TRANS-ATLANTIC RAFTING OF INSHORE MOLLUSCA ON MACRO-LITTER: AMERICAN MOLLUSCS ON BRITISH AND IRISH SHORES, NEW RECORDS

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Abstract Following prolonged westerly gales impacting the south and west coasts of the British Isles in Winter 2013–14 unusually large numbers of rafting organisms have been reported. Six species of bivalve and one gastropod with their normal ranges in the Caribbean and SE coasts of the USA were found attached to plastic macro-litter washed ashore on the south coast of England and west coast of Ireland. Pinctada imbricata *(Roding, 1798) (Atlantic Pearl Oyster) was recorded once before in 1988 as* P. radiata *but is here regarded as the western Atlantic subspecies*. Isognomon bicolor *(CB Adams, 1845) (Bicolor purse oyster),* Pododesmus rudis *(Broderip, 1834) (Atlantic false jingle),* Aequipecten heliacus *(Dall, 1925),* Euvola ziczac *(Linnaeus, 1758) (Zigzag Scallop) and* Chama cf. congregata *Conrad, 1833 (Little Corrugate Jewelbox) are herein reported for the first time from the eastern Atlantic. Should sea temperature rises continue such long distance rafting could be a mechanism for the establishment of alien western Atlantic species in the NE Atlantic.*

Key words Alien species, trans-Atlantic, rafting, drift, macro-litter

INTRODUCTION

"Rafting", the passive, long distance dispersal of marine organisms on biotic or abiotic floating debris is well recorded in the literature (see reviews by Thiel & Gutow, 2005a, b: Thiel & Haye, 2006). Pre-industrialisation, floating debris consisted mostly of algae or wood with tar lumps and pumice of secondary significance. In the twentieth century an additional and growing source of floating debris is plastic increasing the possibilities for the dispersal of sessile organisms (Winston *et al*., 1997). The potential role of marine macro-litter in the dispersal of potentially invasive species is recognised and some instances have been recorded by Gregory (2009).

Thiel & Gatow (2005b) record 51 species of Bivalvia that have been reported as rafting. Of these, 8 are wood boring Teredinidae or Xylophaginae and are routinely found in floating wood. Of the remainder the majority are small, only a few mm in size and could generally be classed as crevice dwelling or juvenile in which the post larval byssus is retained. *Lasaea* is believed typical and regarded by O'Foighil (1989) to be pre-adapted for rafting dispersal primarily on algae dislodged from the normal intertidal habitat. Larger byssally attached bivalves have been rarely recorded except along the coast of Florida where *Pinctada*, *Isognomon*, *Anomia* and the cemented *Chama* have been recorded on anthropogenic material, mainly plastic debris (Winston *et al*., 1987). Although attached to floating debris these bivalves were found within or close to their normal geographic ranges.

Minchin, Cook & Clark (2013) record eighteen marine or brackish water species of bivalve as alien or invasive around the British Isles. Of these perhaps four arrived via rafting and include *Brachidontes exustus (*Linnaeus, 1758) (J. Light in Minchin *et al*., 2013); *Dendrostrea folium* (Linnaeus, 1758) (Turk, 1988); *Pinctada radiata* (Leach, 1814) (Turk, 1988) and *Pteria colymbus* (Röding, 1798) (Turk, 1988). The records made by Turk (1988) came from the floating wreck of a small speedboat rather than the normal range of marine litter. Recently *Dendostrea frons* has been recorded from western Ireland (Quigley and Hill, in press).

Records of rafting gastropods are scarce for the British Isles, but *Stramonita haemastoma* (Linnaeus, 1767) (Oliver, 1988) was recorded from a polystyrene float on the coast of south Wales.

