Research Article

# First record of the invasive Asian date mussel *Arcuatula senhousia* (Benson, 1842) in El Mellah Lagoon (Southern coast of Algerian Basin, Western Mediterranean)

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**Citation:** Hamza H, Mammeria AB, Bairi A, De Wit R, Klein J (2022) First record of the invasive Asian date mussel *Arcuatula senhousia* (Benson, 1842) in El Mellah Lagoon (Southern coast of Algerian Basin, Western Mediterranean). *BioInvasions Records* 11(3): 686–699, https://doi.org/10.3391/bir.2022.11.3.11

**Received:** 25 November 2021
**Accepted:** 16 May 2022
**Published:** 29 July 2022

**Handling editor:** Michal Grabowski
**Thematic editor:** Amy Fowler



## Abstract

This paper presents the first record of the Asian date mussel *Arcuatula senhousia* (Benson, 1842) from the southern coast of the Algerian Basin in the Western Mediterranean Sea. The species was first observed in June 2019 in El Mellah Lagoon, a coastal lagoon located in the El Kala UNESCO biosphere reserve (north-eastern Algeria). Additional individuals were also collected monthly, between July and December. *Arcuatula senhousia* was found in shallow subtidal habitats dominated by the seagrass *Zostera noltei* (Hornemann, 1832) at a maximum density of 1,321 ± 1,167 ind.m$^{-2}$. The maximum observed shell length was 32 mm, indicating that *A. senhousia* may have existed for more than a year in adjacent area in El Mellah Lagoon and moved probably into our survey area in 2019 as either adults (via fouled vessels) or, less likely, planktonic larvae (via currents). Live specimens were observed attached to *Z. noltei* leaves and rhizomes and, to a lesser degree, on empty shells of the cockle *Cerastoderma glaucum* (Bruguière, 1789). The introduction of the invasive Asian date mussel into this lagoon may lead to changes in the structure and functioning of this unique shallow coastal ecosystem and requires further study.

**Key words:** introduced species, invasive alien species, *Zostera noltei*, UNESCO biosphere reserve, biodiversity

## Introduction

*Arcuatula senhousia* (Benson, 1842) (common names: Asian date mussel, green bagmussel, green mussel, Senhouse mussel, Japanese mussel) is a small (common shell length is 25 mm; maximum shell length of 35 mm) mussel that belongs to the Mytilidae family and is native to the West Pacific Ocean (ranging from Siberia to Singapore) (Carpenter and Niem 1998). This filter-feeding bivalve lives on soft, muddy bottoms in sheltered areas such as bays, coastal lagoons and estuaries, from the intertidal zone down to a depth of 20 m. As a sessile, benthic organism, it uses byssal threads to attach to substrate in soft-bottom sediments (Morton 1974; Cohen 2005). *Arcuatula senhousia* embodies several characteristics typical of invasive species, such as high fecundity and rapid growth, a fairly long

