UNIVERSITI MALAYSIA KELANTAN

The Morphometric Characteristics of *Corbicula fluminea* (Asian Clam) from Kelantan and Terengganu

by

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A thesis submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Animal Husbandry Science) with Honours

Faculty of Agro Based Industry
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2018

DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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I certify that the report of this final year project entitled “The Morphometric Characteristics of *Corbicula fluminea* (Asian Clam) from Kelantan and Terengganu by Vinothiran A/L M. Ayappan, matric number F14A0399 has been examined and all the correction recommended by examiners have been done for the degree of Bachelor of Applied Science (Animal Husbandry Science) with Honour, Faculty of Agro-Based Industry, Universiti Malaysia Kelantan.

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ACKNOWLEDGEMENT

First of all, I am very grateful to God for giving me a chance to successfully completing my Final Year Project (FYP) with health and well-being.

Besides, I would like to say thank you to my parents Madam Selina Ingan and Mr. M. Ayappan A/L Muniappan, for giving me all the support in term of financial as well as moral support. Thank you to my beloved supervisor, Assoc. Prof. Dr. Lee Seong Wei who is never tired in consulting and guiding as well as in helping me during the period of finishing my final year project.

To my friends, Nurnadhirah binti Mohd Saufi, Mohd Zharif bin Ramli, Muhamad Amin bin Ibrahim, Azree Faiz bin Anizam who always helping me during the experimental period and giving me the guideline in finishing my thesis, I would like to thank you for always be by my side. Thank you for making me more understand to conduct my experimental task as well as my thesis.

Last but not least, I would like to thank you to all of the UMK staff especially Laboratory Assistants who gave me help to make this final year project success. I appreciate all of your kindness and may God repay all of you with His blesses.

The Morphometric Characteristics of *Corbicula fluminea* (Asian Clam) from Kelantan and Terengganu

ABSTRACT

Asian Clam or *Corbicula fluminea* is a species of freshwater clam and classified under aquatic bivalve, that originated from Asia fresh water. Asian Clam is also locally known as "etak" and being one of the popular food sources or snack in Kelantan, Malaysia. Currently, consumers claimed that this species is natively harvested from local water bodies and it was claimed as similar species. In consequences, this research project was done to determine the morphometric characteristics on *C. fluminea* collected from seven different locations from Kelantan and Terengganu. A total of 15 measurements were taken using vernier caliper. A total of 210 samples were collected from seven location, each location were randomly taken 30 samples of *C. fluminea*. The data taken had been analysed for One-way ANOVA and hierarchal cluster analysis. Therefore, this research had determined that Marang showed the biggest among other location based on the external feature which is SH/SL 0.9852mm ± 0.05 and Jeli showed the biggest in term of its internal feature which is 0.6185mm ± 0.03 for LPAS/SL. Overall, Jeli were considered as the biggest cluster. In fact, the outcomes of this study will give an information of the sizes of Asian Clam which can be utilize for commercialization. Therefore, it may give a benefit to the Asian Clam's future in terms of its quality as well as additional information to the people regarding of this species.

Keywords: Asian Clam (*Corbicula fluminea*), morphometric characteristic

Karakter Morphometrik *Corbicula fluminea* (Etak) dari Kelantan dan Terengganu

ABSTRAK

Kerang Asia atau *Corbicula fluminea* adalah spesies kerang air tawar dan diklasifikasikan di bawah dwicangkerang akuatik, yang berasal dari air tawar Asia. Kerang Asia juga dikenali sebagai "etak" dan menjadi salah satu sumber makanan atau snek popular di Kelantan, Malaysia. Pada masa ini, pengguna mendakwa bahawa spesies ini berasal dari badan air tempatan dan dituntut sebagai spesies yang sama. Hasilnya, projek penyelidikan ini dilakukan untuk menentukan ciri-ciri morfometrik pada *C. fluminea* yang dikumpulkan dari tujuh lokasi berbeza dari Kelantan dan Terengganu. Sebanyak 15 pengukuran diambil menggunakan angkup vernier. Sejumlah 210 sampel telah dikumpulkan dari tujuh lokasi, setiap lokasi secara rawak diambil 30 sampel *C. fluminea*. Data yang diambil telah dianalisis untuk ANOVA satu hala dan analisis kluster hierarki. Oleh itu, kajian ini telah menentukan bahawa Marang menunjukkan yang terbesar di antara lokasi lain berdasarkan ciri luaran iaitu SH/SL 0.9852 mm±0.05 dan Jeli menunjukkan yang terbesar dari segi ciri dalamannya iaitu 0.6185 mm±0.03 untuk LPAS/SL. Secara keseluruhan, Jeli dianggap sebagai kumpulan terbesar. Malah, hasil kajian ini akan memberikan maklumat tentang saiz kerang Asia yang boleh digunakan untuk pengkomersialan. Oleh itu, ia boleh memberikan manfaat kepada masa depan kerang Asia dari segi kualiti serta maklumat tambahan kepada rakyat mengenai spesies ini.

Kata kunci: Kerang Asia (*Corbicula fluminea.*), ciri-ciri morfometrik

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LIST OF ABBREVIATION

Cm	Centimeters
Mm	Millimeters
µm	Micrometers
C	Celsius
ppt	Parts per thousand
m^2	Square meter
mg	Milligram
h	Hours

LIST OF SYMBOLS

≠	Not equal
˚C	Degree Celcius
±	Plus-minus sign

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Asian clam, (*Corbicula fluminea*) is originated from Asian freshwaters. It is a species of freshwater clam and classified under the class of aquatic bivalve. Asian Clam is one of the popular food sources or delicacies in Kelantan, Malaysia. It is also recognized as the golden clam. The Asian clam has a small characteristics of shell slightly round to triangular in shape. Another distinctive feature heavy concentric rings on outside of shell can be seen. The shell has yellowish brown in colour. Asian Clam have two lateral teeth and three cardinal teeth visible inside their shell (Hamli, Idris, Hena, Rajaee & Arshad, 2016).

The method of dispersal of larval clams are through attaching to vegetation and floating debris. The other method of dispersal is through the water current due to their passive movement. Asian Clam can reach the size of one centimeter to two centimeter when they reach at maturity stage. It is a bio-filter animals where they feed on phytoplankton. They burrow themselves under the sand or muddy bottoms to filter the feed from the water column through siphon (Rosa, Pereira, Costa, Gomes & Lourdes, 2014).

It requires well-oxygenated water, and prefers clean sand, clay and coarse sand, but can live in lower densities in almost any substrate (Hamli, Rahim, Idris, Kamal & King, 2014). The reason that Asian clam is known as for its invasive state because they are rapidly reproduce, where a single clam can release an average of 400 juveniles a day and up to 70,000 juveniles per year. In fact, it can produce high amount of quantities of larvae in a short time in modest densities (Moretzsohn & Barrera, 2006).

Asian clam will produce eggs once they reach maturity stage. After they produce the eggs, sperm will be produced by the clam. After this stage, it will produce the eggs and sperm simultaneously where they also can self-fertilize and produce up to 400 juveniles per day as mentioned before. This species take up about four years of age in order to reach it maturity stage from the juvenile (Moretzsohn & Barrera, 2006).

Asian clam is one of the hardy and persistent species that are becoming quite well-known across the United. It is stated that Asian clam favor a quiet waters with a low salinity and sandy substrates. But, some of the populations are also found living in the brackish estuaries as well as in the water bodies with silt sediments. This species favors warmer areas especially near the shore, dislike a low oxygen levels and cooler environments. Thus, it is hardly to find Asian clam at a deeper layer of water bodies (Hamli *et al*., 2016).

For the reproduction of the Asian clam, these unique species will produce eggs once they reach maturity stage. After they produce the eggs, sperm will be produced by the clam. This species can produce up to 100 000 juveniles in a lifetime. This species take up about four years of age in order to reach it maturity stage from the juvenile (Gomes, Sousa, Mendes, Borges, Vilares, Vasconcelos & Antunes, 2016).

In this research project, the morphological characteristic of the Asian Clam had been identified. In order to identify their morphometric, there are 15 measurement that had been used including the shell length (SL), the greatest anteroposterior dimension, shell height (SH), the maximal dorso ventral dimension of the shell taken at the umbo as well as the shell width (SW), and the maximal width of the articulated paired valves (Hamli *et al.,* 2014). All of the measurement had been done by using a vernier calipers with accuracy of 1/50 mm (Hamli, Idris, Rajaee & Kamal, 2015).

