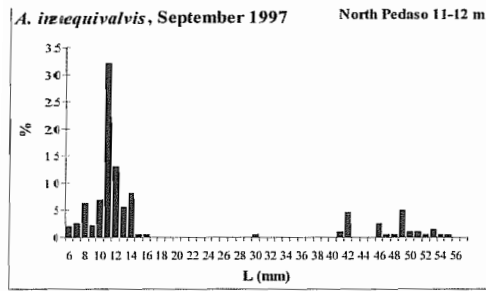


Fig. 4 - Length frequency distributions of the population of *Anadara inaequalvis* in the coastal waters between Civitanova Marche and the mouth of the river Aso between 1997 and 2001

The first record of *A. demiri* in the Adriatic Sea reported the bivalve in a limited area off Ancona and Porto Recanati in 2000 (Morello and Solustri, 2001). Sampling campaigns carried out between 2000 and 2002 have revealed a considerable expansion in its geographic distribution. *A. demiri* is now present in the coastal waters of the entire northern and central Adriatic, from Jesolo to Vasto (Fig. 5). Analysis of the frequency distributions of length, derived from samples collected by experimental hydraulic dredge in the area between Civitanova and Pedaso in October 2001, highlighted a substantial recruitment in 2001 and the presence of older age classes, suggesting that the species had settled in this area as early as 2000 (Fig. 6). To date, *M. senhousia* has only been reported in lagoon environments (Busse lagoon, south Sakhalin, Russia: Kulikova, 1978; Bolinas Lagoon, California: Carlton, 1979 in Crooks, 1992; Te Puru, Firth of Thames, New Zealand: Willan, 1985; Middle Estuary, Swan River, Australia: Slack-Smith and Blearley, 1987; Étang de Thau, France: Hoenselaar and Hoenselaar, 1989; “le piallasse”, Ravenna, Italy: Lazzari and Rinaldi, 1994; Sacca di Goro, Italy: Mistri et al., 2001; Venice lagoon, Italy: Russo and Mel, 2002) and in areas subjected to limited hydrodynamic action (Mission Bay, California: MacDonald, 1969 in Crooks, 1992; Waitemata Harbour, New Zealand: Willan, 1985). The surveys carried out in the coastal waters

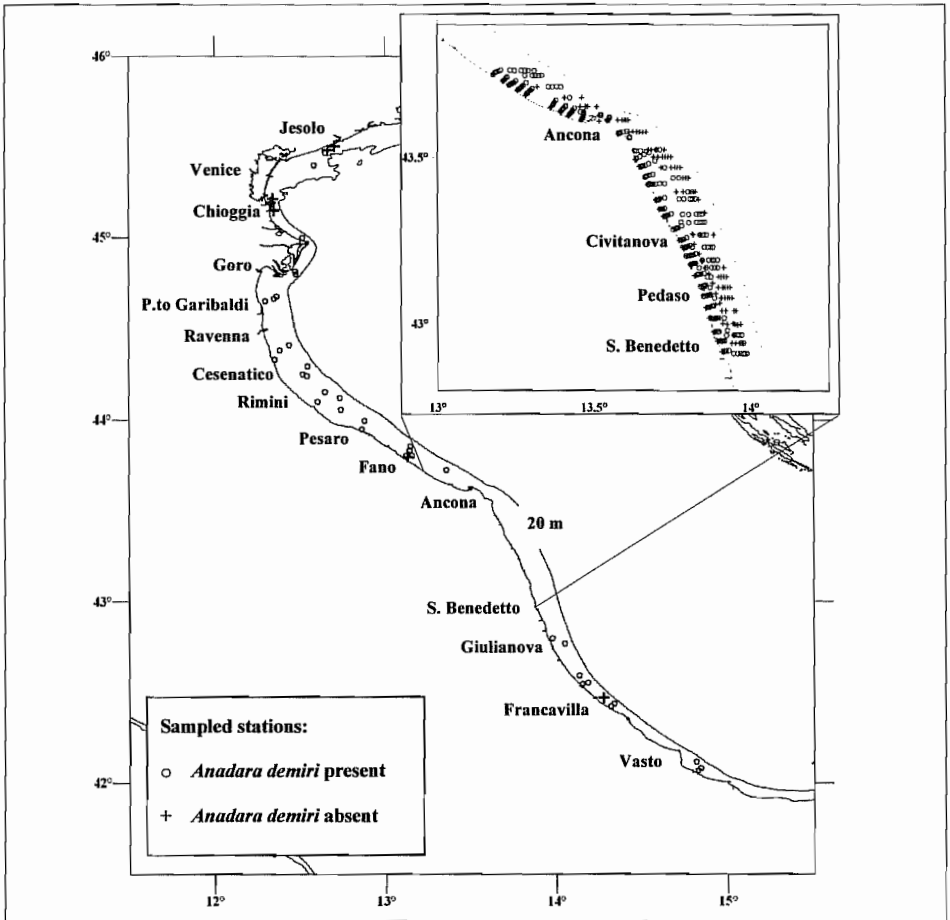


Fig. 5 - Geographical distribution of *Anadara demiri* in the northern and central Adriatic Sea

of the northern and central Adriatic Sea revealed that the species is able, with discrete success, to colonise the sandy-silty substrata in open sea as well. *M. senhousia* was, in fact, found in marine waters, between 5 and 14 m, often with *A. inaequivalvis* and *A. demiri*, from Porto Garibaldi to S. Benedetto del Tronto (Fig. 7), the greatest densities being recorded off Rimini (mean: 60 ind. m<sup>-2</sup>; st. dev.: 52 ind. m<sup>-2</sup>).

