



Occurrence of exotic mussel, *Arcuatula senhousia* (Benson in Cantor, 1842) along southeast coast of India

Durga Prasad Behera, S. Y. Tenjing^{1*} and Laishram Kosygin²

P.G. Department of Marine Sciences, Berhampur University, Berhampur 760 007, Odisha, India.

¹Department of Biosciences, Mangalore University, Mangalore 574 199, Karnataka, India.

²Zoological Survey of India, 27 J.L. Nehru Road, Kolkata 700 016, West Bengal, India.

*Correspondence e-mail: yambemtenjing@gmail.com

Received: 23 June 2018 Accepted: 06 April 2019 Published: 10 June 2019

Original Article

Abstract

The Asian date mussel *Arcuatula senhousia* (Benson in Cantor, 1842) collected from Mandapam (Palk Bay), southeast coast of India is reported for the first time. The mussel were observed in the intertidal regions to depths of 2 m. The occurrence of the non-indigenous species, *A. senhousia* belonging to Mytilidae family is reported with its associate flora and fauna. Its appearance was associated with 11 flora and 13 fauna. In the present paper, notes about the history of invasion of this small green mussel, introduction and dispersal are discussed. Among associate fauna, decapod *Portunus pelagicus* (Linnaeus, 1758) was found to be the predator of this mussel.

Keywords: Mytilidae, alien mussel, associate flora and fauna, predator, Palk Bay

Introduction

The genus *Arcuatula* belongs to the bivalve family Mytilidae of the phylum Mollusca, one of the largest and most successful phyla within the animal kingdom. It is extraordinarily diverse which is adapted in different types of habitat; and has a long planktonic dispersal stage, exhibits rapid growth, has a small and variable body size, high fecundity, and a short life span (Zenetos *et al.*, 2003). Its good dispersal ability in both its native region and in regions to which it have been introduced makes it a successful invader (Creese *et al.*, 1997; NIMPIS, 2002).

Arcuatula senhousia (Benson, 1842) is a typical opportunistic species. It is small and short-lived with a maximum length of 3.5 cm and longevity of approximately 2 years; and has fast growth (Morton, 1974; Tanaka and Kikuchi, 1978; Crooks, 1996). *A. senhousia* can achieve considerable densities; and are suspension-feeder that lives in both intertidal and subtidal soft sediments of bays and estuaries (Kikuchi and Péres, 1977; Crooks, 1992). In its typical sandy or muddy habitat, the byssus is used to form a cocoon, which may protect the thin-shelled bivalve and stabilize the animal in the sediment (Morton, 1974). *A. senhousia* commonly known as Asian date mussel which is widespread in several regions, from the Asian continent to the western coast of the USA, to the New Zealand and Australian coasts, along

the Israel coast to the Red Sea, off the islands of Zanzibar and Madagascar as well as in Indo-China and Japan (Lazzari and Rinaldi, 1994). Where the mussel lives in high densities, these nests can be woven together to create a byssal mat, thereby altering the nature of the habitat (Morton, 1974; Crooks, 1992). In the present study, taxonomy of *A. senhousia*, introduction, dispersal and its associate flora and fauna are studied.

Material and methods

A. senhousia were collected from rocky intertidal zones of (09°16'59.52"N, 79°11'20.98"E) in the Palk Bay (Tamil Nadu) located along south east coast of India. Shells were measured with the help of Vernier caliper. The specimens were preserved in 7% formalin. This species was found at the lower substratum of ascidian colony *Polyclinum saturnium* (Savigny, 1816). A stereo microscope was used to observe this small sized mussel for identification and identified following several standard books (Satyamurti, 1956; Oliver, 1992; Bosch *et al.*, 1995; Fernando and Fernando, 2002; Huber, 2010; Huber, 2015; Subba Rao, 2017). Later the specimen (M.2097) was deposited at the Marine Biology Regional Centre, Chennai (Zoological Survey of India). The status of this mussel was updated from the World Register of Marine Species (WoRMS) database. This taxon does not come in the Red list of the International Union for Conservation of Nature (IUCN).

