

FIRST RECORD OF THE FALSE MUSSEL *MYTILOPSIS SP.* (DREISSENIDAE) FROM GRAND CAYMAN, CARIBBEAN SEA

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Abstract The byssate false mussel *Mytilopsis sp.* was identified for the first time in the Cayman Islands in May 2018. It occurred in the mangrove backwaters on the northern coast of Grand Cayman in great abundance. *Mytilopsis spp.* are highly invasive in many semi-tropical to tropical regions globally and are almost certainly spread by vessels. Identification of *Mytilopsis* species is difficult, as previously used morphological identification characters are highly variable and so, here we report on its occurrence in Grand Cayman, likely further spread and discuss the difficulties in its identification.

Key words False mussel, red mangrove, marina, spread, hull fouling

INTRODUCTION

Mytilopsis spp. belong to the Dreissenidae, whose members occupy a wide range of habitats from freshwater to hypersaline environments. It has three living genera; *Dreissena*, which became distinguishable approximately 11.6 MYA, and two sister lineages *Mytilopsis* and *Congerina*, which separated at 22.6 MYA (Bilandžija *et al.*, 2013). The two closely related *Mytilopsis* species *M. sallei* and *M. leucophaeata* (Conrad, 1831) are thought to have diverged 12.7 MYA (Bilandžija *et al.*, 2013) and were considered as the only extant species in this genus (Therriault *et al.*, 2004). However, Nuttall (1990) also considers *M. trautwineana* (Tryon, 1866) to be a closely related species. The species *M. lopesi* Alvarenga and Ricci, 1989, is a freshwater species from the channels of the Amazon. It has subsequently been re-assigned under a recently proposed genus *Rheodreissena* Geda *et al.*, 2018. This genus now includes two other species from the Amazon and Orinoco basins (Mansur *et al.*, 2019) and differs from *Mytilopsis* by having a septum fused with the apophysis, brooding its young and subsequently releasing them as 'crawlers'.

Mytilopsis sallei (Récluz, 1849) is a small, byssate bivalve, capable of forming locally dense populations, up to 4000 individuals on a single mangrove plant root (Vilardy & Polanía, 2002). It was originally described from Guatemala and considered to be native to the Caribbean region (Bax *et al.*, 2002). It has been recorded from the

Yucatan to Venezuela (Escarbassiere & Almeida, 1976) and the southern peninsula of Florida, USA (Bax *et al.*, 2002). It has rapid growth, early maturity and a high reproductive capacity, with pelagic larvae that can disperse widely, making it a typical 'r' selection species. It can overgrow other sessile species and each other, to form mono-specific clusters and it typically inhabits sheltered brackish water (reviewed in Tan and Tay, 2018). It has been previously recorded as occurring in dense clusters on the roots of the red mangrove *Rhizophora mangle* L. in the Caribbean (Vilardy & Polanía, 2002). It is very likely that this genus had arrived in the region by the late Oligocene (Nuttall, 1990). Other species, such as *M. domingensis* (Récluz, 1852) from the Dominican Republic in the Bay of Mexico, *M. adamsi* J.P.E. Morrison, 1946 from the Pacific coasts of Mexico (Salgado-Barragran & Toledano-Granados, 2006), *M. africana* (Van Beneden, 1835) from west Africa (Nuttall, 1990) and *M. allyneana* Hertlein & Hanna, 1949 and *M. zeteki* Hertlein & Hanna, 1949 from the mid to eastern Pacific are considered synonymous with *M. sallei* (Morton, 1980).

