DISTRIBUTION OF *Corbicula fluminea* AT GUNUNG RENG RIVER, KELANTAN.

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DISTRIBUTION OF *Corbicula fluminea* AT GUNUNG RENG RIVER, KELANTAN.

by

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DECLARATION

I declare that this thesis entitled "Distribution of *Corbicula fluminea* at Gunung Reng River, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ________________________________

Name : ________________________________

Date : ________________________________

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LIST OF ABBREVIATIONS

DO	Dissolved Oxygen
SPSS	Statistical Package for the Social Science
SS	Suspended Solid
NTU	Nephelometric
$NH4^+$	Ammonium
NWQS	National Water Quality Standard

LIST OF SYMBOLS

˚C	Degree Celsius
mm	milimeter
g	gram
m	meter
%	percentage

Distribution of *Corbicula fluminea* at Gunung Reng River, Kelantan

ABSTRACT

Corbicula fluminea (Bivalvia: Corbiculidae), locally known as “Etak” is a species that have been the subject of much research due to its capacity to spread over large areas and become the most important competitor with native species of freshwater bivalves and potentially causing ecological imbalance. Late research done, the distribution and density of *C. fluminea* in this study was conducted in Sg. Pergau at Gunung Reng, because since the observation show that there were populations of *C. fluminea* there. To study the density and distribution of *C. fluminea*, the numbers, weight and the measurement of *C. fluminea* was identified. In addition, water quality and type of substrate was also studied to identify the habitat characteristics that affect the density and distribution of this species. As there was no documentation of distribution and density of *C. fluminea* in Sg. Kelantan, it would be difficult to compare the density and distribution of Etak in the others river in Kelantan. As the finding shows that, the density and distribution of *C. fluminea* at Gunung Reng was not affected by water quality used (conductivity, pH, turbidity, salinity, temperature, DO and nitrate). The most important factor that give the huge effect toward both distribution and density of Etak is substrate composition. In this study shows that the best substrate for *C. fluminea* ranged from 0.25mm and 0.71mm which represent sand (sand-coarse and sand-fine).

Taburan *Corbicula Fluminea* di Sungai Gunung Reng, Kelantan

ABSTRAK

Corbicula fluminea (Bivalvia: Corbiculidae), secara tradisinya dikenali sebagai "Etak" adalah spesies yang selalu dijadikan penyelidikan kerana kapasiti untuk tersebar di kawasan yang besar dan menjadi pesaing yang paling penting dengan spesis asal di kerang air tawar dan berpotensi menyebabkan ketidakseimbangan ekologi. Berdasarkan kajian lepas taburan dan kepadatan *C. fluminea* dalam kajian ini telah dijalankan di Sungai Pergai di Gunung Reng, kerana pemerhatian menunjukkan bahawa terdapat populasi *C. fluminea* di sana. Untuk mengkaji ketumpatan dan taburan *C. fluminea*, nombor, berat dan ukuran *C. fluminea* telah dikenal pasti. Di samping itu, kualiti air dan jenis substrat juga menjadi kajian untuk mengenal pasti ciri-ciri habitat yang memberi kesan kepada ketumpatan dan taburan spesies ini. Oleh kerana tiada dokumentasi pengedaran dan ketumpatan *C. fluminea* di Sungai Kelantan, ia akan menjadi sukar untuk membandingkan ketumpatan dan taburan Etak dalam sungai lain di Kelantan. Sebagai dapatan kajian menunjukkan, ketumpatan dan pengedaran *C. fluminea* di Gunung Reng River tidak dipengaruhi oleh kualiti air yang digunakan (konduktiviti, pH, kekeruhan, kemasinan, suhu, DO dan nitrat). Faktor yang paling penting yang memberi kesan yang besar ke arah kedua-dua taburan dan kepadatan Etak adalah jenis substrat. Dalam kajian inin menunjukkan substrat yang paling sesuai untuk *C.fluminea* ialah daripada ayak yang bersaiz 0.25mm dan 0.71mm yang mana mewakili pasir jenis halus kasar dan pasir halus.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Corbicula fluminea, also known as Asian calm is was from the phylum of Mollusca, categorized in the Bivalve class and in the family of Corbiculidae. It was known as 'Etak' in the Kelantan dialect of Malaysia. For Malaysians, Asian clam is a popular snack (Wei *et al*., 2013). 'Etak' is a popular foods in Kelantan which can be prepared in many ways, such as roasting and in soup (Nasarudin & Bahar, 2013). Etak can be sold in wet markets or sold at roadside stalls in Kelantan.

Asian clam can be found in the eastern Mediterranean, South East Asia, Africa and some place in eastern Australia (Kramer-Welt, 2008). A study claimed the primary place for Asian clam occurred outside its original distribution is in the Pacific coast of US. *C. fluminea* is viewed as one of the world's most invasive freshwater clam, having invaded North America, South America, Europe and northern Africa. Its reproductive capacity, early sexual maturity, short life span (Sousa *et al*., 2008) and early growth and high development rate permits it to quickly colonize and shape thick neighbourhood populations (Castaneda., 2012). In addition, *C. fluminea* is thought to be one of the most critical non- native invasive species in freshwater environments, showing extensive geographic scattering and invasive practices. Hence, it will competitively impact on native species such as macro-invertebrate communities. In addition it will decrease the phytoplankton biomass, change benthic habitats and add biologically available nitrogen and phosphorus to aquatic ecosystems (Caffrey *et al*., 2011).

Drifting is the most likely agents for its spread. In addition, the factors that increase the distribution of *C. fluminea* in one area are boating and angling. However it depends on the different spatial and temporal scales to identify the spread of the species (Lucy *et al*., 2012). The introduction and ensuing scattering of *C. fluminea* in aquatic biological communities is most likely a consequence of different human activities (e.g. balance water transport, sustenance asset, use of examples as fish lure, aquarium discharges, transport of adolescents and/or adults as a visitor interest or the adolescent byssal connection to boat hulls).

This bivalve species is typically found in well oxygenated waters and is intolerant to high salinity values, low pH and low calcium fixations (Crepso *et al*., 2015) but, its high reproductive ability make it more resilient and its population can recover quickly from events of catastrophic mortality (Simard *et al*., 2012). In addition, this *C. fluminea*, functioning as the filter feeder that can increase water clarity by removing broad quantities of planktonic food and fostering the distribution of macrophyte algae (Simard, 2012). The great variation in shell form and the colour itself are two characteristic to determine its species (Araujo *et al*., 1993) Moreover, *C. fluminea* has broad limits for regular scattering, the pediveliger and adolescents are inactively transported by fluvial or tidal streams, and also being additionally transported on the feet or quills of sea-going flying creatures. This sort of normal transportation might have a principal significance in the extent of its spread (Sousa, 2008)

1.2 Problem statement

Gunung Reng River is one of the well-known recreational spot in Kelantan and highly visited. Some of the activities carried out within the vicinity may directly or indirectly affect the aquatic entity particularly the distribution of clamps in Sg. Pergau at Gunung Reng. In this study the focal point was to determine the density and distribution of *Corbicula fluminea*, a species clamp in Kelantan located at Sg. Pergau at Gunung Reng. Very scarce study related with the abundance as the distribution of *Corbicula fluminea*. By establishing baseline data in Sg. Pergau of Gunung Reng, Kelantan, it may benefit the local authority in future river management.

1.3 Research objectives

This research was carried out with the following objectives:

1) To determine the density of *C. fluminea* in Sg. Pergau at Gunung Reng
2) To determine the distribution of *C. fluminea* in Sg. Pegau at Gunung Reng

1.4 Significant of the study

The significance of this study was to document the distribution and density of *C. fluminea* in the upstream of Sg. Pergau at Gunung Reng. The finding could be used as part of a larger study to document its density and distribution in Kelantan.

As it is the favourite freshwater clam in the state, the data could be helpful in monitoring its presence and if in decline, remedial and replenishment could be introduced as its traditional form, roasted and salted is a favourite among Kelantan people. In addition, its harvesting and sales contribute to the income of the locals.

CHAPTER 2

LITERATURE REVIEW

2.1 Morphology (*Corbicula fluminea*)

2.1.1 Juvenile morphology

Fertilization happens in the paleal cavity and larvae are incubated in the branchial water tubes where they are ensured in a supplement rich environment. Larvae are discharged into the water section and along these lines anchor themselves to residue, vegetation, or hard surfaces by means of an adhesive byssal thread structure. At the point when the larvae develop, the juvenile are discharged into the water and cover into the substratum substrate. Juvenile, are generally little, around 250µm, totally formed and effectively scattered by means of water streams and anthropogenic exercises (Sousa *et al*., 2008).

