



HAL
open science

Northern range expansion of the Asian mussel *Arcuatula senhousia* (Benson, 1842) along the French Atlantic coasts

Cécile Massé, Jérôme Jourde, Denis Fichet, Pierre-Guy Sauriau, Manon
Dartois, François Ghillebaert, Chloé Dancie

► To cite this version:

Cécile Massé, Jérôme Jourde, Denis Fichet, Pierre-Guy Sauriau, Manon Dartois, et al.. Northern range expansion of the Asian mussel *Arcuatula senhousia* (Benson, 1842) along the French Atlantic coasts. *BioInvasions Records*, 2022, 11 (3), pp.700-709. 10.3391/bir.2022.11.3.12 . hal-03331497

HAL Id: hal-03331497

<https://hal.science/hal-03331497>

Submitted on 16 Nov 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Rapid Communication**Northern range expansion of the Asian mussel *Arcuatula senhousia* (Benson, 1842) along the French Atlantic coasts**

Cécile Massé^{1,*}, Jérôme Jourde², Denis Fichet², Pierre-Guy Sauriau², Manon Dartois², François Ghillebaert³ and Chloé Dancie⁴

¹UMS 2006 Patrimoine Naturel (PATRINAT), OFB, CNRS, MNHN, CP41, 36 rue Geoffroy Saint-Hilaire 75005 Paris, France

²UMR 7266 LIENSs CNRS, La Rochelle Université, 2 rue Olympe de Gouges, 17000 La Rochelle, France

³ECOTOX, 11 rue Principale, 62380 Affringues, France

⁴Cellule de Suivi du Littoral Normand (CSLN), 53 rue de Prony, 76600 Le Havre, France

*Corresponding author

Author e-mails: cecile.masse@mnhn.fr

Citation: Massé C, Jourde J, Fichet D, Sauriau P-G, Dartois M, Ghillebaert F, Dancie C (2022) Northern range expansion of the Asian mussel *Arcuatula senhousia* (Benson, 1842) along the French Atlantic coasts. *BioInvasions Records* 11(3): 700–709, <https://doi.org/10.3391/bir.2022.11.3.12>

Received: 31 May 2021

Accepted: 1 September 2022

Published: 11 July 2021

Handling editor: Mikhail Son

Thematic editor: Amy Fowler

Copyright: © Massé et al.

This is an open access article distributed under terms of the Creative Commons Attribution License ([Attribution 4.0 International - CC BY 4.0](https://creativecommons.org/licenses/by/4.0/)).

OPEN ACCESS**Abstract**

The Asian mussel *Arcuatula senhousia* is known as a successful invader into coastal and estuarine environments worldwide. We here report its Northward expansion along the French Atlantic coast evidenced by new records from the commercial ports of La Rochelle (Bay of Biscay) and Dunkirk (North Sea), both in 2018, following sampling of benthic macroinvertebrates. To date, the Asian mussel has only been observed along the French coast from the Mediterranean Sea and the Southern part of the Bay of Biscay. Its presence in these new locations, which are important for international maritime transport, is most likely related to ship ballast water and/or sediment as vector of introduction. These new insights suggest that this species has not yet finished its expansion process, which could be at the origin of irreversible impacts on ecosystem structure, functioning and services.

Key words: non-indigenous, maritime traffic, harbour, France

Introduction

The Asian mussel *Arcuatula senhousia* (Benson, 1842) is a small mytilid (Figure 1), with a maximum size of 32 mm, a short lifespan (< 2 years) and high growth rate (Crooks 1996). This semi-buried suspension feeder lives in intertidal and subtidal soft sediments of bays, estuaries and lagoons and is known as a successful invasive species (Crooks 1998; Reusch and Williams 1998; Como et al. 2018). The native area of *A. senhousia* ranges from Siberia to Singapore (Chuang 1961), but it has been introduced in numerous localities worldwide over many decades such as in New-Zealand and Australia (Willan 1985, 1987), the USA (Crooks 1996, 1998; Wasson et al. 2001), India (Kutty et al. 2016) and Africa (Lourenço et al. 2018). Since 1989, it has been regularly reported from European coasts (Figure 2A): in the Mediterranean Sea (Hoenselaar and Hoenselaar 1989; Lazzari and Rinaldi 1994; Mistri et al. 2000; Mistri 2002; Mastrototaro et al. 2003; Zenetos et al. 2003; Doğan et al. 2014; Como et al. 2016; Scirocco and Urbano 2018);



Figure 1. *Arcuatula senhousia* specimens (A) from Dunkirk (© Chloé DANCIE), and (B) from Port Atlantique La Rochelle (© Pierre-Guy SAURIAU).

in the Black Sea (Kovalev et al. 2017; Chartosia et al. 2018; Zhulidov et al. 2021); in the Atlantic Ocean in the South of the Bay of Biscay (Bachelet et al. 2009); in UK in the Solent and particularly from Southampton Water estuary since 2007 (Barfield et al. 2018; Holman et al. 2019; Worsfold et al. 2020; Watson et al. 2021); and in the Netherlands (Faasse 2018).