Identifying species based on morphology character is easier, cheaper, and faster compared to genetic identification. Many other studies were conducted based on shell characters and size for species identification. This can help to differentiate between two different species however, both characters and size are not enough to differentiate. The morphometric method can be used with other methods to help identifying relationship between morphometric measurements with anatomical character for *Corbicula fluminea* Taxonomic clarification (Ronaldo, Rufino, Gaspar, Antunes & Guilhermino, 2006).

1.2 PROBLEM STATEMENT

This research involved in the identification of the variation of morphological characteristic between Kelantan and Terengganu. Morphological characteristics can be used to differentiate between species and to know the sizes of the Asian clam. Based on the previous research, the morphological characteristic of the Asian clam can be distinguish based on 15 types of measurement. However, the information about morphological of local *Corbicula fluminea* especially from Kelantan and Terengganu is still lacking.

1.3 HYPOTHESIS

H_o: One or all locations ≠ in morphometric characteristics.

The Asian Clams that are collected from the selected locations have differ in morphometric characteristics.

H_1: All locations are equal in morphometric characteristics.

The Asian Clams that are collected from the selected locations are equal in morphometric characteristics.

1.4 OBJECTIVE

To characterize the morphometric characteristics of *Corbicula fluminea* (Asian Clam) collected from Kelantan and Terengganu.

1.5 SCOPE OF STUDY

The samples from Kelantan and Terengganu were distinguished in term of their size, colour and shell morphometric. The study revolved an identification of morphological characteristic of Asian clam while focusing on Asian clam collected from selected river in Kelantan and Terengganu.

1.6 SIGNIFICANCE OF STUDY

The quality and production of the Asian clam around Kelantan and Terengganu had been observed and the data were collected through this research. The most population available in Kelantan and Terengganu was also been identified within Asian clam population. As the Asian clam is one of the favourite food at Kelantan, this research provide a benefit to the future of these species. It provide information on the sizes of Asian Clam which can be utilize for commercialization. The outcome of the present study can be established in the database for the future literature review where information can be provided to people. Thus, more information regarding *Corbicula fluminea* can be added in the database and can be used for future study as references.

1.7 LIMITATION OF STUDY

The samples of Asian clam is seasonal. Thus, the samples can only be collected in the season where Asian clam is abundantly found during the temperature changes time usually during the end of wet season which happens only once in a year at Malaysia.

Since the Asian Clam species is still a new finding species in Malaysia, there are not much of articles or information provided as the research materials provided are not sufficient. The database of the Asian clam is still in progress of its information and also it has lacking of references.

CHAPTER 2

LITERATURE REVIEW

2.1 Asian Clam, *Corbicula fluminea*

In Southern Asia especially in Kelantan, Malaysia, a species of clam known as *Corbicula fluminea* was originated from the freshwater river. Another common name for this clam is also known as Asian Clam or Golden Clam. These Asian Clam is a common and widespread invasive freshwater bivalve that originated from Asia (Moretzsohn & Barrera, 2006). The Asian Clam is a bio filter feeder where it feeds on particles or small organism in the water by circulating them through its own system.

2.2 Morphology

The size of *Corbicula fluminea* is usually not exceed than an inch or 25mm. However, these species can still reach the length as large as 25.4 mm which is about 50 until 65 mm. It has either triangular or round outline of shell and the beak are normally located centrally along the dorsal side of the clam. The beak is typically inflated. The Asian Clams are normally absence with a light-coloured shell and typified by evenly spaced concentric sulcations or also known as ridges. There is also presence of lateral teeth on their posterior and anterior sides with many fine serrations. *Corbicula fluminea* have two types of morphs where one with a yellow-green to light yellowish-brown morph on its periostracum and one with a white to light blue or purple nacre. The other morph is usually limited to the South Western of United States where it usually presence with dark olive green to black on its *periostracum* and displays as a dark royal blue nacre. This species is classified as a freshwater species. However, it still can be found in brackish water area as well (Sousa, Antunes & Guilhermino, 2008).

Research has stated that the Asian Clam comes with glossy *periostracum*, prominent and raised sculpture and regular concentric ribs. Usually, the clam with a purple morph will have a purple internal and dark green external featured with whitish pallia line to umbo. While the white morph of clam is described as having a white internal and light green external. This also been characterized by the purple flashes along the anterior and posterior lateral teeth (Wang et al., 2014).

Corbicula fluminea comes with an oval-triangular shells that have strong convex and clear asymmetry. The umbo of the shell is located above the ligament and slightly rotated and directed to the front of the shell. The ribs covered at the *periostracum* are normally comes with 12 to 16 ribs per 10mm of the clam shell surface (Reyna, Morán & Tatián, 2013)

The siphons of the *C. fluminea* come with a two rows of tentacles. It also has a strong pigmentation surrounding both of the siphons. The outer and inner demi branch of the Asian Clam comes with either a similar size or the former reaching half of the latter size (Reyna et al., 2013).

2.3 Morphometric Characteristics Measurement

The samples of the *Corbicula fluminea* collected will be identified based on Hamli *et al*. (2014). A total of 15 characters are used to study the morphometric characteristics including the ratio to standard length (SL) founded by Scheltema and Idris mentioned in the research study of Hamli *et al* (2016). The five general characters of the clam shell has been examined according to Hamli *et al*. (2016) including the shell height (SH), shell width (SW), umbo length (UL), anterior length (AL) as well as the posterior length (PL).

Nine additional characters are also been used to determine the morphology of *C. fluminea*. This included the ligament length (LL), cardinal tooth length (LCT), anterior adductor muscle scar width (AW), the posterior adductor muscle scar width (PW), length from the anterior adductor muscle scar to posterior adductor muscle scar (LPAS), length from anterior adductor muscle scar to anterior margin (AAAM), length from the posterior adductor muscle scar to posterior margin (PAPM), length from the ventral margin to pallial line (PVM) and the last one the ventral posterior margin length (VPM). The shape of each shells were observed and recorded (Hamli *et al*., 2015).

In previous study, the samples were preserved in ice and transferred to laboratory for further analysis. All the morphological structures were identified based on Poutiers (1998) where a total of thirteen shell characters was used (Hamli *et al*., 2016). However, there is another method have been used to identify the morphological and morphometric feature of bivalves. All the shells were cleaned, dried at 38˚C for 48 h and separate the valves. For this research study, only six physical parameters were retained and used in expressing the ratio. The parameters consist of linear and surface measures obtained directly from the shape analysis which is the lateral and ventral views as well as the weight measure of each left valve. 1×10^{-4} mm and 0.1 mg were the respective accuracies associated with the linear and weight measures. The weight measurement used in this research were the length (L), height (H), width (W), lateral area (Al), ventral area (Av) and weight or shell mass (SM) (Caill-Milly *et al*., 2014). Table 2.1 shows the linear and surface measure that can be obtain directly from the lateral and ventral view as well as the weight measure for each left valve.

Table 2.1: Linear and surface measurements of the lateral and ventral view

Acronym	Description
Length (L)	Longest distance from the front edge to the back edge refer to the length obtained from the lateral view.
Height (H)	Distance from the umbo to edge obtained from the lateral view.
Width (W)	Longest distance of the valve in the lateral plane across the valve obtained from the ventral view.
Lateral area (Al)	Surface of the valve projected on a plane in the lateral view.
Ventral area (Av)	Surface of the valve projected on a plane in lateral view.
Weight or shell mass	Dry mass of the left valve measured in milligram.

2.4 Taxonomy

The Asian clam or also known as Golden Clam are the species under the genus *Corbicula* that are native to Australia, Africa, and Middle East as well as in Asia. Nowadays, Asian Clams are distributed worldwide but as a native species. It is stated that the status of this species are still being confused as the range of these species has been expanding speedily. The Asian Clam characters were evaluated to identify the species level of the specimens. These clam was identified in terms of its pigmentation of the area around siphons, siphonal tentacles disposition, size of gill, shape of the shell, number and disposition of the shell ribs as well as the length, height and width of the clam *(Reyna et al.*, 2013). The taxonomy for *Corbicula fluminea* are shown as below.