In spite of their little size, juvenile are furnished with a completely one created shell, adductor muscles, foot, statocysts, gills, and digestive framework (McMahon, 2002), as shown in Figure 1a and Figure 1b. The juveniles change into a pediveliger (shelled juveline furnished with a foot) and settle to the base at around 0.25 mm in size. Pediveligers can crawl around along the base and look for firm substrates where they attach (at around 1.0 to 1.5 mm in size) utilizing a brief byssus which eventually disappears. Juveline clam can achieve maturity in 3-6 months or around 6-10 mm in size, and achieve 10 to 30 mm in size amid their first year relying upon foodt accessibility and temperatures (Menninger, 2012)

2.1.2 Adult morphology

The Asiatic clam is a fascinating channel sustaining freshwater bivalve that feeds primarily on phytoplankton (McCaulou *et al*., 1994) .The adult *C.fluminea* can reach 50mm in length and be differentiated from others. For *C.fluminea*, the shell is ovate and deep at the hinge. The outside of the shell is regularly a yellow-green to brown in shading with thick, concentric rings. Besides, the internal of the shell is layered with polished, light purple nacre. In addition, they have three cardinal teeth in every valve with two parallel serrated teeth in every side of the right valve and one and only in every side of the left valve (Burkhead, 2001).

Asian clams have shot-lived life spanning which is 1-5 years and spawning 1-3 times per breeding season, depending on the biotic and abiotic factors (Sousa *et al*., 2008). In addition, the hermaphroditic adult have high fecundity, and the total average they can produce is between 35,000 larvae depending on the breeding season (McMahon, 2002; Mouthon, 2001)

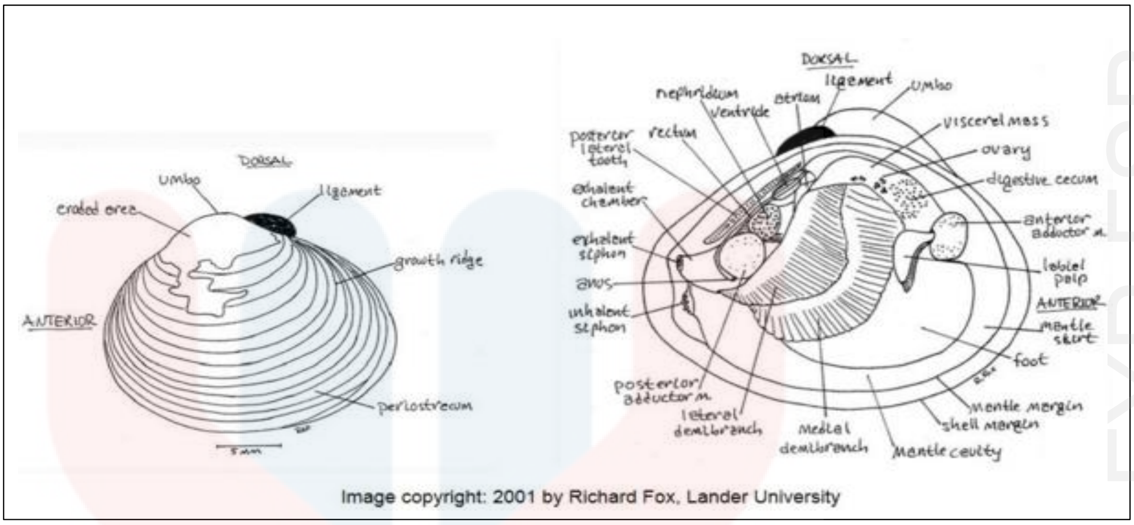

Figure 2.1 a: The internal (right) and external (left) identification body features of *C. fluminea* (Menninger, 2012)

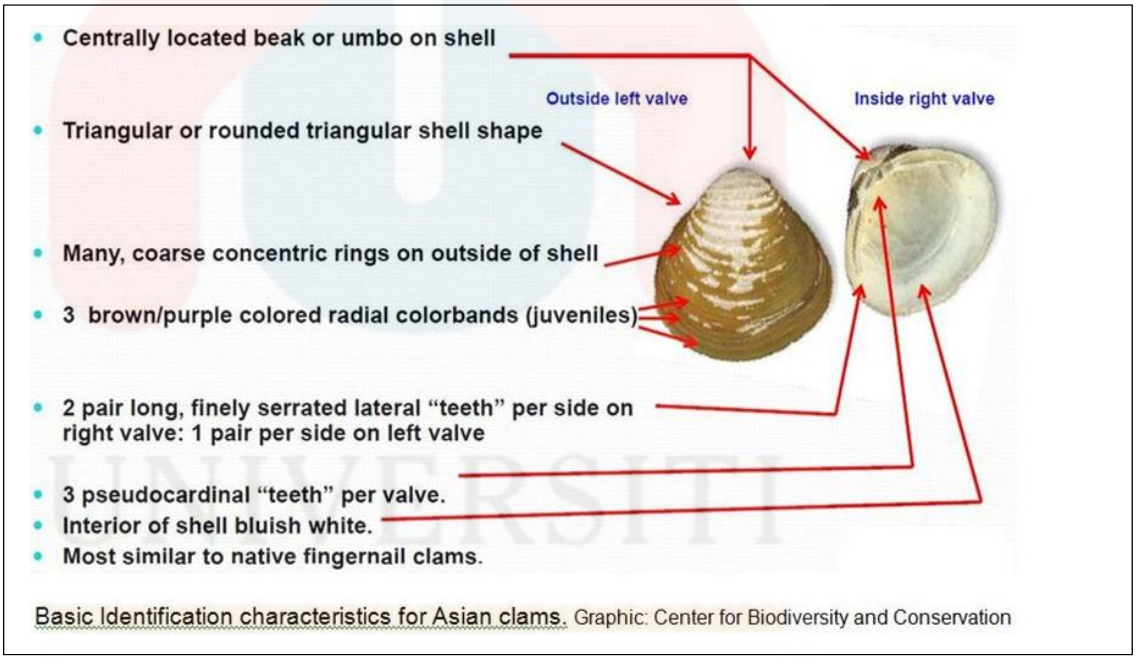

Figure 2.1 b: The basic identification characteristics for Asian clam (Menninger, 2012)

2.2 Life cycle

2.2.1 Reproduction

Full grown Asian Clams are bisexual and they occasionally self-fertilized. The young are incubated inside the wellbeing of the parent's shell, and are discharged in 4-5 days. The young microscopic pedivelligers head out along the substrate to new areas and connect to any accessible reasonable substrate with byssus filaments. The young that are incubated in the spring as a rule achieve sexual development by the fall, and may live for up to seven years. Asian Clams ordinarily spawn between July and September (Robinson, 2004). In addition, the other factor that contributes to the rapid growth of *C. fluminea* is carbon assimilation. This shows that carbon assimilation is be a great extent distributed to growth, about 60%, and 11%, for reproduction (McMahon, 1999)

- Asian Clams can discharge more than 320-387 quantity posterity day by day, contingent upon the conditions (McMahon, 1999)
- Water temperature extremes (above 370˚C and beneath 10˚C) can hinder reproduction (Robinson, 2004)

2.2.2 Reproductive biology

Corbicula fluminea is bisexual and equipped for self-fertilization; gonads contain matured eggs throughout the entire year. Spermatogenesis happens amid the reproductive seasons when temperatures ascend above 17˚ C (McCaulou *et al*., 1994). Juveniles are able to breed within 3-12 months of hatching at shell lengths of 6-10mm. However, they are periodic hermaphrodites that most frequently cross-fertilize. Importantly, Asian clam populations are often dominated by juveniles due to high fertility with high mortality rates going throught the lifespan (Adkisson., 2006). Life span varies with habitat, with a maximum reported life span of approximately 7 years *C. fluminea* can self-fertilize releasing up to 2,000 juveniles per day and more than 100,000 juveniles in a lifetime. Juveniles are only 1mm long when discharged and take one to four years to reach maturity. Adults can reach lengths up to 5 cm as shown in Figure 2.2

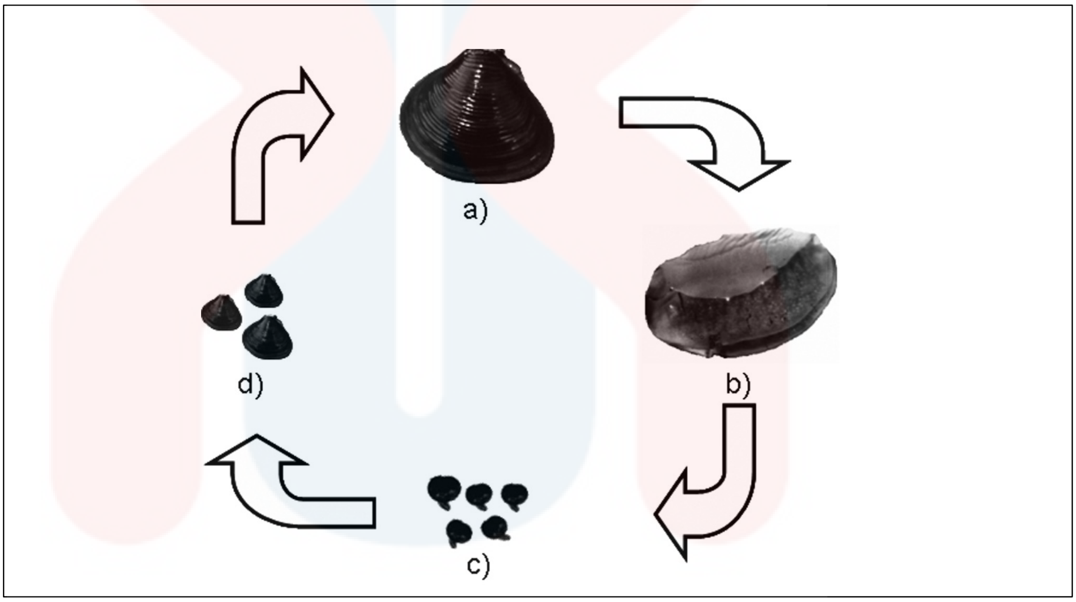

Figure 2.2: The life cycle of *C. fluminea*: a) adult specimen; b) inner demibranch with larvae; c) small juveniles recently released (with a completely developed foot and with the common D-shaped configuration) and d) small adults (Sousa *et al*., 2008).