Previous to this study in France, live specimens were observed at the beginning of the 1970s in oyster-spat batches imported from Japan for seafarming along the French Atlantic coasts, but no live specimens were recorded in the environment at that time (Gruet et al. 1976). Live specimens were reported for the first time during the '80s, in Mediterranean lagoons (Hoenselaar and Hoenselaar 1989; Clanzig 1989). Then, Charles (2007) reported the occurrence of large numbers of dead shells in Arcachon Bay, in southwest France, but the species had likely been already present there since 2002 (Bachelet et al. 2009). New records were also reported in the southern Bay of Biscay from the Bidassoa estuary and Hossegor lake by the end of 2006 (Bachelet et al. 2009). Depending on location, the introduction of *A. senhousia* has been attributed either to maritime traffic (e.g., Doğan et al. 2014) or to the activity of marine culture (e.g. Bachelet et al. 2009; Florio et al. 2008).

This non-indigenous species may be responsible for drastic modifications of structure and functioning of benthic communities (Creese et al. 1997; Reusch and Williams 1998), therefore strengthening the need for signalling any new records of the species, namely its expansion, as suggested by Bernard et al. (2020). We reported here new French records of *A. senhousia* from the commercial ports of La Rochelle (Bay of Biscay) and in Dunkirk (North

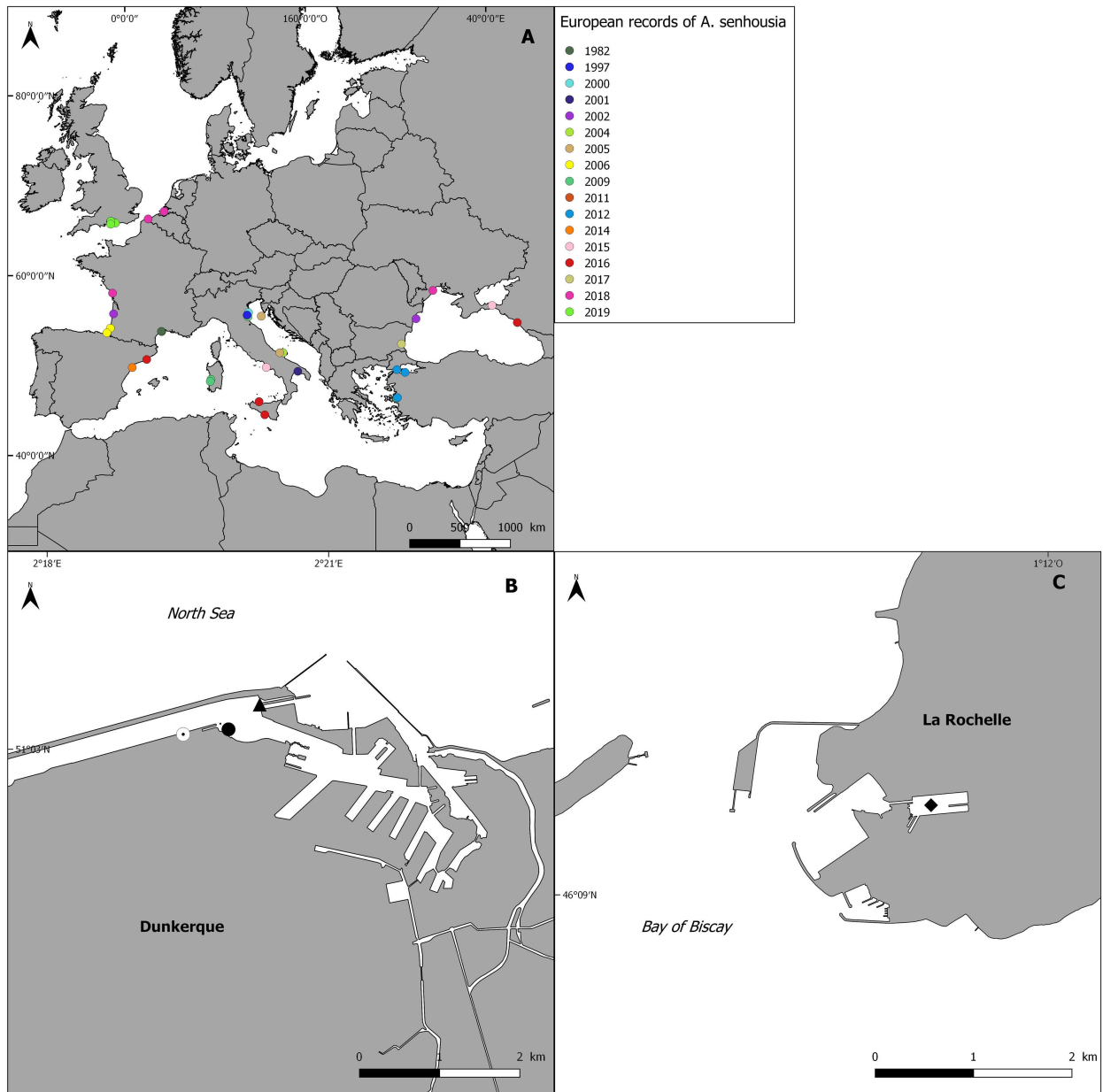


Figure 2. A: Locations of first records of *Arcuatula senhousia* on the different European marine regions by reporting year. Source of records: Bachelet et al. 2009; Chartosia et al. 2018; Como et al. 2016; Crocetta et al. 2015; Doğan et al. 2014; Faasse 2018; Florio et al. 2008; Hoenselaar and Hoenselaar 1989; Kovalev et al. 2017; Lazzari and Rinaldi 1994; Lourenço et al. 2018; Mavrič et al. 2010; Mastrototaro et al. 2003; Micu 2004; Mistri 2002; Mistri et al. 2000; Öztürk et al. 2017; López-Soriano and Quiñonero-Salgado 2014; Ulman et al. 2017; Watson et al. 2021 and references therein; Zhulidov et al. 2021. B: Dunkirk harbour. White dotted circle: Sea Basin Intake station; Black circle: Sea Basin Outfall station; Black triangle: single dead specimen found. C: Port Atlantique La Rochelle. Black diamond: tidal lock basin station with dead and live specimens. For details see Supplementary material Table S1 and Table 1.

Sea) during three different surveys of benthic macrofauna communities (Figure 2B, C). These new records suggest that expansion and/or new introduction events of this species continue and that the invasion process is underway.

Materials and methods

Specimens from Port Atlantique La Rochelle were collected in 2018 by students enrolled in courses from La Rochelle University from the N/O

Table 1. Records of *Arcuatula senhousia* in Port Atlantique La Rochelle (Bay of Biscay) and Dunkirk (North Sea). Lat.: Latitude; Long.: Longitude; Ab: Abundance (individuals per m²).

