Aquatic Invasions (2008) Volume 3, Issue 3: 325-330
DOI 10.3391/ai.2008.3.3.7

Special issue "Invasive Aquatic Molluscs – ICAIS 2007 Conference Papers and Additional Records"
Frances E. Lucy and Thaddeus K. Graczyk (Guest Editors)

Research article

The occurrence of an invasive alien mussel *Mytilopsis adamsi* Morrison, 1946 (Bivalvia: Dreissenidae) in estuaries and lagoons of the lower south of the Gulf of Thailand with comments on their establishment

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Received 13 May 2008; accepted in revised form 25 July 2008; published online 5 October 2008

Abstract

The invasive false mussel, *Mytilopsis adamsi* Morrison, 1946 (Bivalvia: Dreissenidae), is a brackish water bivalve, native to tropical West Pacific coast of central America. The species has now become established in East Asian, South Asian and Southeast Asian countries. Species spread has been especially rapid with its distribution now including the lower part of the Gulf of Thailand. This is the first report of the establishment of this species in the lower part of the Gulf of Thailand, in Haad-kaew Lagoon and Thale Sap Songkhla, in Songkhla province, and the Pak Phanang Estuary in Nakhon Si Thammarat province, south Thailand. Descriptions of its morphology are consistent with previous descriptions from other areas as *M. adamsi*. Based on the available evidence, it is postulated that the species was transported to the areas between the year 1990 and 2000 via international commercial cargo ships. These findings indicate that the spread of *M. adamsi* is still in progress and that this invasive mussel continues to colonize the Songkhla Lagoon System.

Key words: establishment, *Mytilopsis*, Pak Phanang Estuary, south Thailand, Thale Sap Songkhla, Songkhla Lagoon System

Introduction

During a study of temporal and spatial variations of intertidal gastropods in the Haad-kaew Lagoon, Thailand between 2001 and 2003, voucher specimens of both the collected gastropods and bivalves were deposited in the Prince of Songkla University Zoological Collection. In 2006, Markus Huber, a conchologist from the Zoological Museum of the University of Zurich, Switzerland, visited and studied the bivalve specimens deposited in our collection and recognized that one of the unidentified mussels was a member of the genus *Mytilopsis* (Mollusca: Bivalvia: Dreissenidae), an alien invasive bivalve that had not been previously reported in Thailand. After comparison with other materials and type photos it was determined that the mussel was *Mytilopsis adamsi* Morrison, 1946. This was confirmed by Dan Marelli (pers. com. 12/07). *M. adamsi* was originally described from Panama Bay, Pearl Islands. It is a brackish species that invaded the Indo-Pacific Ocean during the 19th century and has reached Fiji (described as *M. allyneana* Hertlein and Hanna 1949), India, Malaysia, Singapore, Taiwan, and Australia (Marelli and Gray 1985; Morton 1989; Willan et al. 2000; Tan and Morton 2006). Whereas most authors report

this species as *M. sallei*, Marelli and Gray (1985) synonymized *M. allyneana* with *adamsi* and considered *M. sallei* as distinct. It is quite likely however that all Asian reports of *M. sallei* are instead referable as *M. adamsi* (Dan Marelli, pers. com. 12/07).

Recently, *M. adamsi* has been observed in the Haad-kaew Lagoon and Thale Sap Songkhla in Songkhla province, and it has also presented in the Pak Phanang Estuary in Nakhon Si Thammarat province. As these mussels have frequently been reported to be alien invasive species (Kalyanasundaram 1975; Rao et al. 1989; Nalepa and Schloesser 1992; Branch and Steffani 2004; Bownes and McQuaid 2006; Tan and Morton 2006), the present report substantially expands their known range and also suggests an important impact in the local community they invade. The purpose of this paper is to report the occurrence of *M. adamsi* in the lower part of the Gulf of Thailand and to provide in addition evidence of the establishment of *M. adamsi* at these locations.