Results and discussion

Taxonomic hierarchy

Taxonomic hierarchy was referred from WoRMS database. The mussel belongs to the genus *Arcuatula* of the family Mytilidae, order Mytilida, of the subclass Pteriomorphia. Detail of taxonomic hierarchy is given below:

Phylum	: Mollusca Linnaeus, 1758
Class	: Bivalvia Linnaeus, 1758
Subclass	: Pteriomorphia Beurlen, 1944
Order	: Mytilida Férussac, 1822
Superfamily	: Mytiloidea Rafinesque, 1815
Family	: Mytilidae Rafinesque, 1815
Genus	: <i>Arcuatula</i> Jousseaume in Lamy, 1919
Species	: <i>senhousia</i> (Benson, 1842)

Common name

A. senhousia, commonly known as the Asian mussel, Asian date mussel or Bag mussel is a marine bivalve mussel. Other common names of this species include the Senhouse's mussel, Japanese mussel and the Green bag mussel.

Description

1842. *Modiola senhausi*: Benson, Ann. Mag. Nat. His., IX: 489.
 1856. *Modiola undulata*: Dunker, Zool. Soc. London Proc., XXIV: 358-366.
 1874. *Modiola ballaridiana*: Tapparone, Zool. Viag. Int. Globo. Rgia. Fpeg. Margenta: 144.
 1911. *Modiola chilkaensis*: Preston, Rec. Ind. Mus., VI: 39.
 1914. *Modiola undulate* var. *crassicostata*: Preston, Rec. Ind. Mus., X: 304.
 1916. *Modiola undulate*: Annandale, Mem. Indi. Mus., V: 358
 1932. *Brachyodontes senhausia*: Nomura et, Hatai. Satio. Hoon Kai Mus. Notes, I: 4.
 1991. *Masculista senhausia*: Sreedhar, Dept. Aquatic Bio. Fish., Univ. Kerala, 7-9, (misspelling).

This species is characterised by elongate and oblong shell with sub-terminal umbo (Fig. 1 and 2). The antero-end part is bluntly rounded; ligamental margin of the dorsal part is almost straight. The posterior margin is arcuate and the ventral margin is slightly concave. Lunule well developed with radial striae which makes the margin crenulated. Umbo is clear and edentulous, located somewhat close to the anterior end; anterior margin is markedly extending beyond the umbo. Teeth-like granulation is present on the dorsal shell margin behind the ligament. Periostracum is thin, shiny, smooth and yellow-green in colour. Anterior adductor is long, thin, curved and located near antero-ventral margin; anterior byssal retractors nearly circular and inserting into the umbonal cavity. Posterior adductor is slightly oval and

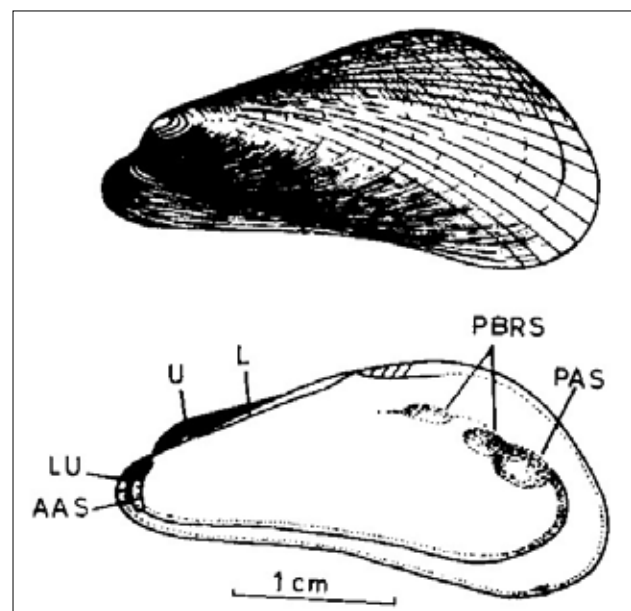


Fig. 1. External and internal view of shell of *A. senhousia* (source: Shredhar, 1991) showing the muscle impressions (Anterior adductor scar: AAS, Posterior adductor scar: PAS), posterior byssal retractor scar (PBRs), Lunule (Lu), Umbo (U) and ligament (L)



Fig. 2. *A. senhousia* collected from Mandapam (Palk Bay); Umbo part is crushed by predator, *Portunus pelagicus* (field observation).

located above the midway between dorso-ventral margins in the posterior quarter of the shell. 17-23 radial lines extend from umbo to the posterior border of the mussel shell. Interior of the shells is white or purple white and iridescence limited to the region of muscle scars. Posterior byssal-pedal retractors entirely or partially split into two main bundles and are inserted to the dorsal shell margin along the posterior adductor.