Location	Station	Date	Lat.	Long.	Habitat	Temperature (°C)	Salinity (‰)	Mean Ab. (ind.m ⁻² ± SD)
Dunkirk	Sea basin cooling water outfall	March 2018	51.05222	2.33222	Subtidal sandy-mud	8.6	28.8	7 ± 6
		October 2018	51.05223	2.33205	Subtidal sandy-mud	No data	No data	23 ± 11
	Sea basin intake	March 2018	51.05167	2.32417	Subtidal sandy-mud	7.8	28.8	7 ± 6
		October 2018	51.05175	2.32367	Subtidal sandy-mud	No data	No data	33 ± 32
La Rochelle	Tidal lock basin	September 2018	46.15820	-1.21540	Subtidal mud	No data	No data	3 ± 5
		September 2019	46.15820	-1.21540	Subtidal mud	19.8	34.9	97 ± 15

l'Estran, and again in 2019 during the Marine Strategy Framework Directive (MSFD) monitoring of non-indigenous species from the N/O l'Astérie. Sampled stations were located within the tidal lock basin of the harbour. Specimens from Dunkirk port were collected in two stations in the sea basin during a general environmental monitoring for the DK6 (Dunkerque) CCGT Gas Power Plant France in March and October 2018. At all locations, sediment was sampled using a Van Veen grab (0.1 m²) and gently sieved through a 1 mm mesh sieve. The remaining fraction was fixed in 4% formalin. Samples were washed in the laboratory to remove formalin, and macrofauna was sorted and preserved in 70% ethanol. The whole benthic faunal community, including *A. senhousia*, was then identified and counted. Temperature and salinity were measured with a multiparameter probe HANNA HI 9828 during sampling. Habitat characteristics, where specimens were recorded, were determined visually.

Species identification: Specimens of *Arcuatula senhousia* were identified following previous descriptions (Slack-Smith and Brearley 1987; Hoenselaar and Hoenselaar 1989; Faasse 2018). Key traits are a brown to greenish periostracum, radiating reddish lines on the posterior part, small internal teeth on the dorsal edge posteriorly to the ligament, and fragile shell with a series of small ribs anterior to the umbones. Some specimens can be more whitish (Figure 1B; Lourenço et al. 2018). *Arcuatula senhousia* cannot be confused with other Mytilidae species from north-eastern Europe (see Tebble 1966).

Results

In the port of Dunkirk, 4 individuals (7 ± 6 ind.m⁻²) were collected at each station in March 2018. In October 2018, 7 and 10 individuals (23 ± 11 and 33 ± 32 ind.m⁻²) were collected in the outfall and intake sea basin, respectively (Table 1). In March 2018, the lengths of live specimens ranged from 2–8 mm and in October 2018, the lengths of live specimens ranged from 30–32 mm. They were sampled in a muddy sediment characterised by a faunal community dominated by bivalves, particularly the non-indigenous clam *Ruditapes philippinarum* (respectively in the sea basin outfall and intake 33 ± 35 ind.m⁻² and 153 ± 215 ind.m⁻² in March 2018, and 1363 ± 270 ind.m⁻² and 357 ± 81 ind.m⁻² in October 2018).