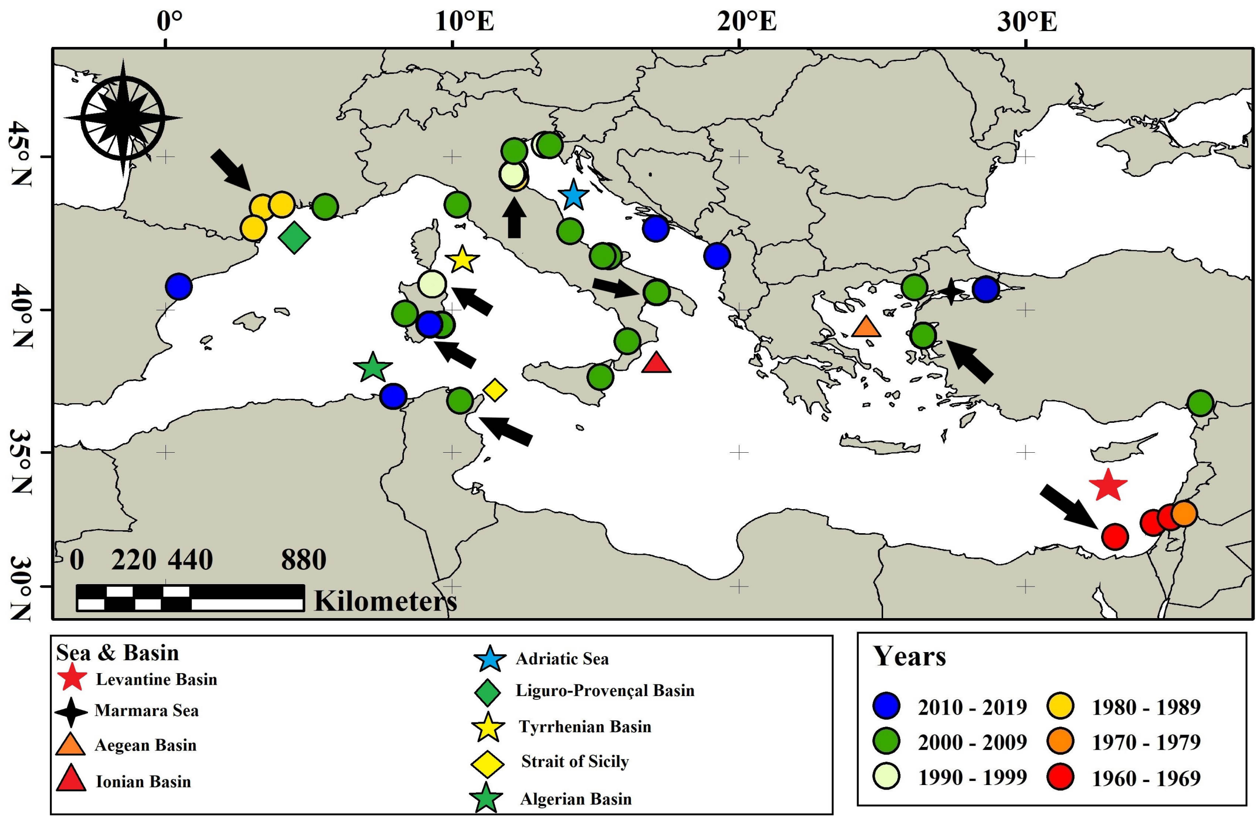


**Figure 1.** Map showing the invasion history of the Asian date mussel, *Arcuatula senhousia*, in the Mediterranean Sea. Circles represent the year of the first species report in each area, and arrows show the first reports in each basin and sea. (See the history of the invasion of *A. senhousia* in the Mediterranean Sea in Supplementary material Table S1).

planktonic larval stage (14–55 days), rapid maturity (9 months), a short maximum lifespan (2 years), and external fertilisation (Otero et al. 2013; Kovalev et al. 2017; Faasse 2018). A single female with a shell length of 20 mm can release up to 137,000 eggs as granular emissions (Sgro et al. 2002; Zenetos 2016). This high fecundity can result in high densities of more than 25,000 ind.m$^{-2}$ (Munari 2008; Öztürk et al. 2017). This species can also tolerate a broad range of environmental conditions, such as temperature (1–31 °C), salinity (18–36 PSU), and low dissolved oxygen concentrations (1–3 mg.L$^{-1}$). These characteristics facilitate both the introduction and successful invasion into various marine ecosystems (coastal lagoons, harbours, river deltas, etc.) (Cohen 2005; Zenetos 2016; Kovalev et al. 2017) and are reasons why *A. senhousia* is included in the Black List of Marine Invasive Species in the Mediterranean (Otero et al. 2013).

*Arcuatula senhousia* has successfully colonised various areas of the world, including the Pacific coast of North America, Australia, New Zealand, the Mediterranean Sea, the French Atlantic coast, the English Channel, West Africa, the Sea of Azov and the Black Sea (Cohen 2005; Bachelet et al. 2009; Chartosia et al. 2018; Watson et al. 2021; Zhulidov al. 2021). In the Mediterranean Sea, *A. senhousia* was first recorded in 1964 as *Modiolus arcuatulus* (from the coastal Bardawil Lagoon, southern Levantine Basin, Egypt) and *Arcuatula arcuatula* (Hanley, 1843) (from "Tel Baruch", eastern Levantine Basin, Tel Aviv) (Barash and Danin 1971, 1973) (Figure 1).

The vector of this first introduction remains unknown. The species then appeared in 1978 in Thau Lagoon, a coastal lagoon in the Liguro-Provençal Basin (north-western Mediterranean), France, most likely due to the transport of oysters (Hoenselaar and Hoenselaar 1989). It has continued its introduction into various areas within the Mediterranean Sea basin (Bachelet et al. 2009) (Figure 1). Since 1986, *A. senhousia* has been recorded from Ravenna in the Adriatic Sea (Lazzari and Rinaldi 1994; Ulman et al. 2017), the Tyrrhenian Basin (Gulf of Olbia, north-western Tyrrhenian Sea) in the 1990s (Mistri et al. 2004), the north-western Ionian Basin (Gulf of Taranto) in 2001 (Mastrototaro et al. 2003), and the Strait of Sicily (Tunisia) in 2004 (Ben Souissi et al. 2005). The first observation of the species in the Algerian Basin was from Sardinia (Cagliari) in 2006 (Delongueville and Scaillet 2006). In the eastern Mediterranean Sea, *A. senhousia* has spread north into the Aegean Basin (Izmir Bay) (Doğan et al. 2014) and the Marmara Sea (Öztürk et al. 2017) (Figure 1 and Supplementary material Table S1). Shipping transport (fouling, ballast water) is hypothesized to be the main vector for this species.