Associate flora/fauna and predator

A total of 11 epiphytes and 13 epifauna species were observed in the present study (Table 1). Of the 11 epiphytic algae, 3 were green algae, 2 were brown algae, 5 were red algae and 1 was blue green algae. The 13 epifauna included Anthozoa (1), Acidiacea (3), Maxillopod (1), Ectoprocta (2), Gastropod (1), Isopods (1), Ophiuroidea (1), Polychaetes (2), Bivalvia (1)

and Decapod (1). Among the epifauna, *Didemnum* sp. was the dominant fauna and in epiphytes, *Enteromorpha intestinalis* was the dominant alga. In the Palk Bay, crab *Portunus pelagicus* were found to prey upon the mussel, *A. senhousia*.

Earlier the species name was *Musculista senhousia* (Benson, 1842) but according to WoRMS taxon this species is now accepted as *Arcuatula senhousia*. The genus *Musculista* (Yamamoto and Habe, 1958) has been wrongly identified as *Modiolus* by Lamarck earlier. There is confusion regarding systematics of this species due to its modioliform shells, but *Musculista* lack periostracum which is an important character for *Modiolus*. Categorically in *Musculista* hinge teeth are absent and teeth-like crenulations are present in the lunar margin. But the teeth-like crenulations are absent in *Modiolus*. In *Musculista* presence of smooth shell surface contain 18-22 radial lines, but it is absent in *Modiolus* (Kuriakose, 1973).

The species was found in abundance in Cochin backwaters, Kerala, covering the bottom, attached by byssal threads (Sreedhar, 1991). In the Palk Bay, these mussels are usually vertically anchored into a soft substrate and surrounded by well-developed byssus, which is used to construct a cocoon that protects the shell. This cocoon is made up of byssal threads and sediment. With only its posterior end protruding, the siphons can access the water enabling it to feed.

A map of global introduction of this species is shown in Fig. 3. *A. senhousia* is native to Asia, where it is found from the Siberian coast (Kulikova, 1978, 1979), the Red Sea (Barash, 1971; Barash and Danin, 1972; Hoenselaar and Hoenselaar, 1989) and around the Malay Peninsula (Chuang, 1961). This species was first

Table 1. Associate epiphytes and epifauna species

Epiphytes		Epifauna	
Group	Species	Group	Species
Green algae	<i>Enteromorpha intestinalis</i>	Anthozoa	<i>Bolocerooides</i> sp.
	<i>Chaetomorpha crassa</i>	Asciacea	<i>Didemnum</i> sp.
	<i>Ulva reticulata</i>	Asciacea	<i>Polyclinum saturnium</i>
Brown algae	<i>Padina gymnospora</i>	Asciacea	<i>Botryllus</i> sp.
	<i>Hydroclathrus clathratus</i>	Maxillopod	<i>Balanus perforate</i>
Red algae	<i>Acanthophora spicifera</i>	Ectoprocta	Unidentified bryozoans-1
	<i>Liagora ceranoides</i>	Ectoprocta	<i>Echinochalina</i> sp.
	<i>Hypnea pannosa</i>	Isopod	<i>Cymodoce truncata</i>
	<i>Gracilaria edulis</i>	Ophiuroidea	<i>Ophioplocus</i> sp.
Blue green algae	<i>G. dura</i>	Polychaete	<i>Nereis</i> sp.
	<i>Lyngbya</i> sp.	Polychaete	<i>Trematode</i>
		Bivavia	<i>Modiolus</i> sp.
		Decapod	Crab (<i>Portunus pelagicus</i>)

