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Distribution, size and density of *Corbicula fluminea* at Pattani and Saiburi rivers in Southern Thailand

ZAWEEN NAJJAH MOHAMAD SHAMSUL[1], AWENG EH RAK[1]*
and SUKREE HAJISAMAE[2]

Abstract: *Corbicula fluminea* has been a traditional food for the locals from both Kelantan and Southern Thailand. However, the ecology of *C. fluminea* has not been fully explored in Malaysia and also in Southern Thailand. The objective of this study is to compare the size and density of *C. fluminea* in Pattani and Saiburi rivers. *C. fluminea* were sampled in two different rivers at Southern Thailand; Pattani River and Saiburi River. The water quality parameters measured are dissolved oxygen, pH, temperature and the nutrient analysis of phosphate and nitrate. Both rivers have a suitable pH levels range (6.53-6.7), temperature range (31-34°C) and dissolved oxygen (3.3-8.1 mg/L) that ensure the survival of *C. fluminea*. *C. fluminea* were collected and measured its shell length which is most abundant in length size 11-20 mm. The highest density of *C. fluminea* recorded at Pattani River was 369 clams per m^2 while only 196 per m^2 at Saiburi River. The over-exploitation by the villagers at Saiburi River has caused the density of *C. fluminea* to differ significantly. The substrate type of these rivers were also analysed; Pattani River has sandy loam substrate while the substrate in Saiburi River is loamy sand. The availability of the phytoplankton was also identified in both rivers and overall there were 29 species from 22 different families in both rivers. This study shows that the density of *C. fluminea* is likely to be influenced by the water quality rather than substrate types and also the phytoplankton availability. Findings of this research are able to add to the existing database of *C. fluminea* nationally and internationally.

Key words: *Corbicula fluminea,* habitat, water quality, sediment, phytoplankton, Pattani River, Saiburi River

INTRODUCTION

C. fluminea is a small clam with an inflated shell, slightly round to triangular in shape. The most distinctive feature is the shell which consists of numerous heavy concentric ridges (Park et al., 2000). It is a freshwater clam commonly found in Southeast Asia including Southern Thailand and Malaysia. It is one of the most invasive species in aquatic ecosystems and is well known by its rapid and extensive spread. It is native in Asia and has invaded several ecosystems worldwide in the last 80 years (Sousa, 2008). *C. fluminea* is present in habitats ranging from bedrock to deep silt, and can be found in ponds, lakes and streams of all sizes (Neck, 1986). There is some controversy about this species habitat preference whether it is a freshwater or brackish water species but the classification as a freshwater species with high tolerance to estuarine habitats has been the most commonly used (Britton, 1982). It was the most abundant species collected and they were found in a larger number on intermediate substrate size unlike density of other freshwater mussels that are not correlated with bottom type (Haag and Thorp, 1991).

[1]Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli Campus Locked Bag No. 100, 17600 Jeli, Kelantan, Malaysia.
*Corresponding author: aweng@umk.edu.my
[2]Department of Fisheries Science, Faculty of Science and Technology, Prince of Songkla University Pattani, Rusamilae, Mueang Pattani District, Pattani 94000, Thailand

As this species is native in semi-tropical or Southeast Asia (Morton, 1979), *C. fluminea* was rarely exposed to the extreme temperature. The lower temperature limit for *C. fluminea* is between 0 and 2°C, and the upper temperature limit is 37°C (Ilarri and Sousa, 2012b). The lowest known pH limit for this species to survive is at 5.6 as the conchiolin layers in unionid shells might retard shell dissolution in lotic habitats with low pH, but data were lacking to test the hypothesis (Karatayev et al.,2007). This species is not significantly affected by the dissolved oxygen as it shows no capacity to regulate oxygen uptake rate with the concentration reduction of the dissolved oxygen (McMahon,1979). The presence of 3 to 10% of oxygen at 20°C (0.6–1.8 mg/L) to be adequate for normal oxygen demands (Badman, 1974). It is very proficient at combining suspension and deposit feeding to meet its energy requirements (Way et al.,1990). It have been observed that juveniles (<1 year old) collect fine organic materials from their substrate by pedal sweep and also by using their cilia to create an anterior suspension feeding current (Yeager et al.,1994). This clam also is primarily a suspension- feeder that can filter phytoplanktons and detritus from the water column at a very high rates (Cherry et al., 1980; Silverman et al.,1980).