Kingdom	Animalia
Phylum	Mollusca
Class	Bivalvia
Order	Veneroida
Superfamily	Cyrenoidea
Family	Cyrenidae
Genus	*Corbicula*
Species	*C. fluminea*
Binomial name	*Corbicula fluminea*
Synonyms	*Tellina fluminea*
Common names	Asian Clam, Asiatic Clam, Prosperity Clam, Pygmy or Gold Clam.

Source: (Moretzsohn & Barrera, 2006).

2.5 Ecology and Distribution

The Asian Clam is claimed as a freshwater species. However, these species has also been found in the brackish water area as well. It can adapt the salinity of water up to 13ppt for a short period of time. Primarily, it can occur in the estuarine, lake as well as in the river habitat. The Asian Clam can survive in a multitude of substrate. This includes the sand, silt, clay and gravel. However, this species prefer a fine and clean sand, clay and coarse sand substrates. Well-oxygenated waters and temperatures below 2 ˚C until 36 ˚C is required by this species to survive. The densities need by these species can be vary and high as 2322.58 per m^2. Normally, the life span of the Asian Clam can up from two until four years. However, its life span can reach as long as up to seven years (Moretzsohn & Barrera, 2006).

The temperature that exceed or less than this range is lethal for the species. *Corbicula fluminea* can endure this wide range of temperatures. But, to reproduce it needs a temperature above 16˚C. For the temperature above 30˚C, the Asian Clam's metabolism and respiration will be reduced. These species is a filter feeder species where they will remove particles from the water column and feed on the phytoplankton and particulate organic matter. Having a higher filtration and assimilation rates than the other freshwater clams makes the Asian Clam one of a species with extremely filter feeder (Sousa et al., 2008).

Having the highest net of production makes these invasive clam one of a unique creature. In addition, *C. fluminea* are capable of deposit feeding where it can transport the sediments across its labial palps by using ciliary tracts on its foot. This species is a simultaneous hermaphrodite where it has an ability to self-fertilize and broadcast its own sperm throughout the water column (Sousa et al., 2008).

The tolerance of these species towards a high turbidity compared to any other freshwater bivalves makes this species more unique. It has a higher average of filtration, assimilation, metabolic rates as well as a higher growth rate. The ability of having higher metabolic rate improves the clam's ability to re-burrow intensely when it is disrupted from substrates. This is a way to protect the clams from damage or predation. This also increases the clam's capability to invade unstable habitat that includes the habitat with higher flow rates as well as having a greater suspended solids and sediments. This makes them able to compete with many of native aquatic species includes the mussels because most of the native species require a longer period of time in order to adapt the sudden change (Sousa et al., 2008).

As mentioned by Paunovi, Csányi, Kneževi, Simi, & Nenadi (2007), the distribution of *Corbicula fluminea* as well as some other invertebrate taxa, indicated that heavily modified navigational waterways were suitable recipient areas for the introduction and adaptation of invasive species. Freshwater bivalves of the genus *C. fluminea* were autochthonous fauna in tropical and subtropical regions of Africa, Asia, the Malaysian Archipelago, the Philippines, New Guinea and Eastern Australia The distribution mechanisms of the clam, which include transport by birds, accidental transport with sand or gravel and release as bait or as aquarium specimens6 (Paunović et al., 2007).

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 Methodology

3.1.1 Design of Experiment

In this research project, 30 samples of Asian Clam, (*Corbicula fluminea*) were taken from the selected locations. These samples were taken back to the laboratory for further observation on its morphometric characteristic. Few parameters were required to determine the difference of morphometric characteristics of Asian Clam. The specific readings based on the Asian Clam shell measurement were taken from all of the 30 samples. All of the readings were recorded for further analysis. The data of the sample's measurements were compared based on their morphometric characteristic from all the selected locations.

3.2 Samples Collection

A total of 30 samples of Asian Clam were taken from each selected locations in the area of Kelantan and Terengganu. At each of the sampling location the coordinates had been recorded. The selected locations were Tumpat (5˚37'08.3˚N 101˚42'21.0"E), Jeli (6˚07'28.7˚N 102˚08'26.4"E), Bachok (5˚58'43.2˚N 102˚20'16.8"E), Pasir Puteh (5˚51'09.1˚N 102˚24'26.5"E), Besut (5˚44'09.8˚N 102˚29'23.6"E), Kuala Terengganu (5˚20'33.2˚N 103˚05'09.0"E), and Marang (5˚11'47.7˚N 103˚11'37.1"E) respectively. A total of 30 samples were randomly collected from seven different location site. The Asian Clam samples were checked to see whether it is dead or alive. Only alive samples were collected for further observations. The Asian Clam were collected by wadding or dug out by using a shovel and cleaned using a sieve box (Renard *et al*., 2000). All the samples that have been collected were transferred immediately in an aquarium containing aeration mechanisms which are suitable for transportation.

3.3 Samples Preparation

The collected samples were examined and observed for collecting further information. The Asian Clam was opened by using a scalpel. It was opened gently to avoid any damage towards the samples. Once the shells were open, the meat of the clams were removed thoroughly without leaving any meat in the shell because any disturbance could make the measurement be very difficult. After that, the shells were cleaned with tap water to remove any excess meat or sediments. The shells must not be separated or broken so that the pair of another shell will be easy to find. Then, the shells were rinsed off using distilled water before it was transfered into the oven. The shells were dried off by an oven. The duration to dry the samples typically will take time about 24 h. The temperature that was set up for the shells about 70-80°C (Moneva, et al., 2014).

3.4 Morphometric Characteristic Measurement

The morphometric variables were measured with a total of 15 measurements. The measurements were taken using a vernier caliper with an accuracy of 1/50mm. A total of 210 samples had been measured. The morphological variable was 0.01 mm using a vernier caliper (Wang et al., 2014).Firstly, the shell morphology were analysed from different location of the samples taken. The morphometric variables that had been measured were the ratio to standard length (SL), the shell height (SH), shell width (SW), umbo length (UL), anterior length (AL), the posterior length (PL), the ligament length (LL), cardinal tooth length (LCT), anterior adductor muscle scar width (AW), the posterior adductor muscle scar width (PW), length from the anterior adductor muscle scar to posterior adductor muscle scar (LPAS), length from anterior adductor muscle scar to anterior margin (AAAM), length from the posterior adductor muscle scar to posterior margin (PAPM), length from the ventral margin to pallial line (PVM) and the last one the ventral posterior margin length (VPM) (Hamli et al., 2015).The samples were measured and the data had been taken for analysis later on. Figure 3.1 below shows the morphometric characteristic measurements for Asian Clam.