In the tidal lock basin of the Port Atlantique La Rochelle, 1 live individual (mean 3 ± 5 ind.m⁻²) was sampled in 2018 and 29 individuals (mean: 97 ± 15 ind.m⁻²) in 2019. The lengths of live specimens from 2018 ranged from 8–9 mm, but one dead specimen 14 mm long was also collected (Figure 1B). The sediment from these locations was muddy, and the community was mainly composed of the native bivalves *Nucula nitidosa* and *Varicorbula gibba* (respectively 1160 ± 676 and 1067 ± 431 ind.m⁻²).

Discussion

Arcuatula senhousia has already demonstrated its ability to invade and impact coastal ecosystems. According to the marine non-indigenous species impacts classification of Katsanevakis et al. (2014), *A. senhousia* was classified as an alien species with a high reported impact on ecosystem services or biodiversity. As summarized in Watson et al. (2021), at high densities, the species modifies benthic habitats by forming dense mats of mussels, as observed seasonally in both its native area in Japan (Takenaka et al. 2018) and in invaded ecosystems in California (Crooks 1998). These habitat modifications have consequences on communities (Crooks 1998) and ecosystem functioning such as food webs (Como et al. 2016; Watson et al. 2021) and nutrient cycling (Takenaka et al. 2018; Bernard et al. 2020).

Carboneras et al. (2018) determined that *A. senhousia* should be prioritised for risk assessment and that this species should be added to the list of Invasive Alien Species (IAS) of Union concern (EU regulation 1143/2014) by 2020. In their study, *A. senhousia* was identified as having a “major” impact (according the EICAT classification, Hawkins et al. 2015), due to its scattered distribution (Carboneras et al. 2018). Since the study of Carboneras et al. (2018), the European distribution of *A. senhousia* has increased from scattered to widespread. It was thus excluded from the updated European horizon scanning promoted by Tsiamis et al. (2020).

The first recent observations of the Asian mussel in neighbouring countries such as southern UK (Barfield et al. 2018; Watson et al. 2021) and the Netherlands (Faasse 2018) suggest a step-by-step northward expansion of the species. Bachelet et al. (2009) predicted an expansion of its distribution in North-Western Europe, but through secondary dispersion. Our new French records seem to be in accordance with these expectations. It could be explained by the planktonic larval stage which gives *A. senhousia* a dispersion capacity estimated at 116 Km (Shanks 2009). However, the presence of the species in semi-enclosed harbour basins suggests a new introduction phenomenon. For Port Atlantique La Rochelle, this is very likely a secondary introduction because ships that enter this tidal lock basin only come from local European or Mediterranean waters (Port Atlantique La Rochelle, *pers. comm.*). Until now, French introductions of *A. senhousia* were thought to be associated with oyster transfers (Hoenselaar and

Hoenselaar 1989; Bachelet et al. 2009) but during benthic community monitoring (Jourde, Sauriau, Aubert, *pers. comm.*), the species has hitherto never been encountered in sediments surrounding oyster farms around La Rochelle and Marennes-Oléron Bay that belong to major shellfish farming areas on the French Atlantic coasts (Gouilletquer and Héral 1997), neither in the marina and in the fishing port. Thus, our observations in the semi-enclosed parts of these two harbours are undoubtedly linked to maritime transport. Absence of the species in surrounding areas where the preferential habitat of *A. senhousia* is found (particularly seagrass habitat) does not support the hypothesis of larval dispersion from an invaded site. Adult specimens live in sediments, and larval stages are planktonic. Thus, ballast waters and sediments are the most likely vectors of these introductions. This hypothesis is supported by the detection of *A. senhousia* DNA in ballast water of a boat coming from the Mediterranean Sea (Slijkerman et al. 2017). The International Convention for the control and management of ships' ballast water and sediment (International Maritime Organization) entered into force in 2017. Since then, ships cannot release untreated ballast water in harbours. Assuming that this species has been introduced through ballast waters in these harbour areas, the introduction certainly took place before 2017.

This species tolerates both subtidal and intertidal environments, up to high tidal levels as in the Arcachon Bay (Bachelet et al. 2009). In its native area, *A. senhousia* is mostly found in estuaries, buried in intertidal and subtidal sediments but also sometimes on hard substrates (Morton 1974; Minchin et al. 2016). The first French historical records, until now, were from lagoons or semi-enclosed bays with freshwater inputs (Hoenselaar and Hoenselaar 1989; Bachelet et al. 2009). Hosozawa et al. (2020) found an optimal salinity range of 9.2 to 17.3 for the species in ecosystems of the Sea of Japan. However, *A. senhousia* can tolerate higher salinities (*e.g.* Bachelet et al. 2009; Watson et al. 2021). Here, specimens were encountered in ecosystems with salinities ranging from 20.7 to 34.8 in Dunkirk port and up to 34.9 in the La Rochelle tidal lock basin. High salinities do not seem to prevent the establishment of the species in this latter location because specimens have been observed there since 2018. Both in La Rochelle and Dunkirk, specimens were found in communities dominated by bivalves, as observed by Watson et al. (2021) and particularly in Dunkirk by the non-indigenous clam *Ruditapes philippinarum*. This is in accordance with the positive correlation between abundances of *A. senhousia* and *R. philippinarum* measured in Sacca di Goro in Italy (Munari 2008).