Despite its origin from Asia (Sousa, 2008), there is no ecological studies on this species for the tropical climate as in Malaysia and Thailand. Most of the researches done for this species are in the temperate zone. *C. fluminea* or known as etak by the locals is commonly being harvested as a traditional food and snack. The population of this species is declining especially in Kelantan and Southern Thailand but to become worse, there is no scientific information on ecological aspect of this species in Southeast Asia that can be used in order to sustain its population from declining. Despite this species is declining, they are still heavily harvested without any management regulation in both Malaysia and Thailand.

With the aim to characterize the habitat of *C. fluminea* at two different rivers in Southern Thailand, the finding from this study can also could be used by the local authority to establish a base to sustain *C. fluminea* habitat and to prevent this species from declining.

MATERIALS AND METHODS

Two rivers were selected for sampling, Pattani River and Saiburi River. For each, there are 5 sampling points selected for sampling. For each sampling, there were 5 replications made. *C. fluminea* were collected by using a clam dredge dragged approximately 1m quadrat. The density was estimated as individuals per square meter (ind./m^2). The structure of the population was analysed according to the following size classes (shell length): small individuals (1-10 mm), medium individuals (11-20 mm) and large individuals (21-30 mm). The size distribution was plotted in a frequency histogram.

Variations in range of environmental parameters such as water temperature, dissolved oxygen, pH, nitrate and phosphate were measured at both rivers. Approximately 300 litres of river water were filtered through the phytoplankton net (40µm) to collect phytoplankton. Data were analysed using SPSS (Scientific Package of Social Science). The density differences and water quality parameters between the sampling sites were analysed by non- parametric Mann- Whitney test with a significance level of 0.05.

RESULTS

Distribution and density

A total of 5 points with 5 trials were sampled for *C. fluminea* and the total number of individuals collected at Pattani River was higher than Saiburi River. A total of 618 individuals were collected within 5 trials in Pattani River while sampling in Saiburi River, a total of 329 individuals were collected. The mean density of *C. fluminea* at Pattani River is 369 clams/m^2 while that at Saiburi River is 196 clams/m^2 (Table 1). There is a significant difference in mean density ($P < 0.05$) of this clams between the two rivers.

Shell size frequency

The range of clams collected were 7.0 to 23.4 mm and 8.9 to 19.5 mm, respectively in Pattani and Saiburi rivers with the majority of the clams collected were in size class 11 to 20 mm. Meanwhile, clams from 11 to 15 mm are found to have a highest length frequency distribution (Pattani, n=320; Saiburi, n=203) followed by the clams from 16 to 20 mm size (Pattani, n=251; Saiburi, n=123). 25 clams were collected in the class size of 6 to 10 mm and 22 clams from the class size of 21 to 25 mm at Pattani River while only 3 clams for the class size of 6 to 10 mm at Saiburi River and no clam collected in the class size of 20 to 23 mm. For the class size of 1 to 5 mm and 26 to 30 mm, no clam was found at both rivers. The results were shown in Figure 1.

Table 1: Comparison of density for *C. fluminea* between Pattani River and Saiburi River.

Station	No of clam measured	Density per m^2	Station	No of clam measured	Density per m^2
Pattani River, *n*=618			Saiburi River, *n*=329		
1	93±8.3	278	1	44±2.7	278
2	114±15.4	340	2	28±0.9	340
3	104±7.3	310	3	97±7.8	310
4	167±9	499	4	64±6.9	499
5	140±13.3	418	5	96±8.7	418
Mean	123.6	369	Mean	65.8	369

Table 2: Comparison of size range and mean shell length of *C. fluminea* between Pattani River and Saiburi River

Sites	Pattani River	Saiburi River
Size range (mm)	7.0-23.4	8.9-19.5
Mean shell length ± SD (mm)	14.9 ± 2.8	14.8 ± 1.9
Total number of individuals	618	329