During the winter of 2013–2014 the British Isles were subjected to an unusual number and severity of storms (Slingo *et al*., 2014). These brought quantities of floating debris onto the southern

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Figure 1 Macro-litter. **A** plastic spool from Chesil Beach (Steve Trewhella). **B** "Scotty pots" from Waterville (photo Declan Quigley). **C** "Scotty pot" from Chesil Beach (photo Steve Trewhella).

and western shores of England and Ireland with more than normal findings of rafting organisms, mainly barnacles, being reported to web forums such as Glaucus (www.glaucus.org.uk) and the Porcupine Society (http://pmnhs.co.uk). This trend has continued into the autumn of 2014. Bivalves found attached to plastic debris were sent to the National Museum of Wales for identification where species of *Pteria*, *Isognomon*, *Pododesmus, Chama, Aequipecten* and *Euvola* were recognised. Similar but more sporadic findings have been made in previous years including some from western Ireland where numerous plastic bait pots have become a regular item of flotsam. Among these the alien gastropod *Cerithium* was found. This paper reports on these findings and to facilitate the identification of such alien species illustrates all species previously recorded.

Methods and materials

The specimens were found by S.T., R.H. and D.Q. on numerous visits to storm beaches particularly Chesil Beach, Dorset, England and at Lohar Beach, Co. Kerry, Ireland. Macro-litter stranded after westerly storms was searched for attached fauna with special attention given to plastic bait pots that are now known to have an American origin.

Over the last decade, Rosemary Hill has found over 30 plastic vented bait jars stranded near Waterville (Fig. 1B), occasionally with lids attached and primarily during the winter months. Some of the stranded bait jars with lids attached contained the remains of unidentified fish bones. Similar bait pots have now been found on the south-west coast of England (Fig. 1C). The bait jars are manufactured by Scotty Fishing and Marine Products (www.Scotty.com), a company based in Sidney, British Columbia, Canada. Their website describes the jar as 'A rugged container for storing bait or for protecting bait in a crab or prawn trap. The quick unscrew lid and vented body have the right size slots to send the bait smell out, yet protect the bait from most parasites'. According to Mr Ryan Emile (pers. comm.), the bait jars are used extensively in inshore crustacean fisheries throughout North America but 'We do not currently have any sales of our bait jars, into Ireland or any other part of Europe'. The jars are baited, inter alia, with proprietary fish bait, such as those manufactured from herring (*Clupea harengus* Linnaeus, 1758) by Ace of Baits Co. Inc. (www.aceofbaits.com), a company based in Ladysmith, British Columbia, Canada (Ryan Schoor, pers. comm.).

The provenance of the bait pots supports the premise of this paper that the contained and attached fauna does originate from the east and south-east coasts of the USA.

Results

Pteriidae Gray, 1847 (1820)

Pinctada Röding, 1798
Type species: *Mytilus margaritiferus* Linnaeus, 1758

Pinctada imbricata imbricata (Röding, 1798)
Fig. 2

Records 3 specimens, attached to a plastic spool (Fig. 1A), Chesil Beach, Dorset, (54.57°N 02.47°W) February, 2014, Coll. Steve Trewhella