Material and Methods

Study sites

The Haad-kaew Lagoon is a relatively small shallow coastal lagoon, (3 km^2, 7°14'14.35"N, 100°33'47.04"E), adjacent to the Songkhla Lagoon System, in Songkhla Province (Figure 1). At present, the area can be divided into two parts, according to its morphology, a seasonally-closed and an open lagoon. The system has an

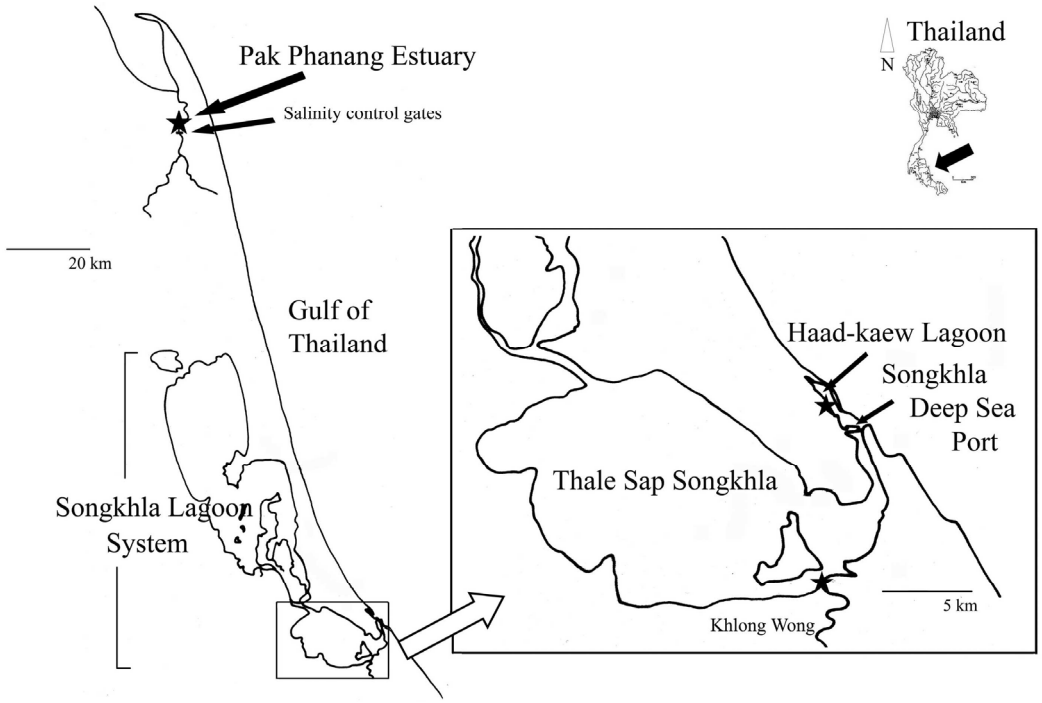

Figure 1. Part of the lower Gulf of Thailand in south Thailand showing the location of the Songkhla Lagoon System and Pak Phanang Estuary and sites of a sampling (indicated by★). Inset: the Thale Sap Songkhla and Haad-kaew Lagoon, showing the Songkhla Deep Sea Port and sampling sites of *Mytilopsis adamsi* Morrison, 1946, in this report (indicated by ★)

average mixed tidal amplitude of 0.8 m, an average depth of 2.0 m, with a substratum of muddy sand. Environmental parameters of the lagoon, especially salinity, change according to the season and distance from the open end (Lheknim and Leelawathanagoon 2004). In general, the salinity gradient changes from a polyhaline (18-30 psu) interior to the marine exterior. At one end the lagoon opens into the mouth of the Songkhla lagoon system near to where the Songkhla Deep Sea Port has been constructed.

Thale Sap Songkhla, (176 km^2, 7°10'34.40"N, 100°34'00"E), is the lowermost part of the Songkhla Lagoon System (Figure 1). The lower southeastern end of the Thale Sap Songkhla is connected to the lower part of the Gulf of Thailand by a narrow channel, allowing tides to inundate this lower region. In general, the salinity of the water in the Thale Sap Songkhla ranges from brackish to seawater depending on the season, with a mean water depth of 1.2 m in a relatively dry season, but the water level rises by about one meter during the northeast monsoon season (November-January). The bottom is muddy sand with debris. The Thale Sap Songkhla is known for the natural catches, and is also intensively utilized for the aquaculture.

The Pak Phanang Estuary (126 km^2, 8°23' 58.10"N, 100°08'54.75"E), is a part of the Pak Phanang River system and located in Nakhon Si Thammarat Province, southeast Thailand (Figure 1). The system has an average depth of 2.0 m. The substratum is muddy sand with debris. The eastern half of the estuary is occupied by a mangrove forest, several tidal creeks and an extensive mud flat (about 1–3 km wide) that emerges at low tide. The salinity in this river usually decreases with distance from the mouth of the river. Salinity control gates were constructed in the lower reach of the river in October 2003, to regulate the water level and salinity. As a result the region of the river above the control gates has become permanently freshwater while the salinity below the control gates is permanently brackish or seawater all the year round. The Pak Phanang Estuary is also well-known for its natural production of fish, shrimp and crabs.