The impact of *A. senhousia* on ecosystem services and biodiversity varies depending on location (Katsanevakis et al. 2014). In its native range in Japan and China, *A. senhousia* can grow on cultivated clams (Cohen 2005). In its introduced range, *A. senhousia* can significantly impact native macrophyte and benthic invertebrate communities (Crooks et Khim 1999; Allen and Williams 2003). For example, in San Diego Bay (southern California, USA), *A. senhousia* covers the leaves eelgrass (*Zostera* spp.) thereby inhabiting the growth and spread of this plant species (Reusch and Williams 1998; Allen and Williams 2003; Cohen 2005). Furthermore, the high density of *A. senhousia* has led to decreases in abundance and the local disappearance of certain native benthic invertebrates in San Diego (Mission Bay) and New Zealand (Tamaki Estuary) (Creese et al. 1998; Crooks 2001).

The present study represents the first report of *A. senhousia* from the southern coast of the Algerian basin (Western Mediterranean), i.e., in El Mellah Lagoon (eastern Algeria) in June 2019. In this study, we describe how the natural densities varied at different locations in this lagoon during the year 2019, discuss some aspects of its ecology.

## Materials and methods

### *Study site and location of stations*

El Mellah Lagoon is the only shallow, brackish coastal lagoon in Algeria and is located in the El-Kala National Park (UNESCO biosphere reserve) in north-eastern Algeria (36.89290N; 8.32623E) (Figure 2). This lagoon is only connected to the Mediterranean Sea through a single long (900 m) and narrow (10–20 m) inlet. El Mellah Lagoon has a surface area of 865 ha

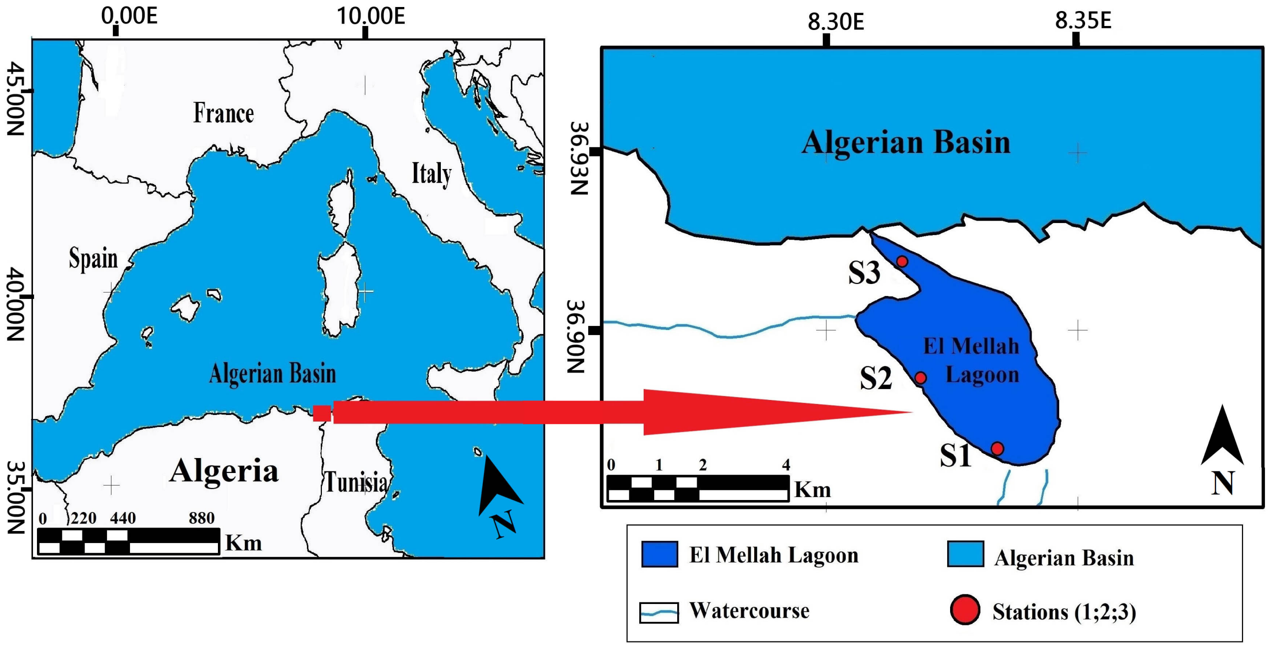


**Figure 2.** The location of the study area in the Mediterranean Sea and the location of the sampling stations in El Mellah Lagoon (Algeria, southern coast of the Algerian Basin) (Station 1: 36.87722N; 8.33083E; Station 2: 36.88722N; 8.31444E; Station 3: 36.90944N; 8.31444E).

and an average depth of 2.7 m, with a maximum depth of 6.4 m (Cataudella et al. 2015).