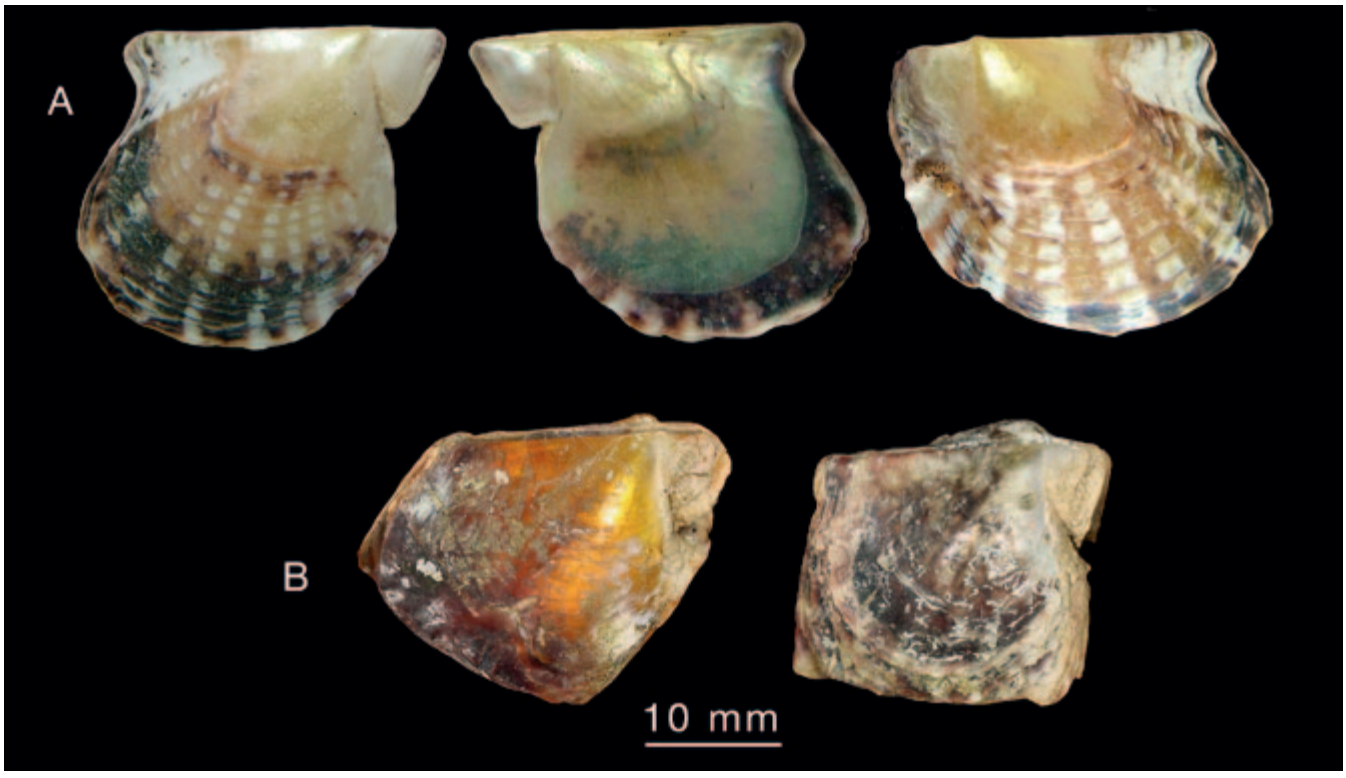

Figure 2 ***Pinctada imbricata imbricata*** (Röding, 1798). **A** views of the shell from Waterville, Ireland. **B** two shells from Chesil Beach.

1 shell, in a bait pot, Loher Beach (51.79°N, 10.17°W), Waterville, Co Kerry. coll. Rosemary Hill (NMINH:2014.45.1).

Many specimens, St Ives, Cornwall, 1986 (Turk, 1988, as *P. radiata* Leach, 1814).

Measurements Largest specimen 25mm.

Diagnosis Shell thin, compressed, inequivalve, obliquely quadrangular to subcircular with beaks in a dorsal anterior position. Dorsal, hinge margin, straight, edentulous, ligament in a single central shallow depression, around one third the length of the dorsal margin. Right valve with a byssal gape beneath the triangular anterior area, left valve entire. External surface scaly, often with radial rows of weak flattened scales. Ground colour, dark purple-rose to beige with paler rays. Interior pale, yellowish-white, pearlescent.

Remarks The rafting shells belong to the group of *Pinctada*, variously referred to as *P. radiata* (Indian Ocean), *P. imbricata* (Western Atlantic) or *P. fucata* (Indo-Pacific). Temkin (2010) found that there were low levels of molecular divergence between these populations and chose to regard this group a single species with three subspecies; *P. imbricata imbricata, P. imbricata fucata* and *P. imbricata radiata*. The shells of this *Pinctada* complex are variable differentiation of the subspecies can be difficult and are recognised by their location rather than morphology.

