FIRST EVIDENCE OF *ARCUATULA SENHOUSIA* (BENSON, 1842), THE ASIAN DATE MUSSEL IN UK WATERS

Five specimens of the Asian Date Mussel, *Arcuatula senhousia*, were discovered at several locations in the Solent on the south coast of England, between October 2017 and February 2018. These records provide the first evidence of the species in UK waters. Reported in the Bay of Biscay in 2009 the Solent records extend the known geographical distribution of *A. senhousia*. In addition these records also push the latitudinal reach of the species to its most northerly position yet at 50°N.

An articulated shell of *Arcuatula senhousia* was found loose on sand in the intertidal mid-high shore area of a site in the Solent on 25th October 2017. The specimen was not living but was generally in good condition (Fig. 1 A–D). The shell is thin and fragile and the left valve has a small hole near the posterior edge (Fig. 1 A–B). It measures 18.7mm (length)×9.0mm (height)×~6.3mm (breadth). As these small Mytilidae can grow up to 30–40mm in length this specimen is not large, though in the Mediterranean the maximum size has been recorded as 25mm[1, 2, 3, 4].

Arcuatula senhousia is known from intertidal and shallow subtidal habitats and can settle on soft sediments or hard substrata including man-made structures, but shows a preference for the former[5]. Both sand and coarse mixed sediments are available at the location where the specimen was discovered. A wider search of the local area did not turn up any further specimens at the time. It is unclear if it may have washed in with the tide from another location. however, given the fragile nature of the shell it is unlikely that it travelled any great distance before coming to rest at the location where it was found.