Our records, which are characterised by relatively high densities (up to 97 ind.m⁻²) of *A. senhousia* in a subtidal marine environment and artificial harbour habitats associated with introductions linked to maritime transport, revealed the high capacity of introduction and establishment of the species. Close to these two introduction sites are ecosystems with the preferred

habitat of the Asian mussel (i.e., large intertidal areas with estuarine environmental characteristics and/or *Zostera noltei* Hornemann, 1832 meadows) (Bachelet et al. 2009; Bernard et al. 2020; Watson et al. 2021). As highlighted by Bernard et al. (2020), these surrounding areas must be monitored for possible further spread of the species.

Acknowledgements

We would like to thank Port Atlantique La Rochelle for the sampling of the tidal lock basin. Authors thank Hervé Derrienic, Benoit Gouillieux and Suzie Humbert for assistance in the field during the sampling of the tidal lock basin of La Rochelle in 2019, the crews of the “Fregate” of Dunkirk Harbour (“Grand Port Maritime” GPMD) for the sampling of the Basin of Dunkirk in 2018, and DK6 (Dunkerque) CCGT Gas Power Plant France for providing authorizations to use proprietary data. Thanks also to Céline Chaignon and Bastien Chouquet for help with the taxonomic determination of fauna samples. We also thank two anonymous reviewers for their useful and constructive comments.

Funding declaration

UMS 2006 Patrimoine Naturel, the Biology Department of La Rochelle University and the DK6 (Dunkerque) CCGT Gas Power Plant France.

Authors' contributions

CM, CD and JJ designed the study, CM, JJ, DF, MD, FG and CD performed the samplings, CM, CD and PGS analysed the results and CM, JJ, CD and PGS wrote the manuscript; all authors reviewed the manuscript.

References

- Bachelet G, Blanchet H, Cottet M, Dang C, de Montaudouin X, de Moura Queiros A, Gouillieux B, Lavesque N (2009) A round-the-world tour almost completed: first records of the invasive mussel *Musculista senhousia* in the North-east Atlantic (southern Bay of Biscay). *Marine Biodiversity Records* 2: e119, <https://doi.org/10.1017/S1755267209001080>
- Barfield P, Holmes A, Watson G, Rowe G (2018) First evidence of *Arcuatula senhousia* (Benson, 1842), the Asian date mussel in UK waters. *Journal of Conchology* 43(2): 217–222
- Bernard G, Kauppi L, Lavesque N, Ciutat A, Grémare A, Massé C, Maire O (2020) An invasive mussel (*Arcuatula senhousia*, Benson, 1842) interacts with resident biota in controlling benthic ecosystem functioning. *Journal of Marine Science and Engineering* 8: 963, <https://doi.org/10.3390/jmse8120963>
- Carboneras C, Genovesi P, Vilà M, Blackburn TM, Carrete M, Clavero M, D'hondt B, Orueta JF, Gallardo B, Geraldes P, González-Moreno P, Gregory RD, Nentwig W, Paquet J-Y, Pyšek P, Rabitsch W, Ramírez I, Scalera R, Tella JL, Walton P, Wynde R (2018) A prioritised list of invasive alien species to assist the effective implementation of EU legislation. *Journal of Applied Ecology* 55: 539–547, <https://doi.org/10.1111/1365-2664.12997>
- Charles L (2007) Premier signalement de *Musculista senhousia* (Benson in Cantor, 1842) (Bivalvia, Mytilidae) sur la côte atlantique française; nouvelle espèce invasive dans le bassin d'Arcachon. *Bulletin de la Société Linnéenne de Bordeaux* 142: 45–52
- Chartosia N, Anastasiadis D, Bazairi H, Crocetta F, Deidun A, Despalatović M, Di Martino V, Dimitriou N, Dragičević B, Dulčić J, Durucan F, Hasbek D, Ketsilis-Rinis V, Kleitou P, Lipej L, Macali A, Marchini A, Ousselam M, Piraino S, Stancanelli B, Theodosiou M, Tiralongo F, Todorova V, Trkov D, Yapici S (2018) New Mediterranean biodiversity records (July 2018). *Mediterranean Marine Science* 19: 398–415, <https://doi.org/10.12681/mms.18099>
- Chuang SH (1961) On Malayan shores. Muwu Shosa, Singapore, 255 pp
- Clanzig S (1989) Invertébrés d'introduction récente dans les lagunes méditerranéennes du Languedoc-Roussillon (France). *Bulletin de la Société Zoologique de France* 114: 151–152
- Como S, Pais A, Rumolo P, Saba S, Sprovieri M, Magni P (2016) Effects of an invasive mussel, *Arcuatula senhousia*, on local benthic consumers: a laboratory ¹³C-labeling study. *Marine Biology* 163: 140, <https://doi.org/10.1007/s00227-016-2912-0>
- Como S, Floris A, Pais A, Rumolo P, Saba S, Sprovieri M, Magni P (2018) Assessing the impact of the Asian mussel *Arcuatula senhousia* in the recently invaded Oristano Lagoon-Gulf system (W Sardinia, Italy). *Estuarine, Coastal and Shelf Science* 201: 123–131, <https://doi.org/10.1016/j.ecss.2015.11.024>