Pinctada imbricata radiata is a lessepsian immigrant and is now established in the eastern Mediterranean (Soufi-Kechaou *et al*. 2005; Dogan & Nerlovic, 2008).

The origin of the Waterville specimen is however not in doubt as it was found in a bait pot, a type not used outside of the USA. Similarly the specimens recorded by Turk (1988) also had an American origin as did the floating wreck that they were attached to – a speedboat with American markings. The Chesil Beach specimens were found with *Isognomon bicolor*, a western Atlantic species supporting our conclusion that all of these rafting specimens are *P. imbricata imbricata*. The natural range of this subspecies is the warm water of N. Carolina, W Indies, Brazil and Bermuda

Rafting pearl oysters have been recorded previously. Oliverio *et al*. (1992) recorded specimens

Figure 3 ***Isognomon bicolor*** (CB Adams, 1845). Shells from Chesil Beach.

of *P. i. radiata* attached to the carapace of a loggerhead turtle (*Caretta caretta*) from the island of Lampedusa (Mediterranean). Winston *et al*. (2007) recorded *Pinctada* attached to marine litter off the coast of Florida.

Isognomon Lightfoot, 1786
Type species: *Ostrea perna* Linnaeus, 1767

Isognomon bicolor (CB Adams, 1845)
Fig. 3

Records 4 specimens, attached to a plastic spool, Chesil Beach, Dorset, (54.57°N 02.47°W) February, 2014, Coll. Steve Trewhella.

Measurements Largest specimen 19mm.

Diagnosis Shell thin, compressed, slightly inequivalve, irregularly obliquely oval with a straight hinge margin and anterior byssal notch. Outer surface smooth or with flaky commarginal lamellae, our shells white with purple tinges but may be brown to purple brown in colour. Interior nacreous. Hinge lacking teeth, ligament in small multiple (here 7in number) grooves along the dorsal margin.

Remarks There are two other species known from the west Atlantic, *Isognomon alatus* (Gmelin, 1791) and *I. radiatus* (Anton, 1838). The first species attaches to mangrove roots, is very compressed and plate-like. The latter commonly attaches to rocks and has radial sculpture as well as the weak flaky lamellae.

Isognomon bicolor is found from Florida to Brazil. It is reported as invasive in Brazil, reaching there in the 1970s and 80s and originating from the Caribbean (the type locality is Jamaica) (Pereira Dias *et al*. 2013). They reported that the method of transport was most likely by relocating petroleum platforms. Although usually attached to rocks or other hard strata, it can attach to floating macroalgae such as *Sargassum* and thus enhance dispersal and recruitment (Pereira Dias *et al*., 2013).

The only eastern Atlantic record of an *Isognomon* species is that of *I. isognomon* (Linnaeus, 1758) in the Canary Islands (Gomez Rodriguez & Perez Sanchez 1998). However this report is questionable considering that this species is native to the Indo-Pacific and has not yet been recorded from the Mediterranean. The Canary Island specimens may also be *I. bicolor* as there is a close resemblance to *I. isognomon.*

Pectinidae Rafinesque, 1815

Aequipecten P. Fischer, 1886
Type species: *Ostrea opercularis* Linnaeus, 1758

Aequipecten heliacus (Dall, 1925)
Fig. 4

Records 2 specimens, inside a bait pot, Chesil Beach, Dorset, (54.57°N 02.47°W), 21 October 2014, Coll. Steve Trewhella.

Measurements Largest specimen 17.5mm.

Diagnosis Valves equally convex, disc circular, ears subequal, byssal notch marked with a ctenolium of 4 teeth. Sculpture of 20 rather acute radial ribs, each bounded by a row of fine spines and finer prickly threads in the interspaces. Left valve more strongly coloured than right valve, shades of orange brown.