The structure of the population was analysed according to the following size classes (shell length): small individuals (1 to 10 mm), medium individuals (11 to 20 mm) and large individuals (21 to 30 mm). The comparison size range and mean shell length for C. fluminea between Pattani River and Saiburi River were tabulated in Table 2. However, the clams collected at the two study area do not show a significant difference for shell length ($P > 0.05$), Pattani (14.9 ± 2.8) and Saiburi (14.8 ± 1.9) (Table 2).\

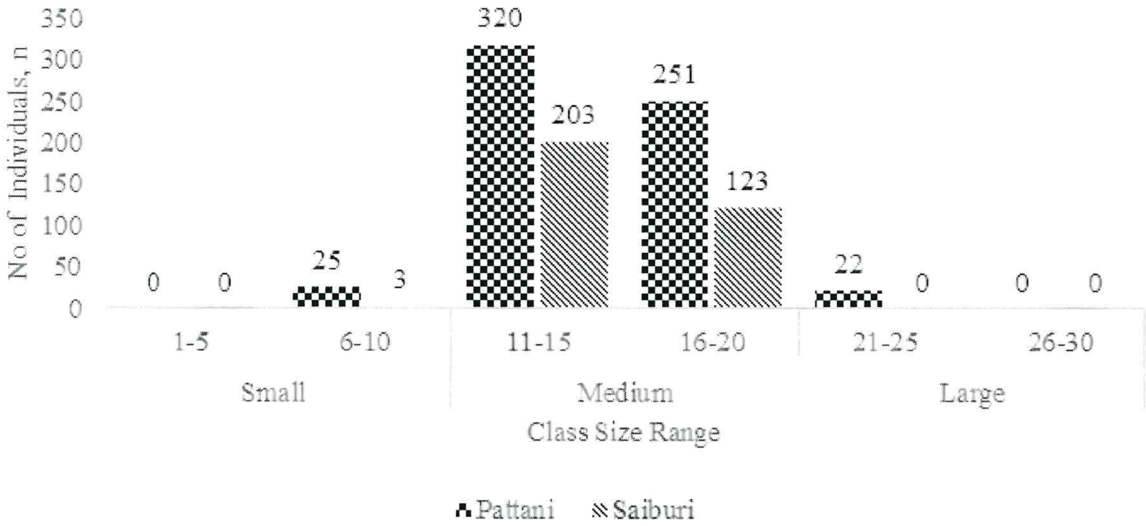

Figure 1. Comparison of Length Frequency Distribution of *C. fluminea* between Pattani and Saiburi River

Substrate type

Analysis of sediment were conducted and the results show the sediment of both rivers were mostly composed of fine sand (0.25-0.10 mm) (Soil Survey Manual Introduction, 1966). Based on the result, 84% of the sediment at Pattani River was classified as fine sand while the percentage of fine sand at Saiburi River is 87%. Pattani and Saiburi rivers both have a clay percentage which is 16% and 12%, respectively. The result of the sediment analysis shows that there is no silt found in the substrate at Pattani River while only 1% of silt found in Saiburi River. Based on the texture triangle, soil analysed in Pattani River is a sandy loam while the substrate in Saiburi River is loamy sand.

Water quality

Parameters of pH, temperature, dissolved oxygen, nitrate and also phosphate were measured in both rivers. The summary of the water quality parameter results were presented in Table 3. The result shows that the pH for both rivers was not significantly different from each other ($P > 0.05$) meanwhile the temperature varies significantly between these two rivers ($P < 005$). For the dissolved oxygen, statistical analysis shows that there are no significant differences between these two rivers ($P > 0.05$).

Table 3: Water Quality Parameters at Pattani River and Saiburi River (Mean ± SD)

Rivers	pH	Temperature	Dissolved Oxygen	Nitrate	Phosphate
Pattani	6.53±0.06	31	3.3±0.10	0.31±0.07	0.07±0.01
Saiburi	6.7±0.15	34	8.1±0.10	0.1±0.07	0.5±0.10

Phytoplanktons

Overall, a total of 29 species of phytoplanktons was identified in these rivers but only 21 phytoplankton species were found in Pattani River while Saiburi River shows the occurrence of 15 species of phytoplankton. These rivers have slightly differences in term of similarity of phytoplankton species. The differences of species of phytoplankton in both rivers may due to the water quality parameters especially the nutrient content of nitrate and phosphate. This nutrient in the water bodies will enhance the growth of the phytoplankton and thus will increase the availability of food source to *C. fluminea*. The identified species of phytoplankton was demonstrated in Table 4.