Sampling of mussels and data analysis

The identification of mussels was based on characteristics presented in Marelli and Gray (1985). Haad-kaew Lagoon, especially the sesonally-closed sector, was visited several times for settlement observations and the mussel specimens were taken from this sector to the laboratory twice, in July 8th, 2006 and June 9th, 2007. Mussel sampling was conducted in the Pak Phanang Estuary adjacent to the salinity control gates and at Thale Sap Songkhla near to the mouth of Khlong Wong on March 31st, 2007 and June 9th, 2007, respectively. During each visit, samples were collected using a 15x15 cm^2 quadrat randomly placed on the substratum about 0.5 m in depth and all mussels from the quadrat were removed. During sampling, salinities at these sites were recorded by using a hand-held refractometer (except on July 2006 in Haad-kaew Lagoon). In the laboratory, shell lengths of the right valve of all the collected specimens were measured to the nearest 0.1 millimeters by using calipers. A shell length frequency distribution of *M. adamsi* from each sampling site was separately constructed and cohort analysis was made by means of Bhattacharya's method, available in FISAT II (FAO 2005), and used to distinguish existing cohorts at each location.

Results and Discussion

The salinities from the Haad-kaew Lagoon, Thale Sap Songkhla and Pak Phanang River (area around the water gate) taken at the times of sampling were 20, 6 and 31 psu, respectively. *M. adamsi* bivalves were observed on the substratum of the whole seasonally-closed portion of the Haad-kaew Lagoon as well as some attached on boat piers and other hard substrata, while densely populated colonies occurred on aquaculture cages in the permanent-ly open lagoon (Figure 2). In Thale Sap Songkhla, colonies of *M. adamsi* were byssally attached to mangrove root systems. In Pak Phanang Estuary, a densely populated colony of *M. adamsi* was found attached to the cement of the water control gate at a depth of 0.5 m. The results from these preliminary observations have indicated that *M. adamsi* is able to survive under brackish water conditions and in a wide range of salinities from 6 to 31 psu, as an euryhaline species. It is interesting to note that *M. adamsi* has an ability to byssally colonize many surfaces, ranging from muddy sand substratum to other submerged materials, such as shells of other molluscs, plastic bags, buoy lines, fish cages and fishing gears. Attachment at many of these sites can rapidly cause changes in local communities, because this mussel generally produces a dense monoculture that excludes other sessile organisms. The mussel subsequently provides a new habitat for associated fauna, such as amphipods and polychaetes to colonize, and probably results in a significant change in the community structure in the future as found in dreissenids and mytilids (Nalepa and Schloesser 1992; Crooks and Khim 1999; People 2006; Borthagaray and Carranza 2007).