Remarks Before the description of *A. heliacus* by Dall (1925) this species was thought to be the western Atlantic population of the European *A. opercularis*. *Aequipecten heliacus* is distributed from S. Carolina, Florida, Bahamas and into the Caribbean.

Figure 4 ***Aequipecten heliacus*** (Dall, 1925). Chesil Beach (photos Steve Trewhella)

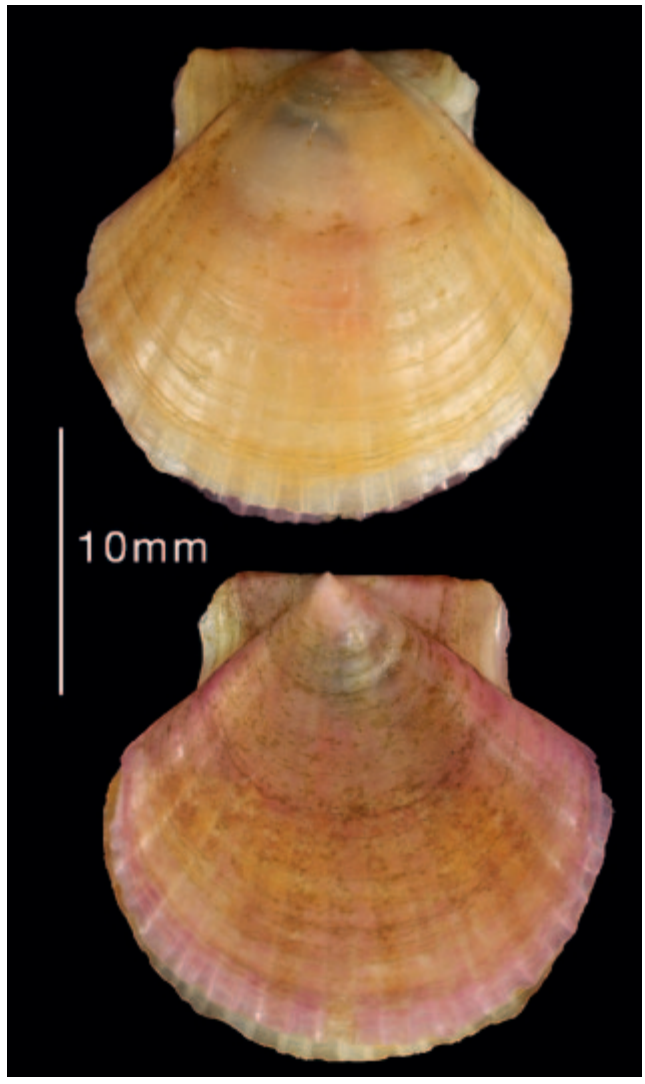

Figure 5 ***Euvola ziczac*** (Linnaeus, 1758). Chesil Beach (photos Steve Trewhella) 18.6mm

Euvola Dall, 1898
Type species: *Ostrea ziczac* Linnaeus, 1758

Euvola ziczac (Linnaeus, 1758)
Fig. 5

Records 3 specimens, inside a bait pot, Chesil Beach, Dorset, (54.57°N 02.47°W), 21 October 2014, Coll. Steve Trewhella.

Measurements Largest specimen 18.6mm.

Diagnosis Upper valve flat or slightly concave, lower valve deeply convex, disc circular, ears equal. Sculpture of smooth radial ribs but these indistinct in juveniles. Upper valve brightly and deeply coloured shades of purple red, lower valve pale in colour white to yellow.

Remarks Distributed from North Carolina, Bermuda and south throughout the West Indies.

Anomiidae Rafinesque, 1815

Pododesmus Philippi, 1837
Type species: *Pododesmus decipiens* Philippi, 1837

Pododesmus cf rudis (Broderip, 1834)
Fig. 6

Records 2 specimens attached to a bait pot, Chesil Beach, Dorset, (54.57°N 02.47°W), 23 February 2014, Coll. Steve Trewhella.