- Creese R, Hooker S, de Luca S, Wharton Y (1997) Ecology and environmental impact of *Musculista senhousia* (Mollusca: Bivalvia: Mytilidae) in Tamaki Estuary, Auckland, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 31: 225–236, <https://doi.org/10.1080/00288330.1997.9516760>
- Crocetta F, Agius D, Balistreri P, Bariche M, Bayhan YK, Çakir M, Ciriaco S, Corsini-Foka M, Deidun A, El Zrelli R, Ergüden D, Evans J, Ghelia M, Giavasi M, Kleitou P, Kondylatos G, Lipej L, Mifsud C, Özvarol Y, Pagano A, Portelli P, Poursanidis D, Rabaoui L, Schembri PJ, Taşkin E, Tiralongo F, Zenetos A (2015) New Mediterranean biodiversity records (October 2015). *Mediterranean Marine Science* 16: 682–702, <https://doi.org/10.12681/mms.1477>
- Crooks JA (1996) The population ecology of an exotic mussel *Musculista senhousia*, in a Southern Californian bay. *Estuaries* 19: 42–50, <https://doi.org/10.2307/1352650>
- Crooks JA (1998) Habitat alteration and community-level effects of an exotic mussel, *Musculista senhousia*. *Marine Ecology Progress Series* 162: 137–152, <https://doi.org/10.3354/meps162137>
- Doğan A, Öztürk B, Bitlis-Bakir B, Önen M (2014) Additions to knowledge of the molluscs of the Aegean Sea with three species: *Crepidula fornicata* (Linnaeus, 1758) *Anadara polii* (Mayer, 1868) and *Arcuatula senhousia* (Benson in Cantor, 1842). *Turkish Journal of Fisheries and Aquatic Sciences* 14: 255–260, https://doi.org/10.4194/1303-2712-v14_1_27
- Faasse M (2018) A record of the Asian mussel *Arcuatula senhousia* (Benson in Cantor, 1842) from NW Europe (the Netherlands). *Spirula* 416: 14–15, <https://www.spirula.nl/wp-content/uploads/2019/01/Spirula-416-Faase-Arcuatula-14-15.pdf>
- Florio M, Breber P, Scirocco T, Specchiulli A, Cilenti L, Lumare L (2008) Exotic species in Lesina and Varano lakes: Gargano National Park (Italy). *Transitional Waters Bulletin* 2: 69–79, <https://doi.org/10.1285/i1825229Xv2n2p69>
- Gouletquer P, Héral M (1997) Marine molluscan production trends in France: from fisheries to aquaculture. In: MacKenzie CL, Burrell VG, Rosenfield A, Hobart W (eds), The history, present condition, and future of the Molluscan fisheries of North America and Europe. NOAA Technical Report NMFS 129, pp 137–164
- Gruet Y, Héral M, Robert JM (1976) Premières observations sur l'introduction de la faune associée au naissain d'huîtres japonaises *Crassostrea gigas* (Thunberg), importé sur la côte Atlantique française. *Cahiers de Biologie Marine* 17: 173–184, <https://doi.org/http://www.sb-roscoff.fr/cbm/downloadpdf.htm?execution=e6s1>
- Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Vilà M, Wilson JR, Genovesi P, Blackburn TM (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). *Diversity and Distribution* 21: 1360–1363, <https://doi.org/10.1111/ddi.12379>
- Hoenselaar HJ, Hoenselaar J (1989) *Musculista senhousia* (Benson in Cantor, 1842) in the western Mediterranean (Bivalvia, Mytilidae). *Basteria* 53: 73–76, <https://natuurtijdschriften.nl/pub/596915>
- Holman LE, de Bruyn M, Creer S, Carvalho G, Robidart J, Rius M (2019) Detection of introduced and resident marine species using environmental DNA metabarcoding of sediment and water. *Scientific Reports* 9: 1, <https://doi.org/10.1038/s41598-019-47899-7>
- Hosozawa T, Kunii H, Nakamura M, Ojima T, Sugiyama Y, Yamaguchi K (2020) Spatial, temporal and vertical variation of distribution and major habitats in Asian mussel (*Arcuatula senhousia*) in a brackish river along Sea of Japan. *Plankton Benthos Research* 15: 121–131, <https://doi.org/10.3800/pbr.15.121>
- Katsanevakis S, Wallentinus I, Zenetos A, Leppäkoski E, Çinar ME, Öztürk B, Grabowski M, Golani D, Cardoso AC (2014) Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions* 9: 391–423, <https://doi.org/10.3391/ai.2014.9.4.01>
- Kovalev EA, Zhivoglyadova LA, Revkov NK, Frolenko LN, Afanasyev DF (2017) First record of the bivalve *Arcuatula senhousia* (Benson, 1842) in the Russian part of the Azov-Black Sea basin. *Russian Journal of Biological Invasions* 8: 316–320, <https://doi.org/10.1134/S2075111717040051>
- Kutty R, Chakkayil, Pura SHPV (2016) Community structure of macrobenthos in Ponnani estuary, South India with reference to occurrence of invasive alien species. *International Journal of Aquatic Biology* 4: 269–276, <https://doi.org/10.22034/ijab.v4i4.168>
- Lazzari G, Rinaldi E (1994) Alcune considerazioni sulla presenza di specie extra Mediterranee nelle lagune salmastre di Ravenna. *Bollettino Malacologico* 30: 195–202
- López-Soriano J, Quiñonero-Salgado S (2014) Primeras citas de diversos moluscos marinos alóctonos en el Delta del Ebro (Cataluña, España). *Spira* 5: 149–151
- Lourenço PM, Henriques M, Catry I, Granadeiro JP, Catry T (2018) First record of the invasive Asian date mussel *Arcuatula senhousia* (Benson, 1842) (Mollusca: Bivalvia: Mytilidae) in West Africa. *Journal of Natural History* 52: 2567–2571, <https://doi.org/10.1080/00222933.2018.1545058>
- Mastrototaro F, Matarrese A, d'Onghia G (2003) Occurrence of *Musculista senhousia* (Mollusca: Bivalvia) in the Taranto Seas (eastern-central Mediterranean Sea). *Journal of Biological Association UK* 83: 1279–1280, <https://doi.org/10.1017/S002531540300866X>