Table 4. Comparison of phytoplankton species availability between Pattani River and Saiburi

Species	Family	Phylum	Pattani River	Saiburi River
Asterionella formosa	Fragilariaceae	Ochrophyta	-	√
Botryococcus braunii	Botryococcaceae	Chlorophyta	√	-
Ceratium hirundinella	Ceratiaceae	Miozoa	-	√
Chroococcus sp.	Chroococcaceae	Cyanobacteria	-	√
Closterium sp.	Closteriaceae	Charophyta	√	√
Coelastrum sp.	Scenedesmaceae	Chlorophyta	√	-
Cosmarium sp.	Desmidiaceae	Charophyta	√	√
Cymbella sp.	Cymbellaceae	Bacillariophyta	-	√
Draparnaldia sp.	Chaetophoraceae	Chlorophyta	√	-
Eudorina elegans	Volvocaceae	Chlorophyta	√	-
Fragilaria sp.	Fragilariaceae	Bacillariophyta	√	√
Gonium formosum	Goniaceae	Chlorophyta	√	-
Haematococcus sp.	Haematococcaceae	Chlorophyta	√	-
Sp. indet.	Hydrodictyaceae	Chlorophyta	√	-
Lyngbya sp.	Oscillatoriaceae	Cyanobacteria	√	√
Melosira varians	Melosiraceae	Bacillariophyta	-	√
Nitzschia sp.	Bacillariaceae	Bacillariophyta	-	√
Oscillatoria sp.	Oscillatoriaceae	Cyanobacteria	√	√
Pediastrum duplex	Hydrodictyaceae	Chlorophyta	√	-
Phacus sp.	Euglenaceae	Euglenozoa	√	-
Pinnularia sp.	Pinnulariaceae	Bacillariophyta	√	-
Rhizoclonium sp.	Cladophoraceae	Chlorophyta	√	-
Scenedesmus sp.	Scenedesmaceae	Chlorophyta	√	-
Spirogyra sp.	Sphaerocystidaceae	Chlorophyta	-	√
Staurastrum sp.	Desmidiaceae	Charophyta	√	-
Surirella sp.	Surirellaceae	Bacillariophyta	-	√
Tetraedron sp.	Hydrodictyaceae	Chlorophyta	√	-
Trachelomonas sp.	Thalassionemataceae	Bacillariophyta	√	-
Volvox sp.	Volvocaceae	Chlorophyta	√	√
Total Species			21	15
	Overall total species		**29**	

DISCUSSION

The density of *C. fluminea* is higher in Pattani River, harvesting activities at the river is lower compared to Saiburi River. Villagers use a basket or a clam dredge to collect the clams at shallow water. The depth of the study area at Pattani River is approximately 50 to 130 cm which has limits the harvesting activities by the locals. On the other hand, at Saiburi River it is very shallow and can be easily assessed by the villagers. The depth of the river is only in the range 20 to 60 cm which enables the villagers to use either basket or clam dredge to collect the clams.

Another factor that contributes to the different density between the two rivers is the water current. Most of the bivalves including *C. fluminea* tend to burrow themselves in the sediment. But, for a juvenile the chance for them to be carried away by the water current is higher than the smaller individuals. This is based on study by (McMahon, 1983) where he claimed that the smaller clams have a high probability to be transported along the water current to the downstream. The frequency of distribution of clams at both rivers varied across the range of size classes and they show the similar trend in the size class distribution. The observed differentials in frequencies between size classes may be a result of a variety of factors. Juveniles, when first being released into the water, will immediately attach to the bottom substrate by secretion of adhesive substances on the foot tip (Heinsohn, 1958 ;Sinclair et al.,1961 and Sinclair et al.,1963). However, the newly released larval stages would be carried downstream and transported passively by water currents and they are incapable of swimming (McMahon, 1983) which may explain the drop in the clam's number between 1 to 5 mm and 6 to 10 mm class size.