1 specimen, inside a bait pot, Chesil Beach, Dorset, (54.57°N 02.47°W), 21 October 2014, Coll. Steve Trewhella.

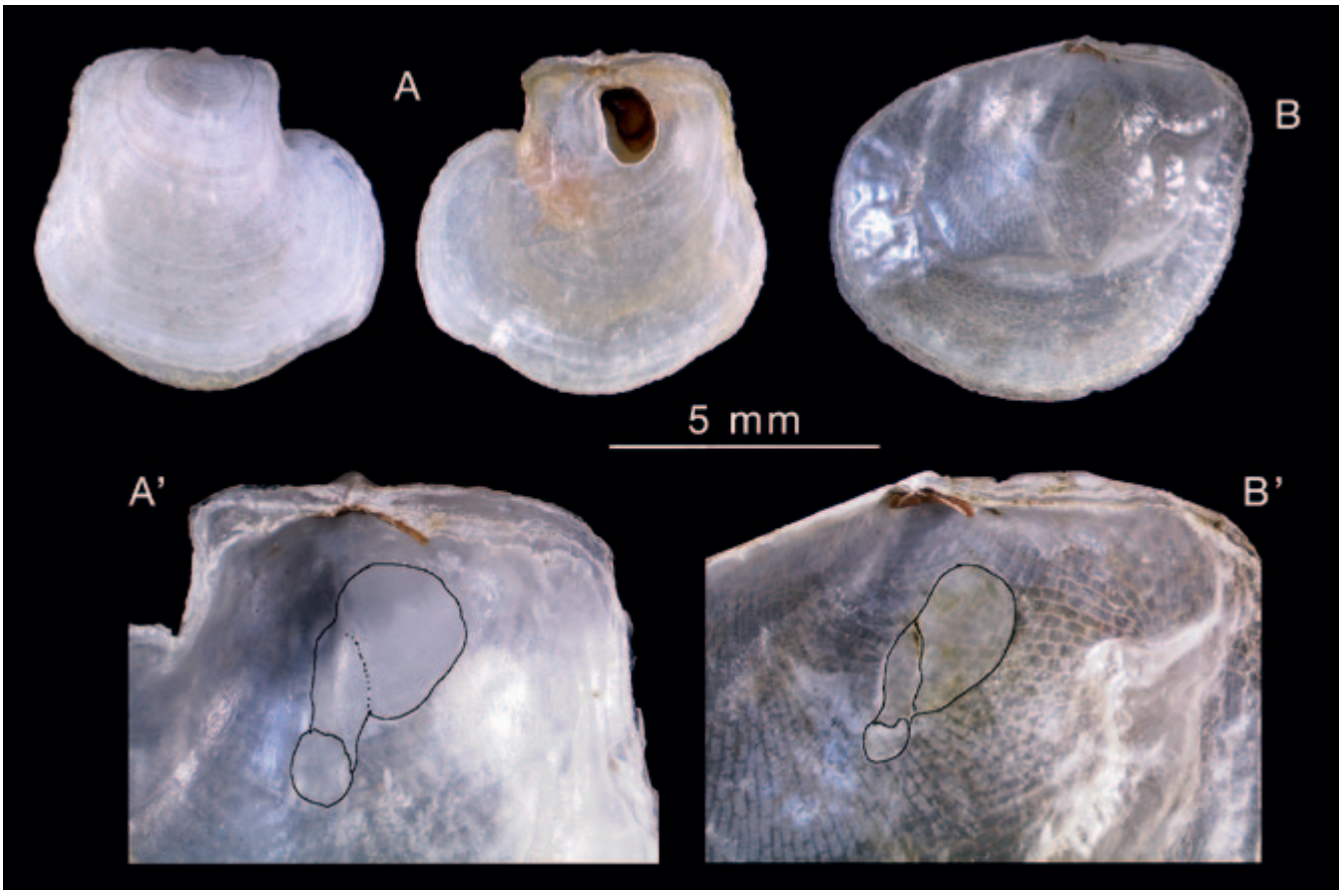

Figure 6 ***Pododesmus cf rudis*** (Broderip, 1834). **A–B** Shells from Chesil Beach; **A'-B'**, muscle scars on the upper valves of corresponding shells above.