This coastal lagoon is subject to a southern Mediterranean climate, which alternates between a dry, hot summer and a wet, cold winter. Freshwater inputs come from rainfall and three seasonal rivers (R'Kibet in the Northwest, El Mellah in the Southwest and Belaroug in the South). The main human activities in El Mellah include an artisanal fishery (bordigues since 1920 and fishing nets) (Cataudella et al. 2015) as well as the harvesting of cockles (*Cerastoderma glaucum* (Bruguière, 1789)) and clams (*Ruditapes decussatus* (Linnaeus, 1758)), especially on the accessible shores of the lagoon (Magni et al. 2015).

### *Sampling of benthic assemblages*

Benthic samples were collected monthly in the shallow subtidal (0.3 m to 0.5 m depth) at three stations in El Mellah Lagoon from February to December 2019. Three replicate manual sediment cores (N = 3) of 0.028 $m^2$ surface (diameter 19 cm) were collected at each of the three stations each month (total samples collected = 11 months × 3 stations × 3 replicates = 99 samples) (Figure 2). Simultaneously, three replicate measurements of the physico-chemical characteristics of the surface water (salinity, pH, temperature, dissolved oxygen) were made *in situ* in each sampling location using a multi-parameter, hand-held probe (HANA HI9829). Individuals of *A. senhousia* were counted, and the largest and smallest individual in each sample was measured to the nearest mm shell length using digital calipers. The seagrass beds (*Zostera noltei*) where sampling was performed were heterogeneous

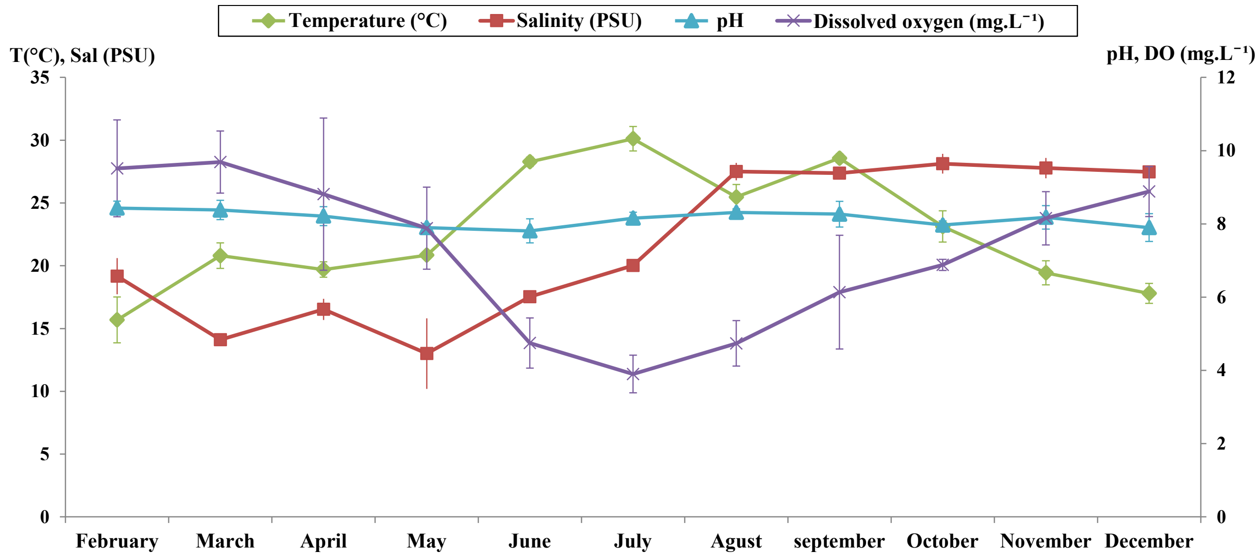


**Figure 3.** Mean values (± SE) of temperature, salinity, dissolved oxygen and pH measured in the surface waters at the sampling stations in El Mellah Lagoon (Algeria, south-western Mediterranean Sea, see Figure 2) in 2019. T = temperature (°C), Sal = salinity (PSU), DO = dissolved oxygen ($mg.L^{-1}$). N = 9 replicate measurements per month.

in terms of seagrass density; mussel density was calculated per core surface sample (0.028 $m^2$) and not extrapolated to larger scales. Specimens were identified by J. Klein as *A. senhousia* at the MARBEC laboratory in Montpellier (France) using Benson (1842) in agreement with the reference provided by the World Register of Marine Species (WoRMS). The original species description by Benson (1842) is available through the web at: https://www.biodiversitylibrary.org/page/18684698#page/500/mode/1up.