*Musculista senhousia*, in contrast to *A. inaequivalvis* which is a long-lived species, has a life cycle one year long (Mistri, 2002).

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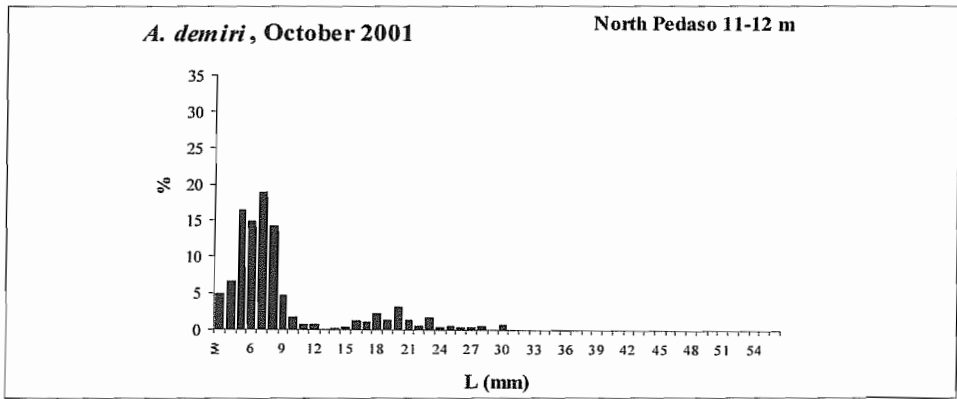


Fig. 6 - Length frequency distribution of the population of *Anadara demiri* in the coastal waters between Civitanova Marche and the mouth of the river Aso in 2001

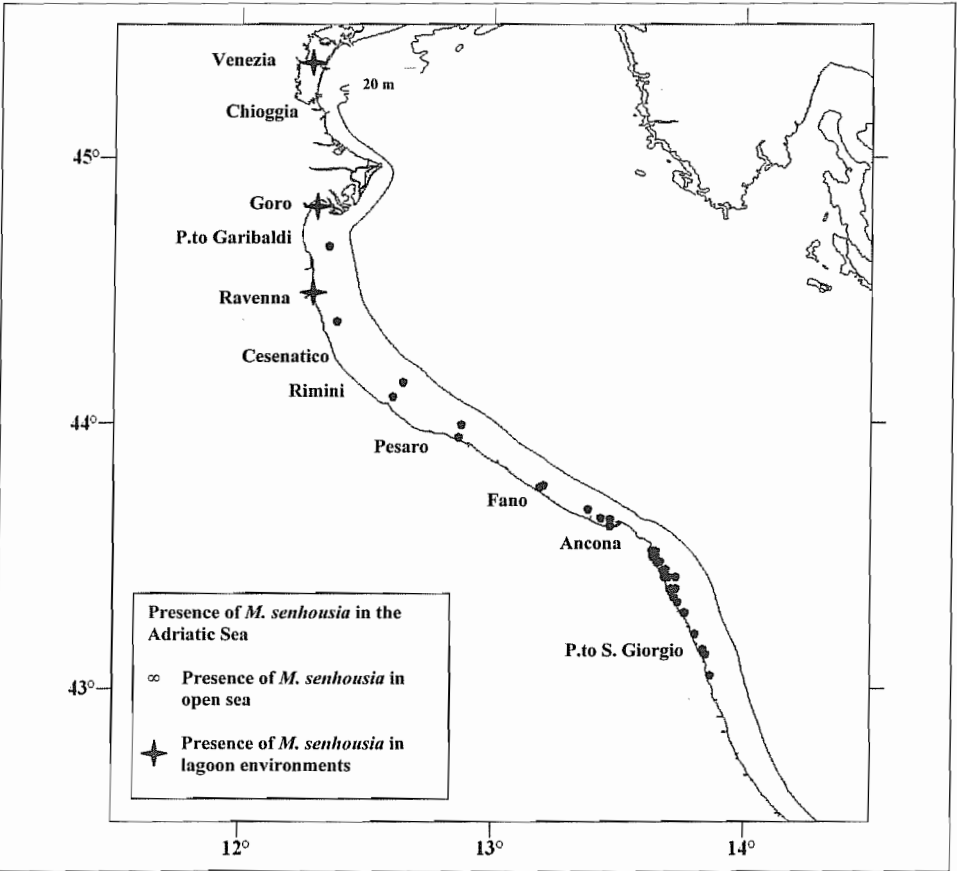


Fig. 7 - Geographical distribution of *Musculista senhousia* in the northern and central Adriatic Sea

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