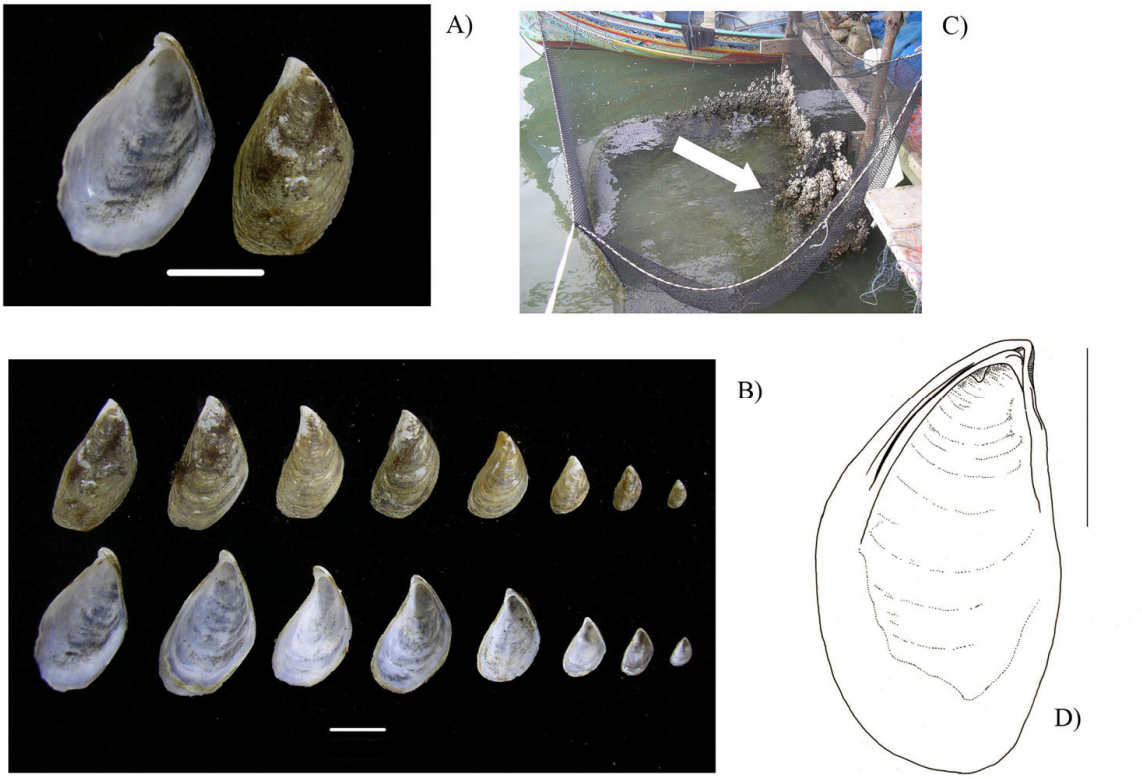

Figure 2. External morphology of *Mytilopsis adamsi* Morrison, 1946 scale bar 1 cm.
A) Right and left valve of *M. adamsi*;
B) Variability of shell shape of *M. adamsi*;
C) A dense colony of *M. adamsi* on the fish cages in Haad-kaew Lagoon, and
D) Interior view of the left valve of *M. adamsi*
(Photographs by Kringpaka Wangkulangkul)

Establishment and recruitment of M. adamsi

The histograms of the length-frequency distribution for all samples from all sampling locations, at Haad-kaew Lagoon, Thale Sap Songkhla and Pak Phanang River (Figures 3A, 3B, 3C and 3D), indicate multiple consecutive cohorts. The population size structure for July 2006 and June 2007 in the temporarily closed portion of Haad-kaew Lagoon (Figures 3A and 3B), shows a similar population structure, indicating that *M. adamsi* is able to establish self-sustaining populations with a tendency to reproduce asynchronously in a continuous spawning season. Interestingly, the recruitment cohorts from the seasonally-closed portion of Haad-kaew Lagoon and the Thale Sap Songkhla reveal a series of regular successive cohorts (Figures 3A, 3B and 3C respectively), while large size class and low successive recruitment is displayed at the mouth of Pak Phanang River (Figure 3D). Such patterns of recruitments may result from only small gradual changes in brackish water conditions within the seasonally-closed portion of Haad-kaew Lagoon and the Thale Sap Songkhla as a result of reduced tidal influence, while the strong tidal effects of seawater with a relatively low freshwater supply were observed at the mouth of Pak Phanang River. Previously, NIMPIS (2002) has suggested that spawning of *M. sallei* may be triggered by changes in salinity. The development of fertilized eggs were predominant in a salinity below 25 psu, allowing for the development of the trochophore and veliger larvae while advanced stages were not observed in salinities higher than

25 psu (Raju et al. 1975). The population structure from the Haad-kaew Lagoon and the Thale Sap Songkhla (Figures 3A, 3b and 3C respectively), reveal that the majority of recruitments seemed to have occurred before the sampling dates i.e., before June 2006 and July 2007 (this phenomena is being investigated in the field, unpublished data showed that the peak of recruitment occurred in February). They probably followed by the time of the peak salinity, usually around August and September at the eastern coast of south Thailand, which may prohibit fertilization of *M. adamsi*. Likewise, the population structure from the mouth of Pak Phanang River with very few specimens smaller than 15.3 mm implies that the higher salinity on the sampling period, (30 psu on the 31st March 2007), reduced the survival of the smaller specimens or inhibited spawning.