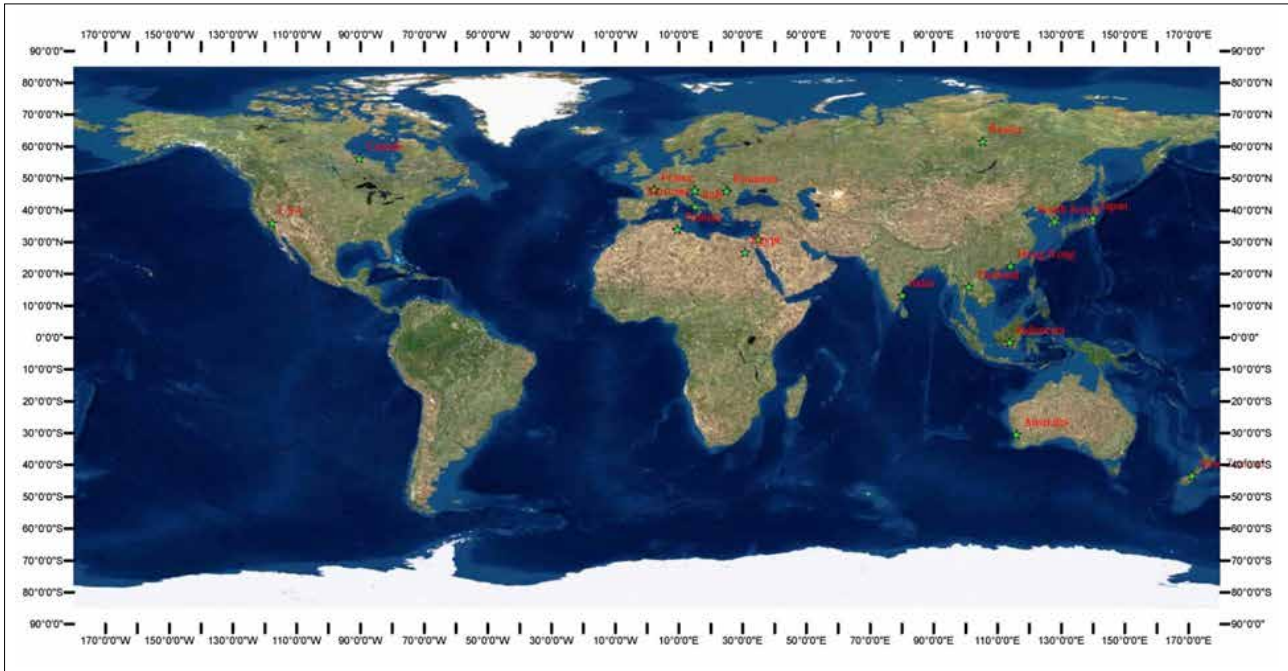


Fig. 3. Global distribution of *A. senhousia*

reported in 1924 in Japanese oyster (*Crassostrea gigas*) beds in the Puget Bay, Washington (Kincaid, 1947), but it probably did not establish at that time (Cohen, 2005). In the 1940s, *A. senhousia* was reported from central California (Carlton, 1979) and in the mid-decade of 1960 in southern California (Crooks, 1996). In the Mediterranean, it was first recorded in 1964 from the coast of Israel (Zenetos *et al.*, 2003), then successively from Bardawil Lagoon, Egypt, in 1971 (Zenetos *et al.*, 2003); three lagoons in Languedoc, France, in the 1980s (Clanzig, 1989; Hoenselaar and Hoenselaar, 1989); in the Northern Adriatic Sea: Sacca di Goro in 1994 (Mistri, 2002), Valli di Comacchio in 1997-98 (Mistri *et al.*, 2000), Slovenia in 1997 (De Min and Vio, 1997); in the Gulf of Taranto, north-western Ionian Sea, in 2001 (Mastrototaro *et al.*, 2003). Mistri (2002) reported this mussel in 2002 from the Gulf of Olbia, north-eastern Sardinia Tyrrhenian Sea. Later, Micu (2004) also reported in 2002 from the Romanian coast of the Black Sea. Besides, its occurrence in the north-eastern Pacific and the Mediterranean, *A. senhousia* has been also introduced to New Zealand in 1978 (Willan, 1985) and Western Australia in 1983 (Slack-Smith and Brearley, 1987). Finally, it has been reported from the Great Bitter Lake (Suez Canal), Red Sea, Aden, Zanzibar, Madagascar, Mauritius, Indo-China and New Caledonia (Barash and Danin, 1972; FAO, 1998), but its status as a native or introduced species in the Indian Ocean remains unclear (NIMPIS, 2002). In India, *A. senhousia* was first reported in Cochin backwater (Sreedhar, 1991). Later, Feebarani (2016) reported this species during 2002-2004 from the Cochin Estuary, southwest of India. The species was reported recently from Mumbai (south west coast