For the medium-sized clams, they have a highest frequency distribution in both rivers. The abundant of this clam size of 11 to 15 mm and 16 to 20 mm size classes is due to the species has a high reproduction potential and also its hermaphroditic nature (McMahon et al., 2001; Karatayev et al., 2003). Besides the high reproduction, *C. fluminea* also has a physical characteristic that give them higher capacity for locomotion and efficient burrowing. This burrowing activity help them to avoid predators either fish and also from human and usually, they will burrow themselves 10 to 15 cm in the sediment. However, the distribution of clam from size class 21 to 25 mm and 26 to 30 mm is very poor. There are significant gap between the total number of clams in medium size compared to the large size. The dramatic decline in large size of clams is because of the routinely harvesting activity by the villagers to be sold and consumed. The larger size clams are preferably collected rather than a medium and small size clams. Both rivers have a sandy substrate but substrate at Saiburi River composed of more clay and silt percentage than substrate in Pattani River. The structure and porosity of the soil influenced the oxygen in the soil itself. *C. fluminea*, showed low density on silt (Karatayev et al., 2003; Karatayev et al., 2005) and achieved the highest population density and greatest success in well-oxygenated substrates such as coarse sand or gravel or sand-gravel mixtures and it is almost always eliminated from areas with reducing sand, mud, or silt sediments of high organic and low oxygen content (McMahon, 1983).

Furthermore, substrate type is also important for the juveniles of *C. fluminea* and other bivalve to attach their byssal thread and preventing them to be transported along with the water current. The juveniles rely on the temporary attachment of the byssal thread to the substrate rather than burrowing themselves like an adult does. Overall, the water quality at both rivers is in the suitable level for the growth of *C. fluminea*. This species, is likely can be very tolerance to the extreme temperature have no problem to live in a warmer water bodies such as in Saiburi River.

The pH level in both rivers was also in the normal range for the aquatic life in river for their optimum habitat. The lower pH value will result in the deformation of the shells which will later cause the high level of calcium carbonate in the water bodies.The lower dissolved oxygen level recorded in Pattani River may result from the higher amount of algae growth that is caused by excessive nutrient (Phelp,1994 and Wittman et al., 2008).

The dissolve oxygen in the water might get consumed by the process of die-off and decomposition of algae (Minnesota Pollution Control Agency, 2008). However, previous study showed that *C. fluminea* can survive the lowest dissolved oxygen of 0.6 mg/L (Badman, 1974).

The nutrient content of phosphate and nitrate in the water bodies is sufficient for the growth of *C. fluminea* as well as for the other aquatic life. Both of these rivers can provide nutrient to be siphoned by C. fluminea and thus helps to enhance its growth and survival. These two nutrients will stimulate the growth of plankton and aquatic plants which provide food for aquatic animals. However, the excessive amount of phosphate will then cause the depletion of dissolved oxygen because of the decaying process by the aquatic plants (Minnesota Pollution Control Agency, 2008). The sediment types of these two rivers were mainly consists of fine sand so it can be said that *C. fluminea* most favourable habitat is from sand. The substrate types is very important for this species as they are pedal-feeders using the organic matter available in the sediment has a food resource (Hakenkamp et al.,1999) and the sedimentary material is transported to the labial palps by using ciliary tracts on the foot (Thorp and Covich, 1991).

The abundances of phytoplankton in these rivers were also one of the factors that enable this species to survive. Phytoplankton was considered as a main food source for bivalves and its abundance in shallow area are strongly controlled by bivalve grazing (Arapov et al., 2010).

CONCLUSION

The result of density and distribution of *C. fluminea* at the two rivers were not fully influenced by the water quality, sediment types and also availability of phytoplankton because of the harvesting activities by the villagers. Both rivers have the most abundance number of individuals of *C. fluminea* in medium size and least in the larger size. These two rivers have a favourable characteristic for this clam to survive. However, the population may decrease from time to time if the villagers keep harvesting the clam without any limits. Further investigation is needed for a better understanding about this species ecological such as to include analysis for organic materials in the sediment as well as the gut content analysis of *C. fluminea* collected to determine its feeding selectivity based on the availability of phytoplankton. The duration of the sampling should also be increased so that that the ecology of this species can be identified throughout the year.

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