2.3 Distribution factors

In spite of the fact that the exact pathways of intrusion by *C. fluminea* are unknown, but the distribution of this species due to high adaptability to various organic qualities. In streams, colonization in the downstream bearing is effortlessly to achieve for the juveniles since they will be transported by the present stream or by byssal connection to floating vegetation. Nonetheless, upstream development is thought to be by means of optional transportations by animals or man (CABI, 2015).

The little size of juveniles encourages transport by water ebbs and flows for long separations downstream and the connection to skimming surfaces and vegetation by means of a solid adhesive byssal thread (Barbour *et al*., 2013). One of the primary elements that influences the distribution and abundance of *C. fluminea* in the river is a suitable substrate. The best substrate for *C. fluminea* is sand, at times blended with sediment or clay. *C. fluminea* are in much lower densities on rocks and in residue, furthermore, as a rule they keep away from sediment under beds of submerged macrophytes (Lucy *et al*., 2012).

The first record of *C. fluminea* in the US happened in 1938 in Washington State along the shores of the Columbia River close to the town of Knappton (Figure 2.3). The original vector is obscure however numerous analysts suggest that it have been introduced by Chinese immigrants who used as a food source or it might have been presented accidently by means of the seafood trade when the Goliath Pacific Oyster was introduced to the US. Besides, it have been predicted that the distribution of the Asian clam will continue to spread throughout the continental US until the lower restriction, which is 2˚C (Foster *et al*., 2016). This is due to its normal and human mediated dispersal there are few geographic limits that will check its spread, except for physiological and ecological limitation to stop it. (McMahon, 2002)

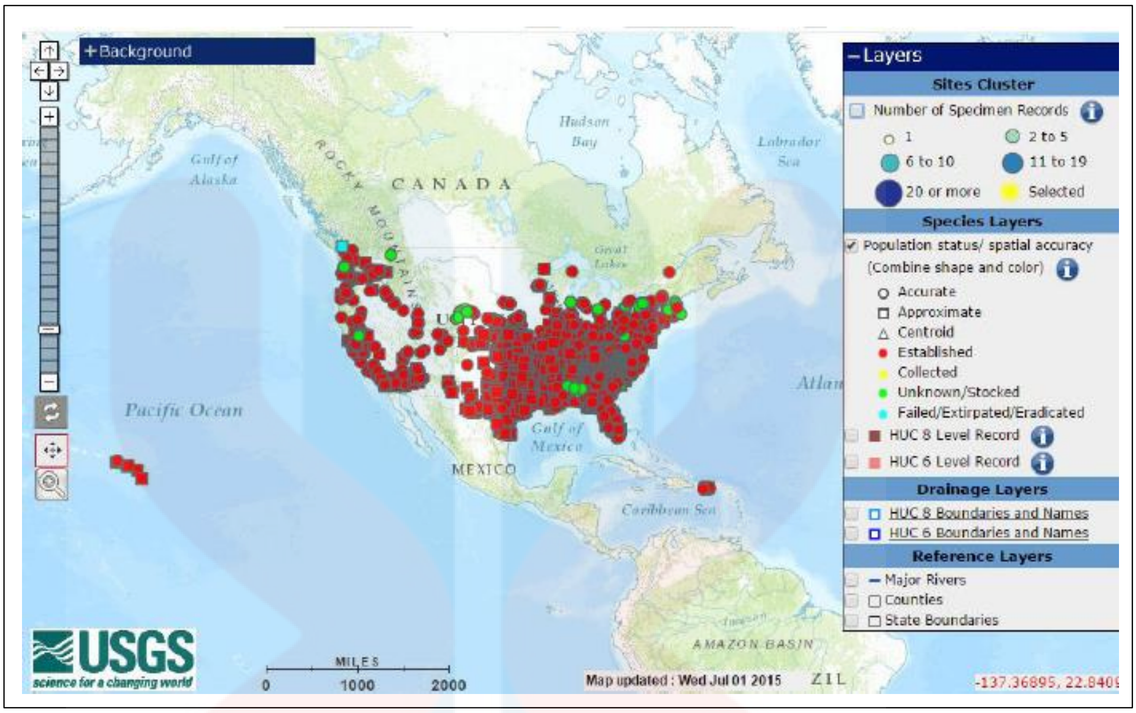

Figure 2.3: The distribution of *C. fluminea* in the United State (Foster *et al*., 2016)

2.4 Feeding Distribution

C. fluminea utilize filter and deposite feeding strategies, getting nourishment from natural matter in base sediments through deposited feeding or from suspended natural matter including phytoplankton, microzooplankton, and even their own veligers through filter feeding. Amid deposit feeding, *C. fluminea* utilizes cilia on its foot to gather organic matter from the sediment surface or interstitially while tunnelling (Freedman, 2013). This strategy, filter feeding, additionally encourages the bioaccumulation of natural toxins and overwhelming metals suspended in the water segment by *C. fluminea*. When nourishment sources in the water segment become exhausted, *C. fluminea* moves from filter feeding to deposit feeding (Hakenkamp *et al*., 2001) (Figure 2.4)

This adaptability and a fast rate of generation add to the clam's capacity to rapidly build up colonizing populaces in a wide scope of aquatic natural surroundings. The clam additionally adequately touches ciliates and is equipped for moving zooplankton groups to support copepods by specifically evacuating rotifers. In addition, the flexible feeding strategy provides the advantage to *C. fluminea* to enhance their success especially when the phytoplankton resources are scarce (Hakenkamp *et al.*, 2001).

Besides that, *C. fluminea* is as one of the successful invasive species due to its adaptations, which is its non-selective diet and this help this species to have exploit to its maximum, maximum exploitation of any available resources (Reid *et al.*, 1992).

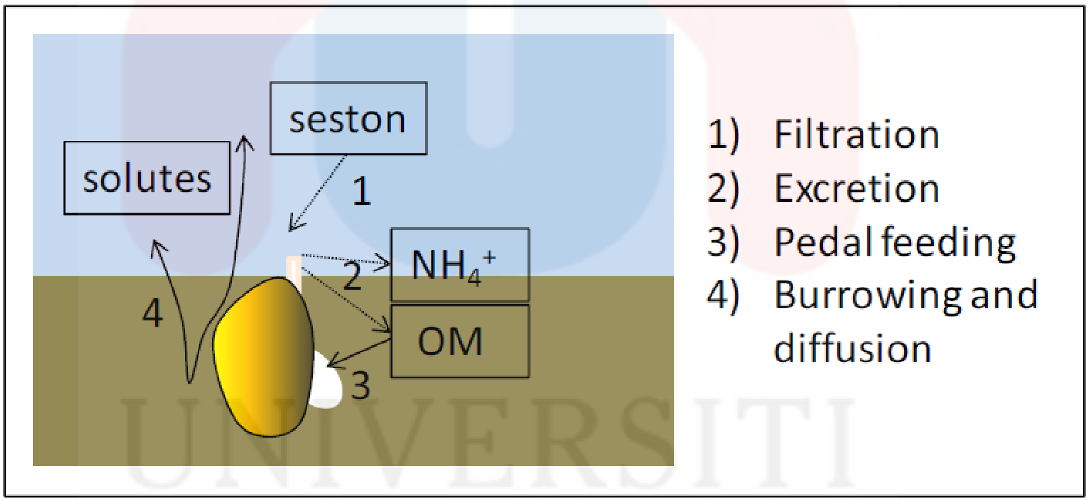

Figure 2.4: *Corbicula fluminea* behaviours (Kayla, 2013)

2.5 Habitat Characteristics

2.5.1 Preferred environment

C. fluminea densities inside of a water body will rely upon suitable substrate and nourishment accessibility, with more prominent populaces in trenches, waterways and lakes with a higher trophic level (Lucy *et al*., 2012) (Table 2.1). The Asian clam is suitable in well oxygenated rivers and oligotrophic lakes with sandy or gravel substrates though they are also found in turbid water, under large submerged boulders or in soft silts of deep lakes. Typically, this clam is found buried within the top 10-15 cm of the substrate in 2m to 40m of water with highest densities occurring between 3-10m depth. *Corbicula fluminea* is unique kind in their capacity to withstand an extensive variety of natural conditions (to a great extent because of valve conclusion), yet research on the physiological resistance of *C. fluminea* proposes a limitation in life history and development of populaces because of anaerobiosis. *Corbicula fluminea* are not able to keep up ordinary O_2 uptake under seriously hypoxic conditions, and this limits to shallow water with very much oxygenated natural surroundings (Wittmann *et al*., 2011).