Measurements Largest specimen 26mm.

Diagnosis Thin, compressed shells, inequivalve, lower valve flat with a moderately sized byssus foramen, upper valve convex. Outline irregularly oval, umbos very low. Hinge weak, lacking teeth, ligament internal. External surface more or less smooth with faint commarginal lines and ridges. Muscle scars on upper valve small co-joined, byssus retractor scar the larger, oval tapering ventrally to the smaller round adductor muscle scar.

Remarks The generic identity of these specimens is based on the arrangement of the muscle scars, the two co-joined scars indicative of *Pododesmus* in contrast to the three separated scars in *Anomia*. However the external surface of *Pododesmus* species, in both east and west Atlantic, usually has, to some degree, radial ridges or grooves. The specimens from the bait pot have an almost smooth surface with faint commarginal sculpture. Furthermore the shells lack any colour whereas both *Pododesmus rudis* and *P. patelliformis* are usually tinged greenish or reddish. Anomiids vary considerably, their shells sometimes reflecting the surfaces they attach to (see *P. squama* in Oliver *et al.*, 2010) such that on smooth plastic surfaces they may not develop surface features.

The species identity is therefore primarily based on the origin of the bait pot.

Chamidae Lamarck, 1809

Chama Linnaeus, 1758
Type species: *Chama lazarus* Linnaeus, 1758

Chama cf. congregata Conrad, 1833
Fig. 7

Records 1 shell attached to a plastic fish box, Chesil Cove, 50°33'31''N 02°26'54''W, 11 March 2012, coll. Steve Trewhella.

Identified as *Pseudochama gryphina* (Lamarck, 1819) in Light, 2012 as *Chama gryphoides* Linnaeus, 1758 in Oliver *et al.*, 2010 accessed 3 November

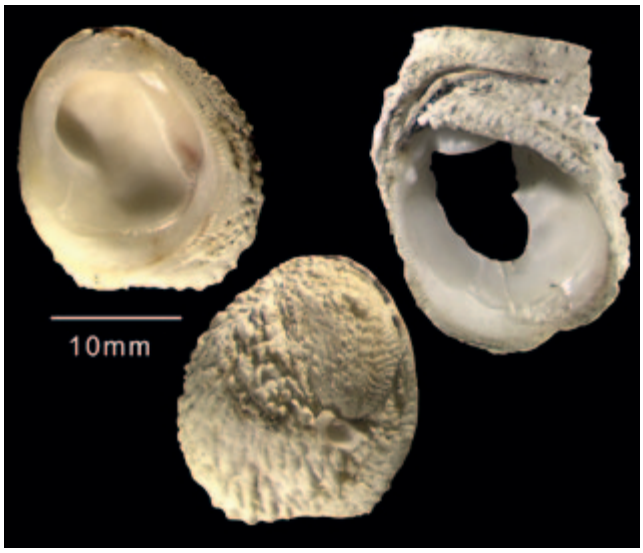

Figure 7 ***Chama cf. congregata*** Conrad, 1833, shell from Chesil Cove.

2014. The exact identity of the *Chama* species could not be confirmed but is believed to be *Chama congregata* Conrad, 1833.

Diagnosis Irregular oval. Attached by left valve. Very thick shelled, worn wavy radial ribs in concentric rows. White to cream in colour. Inner margins crenulated.

Measurements 18mm wide, 20mm high.