of India) (Anil *et al.*, 2004). In the southeast coast of India, this mussel is not reported from anywhere else except from our study area (Palk Bay). According to the findings of Anil *et al.* (2004), this Asian date mussel is a harmful species reported from the Jawaharlal Nehru Port and Mumbai Port. A limitation of the environmental matching approach is that several harmful species appear capable of tolerating relatively saline regimes and wide temperature (Anil *et al.*, 2004).

The earliest records of the *A. senhousia*, indicate its use as a human food source in China (Benson, 1855). In addition, it is used as food for domestic or cultured organisms in Asian countries, including Thailand, Japan, and India. In Thailand, *A. senhousia* is used to feed ducks, chickens, fish, and shrimp (Saraya, 1982; Amornjaruchit, 1988; Chalermwat *et al.*, 1988; Lutz *et al.*, 1991). This mussel occurs in large quantities in areas of Cochin backwaters and it is being used as fertilizer and poultry feed (Sreedhar and Radhakrishnan, 1995).

The role of the non-indigenous mussel, *A. senhousia* was assessed on the growth and mortality of two species of clams reared in Italy namely *Tapes decussatus* and *Ruditapes philippinarum* (Mistri, 2004). *R. philippinarum* grew faster than *T. decussatus*, but the growth of both clams did not seem affected by the presence of *A. senhousia* in its mats. On the other hand, the presence of the alien molluscs, *A. senhousia* stresses the importance of algae as a vehicle and/or receptor habitat for alien species in artificial rocky shores in the Bay of Tunis (Antit *et al.*, 2013). Similarly, this mussel reported in

the present study may stress the habitats of marine flora and fauna. Feebarani (2016) stated that the bivalve *A. senhousia* was found to be a new invader to the system. It formed thick mat over the bottom, preventing the growth of other benthic animals. But their representation was occasional. It generally exhibited clumped distribution. Therefore, the habitat where this alien mussel occurs in India should be monitored regularly to know whether there are positive/negative impacts or not in marine/estuarine ecosystem.

Acknowledgements

The first author is thankful to the Department of Marine Sciences, Berhampur University, Odisha for providing the necessary facilities during the course of work.