Table 2.1: The water body and substrate composition for *C. fluminea* (Lucy *et al*., 2012)

Habitat	Density	References
Water body		
Lake	39-1278	Beaver *et al*., 1991
Reservoirs	30-796	Abbott, 1979; Dreier & Tranquili, 1981; Karatayev *et al*., 2003
Rivers	315-3206	Rodgers *et al*., 1979; Belanger *et al*., 1985; Boltovskoy *et al*., 1997
Streams	54-974	Leff *et al*., 1990; Arias, 2004
Canals	2255-16688	Eng, 1979; Marsh, 1985
Sediment type		
Rocks	0-327	Abbott, 1979; Leff *et al*., 1990
Sand, silty sand	54-1215	Abbott, 1979; Belanger *et al*., 1985; Leff *et al*., 1990
Shells	43	Karatayev *et al*., 2003

2.5.2 Water quality

Given their broad distribution, fast development, and capacity to filter and deposit feed, *C. fluminea* are good biological indicators of water quality. *Corbicula fluminea* can concentrate heavy metals and trace elements from the water to levels orders of size higher than levels in the water, and show a high resilience to introduction of harmful substances. While *C. fluminea* does not accumulate metals and trace elements from sediments to a calculable level, it is successful at accumulating poisons and pesticides from sediments. *Corbicula fluminea* is generally utilized as a part of ecotoxicological studies and may serve to help bioremediation of polluted systems (Doherty, 1990). In addition, water quality that are suitable for *C. fluminea* depend on temperature, salinity, dissolved oxygen and pH, although *C. fluminea* was lower in abundance and sometimes absence from the river is because, the salinity is above their tolerance levels.

2.5.3 Temperature

The range of temperature for this species is between 2-36 ºC. However, for reproduction, *C. fluminea* needs a temperature above 16ºC. However, they can withstand freezing conditions and have the capacity to reduce reproductive rate when exposed to lower temperatures (Robinson, 2004). Its higher metabolic rate enhances the clam's ability to reburrow rapidly when it is dislocated from substrates to avoid the clam from being damaged and protect it from predation. Also, the high metabolic level will increase the clam's capacity to invade unstable habitats, with have higher flow rates and greater suspended solids and sediments (Kramer, 2008)

2.5.4 pH

pH parameter indicates the acidity of the water sample. pH can be described as the measurement of the potential activity of hydrogen ions (H+) in the sample. The scale of pH measurement is between 0-14 of which 7.0 is considered as neutral. Solutions that indicate pH below 7.0 is considered as acids, while pH above 7.0 and up to 14.0 is considered as bases. In addition, the scale of pH is logarithmic which means that every change in one unit in pH represent a ten-fold change in acidity. For example, pH 6.0 is ten times more acidic than pH 7.0 and pH 5.0 is one hundred times more acidic than pH 7.0 (Brian, 2014)

2.5.5 Dissolved oxygen (DO)

Dissolved oxygen (DO) can be defined as the level of free, non-compound oxygen present in water body. This DO is an important parameter in water quality index because the DO can give impact on the organism and aquatic life in a body of water. This means that the very low and high level of DO can harm aquatic life and effects water quality (Kemker & Christine, 2013). In addition, dissolved oxygen in any water body is mainly a function of atmospheric oxygen which is that the oxygen is diffused into the water from the surface, oxygen produced by plants during photosynthesis. Also, the amount of dissolved oxygen in the water changes as a function of temperature, salinity, atmospheric pressure and biological and chemical processes (Richard *et al*., 2003).

The amount of oxygen that is dissolved in water depends on the times during the days and its seasonal patterns. Besides, the temperature, salinity and elevation also influences the amount of dissolved oxygen (RAMP, 2013). For an example, cold water can hold more dissolved oxygen compared to the warm water. Then, in seasonal season, winter and early spring, the dissolved oxygen concentration is high when the water temperature is low and the effect is reversed under high temperature (USGS, 2016). (GISD, 2005) stated that *C. fluminea* is usually found in high density in moving water, because this species required high level of dissolved oxygen. However, it is sensitive to pollution.

2.5.6 Suspended solid (SS)

Suspended solids are mostly contributed by soil particles washed into the water and contribute to turbidity in the river water. Excess amounts of SS indicate the effect of land erosion washed into the water body (Naubi *et al.*, 2015). When effluents enter water bodies, they have will attach to the suspended particulate and will also accumulate in the sediment at the bottom of water bodies. A suspended solid is good indicator for monitoring and detecting the pollution in aquatic systems. When the amounts of organic compounds in the suspended solid have increased, this shows that, the pollution in the water bodies also increases. Suspended solids vary in size, from approximately 10mm to 0.1mm in diameter (Hassan, 2010)

2.5.7 Salinity

All the natural waters contain dissolved salt. The low and high concentration of salts show either the water is suitable for drinkable or irrigation without need for special forethough. The sources of salinity in the river water are from dissolved minerals, excessive irrigation and salt H_2O. It can be form naturally from the geo-chemical weathering intrusions (Silva & Uchida, 2000). High concentration of salinity is one of the major problems in all river in the world (FAO, 1976). This is because when the salinity level in the river water passes 1000mg/l, the usefulless of water decreases as it is not suitable for human consumption (WHO, 1997). In the article by (GISD, 2005), have been stated that *C. fluminea* can tolerate to the salinities where the level is up to 13ppt for a short periods.

2.5.8 Turbidity

Turbidity is the amount of the cloudiness in the water. Turbidity of every river differs according to the amount of the mud and silt. When there is difficulty to see through the water, this is shown high in turbidity level, when the water appears to be completely clear this condition shows low turbidity. The different between high and low level of turbidity is because of:

1. Silt, sand and mud
2. Bacteria and other germs
3. Chemical precipitation

Corbicula fluminea is one of the invasive species that have speciality to tolerate with the environmental changes in aquatic system, but high turbidity level could affect the mortality rate of the species when exposed to the condition when the turbidity level above 150 nephelometric turbidity unit (NTU). In addition, higher turbidity level may cause siltation and this will dramatically affect the aquatic life (Avelar *et al*, 2014).

2.5.9 Conductivity

Conductivity is the measure of the capability of a solution such as water in a stream to pass an electric current. Significant increase in conductivity maybe an indicator that polluting discharge have entered the water. Freshwater is not highly conductive of electricity unless it has certain types of soluble materials in it such as dissolved minerals, salts and acids. Meanwhile, the sea water was much more conductive than freshwater due to its high concentration of dissolved salt. Freshwater river ideally should have a conductivity between 150 to 500µS/cm to support diverse aquatic life (Sharon, 1997)

2.5.10 Nitrate

When plants and animals die or excrete waste, this nitrogen is released into the environment as NH4+ (ammonium). This ammonium is eventually oxidized by bacteria into nitrite (NO2-) and then into nitrate. In this form it is relatively common in freshwater aquatic ecosystems. Nitrate thus enters streams from natural sources like decomposing plants and animal waste as well as human sources like sewage or fertilizer. Natural levels of nitrate are usually less than 1 mg/L. Concentrations over 10 mg/L will have an effect on the freshwater aquatic environment (Sharon, 1997).

2.6 Substrate composition

2.6.1 Sand, silt and clay composition

From the article (John, 2007), stated that the suitable substrate composition for *Corbicula fluminea* was in >40% fine sand, <45% silt, and 8% organic content. This substrate shows high in density and biomass.

2.7 Densities

C. fluminea densities depend on river conditions that include suitable substrates and availability of food. The greater the population of *C. fluminea* in that particular area, the greater is the tropic level. There are many factors that make the population in the river in high and one of them is human activity such as boating and angling. The natural effects of *C. fluminea* are related with their role as bio filters, and are accordingly controlled by their filtration rate and the general population thickness in a given water body (Lucy *et al*., 2012).

Asian clams happen in high densities over a large area, they can filter and channel large volumes of water in short period of times, along these lines depositing vast amounts of organic matter on the base, expanding benthic pelagic coupling, enhancing water clarity and competing with zooplankton for food. Both the economic and biological effects of *C. fluminea* will rely upon their population density in a given water body, which thus relies on upon the predominant substrate sort, food accessibility, oxygen focus, temperature administration and the water body morphometric (Karatayev, 2005).