## Results

### *Physicochemical characteristics*

The physicochemical characteristics of the waters in El Mellah Lagoon fluctuated throughout the year (Figure 3). Water temperature varied strongly, with the highest mean temperature observed in the summer months (30.1 ± 0.9 °C in July) and the lowest mean value in the winter (15.7 ± 1.8 °C in February). Water temperature and mean dissolved oxygen were negatively correlated with one another ($r = -0.910$; $R2 = -0.829$; $P < 0.0001$), such that mean dissolved oxygen concentrations were lowest in the summer (4.0 ± 0.5 $mg.L^{-1}$ in July) and the highest in the winter (9.7 ± 0.8 $mg.L^{-1}$ in March). The salinity was low during the spring and early summer (13.0 ± 2.8 PSU in May) and reached the highest mean value in late summer and autumn (28.1 ± 0.7 PSU in October). The pH of lagoon waters was slightly stable throughout the sampling period, with a mean maximum value of 8.4 ± 0.1 in the winter and a mean minimum value of 7.8 ± 0.3 in the summer (Figure 3).

### *Density and size range of* Arcuatula senhousia

In the present study, *A. senhousia* was recorded for the first time from El Mellah lagoon in June 2019, representing the first record of this invasive


**Figure 4.** The shell of a representative sample of *Arcuatula senhousia* from El Mellah Lagoon, Algeria. A: red radial lines resembling rays extending towards the edges. B: concentric dark violet-brown wavy or zigzag lines. Photograph by Hadjer Hamza.

species from this location and more generally from the southern shore of the Algerian Basin (Western Mediterranean). The species was not observed between February and May 2019.

Collected specimens presented the typical characteristics of *A. senhousia*, including the following: two oval yellow-green or greenish-brown valves, a smooth thin shell, and a smooth, shiny periostracum, which has red radial lines, resembling rays, extending towards the edges, and concentric, dark violet-brown wavy or zigzag lines that were sometimes visible inside. In addition, the longer ventral side of the shell was slightly concave (Figure 4).

The Asian date mussels used several different habitats in El Mellah Lagoon, which varied depending on the sampling location and time of year. Most individuals were attached to the eelgrass *Zostera noltei* (Hornemann, 1832) by their byssus. Smaller individuals were attached to the leaves, while larger ones (> 2 cm), only at two stations (stations 1 and 2), were attached to the rhizomes (Figure 5). In other cases, individuals were attached to empty shells of the cockle *C. glaucum*, sometimes in large aggregations. And still in other cases, small individuals (< 1 cm) were attached to the leaves of *Ruppia maritima* (Linnaeus, 1753), but only at station 3 in June and July.

The density of Asian date mussels in El Mellah Lagoon underwent large temporal fluctuations and differed from station to station during the study period. Furthermore, there was high spatial variability, and abundance differed even between samples within the same location. Station 1 retained the highest densities (38 ± 23 individuals/sample) and the largest and smallest sizes of the mussels. This location is at the southern edge of the lagoon and receives outflow from the El Mellah River. The lowest densities (5 ± 5 individuals/sample), and sometimes complete absence of the species (in August), were observed at station 3 which is the closest station to the Mediterranean Sea (Figure 6). In addition, the largest mussel measured


**Figure 5.** Individuals of *Arcuatula senhousia* attached to the eelgrass *Zostera noltei* collected from El Mellah Lagoon (Algeria). A: a large individual (> 2 cm) on the rhizomes. B: a small individual on the leaves of *Z. noltei*. Photograph by Hadjer Hamza.