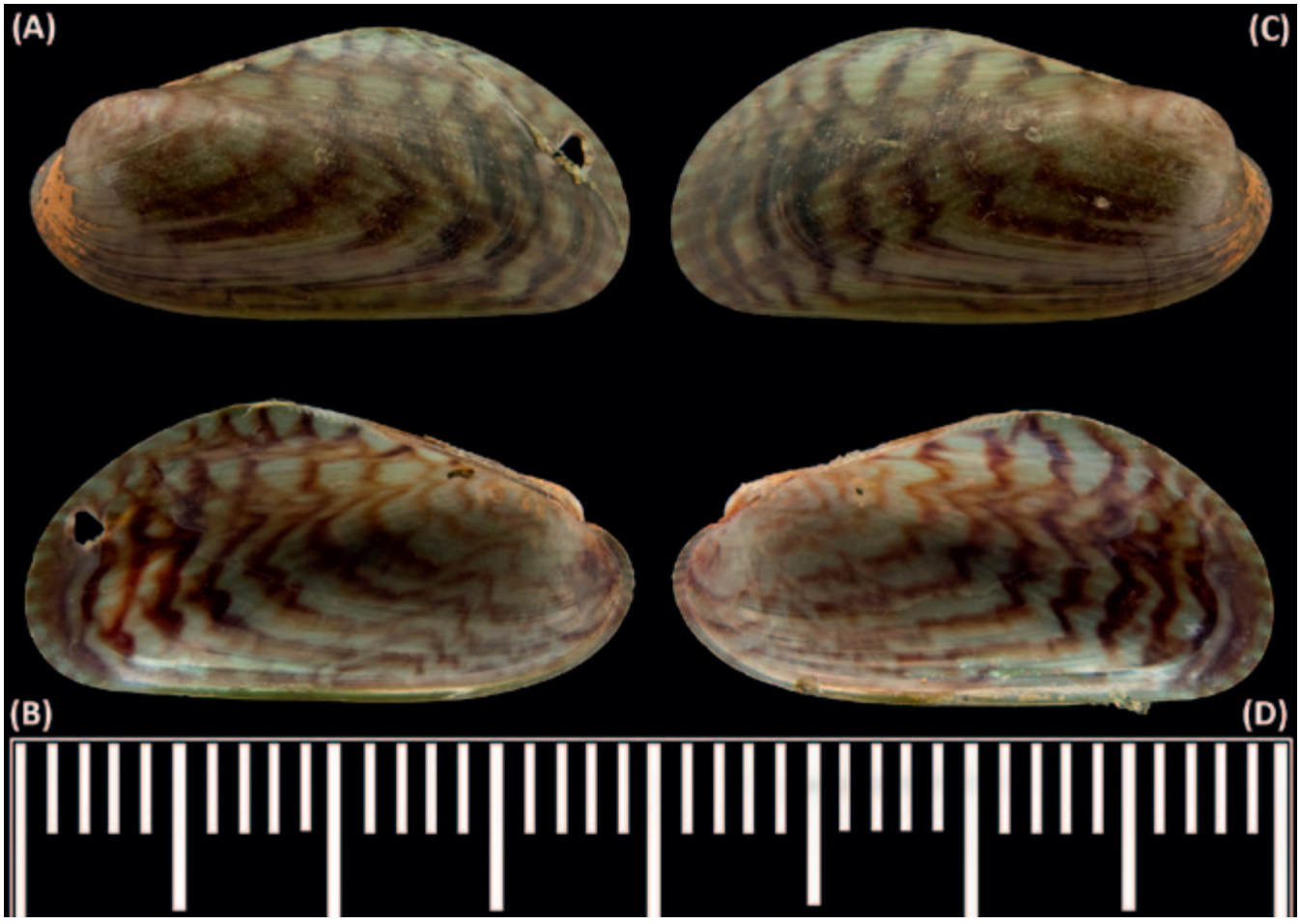

Figure 1 Arcuatula senhousia, external and internal views of the left (A–B) and right valves (C–D).

The shell is transversely oblong, anteriorly confined and posteriorly expanded (Fig. 1). Viewed from above or below the lateral humps or 'subwings' referred to by Benson (1842) are clear (partially visible in external shell images Fig. 1 A and C). The external surface appears smooth and polished, the internal surface iridescent. The periostracum is olive coloured. Chestnut-brown zig-zag, ornate markings give the shell a very characteristic look. Radiating bands are also clear and these, at first glance, suggest that the shell is ribbed posteriorly, but this is not the case. In the narrow anterior area beneath the umbo six small, short ribs radiate out to the edge of the shell. There is a small rusty-orange patch deposited on the shell surface anteriorly on both valves (Fig. 1 A and C). Posterior to the ligament the shell edge is crenulated with 10–12 slightly anteriorly sloping teeth. The specimen is consistent with the descriptions for the species given by Benson[6] and other authors[2, 3]. However, this small specimen lacks the slightly emarginated base reported by Benson[6].

A further two specimens, one of which was living, were found on 3rd December 2017 on a slightly more sheltered intertidal muddy-sand area. The living specimen was located approximately 1km northwest of the initial discovery of 25th October and the dead specimen was somewhat closer at a distance of about 500m (roughly west northwest). The live specimen measured 20.8mm (length)×10.5mm (height)×7.4mm (breadth), a little larger than the initial specimen reported. The slightly emarginate base is just becoming evident in this specimen. It was found relatively high on the shore within a small patch of dwarf eelgrass (Fig. 2). It was neither attached nor buried but was lying exposed on the sediment surface. There are numerous patches of dwarf eelgrass across the intertidal area at this location. It is conceivable that the specimen was washed in from a subtidal location and happened by chance to come to rest where it was found. The *in-situ* image perhaps best illustrates its position in relation to the dwarf eelgrass (Fig. 2). Note the presence of two *Peringia ulvae* (Pennant, 1777), an abundant gastropod on the shore in question, on either side of the mussel.