2.8 Negative impact on irrigation and water supply

The presence of this species, *C. fluminea* in a particular area is due to the deliberate or accidental introduction that comes from the activities of the humans. In some areas, *C. fluminea* cannot grow and reproduce due to the unsuitable condition there. However, in some situations, the *C. fluminea* can adapt to the environment, grow and reproduce, and this is a factor for its spread. However, C.fluminea has a habit of clogging irrigation and water supply systems. Irrigation system can be defined as a system that include earthwork, multi-outlet pipelines, and water control structures that have been installed to distribute water by surface means (NRSV, 2011).

This clam also interfere with riverbed gravel-mining process by fouling gravel aggregated used in cement. For an example, when river sand is poured in the cement processing the cement becomes porous due to the presence of these clams. It can also clog the narrow gauge piping of condensers and reduce the flow of water in the drainage (Minchin, 2008). In agriculture, there are many types of irrigation systems used to water the crops and the presence of *C. fluminea* causes clogging in pivot pipelines and hydrants which reduces the water flow and hence reduce irrigation (Rosa *et al*., 2014). Summary of positive and negative effect of *C. fluminea* is shown in Table 2.2

Table 2.2: The positive and negative effects of the introduction of *C. fluminea* (Sousa et al., 2008)

Positive effects	Negative effects
• Act as the shelter and substrate for others aquatic life (Crooks, 2002; Gutierrez *et al*., 2003) • As nutrient and food for pelagic and benthic species (Cantanhede *et al*., 2008) • High filtration rates make decrease euthorophication rates (Phelps, 1994; McMahon, 2002) • High filtration rates which can increase water clarity (Phelps, 1994) • Function as bioindicator for ecotoxicological (Doherty, 1990; Inza *et al*., 1997; Cataldo *et a*l., 2001b)	• Displace habitat for others aquatic life (Vaughn & Hakenkamp 2001) • Resent of *C. fluminea* will impact the recruitment for others species by their suspension and deposi feeding (Yeager *et al*., 1994; Hakenkamp & Palmer 1999) • Others species need to compete for benthic food (Sousa *et al*., 2005) • Due to high filtration rates, it will decrease planktonic food (McMahon 1991; Strayer 1999) • Cause contaminants by bioaccumulation & bioamplification (Narbonne *et al*., 1990; Tran *et al*., 2001, Cataldo *et al*., 2001 a and b; Achard *et al*., 2004)

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Study area

The identified study area for this research was Sg. Pergau at station Gunung Reng River, Kelantan. This selected location was located at southwest of the state of Kelantan. This river was the location to be chosen because, since the first populations of *C. fluminea* are observed there. The study area is 200m along the river with a total of three station (upstream, middle and downstream) along the study area consists of 10 sampling points and the sampling was repeated three times.

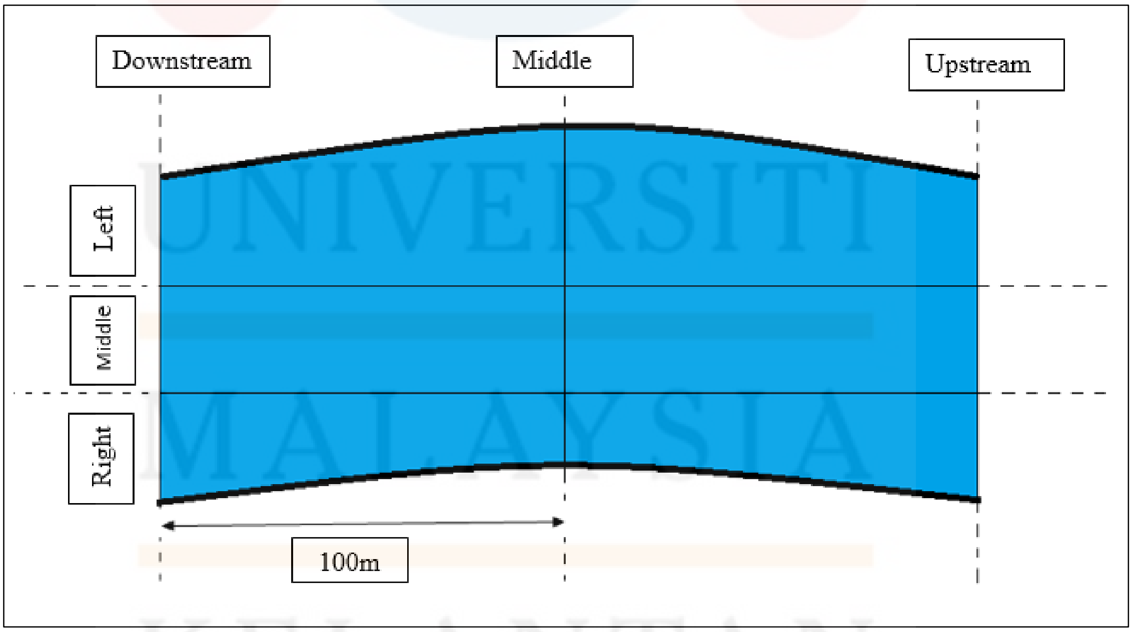

Figure 3.0: The study area consists of 3 stations (upstream, middle and downstream) along 200 meters of Sg. Pergau at Gunung Reng, Kelantan.

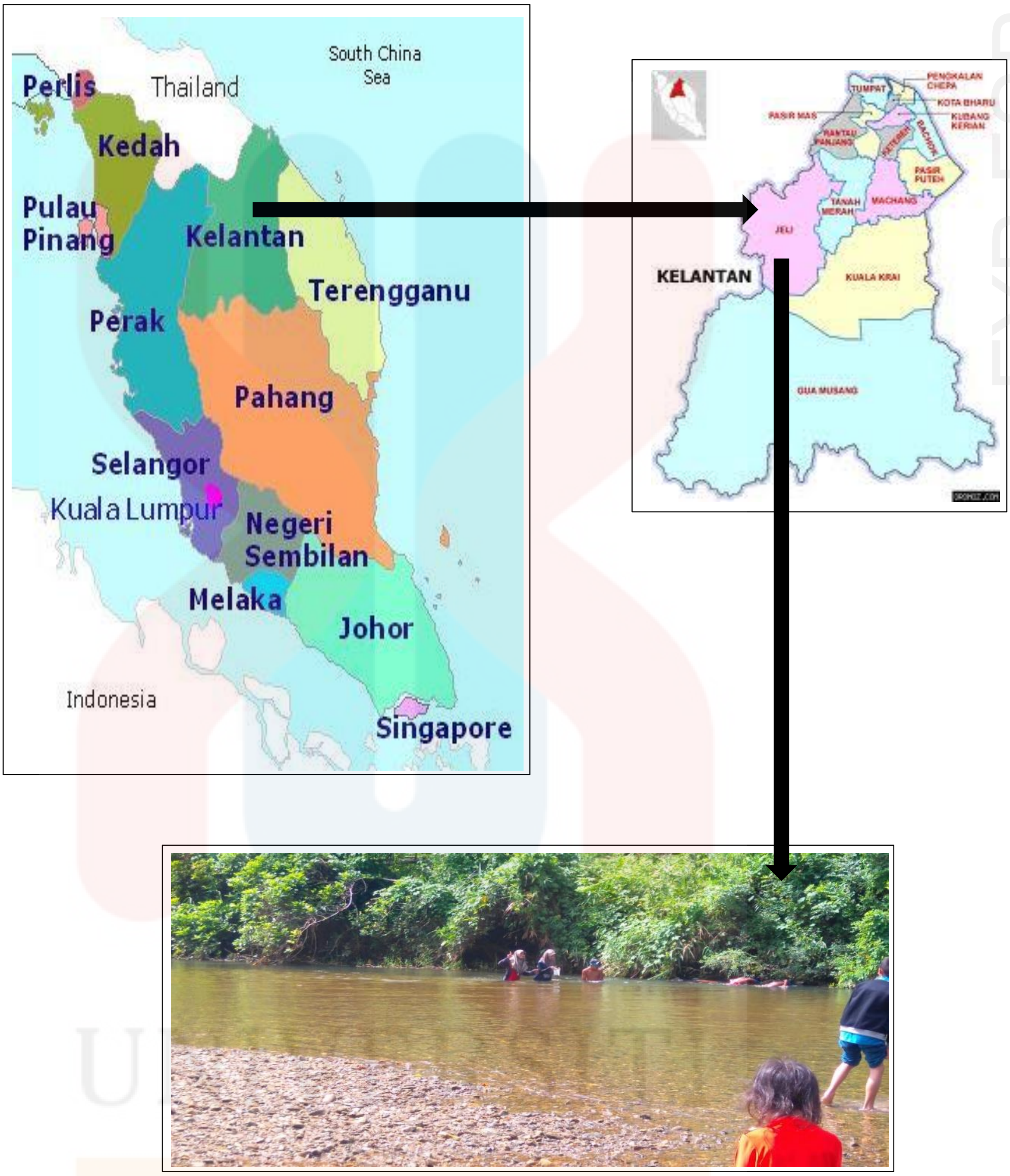

Figure 3.2: Location of study area, Sg. Pergau at Gunung Reng, Kelantan.