References

- Amornjaruchit, S. 1988. Economically important molluscan shellfish of Thailand. Bivalve mollusc culture research in Thailand. International Center for Living Aquatic Resources Management Technical Reports, Bangkok, 18 pp.
- Anil, A. C., C. Clarke, T. Hayes, R. Hilliard, G. Joshi, V. Krishnamurthy, J. Polglaze, S. S. Sawant and S. Raaymakers. 2004. Ballast water risk assessment, Ports of Mumbai and Jawaharlal Nehru, India, October 2003: Final Report. GloBallast Monograph. 11. IMO, London, 63 pp.
- Antit, M., A. Daoulati, J. L. Rueda and C. Salas. 2013. Temporal variation of the algae associated molluscan assemblage of artificial substrata in the Bay of Tunis (Tunisia). *Medit. Mar. Sci.*, 14: 390-402.
- Barash, A. 1971. Mollusca from the stomach of *Sparus auratus* fished in the lagoon of Bardawil. Argamon. *Israel J. Malac.*, 2: 97-104.
- Barash, A. and Z. Danin. 1972. The Indo-Pacific species of Mollusca in the Mediterranean and notes on a collection from the Suez Canal. *Israel J. Zool.*, 21: 301-374.
- Benson, W. H. 1842. Mollusca. In: T. Cantor (Ed.), General features of Chusan with remarks on the flora and fauna of that Islafid. Annals and Magazine of Natural History, London, p. 481-493.
- Benson, W. H. 1855. Chusan shells. *J. Asiat. Soc. Bengal*, 24: 119-140.
- Bosch, D. T., S. P. Dance, R. G., Moolenbeek and P. G. Oliver. 1995. Seashells of Eastern Arabia. Emirates Printing Press, Dubai, 295 pp.
- Carlton, J. T. 1979. History, biogeography, and ecology of the introduced marine and estuarine invertebrates of the Pacific Coast of North America. Ph. D. thesis, University of California, Davis, California.
- Chalermwat, K., R. A. Lutz and P. Menasveta. 1988. Mussel culture in Thailand: A synopsis. *J. Shellfish Res.*, 7: 567.
- Chuang, S. H. 1961. On Malayan shores. Muwu Shosa, Singapore, 225pp.
- Clanzig, S. 1989. Invertébrés d'introduction récente dans les lagunes méditerranéennes du Languedoc-Roussillon (France). *Bull. Soc. Zool. Fr.*, 114: 151-152.
- Cohen, A. N. 2005. *Musculista senhousia* (Benson in Cantor, 1842). In: Guide to the exotic species of San Francisco Bay. San Francisco Estuary Institute, Oakland. www.exoticguide.org/species_pages/msenhousia.html
- Creese, R., S. Hooker, S. DeLuca and W. Wharton, W. 1997. Ecology and environmental impact of *Musculista senhousia* (Mollusca: Bivalvia: Mytilidae) in Tamaki Estuary, Auckland, New Zealand. *New Zeal. J. Mar. Fresh.*, 31: 225-236.
- Crooks, J. A. 1992. The ecology of the introduced bivalve *Musculista senhousia* in Mission Bay, San Diego. M.Sc. thesis, San Diego State University, San Diego, California.
- Crooks, J. A. 1996. The population ecology of an exotic mussel, *Musculista senhousia*, in a Southern California Bay. *Estuaries*, 19: 42-50.
- De Min, R. and E. Vio. 1997. Molluschi conchiferi del litorale sloveno. *Ann. Ser. Hist. Nat.*, 11: 241-258.
- FAO, 1998. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, Corals, Bivalves and Gastropods. FAO, Rome, 686 pp.
- Feebarani, J. 2016. Long-term changes in the species composition of molluscs in Cochin backwaters, southwest coast of India. *IOSR J. Environ. Sci. Toxicol. Food Tech.*, 10: 40-43.
- Fernando, S. A. and O. J. Fernando. 2002. A field guide to the common invertebrates of the east coast of India. Annamalai University, Parangipettai, 258 pp.
- Hoenselaar, H. J. and J. Hoenselaar. 1989. *Musculista senhousia* (Benson in Cantor, 1842) in the Western Mediterranean (Bivalvia, Mytilidae). *Basteria*, 53: 73-76.
- Huber, M. 2010. Compendium of bivalves: A full-color guide to 3,300 of the world's marine bivalves: A status on Bivalvia after 250 years of research. ConchBooks, Hackenheim, 901 pp.
- Huber, M. 2015. Compendium of Bivalves 2. A full-color guide to the remaining seven families. A systematic listing of 8,500 bivalve species and 10,500 synonyms. ConchBooks, Hackenheim, 907 pp.
- Kikuchi, T. and J. M. Peres. 1977. Consumer ecology of sea-grass beds. In: C.P. McRoy and C. Helfferich (Eds.), Seagrass ecosystems. A scientific perspective. Marcel Dekker, Inc., New York, p. 147-193.
- Kincaid, T. 1947. The acclimatization of marine animals in Pacific northwest waters. *Min. Conchol. Club So. Calif.*, 72: 1-3.