Mytilopsis leucophaeata, however, naturally inhabits more temperate environments to the north of those typically inhabited by *M. sallei* and is widely distributed in Europe (Oliver *et al.*, 1998; Rajagopal *et al.*, 2002), occurring as far north as Finland (Forsström *et al.*, 2016). Both *M. sallei* and *M. leucophaeata*, have become widespread globally (Souza *et al.*, 2009; Rizzo *et al.*, 2014; Zhulidov *et al.*, 2015 and in Tan & Tay, 2018)



Figure 1 Grand Cayman in the Caribbean Sea and the area studied, encircled.

with the latter now recorded in the Caribbean (Pérez- Pérez & Espinosa Saez, 1994; Delannoye *et al.*, 2015). The two species have been distinguished to date, by the shape of their septum, to which the anterior adductor muscle attaches, and by the apophysis, a small projection, which lies below the level of the septum and to which the byssal attractor muscle is attached (Morton, 1981). The shape of these structures has been an important feature in the morphological characterisation of the different *Mytilopsis* species. The Baltic *M. leucophaeata*, for example, has a smaller septum, but similar shaped apophysis compared with *M. sallei*.

Here we report on the abundance of *Mytilopsis* *sp.*, for the first time in Grand Cayman and the difficulties in identification to species level using morphological features. The distribution of *M. sallei* and *M. leucophaeata* in the western Atlantic are reviewed and the potential pathways of *Mytilopsis* *spp.* spread are discussed.

METHODS

Sheltered canals, within the west side of the North Lagoon, on the north side of Grand Cayman (Fig. 1) were visited by boat on 6 and 10 May 2018, at both high and low water. Samples were taken from aerial roots of the red mangrove *Rhizophora*

mangle L. at 19°19'19.75"N, 81°22'31.72"W, from a nearby canal at 19°19'18"N, 81°22'28", a stony shore in the same region and from a separate canal located at a disused quay wall at 19°19'06.35", 81°21'59.09"W. A small hand net was used to scrape surfaces for sessile species on the first day, whereas, a favourable low water on the second day allowed the presence of intertidal biota to be easily sampled by hand.

Fourteen specimens of *Mytilopsis*, shell lengths ranging from 10.9–22.4mm were preserved in absolute alcohol, to enable later molecular analysis. Six samples collected were examined using a Leica binocular microscope (×50) using a Volpi-intralux 4000–1, with twin swan-necked fibre-optic illumination. An estimate of white shell frequency was deduced from a close-up picture of specimens attached to a red mangrove root.

RESULTS

Dense clusters of *Mytilopsis* were observed attached to the aerial roots of the red mangrove and intertidally on shores, forming encrustations over intertidal stones. These clusters were observed within the sheltered backwater canals and a lagoon on the north side of Grand Cayman (Fig. 2a and 2b). The canals were lined with dense stands of the red mangrove, with

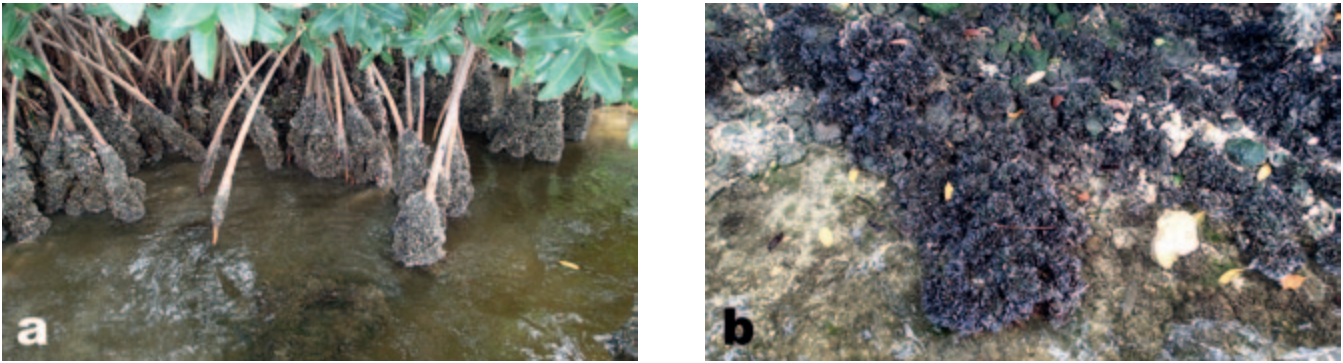


Figure 2 a *Mytilopsis* sp. attached to the aerial roots of the red mangrove. b *Mytilopsis* sp. attached to shore stones in a mangrove canal (Photos. D. Minchin).