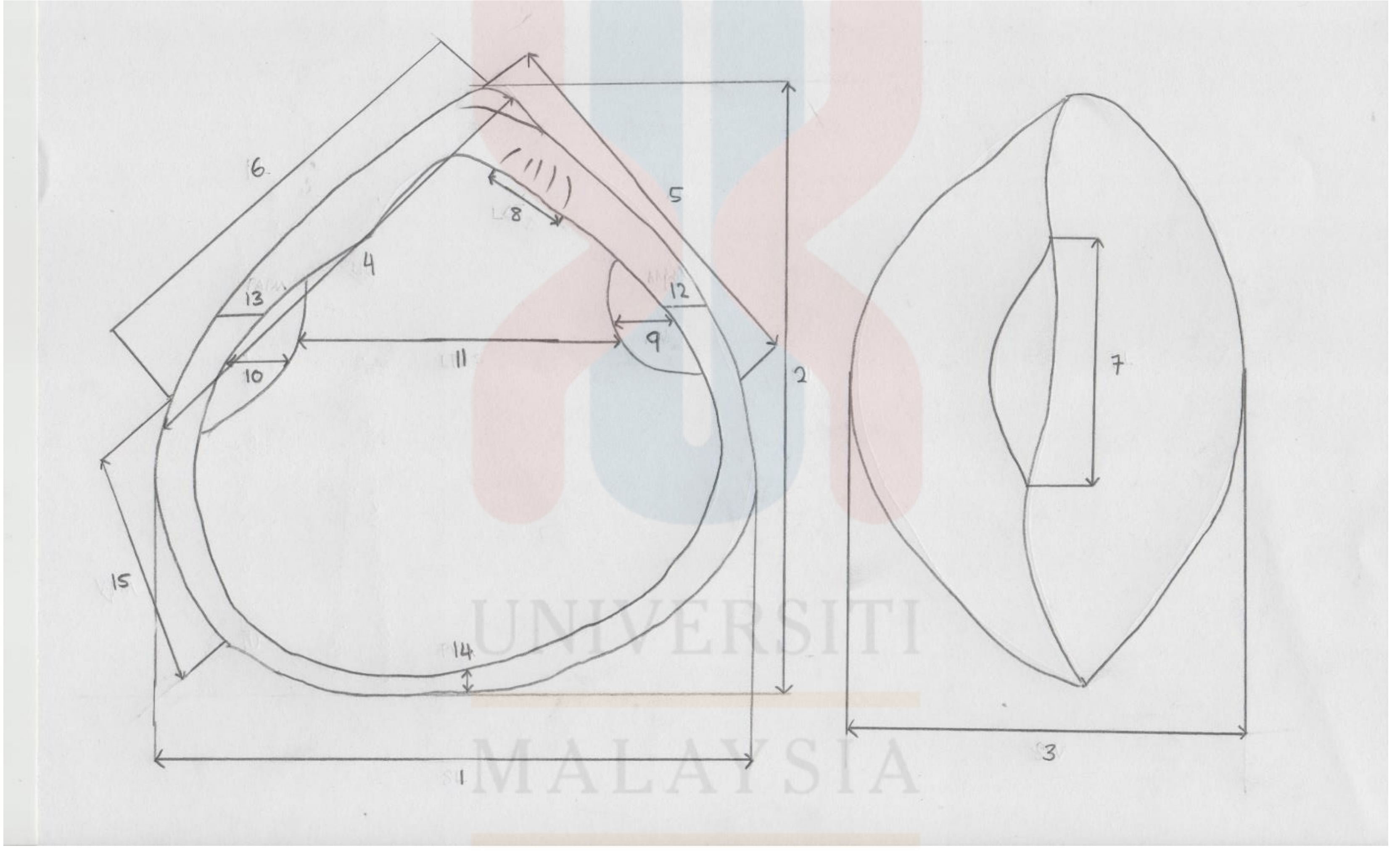


Figure 3.1: Morphometric Characteristic Indices (Hamli et al., 2015).

Table 3.1: Phenotype traits based on morphometric characteristic for the differentiation analysis among the Asian Clam based on Figure 3.1.

Number	Morphometric Characteristic	Acronyms
1	Standard length	SL
2	Shell height	SH
3	Shell width	SW
4	Umbo length	UL
5	Anterior length	AL
6	Posterior length	PL
7	Ligament length	LL
8	Cardinal tooth length	LCT
9	Anterior adductor muscle scar width	AW
10	Posterior adductor muscle scar width	PW
11	Length from anterior adductor muscle scar to posterior adductor muscle scar	LPAS
12	Length from anterior adductor muscle scar to anterior margin	AAAM
13	Length from posterior adductor muscle scar to posterior margin	PAPM
14	Length from ventral margin to pallial line	PVM
15	Ventral posterior margin length	VPM

Source: Hamli et al.,(2015)

3.5 Comparison of Asian Clam Based on Colour.

All the collected samples from seven main locations were observed in terms of their morphological appearance including the type of clams, colour of the clam's shell, and shell morphometric of the clams. The morphs of the clams were identified either it comes with a yellow-green to light yellowish-brown morph on its periostracum or with a white to light blue or purple nacre (Sousa *et al*., 2008). The size of the samples collected from the seven different region were compared by using the 15 morphometric characteristic.

3.6 Statistical Analysis

The values were presented as means ± standard deviation. The raw data was changed into allometric data to minimize the external factor where it can be presentable. The differences of morphometric variables of the samples had been analyzed by using one way analysis of variance (ANOVA) (Hamli et al., 2015). Along with ANOVA method, general linear model (GLM) also can be used using statistical analysis software. Tukeys's mean comparison test was used to determine the comparison between the morphometric ratios. The significance differences was tested at ($p<0.05$) (Hamli et al., 2016).

ANOVA was used to analyze the differences among the group means and their associated procedures like the variation among and between the groups. The observed variances that are in a particular variable was partitioned into the components that attributable to different sources of variation. Other than that, hierarchal cluster analysis was carried out by computer program SPSS, (Hamli et al. 2014).

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Morphometric and Morphology of Asian Clam in Kelantan and Terengganu

The morphometric characteristic for Asian clam had been measured based on the 15 measurement by Hamli et al., (2015). All of the measurement had been recorded and shown in the Table 4.1.

Table 4.1: Analysis of one-way ANOVA with general linear model (GLM) for 14 morphometric characteristic proportion with standard length of Asian clam from seven different locations.

Parameter	Tumpat	Jeli	Bachok	Pasir Puteh	Besut	Kuala Terengganu	Marang
SH/SL (mm)	0.9309 ± 0.05^{b}	0.8451 ± 0.03^{d}	0.8784 ± 0.07^{cd}	0.9001 ± 0.05^{bc}	0.8908 ± 0.02^{c}	0.9672 ± 0.04^{a}	0.9852 ± 0.05^{a}
SW/SL (mm)	0.5751 ± 0.06^{e}	0.5769 ± 0.03^{e}	0.5855 ± 0.04^{de}	0.6372 ± 0.04^{bc}	0.6106 ± 0.03^{cd}	0.6527 ± 0.04^{ab}	0.6749 ± 0.04^{a}
UL/SL (mm)	0.6532 ± 0.06^{c}	0.7523 ± 0.04^{a}	0.6756 ± 0.13^{bc}	0.6552 ± 0.03^{c}	0.6502 ± 0.02^{c}	0.6842 ± 0.03^{bc}	0.7137 ± 0.04^{ab}
AL/SL (mm)	0.5598 ± 0.07^{a}	0.4948 ± 0.03^{c}	0.5228 ± 0.04^{bc}	0.5060 ± 0.02^{bc}	0.5012 ± 0.03^{bc}	0.5284 ± 0.04^{b}	0.5620 ± 0.04^{a}
PL/SL (mm)	0.5981 ± 0.05^{ab}	0.5850 ± 0.04^{bc}	0.5534 ± 0.05^{d}	0.5769 ± 0.02^{bcd}	0.5693 ± 0.02^{cd}	0.5814 ± 0.03^{bc}	0.6171 ± 0.04^{a}
LL/SL (mm)	0.2572 ± 0.03^{c}	0.3039 ± 0.03^{a}	0.2182 ± 0.03^{d}	0.2776 ± 0.03^{abc}	0.2702 ± 0.03^{bc}	0.2930 ± 0.04^{ab}	0.2911 ± 0.05^{ab}
LCT/SL (mm)	0.2143 ± 0.03^{cd}	0.2492 ± 0.02^{a}	0.2089 ± 0.02^{d}	0.2367 ± 0.02^{ab}	0.2261 ± 0.02^{bc}	0.2435 ± 0.02^{a}	0.2524 ± 0.02^{a}
AW/SL (mm)	0.1353 ± 0.02^{bc}	0.1416 ± 0.01^{ab}	0.1284 ± 0.02^{c}	0.1339 ± 0.01^{bc}	0.1296 ± 0.01^{c}	0.1485 ± 0.02^{a}	0.1491 ± 0.02^{a}
PW/SL (mm)	0.1611 ± 0.02^{b}	0.1560 ± 0.02^{b}	0.1418 ± 0.02^{c}	0.1557 ± 0.02^{bc}	0.1602 ± 0.02^{b}	0.1786 ± 0.02^{a}	0.1852 ± 0.02^{a}
LPAS/SL (mm)	0.5338 ± 0.08^{c}	0.6185 ± 0.03^{a}	0.5920 ± 0.04^{ab}	0.5978 ± 0.02^{ab}	0.5839 ± 0.02^{b}	0.5771 ± 0.02^{b}	0.5953 ± 0.02^{ab}
AAAM/SL (mm)	0.0602 ± 0.01^{c}	0.0608 ± 0.01^{c}	0.0672 ± 0.01^{b}	0.0647 ± 0.01^{bc}	0.0685 ± 0.01^{b}	0.0705 ± 0.01^{ab}	0.0748 ± 0.01^{a}
PAPM/SL (mm)	0.0596 ± 0.01^{d}	0.0660 ± 0.01^{bc}	0.0651 ± 0.01^{cd}	0.0662 ± 0.00^{bc}	0.0677 ± 0.01^{bc}	0.0717 ± 0.01^{ab}	0.0771 ± 0.01^{a}
PVM/SL (mm)	0.2130 ± 0.03^{abc}	0.2015 ± 0.02^{c}	0.2131 ± 0.02^{abc}	0.2059 ± 0.01^{c}	0.2106 ± 0.02^{bc}	0.2283 ± 0.02^{a}	0.2251 ± 0.02^{ab}
VPM/SL (mm)	0.3490 ± 0.04^{a}	0.3059 ± 0.03^{c}	0.2625 ± 0.03^{d}	0.2762 ± 0.02^{d}	0.2637 ± 0.02^{d}	0.3391 ± 0.03^{ab}	0.3235 ± 0.04^{bc}