Two more specimens were found in February 2018. A single valve was found lying on more mixed coarse sediment but the fifth specimen, picked up two days later on 15th February 2018,

Figure 2 Live specimen of A. senhousia, the Solent, December 2017.

was of more significance. It was live and buried just beneath the surface with its posterior end very slightly exposed. This is a feeding orientation allowing its siphons free access to the water column[7]. The animal was partially surrounded by a fluffy sediment cocoon. These cocoons are considered protective and are constructed using fine byssal threads[7]. The habitat was muddy-sand roughly 400m from the where the previous live specimen occurred. This is clear evidence that the species is both present and feeding in the intertidal area in question. Given its preference for soft sediments the habitat choice is not unexpected[7].

William Henry Benson (1842), who first described the species worked for the Bengal Civil Service in British India[6]. Benson gave it the name *Modiola senhousia* and listed the habitat for the species in broad terms as 'Coasts of Chusan and Canton Province' in China (now known as Zhoushan and Guangdong respectively). The species name '*senhousia*' appears to be a tribute by Benson to Captain Sir Humphrey Fleming Senhouse, a British Royal Navy officer who died in June 1841 on board HMS Blenheim in Hong

Kong from fever contracted during the British capture of Canton in May 1841 (part of the First Anglo-Chinese, or Opium War) [7]. Benson joined the East India Company in Bengal[8]. It was this company that drove the sale of opium to China in exchange for silver, a British strategy to counteract a large trade deficit with China and strengthen its influence in Asia[9, 10]. In this context Benson's choice of name for the species is understandable.

The Latin name for the Genus '*Arcuatula*' derives from '*Arcus*' meaning shaped like a bow, curved or arched. The ending '*tula*' denotes a diminutive hence '*Arcuatula*' translates as 'little arch'. The type species of the genus is *Modiola arcuatula* Hanley, 1843. Hanley noted that this species 'is destitute of any dorsal angle' and that 'it is remarkable for its narrow sickle-shaped contour, and the few narrow ribs of its posterior extremity'[11]. When erecting the new genus '*Arcuatula*' Félix Pierre Jousseaume, the French malacologist, notes that '*Modiola senhausi*' (*Arcuatula senhousia*) is very close to *M. arcuatula* by its colouring, but that its shell is more triangular, shorter and less arcuate'[12]. This is consistent with overall shape of the shell and the subtle nature of the emarginated base noted for the specimen recorded here.

The type specimen from Benson (1842) has been photographed by the Natural History Museum, London and their image is presented here for visual comparative purposes (Fig. 3). The type specimen compares well with the Solent specimen, however, minor differences are evident. The anterior margin below the beaks is more broadly rounded and the ventral margin is straight in the Solent specimen. Phenotypic variation in shell morphology of molluscs due to local environmental conditions such as tidal excursion, shore level, wave exposure, currents and sediment type is well documented[13, 1]. The largest live specimen (length 20.6mm) found has a slightly emarginate base and resembles the type specimen (length 23mm); growth may therefore be a factor in the expression of this shell characteristic.

Figure 3 A. senhousia Benson (1842), type specimen (courtesy of the Natural History Museum, London, Ref. NHMUK1985011).

The native range of *A. senhousia* extends from the type locality of Zhoushan, China (near Shanghai) north to the Kuril Islands and the Siberian coast and southwards through the Sea of Japan, the Yellow Sea, the East China Sea, and the South China Sea to Singapore [15, 14, 16, 17].

The Kuril Islands form a thin chain that stretches from northern Japan to the southern tip of the Kamchatka Peninsula. The question of where *A. senhousia* has been recorded in this region is of interest in terms of identifying the northern edge of its native distribution. The available literature indicates the records are from the southern part of the area. One Kuril Island reference is attributed to a Japanese paper published in 1971 concerned with the seashells of Sagami Bay in Northern Japan (just south of the Kuril Islands)[18]. However, further research identified another work published by the Vladivostok Institute of Marine Biology in 1975[19]. This paper lists the intertidal macrofauna of the Kuril Islands. It clearly identifies that *A. senhousia* is limited in its distribution and makes specific reference to Kunashir Island located just east of Hokkaido (northern Japan). In fact it places it within the following category: 'Asiatic subtropical-low-boreal species, more or less widely distributed in the Yellow and Japan Seas, around Japan and reach only the warmest parts of low boreal areas. Here also belong a few Asiatic tropical-low boreal species'[19]. In 1978 specific reference was made to a Siberian population centred on Busse Lagoon in South Sakhalin (N46.5378, E143.3293)17. Additionally, the species was recorded from the lagoon lake Izmenchivoye just north of Busse Lagoon[20]. All this strongly suggests the northern edge of the native distribution is at the southern end of the Kuril Islands, north of Japan.