occasional spaces of hard shoreline. Densities of *Mytilopsis* sp. were greatest close to low water and extended for a short distance below and close to the mid-tide level. The mangrove flat tree oyster *Isognomon alatus* (Gmelin, 1791) and the barnacle *Chthamalus angustitergum* Pilsbry, 1916, generally occurred in a zone above *Mytilopsis* sp., but also overlapped with this species. The density of *Mytilopsis* sp. in the order of 1000s m⁻², was greatest on the mangrove aerial roots (Fig. 3a) and present at the entrance to a canal, which was adjacent to a disused quay. The abundance was also greatest where the water was turbid and green in colour, indicating likely eutrophication. Abundance typically declined towards the canal entrances. Near-surface salinities, for three adjacent tidal ponds to the study area for January and June 1997, ranged from 26.9 to 33.9‰ (Suárez-Morales *et al.*, 1999).

The Grand Cayman population of *Mytilopsis* sp. exhibited a larger septum, when compared with septum dimensions of *M. leucophaeta* in the literature and specimens examined had a smooth, low arched to pointed apophysis (Fig. 3b). Shells were slightly pointed anteriorly, and are clearly not blunt, as reported for *M. leucophaeata* specimens, being intermediate between figures for groups: 'A' consisting of *M. adamsi* and *M. leucophaeata* and 'B' of *M. africana*, *M. sallei* and *M. trautwineana* (Marelli & Gray, 1983), the latter originally known as *Tichogonia rossmaessleri* (Dunker, 1853), which is now a synonym for *M. sallei* (Molluscabase, 2019).

Shells were generally off white to light brown in colour (Fig. 3c). However, an infrequent white form, at a frequency of ~2%, was also apparent in the clusters on the mangrove roots (Fig. 3d).

DISCUSSION

The principal feature for the identification of the different *Mytilopsis* species, apart from the shell shape, has been the shape of the apophysis and size of the septum. It is difficult to reconcile our material with those described and figured in published accounts. Archambault-Guezou (1982) claimed the usefulness of the apophysis and septum as identifying features for this family is "...questionable..." in contrast to Nuttall (1990), who stated these features have some value. Mansur *et al.* (2019) agreed that the morphological features are highly variable and can lead to "...controversial classifications...". In their discussion they refer to the apophysis in *M. leucophaeata* being small, rounded and close to the septum, whereas in *M. sallei* the apophysis is almost always pointed or hook-shaped and more closely associated with the hinge-plate. The large septum and low slender arched to pointed apophysis of samples in this study are intermediate between *M. leucophaeata* and *M. sallei* (Table 1). It is clear the Grand Cayman population requires a genetic study to place its specific status correctly.

The apophysis of the Grand Cayman *Mytilopsis* specimens are smooth and slender, with a slightly rounded outline, to pointed rather than the more prominent arched apophysis of the European form of *M. leucophaeata* (Oliver *et al.*, 1998). However, this smooth slender form in Fernandes *et al.* (2018) is attributed to the Brazilian *M. leucophaeata*. This is confusing as the *Mytilopsis* in this study has an apophysis shape similar to the *M. leucophaeata* and that of *M. (Trichogonia) rossmaessleri* (now recognized as *M. sallei*) of Fernandes *et al.* (2018). This suggests, therefore,