- Kulikova, V. A. 1978. Morphology, seasonal population dynamics, and settlement of larvae of the bivalve mollusc *Musculista senhousia* in Busse Lagoon (South Sakhalin). *Soviet J. Mar. Biol.*, 4: 769-773.
- Kulikova, V. A. 1979. Reproduction peculiarities of bivalve mollusks in Busse Lagoon in relation to water temperature. *Soviet J. Mar. Biol.*, 5: 25-48.
- Lazzari, G. and E. Rinaldi. 1994. Alcune osservazioni sulla presenza di specie extra mediterranee nelle lagune salmastre di Ravenna. *Bollettino Malacologico*, 30: 195-202.
- Lutz, R. A., K. Chalermwat, A. J. Figueras, R. G. Gustafson and C. Newell. 1991. Mussel aquaculture in marine and estuarine environments throughout the world. In: W. Menzel (Ed.), Estuarine and marine bivalve mollusc culture. CRC Press, Boca Raton, p. 57-97.
- Micu, D. 2004. Annotated checklist of the marine Mollusca from the Romanian Black Sea. In: B. Ozturk, V.O. Mokievsky, and B. Topaloglu (Eds.), International workshop on Black Sea benthos. Turkish Marine Research Foundations, Turkey, p. 184-149.
- Mastrototaro, F., A. Matarrese and G. Donghia. 2003 Occurrence of *Musculista senhousia* (Mollusca: Bivalvia) in the Taranto seas (eastern-central Mediterranean Sea). *J. Mar. Biol. Assoc. UK*, 83: 1279-1280.
- Mistri, M., E. A. Fano, G. Rossi, K. Caselli and R. Rossi. 2000. Variability in macrobenthos communities in the Valli di Comacchio, Northern Italy, a hypereutrophized lagoonal ecosystem. *Estuar. Coast. Shelf Sci.*, 51: 599-611.
- Mistri, M. 2002. Ecological characteristics of the invasive Asian date mussel, *Musculista senhousia*, in the Saccadi Goro (Adriatic Sea, Italy). *Estuaries*, 25: 431-440.
- Mistri, M., R. Rossi and E. A. Fano. 2004. The spread of an alien (*Musculista senhousia*, Bivalvia) in the Sacca di Goro lagoon (Adriatic Sea, Italy). *J. Mollus. Stud.*, 70: 257- 261.
- Morton, B. 1974. Some aspects of the biology, population dynamics, and functional morphology of *Musculista senhousia* Benson (Bivalvia, Mytilidae). *Pac. Sci.*, 28: 19-33.
- NIMPIS. 2002. *Musculista senhousia* species summary. In: C. L. Hewitt, R. B. Martin, C. Sliwa, F. R. McEnnulty, N. E. Murphy, T. Jones and Cooper, S. (Eds.), National Introduced Marine Pest Information System. <http://crimp.marine.csiro.au/nimpis> (accessed on 15 September 2008)
- Oliver, P. G. 1992. Bivalved shells of the Red Sea. An identification guide. Christa Hemmen, Verlag and the National Museum of Wales, Cardiff, 330 pp.
- Saraya, A. 1982. Country report : Thailand. In: F. B. Davy and M. Graham (Eds.), Bivalve culture in Asia and the Pacific. International Development Research Center, Ottawa, Canada, p. 73-78.
- Satyamurti, S. 1956. The Molluca of Krusadai Island (the Gulf of Mannar). II. Scaphopoda, Pelecypoda and Cephalopoda. Superintendent Government Press, Madras, 202 pp.
- Slack-Smith, S. M. and A. Brearley. 1987. *Musculista senhousia* (Benson, 1842); a mussel recently introduced into the Swan River estuary, Western Australia. (Mollusca: Mytilidae). *Rec. West. Aust. Mus.*, 13: 225-230.
- Sreedhar, K. S. 1991. Studies on the biology of bivalves *Musculista senhousia* (Benson) from Cochin backwater. Ph. D. thesis, Cochin University of Science and technology, Cochin.
- Sreedhar, K. S. and C. K. Radhakrishnan, 1995. Energy storage and utilisation in relation to gametogenesis in the mussel, *Musculista senhousia* (Bivalvia: Mytilidae) from Cochin backwaters, west coast of India. *Indian J. Mar. Sci.*, 24: 203-206.
- Subba Rao, N. V. 2017. Indian seashells, Part 2: Bivalvia. Zoological Survey of India, Kolkata, 568 pp.
- Tanaka, M. and T. Kikuchi. 1978. Ecological studies on benthic macrofauna in Tomoe Cove, Amakusa II. Production of *Musculista senhousia* (Bivalvia, Mytilidae). *Publ. Amakusa Mar. Biol. Lab. Kyushu Univ.*, 4: 215-233.
- Willan, R. C. 1985. Successful establishment of the Asian mussel *Musculista senhousia* (Benson in Cantor, 1842) in New Zealand. *Rec. Auckland Inst. Mus.*, 22: 85-96.
- Zenetos, A., S. Gofas, G. Russo and J. Templado. 2003. CIESM atlas of exotic species in the Mediterranean. CIESM Publishers, Monaco, 376 pp.