Remarks This shell has been identified as both *Pseudochama gryphina* and *Chama cf. gryphoides*. The generic distinction between *Chama* and *Pseudochama* is based on which valve is attached, left in *Chama*, right in *Pseudochama*. In this specimen the lower attached valve curves in an anticlockwise direction and is therefore the left valve and thus *Chama*. However recent studies employing molecular techniques have shown that the coiling is not a specific character – some species show a 50:50 ratio of left or right valve attachment (Campbell *et al*. 2004).

It was at first thought most likely to be a northwards range extension of an eastern Atlantic/Mediterranean species and thus identified as *P. gryphina* or *C. gryphoides*. However it was attached to macro-litter much of which is now known to have a western Atlantic origin. The identification of *Chama* is problematic but in size, sculpture and colour the Chesil specimen is most like *C. congregata*, which is distributed in the Caribbean northwards to South Carolina.

Figure 8 ***Cerithium litteratum*** (Born, 1778), shell from Waterville.

Cerithiidae Fleming, 1822

Cerithium Bruguière, 1789
Type species: *Cerithium adansonii* Bruguière, 1792

Cerithium litteratum (Born, 1778)
Fig. 8

Records 1 shell, in a bait pot, Loher Beach (51.79°N, 10.17°W), Waterville, Co Kerry. coll. Rosemary Hill (NMINH:2014.46.1)

Measurements Height 17mm

Diagnosis Usually about 3cm in height, stout, stubby, with 8–9 whorls. Body whorl relatively broad, aperture large with a short slightly reflected siphonal canal, anal canal deep. Sculpture prominent of spiral threads with a subsutural row of nodules and a second but weaker row on the periphery with finer nodular spiral bands between. Colour pale cream to light brown, with the spaces between the nodules and spiral bands picked out in black.

Remarks *Cerithium litteratum* is a common shell in shallow water ranging from S. Carolina, Bermuda and south to Brazil (Houbrick, 1974). It is distinguished from the other five West Atlantic species by its heavy shell, presence of the spiral band of subsutural nodules and prominent

posterior canal (Houbrick, 1974). This species has been recorded from the Aegean (Garilli & Vardala-Theodorou, 2005) and as here based on the finding of a single shell. Garilli & Vardala-Theodorou (2005) postulated that their shell originated from "shipping". It was found in debris from fishing nets and was inhabited by a hermit crab.

Discussion

The recent discoveries of byssate and cemented bivalves attached to floating macro-litter highlight rafting as a mechanism for dispersal across the Atlantic, from west to east. The species identified are southern, warm water taxa and have a distribution in the south-east coast of the USA and Caribbean. Rather, one might expect to find more northern, colder water taxa but the path of the Gulfstream veers away from the north-west coasts and will not pick up inshore species. The majority of the specimens were either alive or had soft tissues remaining indicating their long-term survival and therefore possible ability to recruit. While the majority of the specimens are of byssate or cemented bivalves the finding of a gastropod inside a lidded bait pot suggests that the snail grew inside the pot or that it was placed in the pot by some human agent. If juvenile organisms can grow inside these bait pots then there is the potential of a much larger range of taxa than can be dispersed in this way. A living sea urchin and scale worms were found inside one of the bait pots, both were too large to move through the perforated walls and this further supports the long-term growth of organism settling at the larval stage. There is no evidence to suggest that the rafting species are currently breeding and are therefore not invasive at this time. However, with sea temperature rises this could be possible in the future, hence allowing establishment of possible alien and invasive species.

These findings are the results of the efforts of only two people but the American Scotty Pots have been found on beaches in west and north Wales suggesting that trans-Atlantic macro-litter is widespread on the south-western approaches of Britain and Ireland. Extending the efforts and range of regular collecting of stranded macro-litter would undoubtedly reveal that the extent of Western Atlantic alien species reaching European shores is much greater than evidenced here. A structured quantitative and experimental approach may give a new perspective on the potential threat of alien and invasive species arriving on floating macro-litter.

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