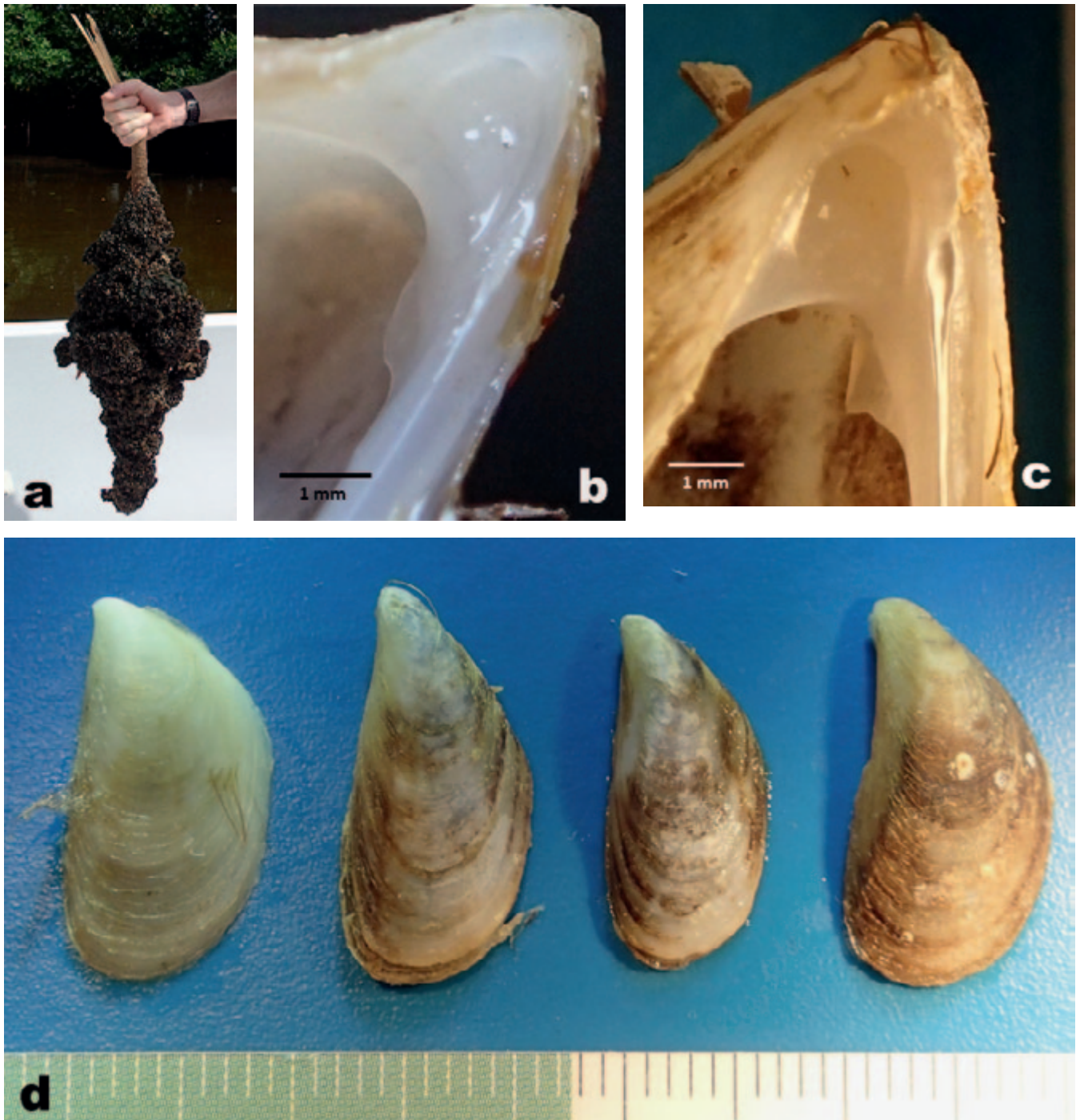


Figure 3 a Example of a monoculture cluster of *Mytilopsis* sp. attached to the aerial root of the red mangrove. b. The septum and apophysis of a specimen of *Mytilopsis* sp. 17.0mm. c. Showing a posteriorly pointing apophysis. d. White shell morph (left) and to the right three typical shell colours with mm scale shown below. (Photos. D. Minchin).

that the apophysis is more variable in shape than once thought and that it can vary dependent on the population. Furthermore, the shape of the shell valves, according to Nuttall (1990) can result in considerable variation due to its habit of forming tight clusters. This feature is common

to many densely occurring byssate bivalves (i.e. *Mytilus* spp.) (Seed, 1968; Illesca *et al.*, 2018).