3.2 Data collection

3.2.1 Preliminary assessment

Preliminary assessment is an important tool for receiving the information about a site and its surrounding. In this research the preliminary assessment was conducted in term of substrate composition and also 7 parameter of water quality samples. Both of substrate composition and water quality collected were to identify either every points selected have the same characteristics, sizes and level of water quality for every point that have been chosen along 200m of Gunung Reng River.

For substrate composition, the substrate sample from each station was retained for granulometric analysis (Rory *et al*., 2014). Sample were sun dried for 24 hours and 500g of sample was shaken on a mechanical sieve shaker in test sieves ranging from 2.36 mm to 0.02mm unit mesh. First of all, a representative weighed sample, 500g was poured into the top of the sieve which has the larger opening of 2.36mm. The sieve was arranged according to their screen opening size, which each lower sieve in the column must has the smaller screen opening than the one above it. Lastly, the bottom of the sieve, there were a round pan, called receiver. Then, the column was placed into the mechanical shaker. This test of sieve shaker provides both circular and tapping energy with uniform mechanical motion to ensure consistent result (Sonaye & Baxi, 2012). In this experiment, the shaker was set for 10 minutes for every process. After the shaking was complete, the sample in each sieve was weight. The weight of the samples for each sieve then divided by the total weight to get the percentage retained on each sieve.

3.2.2 Sample collection

The bivalve, *C. fluminea* were collected by sieving the sediments through the sieve for Etak in size of 17.85m^2, at random point. At every point, the samples were taken triplicates to take the average value. However, the choice of the sampling was depends on the water depth, water transparency and flow of velocity (Caffrey *et al*., 2011). This sieve for Etak used shows the covering area cover for collecting the *C. fluminea* at the selected points.

The *C. fluminea* within each quadrat were handpicked and retained in marked zipper bags plastic. The conventional morphometric characteristics, which were, shell height (H- umbo to gape) and length (L-anterior to posterior margins of the shell) of each specimen were measured to the nearest 0.1 mm using vernier caliper. The total shell length was used as a standard size measure for statistical adjustment of the measured variables (Araujo *et al*., 1993). Besides, the weight of asian clams was also recorded to know the density of population *C. fluminea* at every points.

3.2.3 Sample measurement

Two measurements are taken for every *C. fluminea* utilizing vernier calipers. Measurement 1 is the longest separation from the umbo, or shell hinge, to the edge of the shell opening. Estimation 2 is the longest separation from the anterior to posterior edge (Wittmann *et al*., 2011) (Figure 3.1 and Table 3.1).

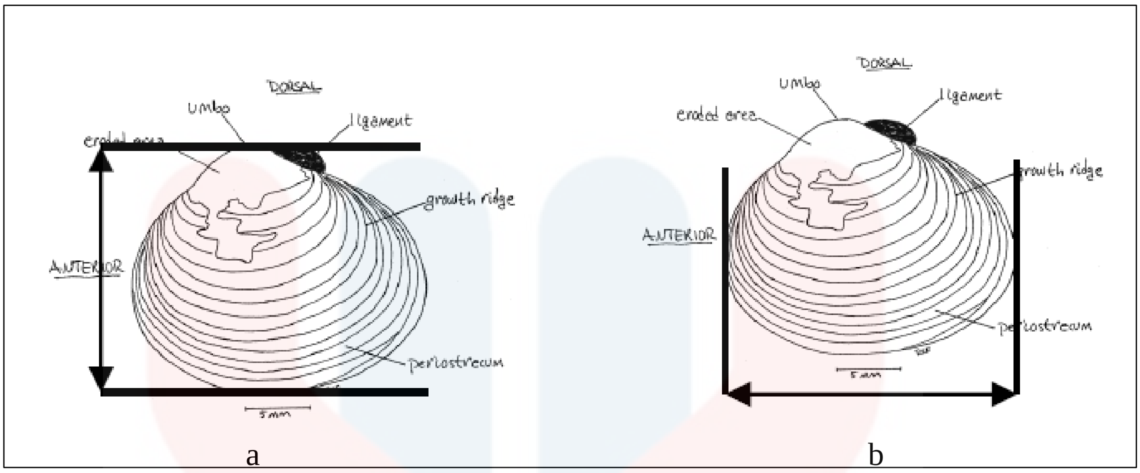

Figure 3.3: The measurement for *C. fluminea* for data collection. Measurement 1 for (a) and Measurement 2 for (b). The accuracy of weighing was 0.01 g, and the morphological variable was 0.01 mm using a vernier caliper (Wang *et al*., 2014)

Table 3.1: Biological measurement of *Corbicula fluminea* used during the experiment

Biological measurement	Large size/mm	Medium size/mm	Small size/mm
Shell length	28.194±2.110	24.238±1.514	19.310±1.137
Shell height	25.514±1.961	22.072±1.333	17.701±1.438
Shell width	17.084±1.494	15.094±1.129	12.884±1.104
Soft tissue dry weight	1.310±0.219	0.903±0.169	0.526±0.071
Shell dry weight	21.847±2.627	15.132±1.766	7.684±0.665

(Xiao *et al*., 2014)

3.2.4 Water Sampling

There were 3 station selected from Gunung Reng River whish was upstream, middle and downstream of the river. in this study, six parameter was identified the concentration using YSI instrument, which was conductivity, pH, temperature, DO, salinity and turbidity, while for lab analysis was made for nitrate to know the concentration of nitrate at each point selected for collection of *C. fluminea* samples. Sampling for nitrate was conducted and water samples was brought to the lab for analysis.

Before sampling, the ice box is completely filled with ice. The ice box is to be fully covered with ice at all times by constant replenishment. Extra ice is brought contained in an ice box for this purpose. Next, disposable gloves were used at all times during sampling to prevent any contamination. The sample bottles were labelled with station number, date and time. Furthermore, the collected water samples were filled carefully to avoid any air bubbles and then were stored in the ice box immediately for the lab analysis.

3.3 Data Analysis

Statistics is a way about data that are variable where implied both data and statistical methods. Statistic involved with the treatment of numerical data obtained from the group of individual. Mean is used in calculation of average measured of central tendency. In this research the frequency bar chart for length of *C. fluminea* was getting from SPSS software. While, for the density of C. fluminea, the data was insert in Excel and the graph will generated in Excel software.

For sieve analysis of substrate sample, the weight of the sample of each sieve then divided by total weight of the sample to give the percentage retained at each sieve.

% retained = (W_{sieve}/ W_{total}) x 100% (Sonaye & Baxi, 2012). Where W_{sieve} was the weight of sample in each sieve and W_{total} was the total weight of sample.

CHAPTER 4

RESULTS AND DISCUSSION

In this study, it have been found that the sample of *C. fluminea* collected were all from the middle river, but only in left bank of the river. Hence in this study, will discuss more in the relationship of distribution, density of *C. fluminea* with substrate size and seven water quality.

4.1 Substrate composition

Based on Table 4.1, shown that the substrate size in three different locations, which was downstream, middle and upstream. From the table, its shows that the right, middle and left side when we were against the flow of the river. Hence it can be said that, from the right and middle of the river, the substrates size was more in the sieve with the opening was larger than the left side of the river. While the left side on the river, the highest substrate retained at the sieve was from sieve, 0.25mm and 0.71 mm. Both of the sieve size contain sand in category of sand-coarse and sand-fine. From the three location, downstream, middle and upstream, the average substrate for every sieve size was have no different. As the fact said that, *C. fluminea* was highly populated at an area which the substrate composition was in range of >40% fine sand, <45% silt, and 8% organic content (John, 2007).

According to the Table 4.2 below, its shows that the substrate characteristic according to the Wentworth Grain Size Chart. In sieve size of 2.36mm, the substrate was in category of pebbles (fine granules). While 1.18mm, 0.71mm, 0.50mm, 0.25mm and 0.125mm was from sand which each of the stated sieve size was very coarse, coarse, medium, fine and very fine sand respectively. In addition, according to Wentworth Grain Size Chart silt (coarse) and clay was from the sieve size of 0.045 and 0.02 respectively.