A. senhousia is reported to have a global distribution[14]. Outside of its native range this northerly extent is exceeded in at least one location. In the Pacific North West there is a record from Savary Island in the Strait of Georgia, British Columbia (N49.94°)[15]. The UK find reported herewith pushes the northerly extent higher to 50.82°North.

The Conchological Society database has no previous records for the species and the closest record to the UK prior to the current find was reported in 2009 from Arcachon Bay, in the southern Bay of Biscay[14]. It is therefore considered most likely that those found in the Solent in 2017 come from an introduction event somewhere nearby. If the population recorded from Arcachon Bay had gradually extended northwards unaided by any direct anthropogenic vector, it is reasonable to assume that its presence would have been recorded elsewhere before it reached the UK. The specific pathway can only be guessed at currently. In other parts of the world introduction has often been attributed to accidental translocation through aquaculture and fisheries activities e.g. oyster farming[15, 5, 21]. But another important vector is shipping. Biofouling or carriage in ships' seawater systems or in ballast water is well documented[15, 21]. For example, *A. senhousia* was recorded in the internal seawater systems of vessels in south Australia (1988) and north Australia (1999)[15]. It is possible that molecular analysis of the specimen found live may help point to a potential origin for the Solent examples.

Studies have noted the complex interactions between *A. senhousia* and *Zostera marina*[22, 23] but information on its potential interaction with dwarf eelgrass is limited[24]. More generally, positive and negative effects have been reported[15]. Identified predators in other parts of the world include gastropods, crustaceans, echinoderms, fish, shore birds and diving ducks[4]. As previously noted the original shell find reported here had a hole in the left valve near the posterior edge (Fig. 1 A–B). Close examination of this hole indicated a smooth sloping edge and no associated fractures, as might be expected if a physical force had knocked a chip out of the shell wall. The hole, though somewhat irregular in shape, is reminiscent of those left in bivalve molluscs that have been drilled by a predatory gastropod. It has been reported in the literature that native predators can limit the degree to which the species is able to establish itself[25].

Statements as to the potential effects of *A. senhousia* can be readily found online but reports are conflicting. There appears to be some agreement that if conditions support a population increase such that continuous mats form then negative impacts may be observed. These mats have been reported as having densities in excess of $1500 m^{-2}$. However, what happens at one location may not occur at another indicating perhaps that context is definitive. It is therefore prudent to monitor the species and communities where this new arrival has settled.

Although it is clear that *A. senhousia* is living in the intertidal area sampled it remains unclear whether or not there is an *established* population both living and reproducing in the UK. An 'established' population, according to the Convention on Biological Diversity, is one that is 'successfully producing viable offspring with the likelihood of continued survival' (COP 6, decision VI/23). Or, in other words, one that is 'self-sustaining and does not need re-introduction to maintain a population base such that it continues to survive and thrive'[26]. Further work will be undertaken as part of the PhD associated with this find. The species has been found elsewhere at certain times only to disappear and return at a much later date and become established (e.g. in Puget Sound)[15]. It is non-native but whether it is necessary to apply other terminology in the UK context has yet to be seen. Certainly in ecological terms it should not axiomatically be labelled any more strongly than this at the current time[27].

Specific site details and other relevant information have been recorded and entered into the database held by the Conchological Society. One whole specimen has been deposited at Amgueddfa Cymru – National Museum Wales, Cardiff: NMW.Z.2018.003.00001.

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