In this study, a white shell form was observed. A similar observation was made of *M. sallei* populations in Kaohsiung port, Taiwan (Minchin

Table 1 Features of the septum and apophysis of *Mytilopsis* species in figures published by various authors and compared with samples from this study. **M. africana* is considered to be a synonym for *M. sallei*. ***M. rossmaessleri* also considered to be a synonym for *M. sallei*

Reference	Septum <i>M. leucophaeata</i>	Apophysis <i>M. leucophaeata</i>	Septum <i>M. sallei</i>	Apophysis <i>M. sallei</i>
This study	large	long, slender, posteriorly arched to pointed	large	long, slender, posteriorly arched to pointed
Nuttall, 1990: Fig 16	moderate	greatly arched	large	rounded, posteriorly arched
Oliver <i>et al.</i> , 1998: Figs 10–15	moderate	greatly arched to pointed	large*	hooked posteriorly*
Fernandez <i>et al.</i> , 2018: Fig. 1	moderate/large	long slender, posteriorly arched	small	well hooked posteriorly
Fernandez <i>et al.</i> , 2018: Fig. 1			moderate**	long slender, low arch**
Oliver, 2015: Fig 1	moderate	long slender, posteriorly arched		
Risso <i>et al.</i> , 2014: Fig 2	moderate/large	double pointed, arched posteriorly		
Tan & Tan, 2018: Fig 3			large	long slender, posteriorly arched
Marelli & Gray, 1985: Figs 7,8	moderate	long slender, posteriorly arched	large	hooked posteriorly

et al., 2016), where this colour morph appeared at a similar frequency.

There is some overlap in the distribution of *M. leucophaeata* and *M. sallei* (Fig. 4). This overlap may be due to varying interpretation of morphology of the populations examined. Genetic identification, however, will be the only means of resolving the true status of the *Mytilopsis* species at the different sites globally. *Mytilopsis leucophaeata* being described from the southern Gulf of Mexico, also occurs at high densities on red mangrove roots (Ruiz & López-Portillo, 2014). This account, however, is the first record of a *Mytilopsis* species from Grand Cayman (<http://www.jaxshells.org/cayman.htm>). The species this population represents, however, is not certain and consequently, some material has been retained at the Natural History Museum in Dublin to elucidate its exact status at some future time.

It is not known how long this species has been established in Grand Cayman. Since this is the first recorded sighting of *Mytilopsis sp.* on the island, it might suggest that this species may be a more recent arrival. This is unlikely, however, as *Mytilopsis sp.* has a great ability to be carried on a wide range of vessel types (Table 2), including

those without effective anti-fouling methods in the days of colonization. Given that these early voyages would have moved between sheltered regions within the Caribbean region, such a pathway of spread is indeed likely. The usage of tri-butyl-tin oxide was an effective antifouling agent incorporated within hull paint applications for almost forty years until the late 1980s (Alzieu, 1998). The high tolerance of *Mytilopsis spp.* to this substance (Karande *et al.*, 1993) may have selectively aided in its spread, providing less competition for settlement within contaminated ports and marinas often occurring in brackish environments.

In a British collection from the Welsh port of Tenby, specimens date from about 1790 to 1830. This indicates that at least some vessels were carrying *Mytilopsis* species, perhaps before they were described by Conrad in 1831 (Oliver, 2015). It is also possible that *Mytilopsis spp.* may similarly have been transported, and most probably at a greater frequency, to nearby regions in the Caribbean during this time.