Table 4.1: The substrate size in downstream, middle and upstream of Gunung Reng River

Sieve size's (mm)	Weight (%)								
Conversion 1μm = 0.001 mm	Downstream			Middle stream			Upstream		
	Right	Middle	Left	Right	Middle	Left	Right	Middle	Left
2.36	43.64	31.62	4.50	43.82	31.71	3.81	43.43	31.94	4.22
1.18	26.35	27.42	8.07	25.52	27.46	7.72	26.05	27.60	7.42
0.71	14.10	21.78	33.44	14.11	21.37	34.04	14.23	21.4	33.21
0.50	10.15	8.62	11.29	10.24	8.92	11.23	10.37	8.64	11.89
0.25	3.21	6.02	35.83	3.40	6.55	36.18	3.41	6.16	36.00
0.125	2.50	4.43	6.62	2.85	3.88	6.81	2.44	4.17	7.04
0.045	0.03	0.07	0.18	0.03	0.07	0.14	0.03	0.05	0.15
0.02	0.02	0.03	0.05	0.02	0.04	0.01	0.04	0.02	0.06
Pan	0.01	0.01	0.02	0.002	0.002	0.04	0.004	0.004	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.2: Substrate size according to Wentworth Grain Size Chart

Sieve size (mm)	Substrate Category
2.36	Pebbles-Fine granules
1.18	sand-very coarse
0.71	sand-coarse
0.50	sand-medium
0.25	sand-fine
0.125	sand-very fine
0.045	silt-coarse
0.02	clay

Based on Table 4.1, it show that the composition of fine sand retained at sieve size 0.25mm (sand-fine) for each downstream, middle stream and upstream was lower than 40%. As said by (John, 2007), the composition of fine sand suitable for *C. fluminea* was greater than 40 %(fine sand). However, in the left side of middle stream there was *C. fluminea* sample collected this show that the species could withstand with the substrate size even though (John, 2007) said in the journal that the suitable substrate composition for *C. fluminea* was greater than 40% of fine sand.

As shown in Table 4.3, in upstream and downstream of the river, there were no density of *C. fluminea* recorded even though the substrate composition and size was no different in every left side of each upstream and downstream of the river. This is because, in both upstream and downstream of the river, maybe the harvesting system of *C. fluminea* was high that make the numbers of this species decrease. As the villagers at Kampung Gunung Reng said that, at the study area, there were ‘Etak’ and this species was the favourite food among the villagers. It will be one of the factor that make the density of Etak at upstream and downstream of the river was decrease.

Besides, as the method in this study was in random sampling, it maybe the points that I selected to collect Etak was exactly no Etak present at that points.

From Table 4.1, either at upstream, middle or downstream, every right and middle of the river was higher in the numbers of pebbles which was fine granules and the sand was in categorize of very coarse. While in the left side of the river for upstream, middle and downstream, that prove the highest percentage of weight retained in the sieve size of, 0.71mm and 0.25mm. Both of the sieve size was sand (coarse) and sand (fine) respectively. Besides, when the substrate particles size was increases, especially the largest gravel, it will slowed *C. fluminea* burrowing speed and impaired horizontal movement. In addition, freshwater mussels have been known that they were move only in very small distance over the course of a year (Balfour& Smock, 1995)

4.2 Water Quality

From the Table 4.3 below, its shows the relationship of *C. fluminea* and the chemical parameter for water quality that have been chosen. Seven parameters that have been chosen to conduct this study which were conductivity (µS), pH, temperature, salinity, DO, turbidity (NTU) and nitrate. Five parameters except for pH and DO was compared the concentration to NWQS and DOE water quality index classification for both pH and DO. NWQS defined six classes (I, IIA, IIB, III, IV and V) for river water classification based on the descending order water quality, Class I being the 'best' and Class V being the 'worst' water quality.

Table 4.3: Relationship of *C. fluminea* with seven parameters of water quality.

Station	Numbers	Weight (g)	Chemical parameter		WQI (Class)
Downstream	0	0	1)Conductivity (µS/cm)	0.038	I & IIA
			2) pH	7.18	I
			3) Temperature (^{0}C)	29.23	-
			4) Salinity (Sal)	0.01	I
			5) DO (mg/l)	3.52	III
			6) Turbidity (NTU)	2.66	I
			7) Nitrate (mg/l NO_3^-)	0.15	-
Middle stream	166	77.3			
			1)Conductivity (µS/cm)	0.026	I & IIA
			2) pH	6.44	I
			3) Temperature (^{0}C)	28.95	-
			4) Salinity (Sal)	0.01	I
			5) DO (mg/l)	3.71	III
			6) Turbidity (NTU)	2.57	I
			7) Nitrate (mg/l NO_3^-)	0.14	-
Upstream	0	0	1)Conductivity (µS/cm)	0.038	I & IIA
			2) pH	6.59	I
			3) Temperature (^{0}C)	26.26	-
			4) Salinity (Sal)	0.02	I
			5) DO (mg/l	2.54	IV
			6) Turbidity (NTU)	2.06	I
			7) Nitrate (mg/l NO_3^-)	0.10	-

Table 4.4: National River Water Quality Standards River Classification (DOE, 1986)

Class	Definition
I	• Conservation of natural environment. • Water supply I- Practically no treatment necessary (except by disinfection or boiling only). • Fishery I- Very sensitive aquatic species.
IIA	• Water supply II- Conventional treatment required.

	• Fishery II- Sensitive aquatic species.
IIB	• Recreational use with body contact
III	• Water supply III- Extensive treatment required. • Fishery III- Common of economic value, and tolerant species; livestock drinking.
IV	• Irrigation
V	• None of the above

For conductivity, the highest value recorded was from downstream and upstream of the which both of the station recording value was 0.038(mS/cm). For station 2 the value that have been recorded was 0.026 which the different between the two station was 0.012 (mS/cm). Conductivity was one of the important water quality parameter used to identify the volume of influence of runoff and effluent discharge in the aquatic system. Besides, conductivity level in the river give us the information on how well a solution conduct electricity. This is because there were salts dissolved in the water that make the river water ability to conduct electricity. Aquatic life cannot tolerate large increase in the saltiness of the solution. Low conductivity (0-200 µS/cm), mid-range conductivity (200 to 1000 µS/cm) and high conductivity (1000 to 10,000 µS/cm) was an indicator of saline conditions. From the result obtained, the conductivity level in Gunung Reng River can be categorized as Class II and Class III for the three stations (upstream, middle and downstream) according to NWQS. However, the conductivity level here was still within the permissible limit where river water with conductivity less than 1000 mS/cm was still suitable for either aquatic life or other water inhabitants.

As we know the standard parameters that shows whether the river was acidic, neutral or bases was by determining the range pH value. The solution that indicate pH 7 was neutral. While pH below 7.0 is considered as acids, above 7.0 and up to 14.0 is considered as bases. From the data that have been tabulated, its shows that middle stream and upstream both were acidic condition with 6.44pH and 6.59pH respectively. While in downstream, the pH was recorded at pH 7.18. From the Table 4.3, the pH reading of river water at downstream have high potential for massive invasion while for both middle and upstream was 6.44 and 6.59 respectively, this reading make the potential for nulsance invasion being moderate. When compared to DOE water quality index classification, this three station (upstream, middle and downstream) the pH can be classified into Class I, which mean that the pH value at Gunung Reng river was good in the term of standard level of good water quality.

In term of temperature, the highest temperature recorded in this study was from the downstream station which was 29.23 ^{0}C. Temperature at middle and upstream of Gunung Reng River was 28.95 ^{0}C and 26.26 ^{0}C respectively. As we know that *C. fluminea* was able to withstand freezing conditions, but it will affect the reproduction process when exposed to lower temperature which was below 10˚C. From the result that have been recorded, its shows that the temperature for 3 station selected was not exceed the standard limit. From (Saucedo et al., 2004) concluded that the small size of *C. fluminea* experience little energy loss at lower (4-11˚C and 11-18˚C) and upper (25-32 ˚C) temperature ranges and is capable of performing seasonal compensation to maintain their capacity to survive in their range of temperature tolerance. An adequate metabolic temperature range for small *C. fluminea* may lie between 18-25 ˚C because of significantly increasing OCR with the increasingly temperature.

Salinity shows either the concentration of the water salinity was high or low that determine the suitability of the water for the human activities or for the aquatic habitat. The salinity concentration that have been recorded at the Gunung Reng river, along 200meters was 0.01(Sal) for both downstream and middle stream. Which shows the concentration for both of them was the same. For upstream of river the different was only 0.01(Sal) which the concentration for upstream was 0.02(Sal). According to the NWQS, this salinity concentration for three stations can be classified as Class 1 which Class I was the 'best' water quality recorded. Based on Table 4.3, it can be said that, the salinity level of river water at Gunung Reng River was suitable for *C. fluminea* to live, as the data collected for salinity was in between 0.01 and 0.02Sal. According to (Sousa et al., 2008) *C. fluminea* could tolerate salinities ranging from 0% to 5%.

Dissolved Oxygen or as known as DO (%) shows that the amount of oxygen dissolved in water and it was non compound oxygen. The higher DO value showed the water quality was good and represent healthy ecosystem. The highest concentration of DO (%) was in the middle stream which the concentration was 48.3%, followed by downstream of river which the concentration was 45.9%. In upstream of river, the concentration for DO (%) was the lowest which the data collected by the YSI was 31.4%. The reading recorded for DO (mg/l) was suitable for *C. fluminea* as the DO (mg/l) was in average 3.26 mg/l. *C. fluminea* could not withstand the DO lower than 0.5 mg/l, however when the DO level was larger than 6mg this species have higher potential for massive invasion. When compared to DOE, upstream and middle stream stations can be categorized as Class III while concentration DO in downstream as Class IV. From this it can be said, the lower concentration DO recorded could be from the discharge of organic matter and nutrient-rich industrial effluents.