Values are mean ± S.D of 30 samples from seven locations. Values in same row with difference superscripts indicate a significantly different at level ($p<0.05$) subjected to Tukey test.

*SL = Standard length, SH = Shell height, SW = Shell width, UL = Umbo length, AL = Anterior length, PL = Posterior length, LL = Ligament length, LCT = Cardinal tooth length, AW = Anterior adductor muscle scar width, PW = Posterior adductor muscle scar width, LPAS = Length from anterior adductor muscle scar to posterior adductor muscle scar, AAAM = Length from anterior adductor muscle scar to anterior margin, PAPM = length from posterior adductor muscle scar to posterior margin, PVM = Length from ventral margin to pallial line, VPM = Ventral posterior margin length.

Based on the Table 4.1, the SH/SL for Kuala Terengganu showed no significant difference ($p<0.05$) between Marang as the value for their means are 0.9672 ± 0.04 and 0.9852 ± 0.05 respectively. The SH/SL from Tumpat showed significant difference between other locations but share the same group with Pasir Puteh. This indicated that there is no significant difference ($p<0.05$) between these three locations. SH/SL from Jeli shows no significant difference between Bachok but have significant difirence between other locations. For SW/SL, Asian clam from Tumpat, Jeli and Bachok showed no significant differences. But, Besut, Pasir Puteh, Kuala Terengganu and Marang have significant differences between each other.

The PL/SL for each of the locations showed that there were significant differences ($p<0.05$) between each locations. PL/SL for Marang have the highest value followed by Tumpat, Jeli, Kuala Terengganu, Pasir Puteh, Besut and lastly Bachok. For LL/SL, Jeli, Tumpat and Bachok showed significant difference between other locations. There was no significant difference ($p<0.05$) between Kuala Terengganu, Marang, Pasir Puteh and Besut.

LCT/SL of Marang, Jeli, Kuala Terengganu and Pasir Puteh showed that there were no significant differences between those locations. Asian clam from Bachok showed that there is significant difference ($p<0.05$) between other locations except for Tumpat.

The AW/SL for the Asian clam can be group into three where Marang and Kuala Terengganu showed no significant difference with mean value of 0.1491 ± 0.02 and 0.1485 ± 0.02. There was also no significant difference of AW/SL between Bachok and Besut. Based on the results, Marang have the biggest value of AW/SL compared to other locations followed by Kuala Terengganu, Jeli, Tumpat, Pasir Puteh, Besut and Bachok.

The PW/SL for Marang and Kuala Terengganu showed significant difference between Tumpat Besut, Jeli, Pasir Puteh and Bachok and they were in the biggest group for PW/SL. However, there was no significant difference ($p<0.05$) between Tumpat, Besut, Jeli and Pasir Puteh except for Bachok. Bachok had the smallest PW/SL with the value of 0.1418 ± 0.02. Tumpat showed significant difference between other locations with the smallest value of LPAS/SL which was 0.5338 ± 0.08. Jeli had the highest value of LPAS/SL which was 0.6185 ± 0.03. Pasir Puteh, Marang, Bachok, Besut and Kuala Terengganu showed no significant difference ($p<0.05$) for LPAS/SL.

Jeli and Tumpat showed no significant difference between each other for AAAM/SL same goes to Kuala Terengganu, Besut, Bachok and Pasir Puteh. There was significant difference ($p<0.05$) between Marang and other locations. For PAPM/SL, Marang showed the biggest value which was 0.0771 ± 0.01 and have the significant difference ($p<0.05$) between other locations. Kuala Terengganu, Besut, Pasir Puteh, Jeli and Bachok showed no significant difference between their PAPM/SL except for Tumpat that had the smallest value of PAPM/SL which was 0.0596 ± 0.01.

Jeli and Pasir Puteh showed no significant difference ($p<0.05$) between each other for PVM/SL as well as for Besut, Tumpat, Bachok and Marang. Kuala Terengganu showed significance difference ($p<0.05$) between other location. For VPM/SL, Bachok, Besut and Pasir Puteh showed no significant differences ($p<0.05$) between each other and had the smallest value. Tumpat showed the highest value of VPM/SL which was 0.3490 ± 0.04.

Asian clam and also scientifically known as *Corbicula fluminea* is a bivalve mollusk native from Asia and known to abundantly available in the river and lake around the Asia

(Moretzsohn & Barrera, 2006). According to Mouthon (2001), Asian clam normally lives in freshwater but it can tolerate salinities up to 13 ppt for a short period. According to the results obtained, Asian clam in Marang showed the biggest morphology characteristics compared to other locations based on the allometric data shown in the Table 4.1. The results on shell measurement and their ratios was significantly different in most of the characteristics to be compared with other locations. Most of the characteristics are bigger than characteristics of Asian clam from other locations.

The standard length, shell height and shell width of the Asian clam showed the age and maturity of the clam itself. Most of the matured clam had a bigger shell size and the size of Asian clam could averagely reach until 25mm and rarely exceed 50mm, (Robinson, 2004). As the shell size of Asian clam from Marang and Kuala Terengganu shows high value of mean, Asian clam from Jeli and Bachok showed a different results where it had a smaller value compared to other locations.

According to their morphological characteristic that showed differ size of outer shell, it could be concluded that most of the Asian clam that came from Marang and Kuala Terengganu were much more matured and had lived longer than the Asian clam from other locations. Some of the reasons is that Asian clam was not considered as one of favourite food for native in Terengganu and not many people in Terengganu harvest it for food consumption. As a results, the Asian clam around Terengganu had bigger and more matured than other locations as they were not being harvested regularly and had a longer life span.

As for Asian clam in Jeli and Bachok, it was known to be one of the famous places of harvesting the clams. Asian clam was known as one of favourite food delicacies in Kelantan and consumed by most of the native. Based on the survey, most of the Asian clam were harvested from Bachok and Jeli and this could be a reason on why it had a smaller value of morphological characteristics. The Asian clam from Jeli and Tumpat were always being harvested regularly and this might interrupt the growth of the clam itself. Due to frequently harvesting activity, Asian clam from this locations might not reach the right time of entering the adult stage.

As for the external features, most of Asian clam from Terengganu had higher reading compared to Kelantan. This could be clearly seen from the Table 4.1, where the reading of the morphological characteristic for the Asian clam form the Terengganu showed the highest value to be compared with other locations. It could be clearly seen based on the SH/SL reading that record the highest value which is 0.9852 mm. this indicates that Asian clam from Terengganu have the biggest shell size.

However, in term of internal features, it could be concluded that most of the Asian clam from Kelantan had a higher reading compared to Terengganu especially from Jeli. The reading of LPAS/SL for Asian clam from Jeli have the biggest value for its flesh size which is 0.6185 mm compared to other six locations. The Asian clam from Jeli that had a higher reading for the internal features might had a better environment and received enough nutrients for their growth.

The environmental factor that may influence the growth of Asian clam includes the temperature of the water as well as the oxygen level available in the surrounding. They prefer sandy substrate compared to muddy substrate as sandy substrate provide higher oxygen level for their nutrient absorption (Wang et al, 2014)

4.2. Hierarchal cluster analysis

A total of 210 of populations of Asian clam from seven locations were tested for Hierarchal cluster analysis using IBM SPSS Statistic version 22. Five groups of clusters have been formed through similarity based on their morphological characteristics. The data were shown on the figure below.