The presence of *M. africana*, considered to be a synonym of *M. sallei*, on the west coast of Africa has also been linked to fouled vessels involved in the slave trade (S. Morris in Nuttall, 1990).

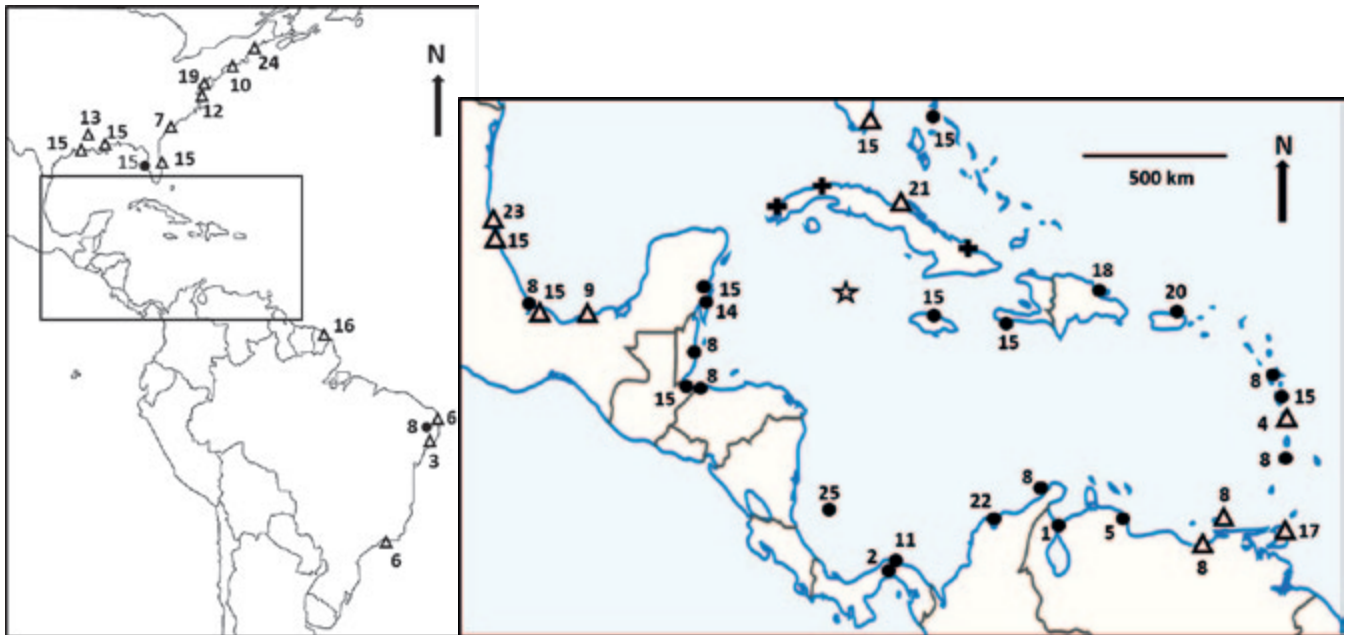


Figure 4 (left) distribution in the western Atlantic of *Mytilopsis* spp. with inset for details (right). Cayman Island population (star). *M. leucophaeata* (open triangles) and *M. sallei* (solid dots) and for unspecified localities as crosses in records of Marelli & Gray 1983 (Fig. 3).