- Mavrič B, Orlando-Bonaca M, BÉttoso N, Lipej L (2010) Soft-bottom macrozoobenthos of the southern part of the Gulf of Trieste: faunistic, biocenotic and ecological survey. *Acta Adriatica* 51(2): 203–216
- Minchin D, Olenin S, Liu TK, Cheng M, Huang SC (2016) Rapid assessment of target species: Byssate bivalves in a large tropical port. *Marine Pollution Bulletin* 112: 177–182, <https://doi.org/10.1016/j.marpolbul.2016.08.023>
- Micu D (2004) First record of *Musculista senhousia* (Benson in Cantor, 1842) from the Black Sea - Int. Symp. Of Malacology, Romania, Sibiu, 2004, Abstracts of Papers, Sibiu, p 47
- Mistri M (2002) Ecological characteristics of the invasive Asian date mussel *Musculista senhousia*, in the Sacca di Goro (Adriatic Sea, Italy). *Estuaries* 25: 431–440, <https://doi.org/10.1007/BF02695985>
- Mistri M, Fano EA, Rossi G, Caselli K, Rossi R (2000) Variability in macrobenthos communities in the Valli di Comacchio, Northern Italy, a hypereutrophized lagoon ecosystem. *Estuarine, Coastal and Shelf Science* 51: 599–611, <https://doi.org/10.1006/ecss.2000.0697>
- Morton B (1974) Some aspects of the biology, population dynamics, and functional morphology of *Musculista senhousia* Benson (Bivalvia, Mytilidae). *Pacific Science* 28: 19–33
- Munari C (2008) Effects of the exotic invader *Musculista senhousia* on benthic communities of two Mediterranean lagoons. *Hydrobiologia* 611: 29–43, <https://doi.org/10.1007/s10750-008-9459-0>
- Öztürk B, Bitlis-Bakir B, Doğan A, Türkçü N (2017) Alien marine molluscs along the Turkish coast, with a new record of *Varicopeza pauxilla* (A. Adams, 1855) (Mollusca: Gastropoda) from the Mediterranean Sea. *Acta Zoologica Bulgarica* Suppl. 9: 83–92
- Reusch TBH, Williams SL (1998) Variable responses of native eelgrass *Zostera marina* to a non-indigenous bivalve *Musculista senhousia*. *Oecologia* 113: 428–441, <https://doi.org/10.1007/s004420050395>
- Shanks AL (2009) Pelagic larval duration and dispersal distance revisited. *Biology Bulletin* 216: 373–385, <https://doi.org/10.1086/BBLv216n3p373>
- Sciocco T, Urbano F (2018) The population of the non-indigenous bivalve *Arcuatula senhousia* of the Varano Lagoon (Adriatic Sea, Italy). *Journal of Environmental Science and Engineering A* 7: 345–353, <https://doi.org/10.17265/2162-5298/2018.09.001>
- Slack-Smith SM, Brearley A (1987) *Musculista senhousia* (Benson, 1842); a mussel recently introduced into the Swan River Estuary, Western Australia (Mollusca, Mytilidae). *Records of the Western Australian Museum* 13: 225–230
- Slijkerman DME, Glorius ST, Gittenberg A, van der Weide BE, Bos OG, Rensing M, de Groot GA (2017) Monitoring Groningen Sea Ports. Non-indigenous species and risks from ballast water in Eemshaven and Delfzijl. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report C 045/17 A, 81 pp, <https://doi.org/10.18174/417717>
- Takenaka R, Komorita T, Tsutsumi H (2018) Accumulation of organic matter within a muddy carpet created by the Asian date mussel, *Arcuatula senhousia*, on the Midori River tidal flats, Japan. *Plankton and Benthos Research* 13: 1–9, <https://doi.org/10.3800/pbr.13.1>