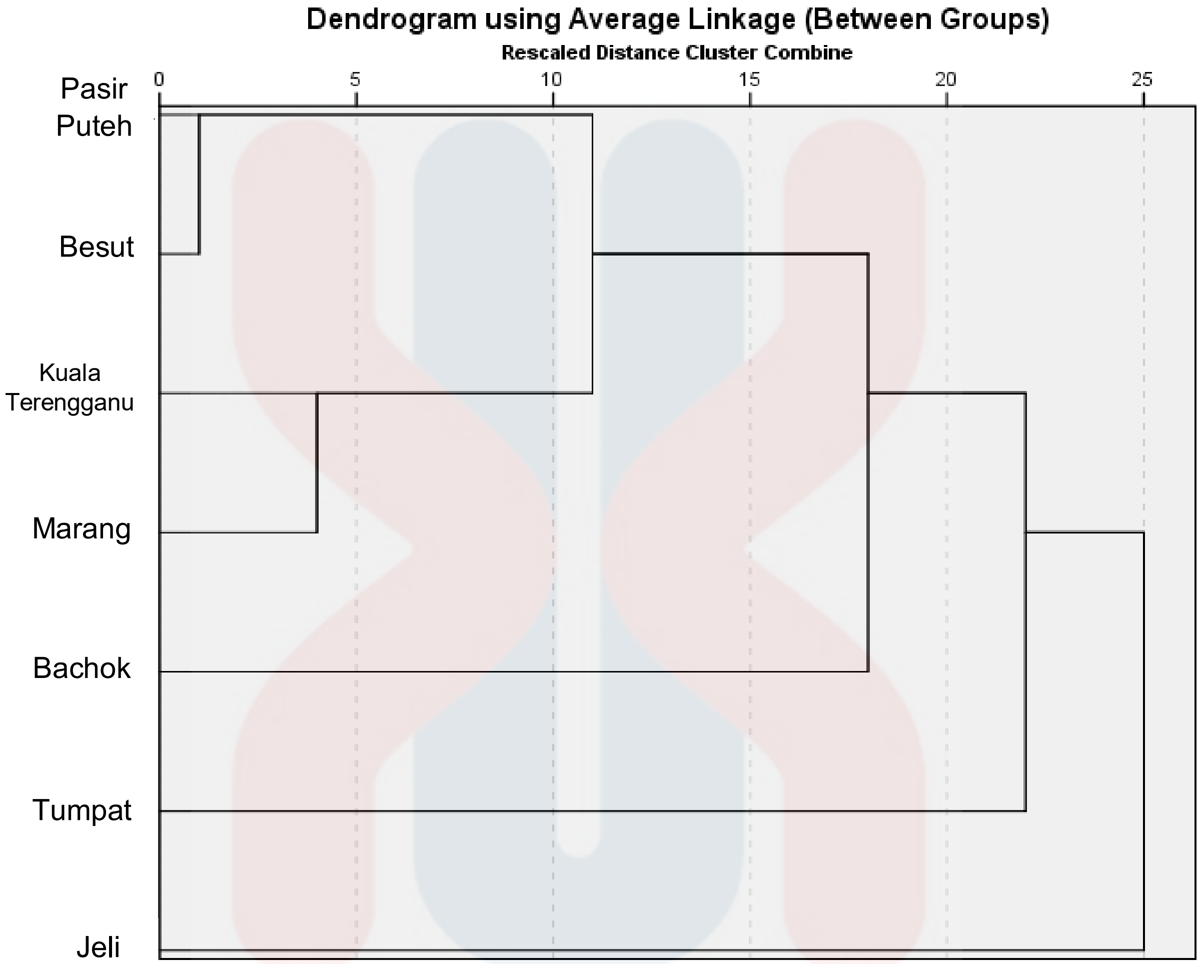


Figure 4.1: Cluster group of Asian clam from seven locations based on the morphological characteristic.

Cluster analysis is one of the data exploration tool for dividing multivariate dataset natural groups. Cluster analysis were used in this research to investigates the number of distinct populations or sub-populations sample units of the Asian clam from Tumpat, Jeli, Bachok, Pasir Puteh, Jertih, Kuala Terengganu and Marang. Figure 4.1 is a tree diagram that illustrate the arrangement of the clusters for Asian clam from seven different locations.

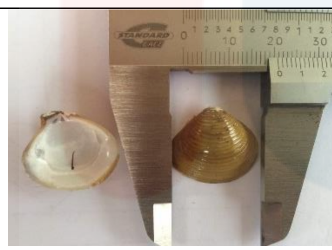
Based on the dendrogram, Asian clam from Pasir Puteh is clustered with Besut with Euclidean distance between these two cluster is 0.033. Kuala Terengganu is clustered with Marang at 0.047 while Pasir Puteh and Kuala Terengganu was clustered at 0.079 in distance. Bachok and Pasir Puteh was clustered at stage four with the Euclidean distance between these two cluster was 0.113. Tumpat and Bachok was clustered at stage five with distance of 0.131 and 0.145 for Jeli and Tumpat.

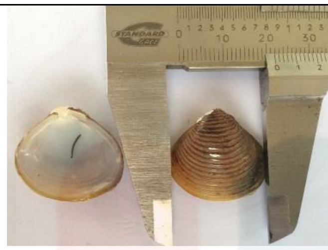
The distance of the Asian clam from these seven different locations were arranged bottom up according to their general size including the internal as well as the external features. Asian clam from Jeli was in the largest cluster followed by Tumpat, Bachok, Marang, Kuala Terengganu, Besut and Pasir Puteh. Generally, the Asian clam from seven locations could be grouped into five cluster. According to the dendrogram, Asian clam from Kuala Terengganu and Marang was clustered into the same group. One of the factor was that the Asian clam from Kuala Terengganu and Marang came from the same river flow. Thus, they shared the same morphological characteristic and came from similar species of Asian clam.

Besides, Asian clam from Besut and Pasir Puteh also came in the same cluster due to geographical characteristic where both place had a muddy type substrate at the bottom. According to Wang et al. (2014), Asian clam prefer sandy substrate compared to muddy substrate as sandy substrate provide higher oxygen level for their nutrient absorption. Pasir Puteh and Besut was located near to each other and also shared a similar water bodies. They shared similar morphological characteristic and came from the same species. Other Asian clams were clustered into different group according to their size that might be affected from environmental factors as well as the geographical factors.

4.3. Description of the Asian clam

Table 4.2: Comparison of Asian clams from seven locations.

Sample	Description
	Location: Tumpat Coordinate: 5˚37’08.3˚N 101˚42’21.0”E Shape: Sadle Inner shell colour: White
	Location: Jeli Coordinate: 6˚07’28.7˚N 102˚08’26.4”E Shape: Round Inner shell colour: White
	Location: Bachok Coordinate: 5˚58’43.2˚N 102˚20’16.8”E Shape: Round Inner shell colour: White
	Location: Pasir Puteh Coordinate: 5˚51’09.1˚N 102˚24’26.5”E Shape: Sadle Inner shell colour: White to purple
	Location: Besut Coordinate: 5˚44’09.8˚N 102˚29’23.6”E Shape: Sadle Inner shell colour: White to purple

	Location: Kuala Terengganu Coordinate: 5˚20’33.2˚N 103˚05’09.0”E Shape: Round Inner shell colour: White
	Location: Marang Coordinate: 5˚11’47.7˚N 103˚11’37.1”E Shape: Sadle Inner shell colour: Purple

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In conclusion, the Asian clam from seven different locations had been identified and characterized based on 15 measurement of morphological characteristic. A total of 210 samples of Asian clam with 30 clams for one location had been characterized into five major cluster group where Pasir Puteh and Besut might share similar morphological characteristic as well as for Asian clam from Marang and Kuala Terengganu due to similar water bodies they shared. In term of external features, Asian clam from Marang had the biggest shell measurement. However, Jeli had the biggest measurement for internal features. There were several factors that might affect the growth of the Asian clams including the geographical factors as well as the environmental factors.