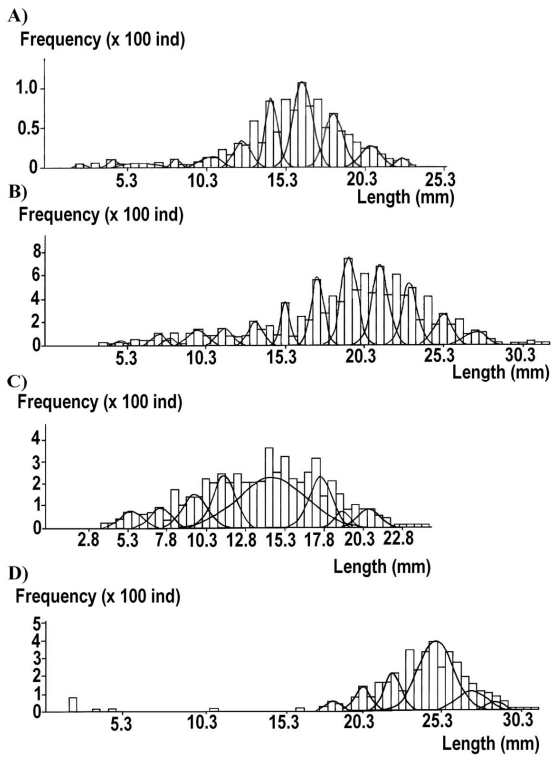

Figure 3. Length frequency distribution histogram of *Mytilopsis adamsi* Morrison, 1946. A) - specimens from Haad-kaew Lagoon in south Thailand on the July 8th, 2006 (n= 1185); B) - specimens from Haad-kaew Lagoon in south Thailand on the June 9th, 2007 (n=1104); C) - specimens obtained from the Thale Sap Songkhla (mouth of Khlong Wong) in south Thailand on the June 9th, 2007 (n=545) and D) - specimens collected from Pak Phanang River (salinity control gates) in south Thailand on the March 31st, 2007 (n= 405)

Hypothetical sources in south Thailand

The incidence of the mussel *M. adamsi* in south Thailand was probably the result of the accidental introduction of the species by international ships traveling to Hong Kong and Singapore between the 1980s and 1990s (Tan and Morton 2006), then subsequently to ports in the Gulf of Thailand. In an early study of Marine Lamellibranchiata in the Gulf of Thailand (Lynge 1909) and later in the Fauna of Thailand (Suvatti 1967), there is no mention *M. adamsi*. Recently, Swennen et al. (2001) reported the mussel at Panarae, Pattani Province, approximately 100 km south of Songkhla and identified it as *Mytilopsis adamsi* Morrison. This indicates that *M. adamsi* was possibly transported to Haad-kaew Lagoon and Thale Sap Songkhla between the years 1990 and 2000 via international commercial cargo ships operating between the Songkhla Deepwater Sea Port (see also Figure 1) and other regional ports of Hong Kong and Singapore. It is probable that the same method of introduction occurred in the Pak Phanang River, as there are several local shipyards and dock facilities located along the river. In conclusion, the most likely routes of introduction *M. adamsi* to these areas are believed to be from larvae released in discharged ballast water or adults attached to a boat or ship's hull, rather than to a natural dispersal of the species.

Conclusion

Although the presence of *M. adamsi* has been recorded in the south of Thailand since 2001 (Swennen et al. 2001), this is the first report of its widespread distribution and abundance in different habitats. It presently well established in the Haad-kaew Lagoon and continues into the lower part of the Songkhla Lagoon System and possibly also in the Pak Phanang Estuary. There are several passive dispersal routes upstream in the above mentioned systems, for example, by transportation on fishing and recreation boats and may be even by waterfowl. Further research on biology, potential impacts and control of this species is required for neighbouring coastal habitats, particularly in the Thale Sap and Thale Sap Songkhla of the Songkhla Lagoon System, due to its potential negative ecosystem impacts, especially in terms of economic damage to local communities.

Acknowledgements

Field assistance was provided by Wason Wangkulangkul and Suebpong Sa-nguansil. VL is especially indebted to Dr. Markus Huber of the Zoological Museum of the University of Zurich, Switzerland and Dr. Dan Marelli, Invertebrate Biologist, of Scientific Diving International, Florida, U.S.A. for their suggestions on the biology of the species as well as helpful discussions. We also thank Dr. Brian Hodgson (Faculty of Science, Prince of Songkla University, Thailand) for language editing. This work is supported by the Thailand Research Fund/Bio-Technology Special Program for Biodiversity Research and Training grant BRT T_351007 and Research Assistantship (2006), Faculty of Science, Prince of Songkla University, Thailand to KW.

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