- Tebble N (1966) British bivalve seashells. A handbook for identification. London, Trustees of the British Museum (Natural History), 212 pp
- Tsiamis K, Azzurro E, Bariche M, Çinar ME, Crocetta F, De Clerck O, Galil B, Gómez F, Hoffman R, Jensen KR, Kamburska L, Langeneck J, Langer MR, Levitt-Barmats Ya, Lezzi M, Marchini A, Occhipinti-Ambrogi A, Ojaveer H, Piraino S, Shenkar N, Yankova M, Zenetos A, Žuljević A, Cardoso AC (2020) Prioritizing marine invasive alien species in the European Union through horizon scanning. *Aquatic Conservation: Marine and Freshwater Ecosystems* 30: 794–845, <https://doi.org/10.1002/aqc.3267>
- Ulman A, Ferrario J, Occhipinti-Ambrogi A, Arvantidis C, Bandi A, Bertolino M, Bogi C, Chatzigeorgiou G, Çiçek BA, Deidun A, Ramos-Espla A, Koçak C, Lorenti M, Martínez-Laiz G, Merlo G, Princisgh E, Scribano G, Marchini A (2017) A massive update of non-indigenous species records in Mediterranean marinas. *PeerJ* 5: e3954, <https://doi.org/10.7717/peerj.3954>
- Wasson K, Zabin CJ, Bedinger L, Diaz MC, Pearse JS (2001) Biological invasions of estuaries without international shipping: the importance of intraregional transport. *Biological Conservation* 102: 143–153, [https://doi.org/10.1016/S0006-3207\(01\)00098-2](https://doi.org/10.1016/S0006-3207(01)00098-2)
- Watson GJ, Dyos J, Barfield P, Stebbing P, Dey KG (2021) Evidence for self-sustaining populations of *Arcuatula senhousia* in the UK and a review of this species' potential impacts within Europe. *Scientific Reports* 11: 9678, <https://doi.org/10.1038/s41598-021-86876-x>
- Willan RC (1985) Successful establishment of the Asian mussel *Musculista senhousia* (Benson in Cantor, 1842) in New-Zealand. *Records of the Auckland Institute and Museum* 22: 85–96, <https://www.jstor.org/stable/42906352>
- Willan RC (1987) The mussel *Arcuatula senhousia* in Australasia; another aggressive alien highlights the need for quarantine at ports. *Bulletin of Marine Science* 41: 475–489
- Worsfold TM, Pennisi N, Ashelby CW (2020) *Theora lubrica* Gould, 1861 (Bivalvia: Semelidae), new to the UK, with notes on associated non-native species, and an earlier date of introduction for *Arcuatula senhousia* (Bivalvia: Mytilidae) to the UK. *Journal of Conchology* 43: 665–674

- Zenetos A, Gofas S, Russo G, Templado J (2003) CIESM Atlas of Exotic Species in the Mediterranean. Volume 3. Molluscs. CIESM Publihers, Monaco, 376 pp, <http://www.ciesm.org/atlas/appendix3.html>
- Zhulidov AV, Kozhara AV, Son MO, Morhun H, van der Velde G, Leuven RSEW, Gurtovaya TY, Zhulidov DA, Kalko EA, Kuklina YA, Kosmenko LS, Santiago-Fandino JR, Nalepa TF (2021) Additional records of the bivalves *Mytiopsis leucophaeata* (Conrad, 1831) (Dreissenidae) and *Arcuatula senhousia* (Benson, 1842) (Mytilidae) in the Ponto-Caspian region. *BioInvasions Records* 10: 119–135, <https://doi.org/10.3391/bir.2021.10.1.14>

Supplementary material

The following supplementary material is available for this article:

Table S1. Locations of first records of *Arcuatula senhousia* on the different European marine regions.

This material is available as part of online article from:

http://www.reabic.net/journals/bir/2022/Supplements/BIR_2022_Masse_etal_SupplementaryMaterial.xlsx