As for recommendation, it is recommended to improve the research by supporting the research with genetic characteristic of Asian clam. Some information can be added up by doing additional research regarding the factors that can affect the characteristic of Asian clam based on the environmental factors such as the water quality factor. In addition, the research can be modified by doing some study about the difference between species of Asian clam available in Asia especially in Malaysia.

REFERENCES

Caill-Milly, N., Bru, N., Barangger, M., Gallon, L., & D'Amico, a. F. (2014). Morphological trends of Four Manila Clam Populations (*Venerupis Philippinarum*) on the French Atlantic Coast: Identified Spatial Patterns and Their Relationship to Environmental Variability. *Journal of Shellfish Research*, 355-372.

Gomes, C., Sousa, R., Mendes, T., Borges, R., Vilares, P., Vasconcelos, V., . . . Antunes, a. A. (2016). Low Genetic Diversity and High Invasion Success of *Corbicula fluminea* (Bivalvia, Corbiculidae) (Müller, 1774) in Portugal. *PLos ONE*.

Hamli, H., Rahim, A. A., Idris, M. H., Kamal, A. H., & King, a. W. (2014). Morphometric variation among three local mangrove clam species of Corbiculidae. *Songklanakarin J. Sci. Technol.*

Hamli, H., Idris, M. H., Rajaee, A. H., & Kamal, a. A. (2015). Reproductive Cycle of Hard Clam, *Meretrix lyrata* Sowerby, 1851 (Bivalvia: Veneridae) from Sarawak, Malaysia. *Tropical Life Sciences Research*, 59-72.

Hamli, H., Idris, M. H., Hena, M. K., Rajaee, A. H., & Arshad, a. A. (2016). Inner shell as variation key of local hard clam Meretrix spp. *Journal of Environmental Biology*.

Moneva, C. S., Paolo Miguel L. Baquiano, J. O., Borlaza, K. M., Burias, D. M., Flores, K. A., Fuentes, G. R., . . . Sanchez, a. R. (2014). Comparative morphological descriptions of interior shell patterns of the Venerid bivalves: *Meretrix lyrata*, *Mercenaria mercenaria* and *Venerupis philippinarum* using Landmark-based. *AACL Bioflux*.

Moretzsohn, F., & Barrera, a. N. (2006). Occurrence of the Asian Clam, *Corbicula fluminea*, in the Jim Naismith Reservoir, Ingleside, Texas. *Texas A&M University*.

Mouthon, J. (2001). Life cycle and population dynamics of the Asian clam C*orbicula fluminea* (Bivalvia: Corbiculidae) in the Saone River at Lyon (France). *Hydrobiologia*, 109-119.

Paunović1, M., Csányi, B., Knežević, S., Simić, V., Nenadić, D., & Dunja, a. (2007). Distribution of Asian clams *Corbicula fluminea* (Müller, 1774) and *C. fluminalis* (Müller, 1774) in Serbia. *Aquatic Invasions*, 99-106.

Renard, E., Bachmann, V., Cariou, M. L., & Moreteau, a. J. (2000). Morphological and molecular differentiation of invasive freshwater species of the genus Corbicula (Bivalvia, Corbiculidea) suggest the presence of three taxa in French rivers. *Molecular Ecology*.

Reyna, P. B., Morán, A. G., & Tatián., a. M. (2013). Taxonomy, distribution and population structure of invasive Corbiculidae (Mollusca, Bivalvia) in the Suquía River basin, Córdoba, Argentina. *Iheringia Serie Zoologia*, 77-84.

Robinson, M. (2004). Asian Clam: An Exotic Aquatic Species. *dcr Massachusetts*.

Ronaldo Sousa 1, 2., 3, R. F., 3, J. M., Rufino, M., Gaspar, M., Antunes, C., & Guilhermino., a. L. (2006). The Asiatic clam *Corbicula fluminea* (Müller, 1774) in the Minho and Lima estuaries: genetic vs. morphometry. *Bivalvia*.

Rosa, I. s., Pereira, J. L., Costa, R., Gomes, J. o., & Lourdes, a. M. (2014). Dispersal of *Corbicula fluminea*: factors influencing the invasive clam's drifting behavior. *Ann. Limnol*, 37-47.

Sousa, R., Antunes, C., & Guilhermino., a. L. (2008). Ecology of the invasive Asian clam *Corbicula fluminea* (Müller, 1774) in aquatic ecosystems: an overview. *Ann. Linnol.*, 85-94.

Wang, G.-P., Zhang, T., Zhang, J., Li, D.-L., & Xiao., a. T.-Y. (2014). Morphological and molecular differentiation of genus Corbicula suggests that two species are sympatrically distributed in Datong Lake in the Central Yangtze River Basin. *Zoological Studies*, 53-64.

APPENDICES

Table A. 1: One-way ANOVA for morphometric characteristic

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SHSL	Between Groups	.448	6	.075	35.631	.000
	Within Groups	.426	203	.002		
	Total	.874	209			
SWSL	Between Groups	.283	6	.047	24.997	.000
	Within Groups	.383	203	.002		
	Total	.666	209			
ULSL	Between Groups	.256	6	.043	11.828	.000
	Within Groups	.732	203	.004		
	Total	.988	209			
ALSL	Between Groups	.133	6	.022	13.591	.000
	Within Groups	.331	203	.002		
	Total	.464	209			
PLSL	Between Groups	.075	6	.012	9.622	.000
	Within Groups	.263	203	.001		
	Total	.338	209			
LLSL	Between Groups	.149	6	.025	20.204	.000
	Within Groups	.249	203	.001		
	Total	.398	209			
LCTSL	Between Groups	.052	6	.009	20.917	.000
	Within Groups	.084	203	.000		
	Total	.137	209			
AWSL	Between Groups	.013	6	.002	8.973	.000
	Within Groups	.049	203	.000		
	Total	.062	209			
PWSL	Between Groups	.039	6	.007	19.129	.000
	Within Groups	.069	203	.000		
	Total	.108	209			
LPASSL	Between Groups	.124	6	.021	14.354	.000
	Within Groups	.292	203	.001		
	Total	.415	209			
AAMSL	Between Groups	.005	6	.001	13.481	.000
	Within Groups	.012	203	.000		

	Total	.017	209			
PAPMSL	Between Groups	.005	6	.001	13.696	.000
	Within Groups	.014	203	.000		
	Total	.019	209			
PVMSL	Between Groups	.017	6	.003	6.868	.000
	Within Groups	.083	203	.000		
	Total	.100	209			
VPMSL	Between Groups	.232	6	.039	43.458	.000
	Within Groups	.181	203	.001		
	Total	.413	209			

Homogeneous Subsets

Table A.2: Means for SHSL homogeneous subsets.

SHSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05			
		1	2	3	4
Jeli	30	.845071			
Bachok	30	.878387	.878387		
Besut	30		.890754		
Pasir Puteh	30		.900131	.900131	
Tumpat	30			.930876	
Kuala Terengganu	30				.967189
Marang	30				.985239
Sig.		.077	.523	.131	.728

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.3: Means for SWSL homogeneous subsets.

SWSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05				
		1	2	3	4	5
Tumpat	30	.575072				
Jeli	30	.576935				
Bachok	30	.585459	.585459			
Besut	30		.610615	.610615		
Pasir Puteh	30			.637212	.637212	
Kuala Terengganu	30				.652675	.652675
Marang	30					.674914
Sig.		.968	.277	.216	.812	.428

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.4: Means for ULSL homogeneous subsets.

ULSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Besut	30	.650162		
Tumpat	30	.653173		
Pasir Puteh	30	.655151		
Bachok	30	.675613	.675613	
Kuala Terengganu	30	.684194	.684194	
Marang	30		.713654	.713654
Jeli	30			.752254
Sig.		.303	.182	.169

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.5: Means for ALSL homogeneous subsets.

ALSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Jeli	30	.494812		
Besut	30	.501168	.501168	
Pasir Puteh	30	.505963	.505963	
Bachok	30	.522823	.522823	
Kuala Terengganu	30		.528352	
Tumpat	30			.559765
Marang	30			.562001
Sig.		.107	.129	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.6: Means for PLSL homogeneous subsets.

PLSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05			
		1	2	3	4
Bachok	30	.553409			
Besut	30	.569337	.569337		
Pasir Puteh	30	.576857	.576857	.576857	
Kuala Terengganu	30		.581393	.581393	
Jeli	30		.584985	.584985	
Tumpat	30			.598126	.598126
Marang	30				.617096
Sig.		.157	.629	.256	.393

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.7: Means for LLSL homogeneous subsets.

LLSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05			
		1	2	3	4
Bachok	30	.218192			
Tumpat	30		.257231		
Besut	30		.270169	.270169	
Pasir Puteh	30		.277622	.277622	.277622
Marang	30			.291137	.291137
Kuala Terengganu	30			.292956	.292956
Jeli	30				.303854
Sig.		1.000	.272	.158	.062

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.8: Means for LCTSL homogeneous subsets.

LCTSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05			
		1	2	3	4
Bachok	30	.208900			
Tumpat	30	.214257	.214257		
Besut	30		.226058	.226058	
Pasir Puteh	30			.236713	.236713
Kuala Terengganu	30				.243474
Jeli	30				.249162
Marang	30				.252378
Sig.		.950	.279	.403	.051

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.9: Means for AWSL homogeneous subsets.

AWSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Bachok	30	.128434		
Besut	30	.129641		
Pasir Puteh	30	.133898	.133898	
Tumpat	30	.135271	.135271	
Jeli	30		.141579	.141579
Kuala Terengganu	30			.148504
Marang	30			.149097
Sig.		.612	.471	.498

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.10: Means for PWSL homogeneous subsets.

PWSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Bachok	30	.141776		
Pasir Puteh	30	.155746	.155746	
Jeli	30		.155979	
Besut	30		.160184	
Tumpat	30		.161115	
Kuala Terengganu	30			.178624
Marang	30			.185224
Sig.		.056	.919	.809

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.11: Means for LPASSL homogeneous subsets.

LPASSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Tumpat	30	.533820		
Kuala Terengganu	30		.577111	
Besut	30		.583930	
Bachok	30		.592014	.592014
Marang	30		.595329	.595329
Pasir Puteh	30		.597768	.597768
Jeli	30			.618514
Sig.		1.000	.350	.101

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.12: Means for AAMSL homogeneous subsets.

AAMSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Tumpat	30	.060194		
Jeli	30	.060771		
Pasir Puteh	30	.064660	.064660	
Bachok	30		.067152	
Besut	30		.068546	
Kuala Terengganu	30		.070533	.070533
Marang	30			.074773
Sig.		.294	.061	.358

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A13: Means for PAPMSL homogeneous subsets.

PAPMSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05			
		1	2	3	4
Tumpat	30	.059584			
Bachok	30	.065129	.065129		
Jeli	30		.066037	.066037	
Pasir Puteh	30		.066189	.066189	
Besut	30		.067673	.067673	
Kuala Terengganu	30			.071703	.071703
Marang	30				.077125
Sig.		.122	.891	.106	.140

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.14: Means for PVMSL homogeneous subsets.

PVMSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05		
		1	2	3
Jeli	30	.201471		
Pasir Puteh	30	.205916		
Besut	30	.210619	.210619	
Tumpat	30	.213012	.213012	.213012
Bachok	30	.213138	.213138	.213138
Marang	30		.225116	.225116
Kuala Terengganu	30			.228303
Sig.		.284	.087	.058

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Table A.15: Means for SHSL homogeneous subsets.

VPMSL

Tukey HSD[a]

Location	N	Subset for alpha = 0.05			
		1	2	3	4
Bachok	30	.262505			
Besut	30	.263703			
Pasir Puteh	30	.276249			
Jeli	30		.305878		
Marang	30		.323481	.323481	
Kuala Terengganu	30			.339102	.339102
Tumpat	30				.348951
Sig.		.561	.257	.401	.861

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 30.000.

Cluster

Table A16: Values for average linkage

Case Processing Summary[a]

Cases							
Valid		Rejected				Total	
		Missing Value		Negative Value			
N	Percent	N	Percent	N	Percent	N	Percent
7	100.0	0	.0	0	.0	7	100.0

a. Average Linkage (Between Groups)

Table A.17: Values for dissimilarity matrix

Proximity Matrix

Case	Chi-square between Sets of Frequencies						
	1: 1	2: 2	3: 3	4: 4	5: 5	6: 6	7: 7
1: 1	.000	.177	.156	.122	.127	.145	.141
2: 2	.177	.000	.149	.147	.145	.105	.110
3: 3	.156	.149	.000	.103	.092	.141	.117
4: 4	.122	.147	.103	.000	.033	.090	.069
5: 5	.127	.145	.092	.033	.000	.091	.065
6: 6	.145	.105	.141	.090	.091	.000	.047
7: 7	.141	.110	.117	.069	.065	.047	.000

This is a dissimilarity matrix

Average Linkage (Between Groups)

Table A.18: Values for agglomeration schedule

Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	4	5	.033	0	0	3
2	6	7	.047	0	0	3
3	4	6	.079	1	2	4
4	3	4	.113	0	3	5
5	2	3	.131	0	4	6
6	1	2	.145	0	5	0

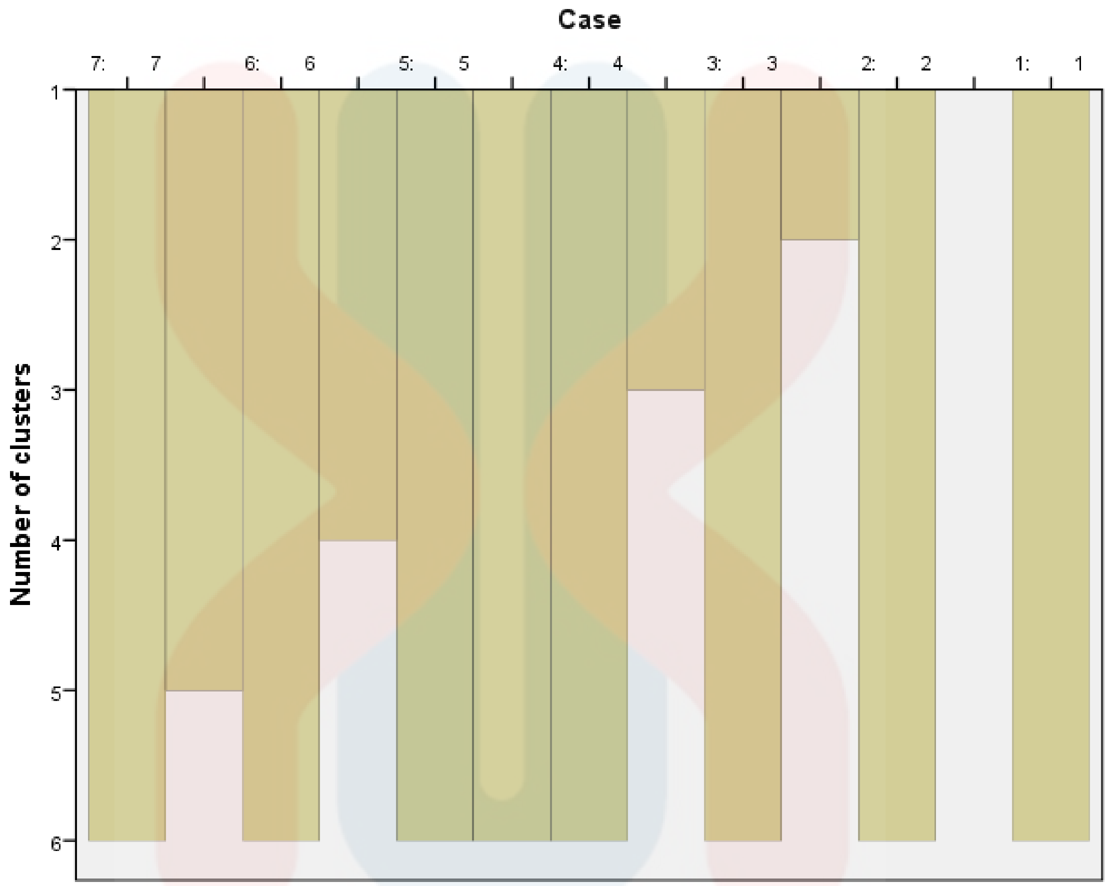


Figure B.1: Case for hierarchal cluster analysis.