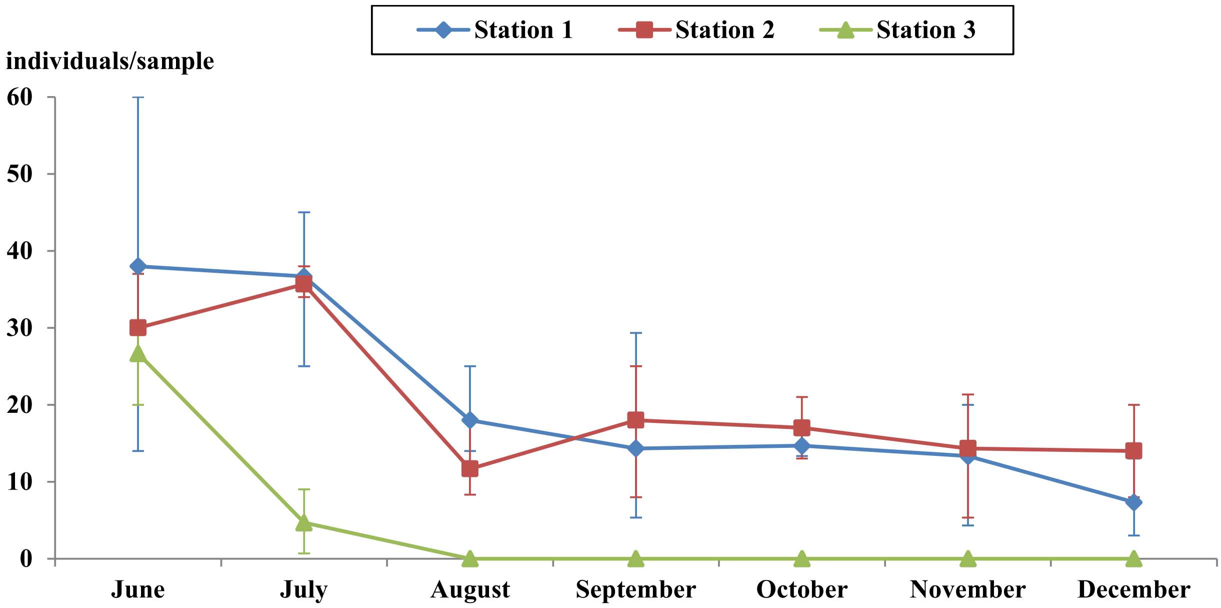


**Figure 6.** Average mean density (individuals/sample = number of individuals per sample of 0.028 m²) of *Arcuatula senhousia* from three sediment cores collected monthly from three stations in El Mellah lagoon, Algeria (see Figure 2) between June and December 2019.

**Table 1.** Mean maximum and minimum size (mm) of *Arcuatula senhousia* collected from the three stations from El Mellah lagoon, Algeria, from June to December 2019. Three sediment cores (0.028 m²) were collected per station per month.

| Months | Station 1 Size (mm) | | Station 2 Size (mm) | | Station 3 Size (mm) | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| June | 3 | 21 | 22 | 30 | 10 | 17 |
| July | 20 | 28 | 20 | 25 | 5 | 12 |
| August | 22 | 30 | 20 | 31 | – | – |
| September | 25 | 32 | 30 | 31 | – | – |
| October | 22 | 31 | 27 | 31 | – | – |
| November | 21 | 27 | 24 | 25 | – | – |
| December | 3 | 22 | 10 | 28 | – | – |

throughout El Mellah Lagoon was collected in September from station 1. This individual had a shell length of 32.0 mm and a width of 15.0 mm and was attached to a rhizome of *Z. noltei*; the smallest observed mussels were collected in June and December from station 1 and both had a shell length of 3 mm (Table 1).

## Discussion and conclusion

Since 1964, various coastal ecosystems in the Mediterranean Sea (i.e., coastal lagoons, river deltas and harbours) have been invaded by the Asian date mussel *A. senhousia*. The present study represents a new record of this invasive species in El Mellah Lagoon, representing the first report from coastal systems on the southern coast of the Algerian Basin (Western Mediterranean). The maximum size of mussels found here (32 mm shell length) was similar to maximum lengths (30–33 mm) recorded from other areas of its introduced range (Ionian Basin: Taranto Sea; Atlantic Ocean: Arcachon Bay, the Solent) (Mastrototaro et al. 2003; Bachelet et al. 2009; Watson et al. 2021). In contrast, smaller individuals, generally less than 27 mm long have previously been observed from the Eastern Adriatic coast (Neretva River Delta), in the Algerian Basin (South Sardinia) and in the Aegean Sea (Izmir Bay) (Atzori et al. 2013; Despalatović et al. 2013; Doğan et al. 2014).

In the Mediterranean Sea (Sacca di Goro Lagoon, northern Adriatic Sea), densities of *A. senhousia* may exceed 25,000 ind.m$^{-2}$ (Munari 2008). In the current study, densities in El Mellah lagoon did not reach these high values and were equivalent to 1,321 ± 1,167 ind.m$^{-2}$, which mirrors previous observations from the southern Adriatic Sea (Varano Lagoon, 1,266 ± 1,416 ind.m$^{-2}$) (Scirocco and Urbano 2018). Lower densities of self-sustaining populations have also been previously recorded (i.e., 290 ind.m$^{-2}$ from Solent, Southampton estuary, English Channel) (Watson et al. 2021). These disparities in density may be explained by spatial differences in physico-chemical characteristics. For example, the minimum water temperature for reproduction to take place is 22.5 °C (Inoue and Yamamuro 2000). The temperature varied between 9 and 17 °C in the Solent (English

Channel) but fluctuates between 15.7 and 30 °C in El Mellah; from June to September the temperature was above 22.5 °C (Figure 3) which facilitates reproduction during this period. However, temperature alone cannot explain the differences in densities at smaller scales (i.e., within our study region and the Adriatic Sea). It is possible that other abiotic factors, such as time since invasion, or biotic factors (predators, or parasites) also affect densities. Future work could examine drivers of density for this species in introduced locations.