Records: 1 Carrizo *et al.*, 2016; 2 Cohen, 2006; 3 de Souza *et al.*, 2005; 4 Delannoye *et al.*, 2015; 5 Escarbassiere & Almeida, 1976; 6 Fernandes *et al.*, 2018; 7 Flemming *et al.*, 2008; 8 GBIF, 2018; 9 Hernández *et al.*, 2015; 10 Jacobsen, 1953; 11 Jones & Rützler, 1975; 12 Kennedy, 2011; 13 Koch, 1989; 14 Llanes-Baeza & González, 2002; 15 Marelli & Gray, 1983; 16 Masseurin *et al.*, 2011; 17 Mohammed *et al.*, 2018; 18 Nuttall, 1990; 19 Pathy & Mackie, 1993; 20 Pérez *et al.*, 2001; 21 Pérez- Pérez & Espinosa Saez, 1994; 22 Puyana, 1995; 23 Ruiz & López-Portillo, 2014; 24 Smith & Boss, 1996; 25 Vilarly & Polanía, 2002.

Table 2 Modes of transport of *Mytilopsis* worldwide. Levels of confidence follows that of AquaNIS (2019)

Dispersal modes	level of confidence	References
Yacht hulls	direct evidence	Willan <i>et al.</i> , 2000; Hutchings <i>et al.</i> , 2002
Ships' ballast water	direct evidence	Chu <i>et al.</i> , 1997;
Motorised leisure craft	very likely	This study
Fishing vessel hulls	very likely	Minchin <i>et al.</i> , 2016;
Tug boats	very likely	Farrapeira <i>et al.</i> , 2010;
Barge hulls	very likely	Minchin <i>et al.</i> , 2016;
Ship hulls	very likely	Willan <i>et al.</i> , 2000; Oliver <i>et al.</i> , 1998; Morton, 1981; Marelli & Gray, 1983
Canals	very likely	Galil <i>et al.</i> , 2009; Cohen, 2006;
Ship hulls	possible	Nuttall, 1990;
Aquaculture equipment	possible	Liao <i>et al.</i> , 2010;
Refugee craft	possible	Morton, 1980;
Ships' ballast water	possible	Jacobson, 1953; Bamber & Taylor, 2002; Therriault <i>et al.</i> , 2004

This trade generally involved a triangular route from Africa to the New World, then to northern Europe and finally back to west Africa. Should this have been the route that *M. africana*, as *M. sallei*, arrived in west Africa, then this species

shows a similar physiology tolerance to that of *M. leucophaeata*.

In Grand Cayman, where *Mytilopsis* sp. is now abundant in the canals and lagoons, there are numerous marinas and jetties, which host visiting

craft. Barges and yachts have already been implicated in its spread elsewhere and it has also been found on the hulls of fishing vessels and the steel hulls of commercial ships. These vessels have the potential to spread *Mytilopsis* spp. to other localities within the archipelago, and beyond.

The natural spread of *Mytilopsis* to Grand Cayman may also have been possible, most probably at a local scale, particularly through rafting on other species. Evidence of rafting includes the remarkable spread of the oyster *Ostrea chilensis* from the SE Pacific Ocean to New Zealand, where the oyster was previously considered to be a separate species, *Tiostrea lutaria* (Ó'Foighil, 1999). This species has a short pelagic phase and so would not have been able to cover such a distance through natural dispersal. Tectonic events, however, can also lead to a significant spread of species between biogeographical areas. Such a suggestion was made for the arrival of *Mytilopsis*, 30 MYA as a genus to the new world (Nuttall, 1990), at a time when it was widespread in the old world. More recently, following the tsunami off the coast of Japan, many species, including a number of byssate bivalves were recorded for the first time on the west coast of North America (Carlton *et al.*, 2017). Over geological time, such happenings may have been a frequent occurrence.

To conclude, confusion within the genus *Mytilopsis*, with many species considered to be synonymous, and their status varying between authors, means that we cannot be certain which species was identified in Grand Cayman, however, this the first record of this *Genus* on the island. The current knowledge, however, of *Mytilopsis* morphology, the ability of this family to be spread by a wide range of vessels, together with further genetic studies of populations worldwide in the future (Therriault *et al.*, 2004, Wong *et al.*, 2011; Fernandes *et al.*, 2018), may hopefully enable the geographic distribution of this *Genus* to be fully elucidated in the future.

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