In the present study, the abundance of *A. senhousia* decreased over the period from June to December 2019. As *A. senhousia* only lives a maximum of two years, and many of the individuals observed were adults, the reduction in abundance could be due to natural mortality and a lack of sustained recruitment to the area. While the species varies in abundance yearly due to natural mortality rates, abundances could also change seasonally due to changes in biotic conditions, such as decreasing water temperature during the winter. This reduction could also be due to predation of the mussel by several animals. In both native and invasive populations, the mussel has various predators, including crabs, snails, lobsters, starfish, fish, diving ducks, and shorebirds (Crooks 2002). In El Mellah Lagoon, possible predators include fish (*Conger conger* (Linnaeus, 1758), *Dicentrarchus labrax* (Linnaeus, 1758), *Chelon labrosus* (Risso, 1827), *Chelon auratus* (Risso, 1810), *Mugil cephalus* (Linnaeus, 1758), *Chelon ramada* (Risso, 1827), *Chelon saliens* (Risso, 1810), *Muraena helena* (Linnaeus, 1758), *Solea senegalensis* (Kaup, 1858), *Sparus aurata* (Linnaeus, 1758), *Diplodus sargus* (Linnaeus, 1758), *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817)), crustaceans (*Penaeus kerathurus* (Forsskål, 1775)), and diving ducks (*Aythya nyroca* (Güldenstädt, 1770)) (Crooks 2002; Cataudella et al. 2015). As of yet, none of these predators have been observed to feed on Asian date mussels. Future work should describe the population demography of the Asian date mussels in this location, with detailed information on the changes in density and abundance across multiple size classes throughout the year.

Asian date mussels ranged from 21 to 30 mm shell length when they were first collected from El Mellah lagoon in June 2019. Taking into account the maximum growth rate of the species—25 mm in the first year (Crooks 1996)—it is possible that *A. senhousia* individuals were introduced into the lagoon before June 2018. Although a minority of individuals can live up to 2 years, most individuals are annuals (Crooks 1996). An annual population is most likely in the El Mellah, as Crooks (1996) sampled Mission Bay, California, USA with temperatures ranging from 12 and 26 °C, while the temperatures of El Mellah during the summer can reach 30 °C. Mussels live attached to the substratum or on other organisms; however, they can move via byssal threads. Their movement activity varies according to their size, and small mussels move more often than larger ones (Burks et al. 2002; Toomey et al. 2002; Kobak et al. 2009). It is possible that *A. senhousia* was present in adjacent areas within El Mellah before 2019, but remained unnoticed, and moved into our survey area midway through 2019.

Aquaculture activities, maritime traffic, and ballast water are the major introduction vectors of the Asian date mussel (Munari 2008; Como et al. 2018). In El Mellah Lagoon, shellfish farming occurred between 1981 and 2004 at the northern end of the lagoon, near the inlet. The native mussel *Mytilus galloprovincialis* (Lamarck, 1819) and the introduced oyster *Crassostrea gigas* (Thunberg, 1793) were cultivated successfully until massive die-offs destroyed the production in the early 1990s (Benmarce 2012; Cataudella et al. 2015). *Arcuatula senhousia* may have been introduced with *C. gigas* during aquaculture activities. Fishermen, however, have not observed *A. senhousia* in the lagoon prior to 2019 (M. Boumhani *pers. comm.*). A second possible introduction vector is the artisanal fishery, which is an important human activity in the lagoon. The Asian date mussel may have been accidentally introduced via boat engines or as bait purchased from Tabarka (Tunisia) and used by local fishermen (M. Boumhani *pers. comm.*). Another possible introduction vector is natural current transport from the Atlantic Ocean (Bay of Biscay, Bachelet et al. 2009). Currents in this region generally flow west to east, at about a few km per day just after water passes through the Strait of Gibraltar. Moreover, the major current in the Southern Mediterranean Sea (in the Algerian Basin) flows from west to east (Millot and Taupier-Letage 2005; Ayache 2016). This introduction vector is not very likely because *A. senhousia* has not been reported in the Alboran Sea nor from the part of the southern Algerian Basin which lies between the Atlantic Ocean and El Mellah Lagoon. Finally, recreational boating (e.g., jet-skis and small boats) may be another potential introduction vector, as citizens move frequently between El Mellah Lagoon and Tabarka waters in Tunisia.

Invasive *A. senhousia* can have significant impacts on native assemblages of benthic invertebrates (Creese et al. 1998; Munari 2008). There have been limited reports of *A. senhousia* causing the direct mortality of cultivated clams in Japan through smothering as it creates dense byssal thread mats on the surface of the sediment (Cohen 2005). In New Zealand (Auckland Harbour), the abundance of infaunal bivalves decreased eightfold in areas where *A. senhousia* formed dense mats compared to areas without the mussels (Creese et al. 1998). In the eastern Pacific Ocean (Mission Bay, San Diego), *A. senhousia* is now 100 times more abundant than any native bivalve and has caused a decrease in native species richness (i.e., disappearance of *Chionista fluctifraga* (G.B. Sowerby II, 1853) and a decrease in density of *Solen rostriformis* (Dunker, 1862)) (Crooks 2001). In this study, *A. senhousia* was found in aggregates attached to empty shells of the cockle *C. glaucum*; while not observed, it is possible that *A. senhousia* smothered the cockles, leading to high mortality events. Similarly, in the Atlantic Ocean (the Solent), *A. senhousia* was found attached to dead oyster, *Ostrea edulis*

(Linnaeus, 1758), shells and live blue mussels, *Mytilus edulis* (Linnaeus, 1758). In Hong Kong, *A. senhousia* colonizes cultured, live oysters, *Crassostrea hongkongensis* (Lam and Morton, 2003) (Lau et al. 2018; Watson et al. 2021). Future work in El Mellah Lagoon should focus on studying the effect of *A. senhousia* mats on bivalve assemblages to determine if the death of *C. glaucum* is a result of this invasion.

In the present study, *A. senhousia* was observed attached to eelgrass, *Z. noltei*, leaves and rhizomes. In other introduced regions, *A. senhousia* was also found associated with eelgrass (*Zostera* spp.), including the Solent, San Francisco Bay, and San Diego Bay (Cohen 2005; Kushner and Hovel 2006; Watson et al. 2021). Indeed, high densities of *A. senhousia* (15,000 ind.$m^{-2}$ in San Diego Bay) inhibited the spread and growth of *Zostera marina* in these areas (Reusch and Williams 1998). However, densities of the mussel in El Mellah Lagoon were comparatively low (1321 ind.$m^{-2}$) and may currently have limited effects on seagrasses. With increasing mussel densities, however, a decline of *Zostera* spp. becomes very likely in this lagoon and should be monitored further.

Moreover, *A. senhousia* effectively contributes to nutrient cycling in the sediment underneath seagrass meadows (Bernard et al. 2020), and dense populations can significantly modify sediment features (Crooks 1998). In sparse *Z. noltei* meadows, *A. senhousia* enhanced solute fluxes across the sediment-water interface through increasing phosphate-ammonium efflux (Arcachon bay, France; Bernard et al. 2020). Seagrasses unquestionably provide many ecosystem services. Seagrasses meadows formed by species such as *Zostera* spp. are in decline globally due to anthropogenic forces, water quality declines, and the ongoing threat from climate change. Their degradation causes strong consequences on diversity, carbon storage, nutrient cycling, and coastal protection (Reusch and Williams 1998; Evans et al. 2018). These findings highlight the need to perform additional studies to determine the impact of *A. senhousia* in El Mellah Lagoon to preserve diversity as well as ecosystem services in this protected area.

## Acknowledgements

The authors would like to pay tribute and thank Professor Abdelkrim Tahraoui, who helped us enormously and who unfortunately passed away because of Covid-19. We are also grateful to the members of the Laboratory of Applied Animal Biology (Faculty of Sciences of Annaba, Algeria), particularly to Pr. Noureddine Soltani, for their help. We thank the anonymous reviewers for their valuable and helpful comments.

## Funding declaration

This project was partly funded by the MARBEC research centre through its IRD-supported "North-South Partnership" funding programme.

## Author's contribution

Rutger De Wit, Aicha Beya Mammeria and Hadjer Hamza: have made substantial contributions to research conceptualization, sample design and methodology. Hadjer Hamza: has made investigation and data collection, data analysis and interpretation, and writing the original draft. Judith Klein: has identified the species in the laboratory. Judith Klein, Rutger De Wit and Aicha Beya Mammeria: have made substantial contributions to data analysis and interpretation, writing, review and editing.

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**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_Hamza_etal_SupplementaryMaterial.xlsx