The sixth chemical parameter that used in this research was turbidity (NTU). Concentration of turbidity in the river water was studied to determine the clarity of the water .In this research, 2.66 NTU was the highest concentration of turbidity recorded which the reading was from the downstream. The lowest concentration recorded was in upstream which the concentration recorded was 2.06 NTU. However, according to

NWQS the turbidity value for the three stations was in Class I. Turbidity level was very important in the river because when the level of turbidity increase, it will affect the mortality of the species when the reading was increase to and exceed 150 NTU. From the study, it can be said that Gunung Reng River was in low level of turbidity and will not give effect to the aquatic life especially *C. fluminea*. However, the changes in water turbidity will have significant impact to *C. fluminea* because their function as a filter feeder will depend on the stable water and water quality condition to regulate their physiological functions (Neves et al., 2014)

For nitrate parameter, its shows that there was no big different in the value recorded among the upstream, middle and downstream. Which the value recorded was 0.15, 0.14 and 0.10 mg/l NO_3^-respectively. In nitrate at downstream, middle and upstream of the river, this show that there was no big different of nitrate value. In downstream and upstream there is no *C. fluminea* sample recorded. In this study, the nitrate value may be from the agriculture activities near the river. This is because, the villagers at Kampung Gunung Reng was used fertilizer which help the farmers to produce more crops with lower food price.

4.3 Shell Length Frequency of *Corbicula fluminea*

From the Figure 4.1 below, the bar chart represented the frequency for every length of *C. fluminea* collected at middle stream (left side when facing against the flow) of Gunung Reng River, Kelantan. From the bar chart its shows that the highest frequency of *C. fluminea* was at 11.90mm which the frequency was 32 numbers. The shell length of this species collected was in range from 11.00mm which the lowest shell length, and the highest shell length was 12.50mm. Meanwhile, the others shell length of this species was in between the lowest and the highest shell length stated.

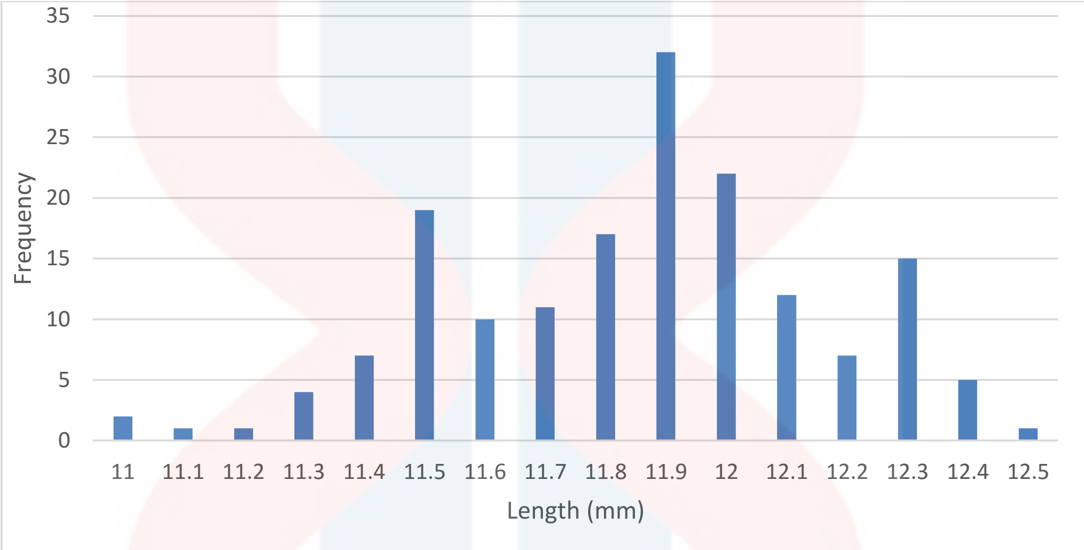

Figure 4.1: Total length frequency at middle stream and left side of the river with the total numbers collected was 166

From the Table 3.1, have been stated the range of shell length. The range of shell length from the larger, medium and small size was according to the guideline of 28.194±2.110 (mm), 24.238±1.514 (mm) and 19.310±1.137 (mm) respectively. Meanwhile, all the *C. fluminea* found in middle stream (left side of the river) was all in small size. The shell length frequency was determined the size distribution of *C. fluminea* (Sheehan, 2014). Hence, the size distribution of *C. fluminea* was only in small size. It maybe happened, this species was not from the Gunung Reng River however they were from the Pergau River Dam and have been brought through the high flow of river when the water from the Pergau Dam was released.

4.4 Density of *C. fluminea*

Based on the Figure 4.3 below, it show the density of *C. fluminea* at the middle stream of the river (left side when facing against the flow of river) which the total of 6 points. The highest density among the 6 points was from point 2 which the density calculated was 749.7m^2 and the lowest density was from point 1 which the density was 160.65 m^2. The density for the others 4 points was in the between the density value calculated in point 1 and point 2, as the both of the point recorded the lowest and highest density of *C. fluminea* at Gunung Reng River. Therefore, the density for point 3, point 4, point 5 and point 6 was 517.65 m^2, 642.6 m^2, 214.2 m^2 and 678.3 m^2 respectively.

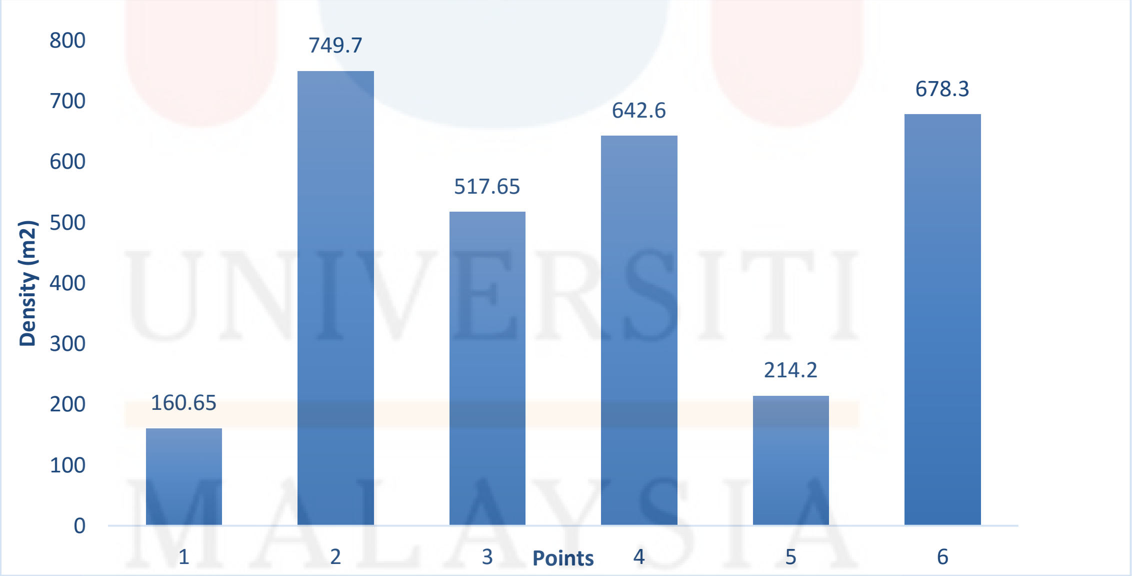

Figure 4.3: Graphical bar chart represent the different density of *C. fluminea* collected at middle stream (left side when facing against the flow) of study area.

It can be said that the total 6 point showed the density of *C. fluminea* was not affected by water quality. It is because in upstream, middle stream and downstream, 7 parameters that have been tested was shows no different among the 3 stations stated. However, the one most important factor that affect the distribution of *C. fluminea* was the substrate size. In middle stream, the point randomly selected to collect the sample was from the left side of the river when facing the flow. The characteristic of the substrate in the left side of the middle stream was higher in sieve size of 0.71mm and 0.25mm (Table 4.1) which the substrates was sand (coarse and fine sand). Both of the sand characteristic was the suitable substrate size for *C. fluminea*. Furthermore in this study, in Table 4.1 shows that, the substrate size in every left side of upstream, middle stream and downstream shows no different, however there was no *C. fluminea* sample collected due to the point selected in upstream and downstream of the river. In downstream and upstream of the river, the point randomly selected in the right and middle side of the river when facing against the flow of the river. The substrate size in right and middle side of the river was larger in greater size of substrate. As shown in Table 4.1, the greater weight retained was in the sieve size of 2.36mm and 1.18mm which the substrate size showed that the substrate was in category of pebbles (fine granules) and sand (very coarse). The suitable substrate size for *C. fluminea* was sand (fine).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study was to determine the density and distribution of *C. fluminea* at Sg. Pergau at Gunung Reng. It can be concluded that in this study, both distribution and density of *C. fluminea* in Sg. Pergau at Gunung Reng was not affected by water quality tested throughout this study. However, their distribution and density was heavily influenced by substrate type. Substrate type in the river was one of the indicator of present or absent of *C. fluminea*. From this study, it proved that, the best substrate for *C. fluminea* was sand, sometimes mixed with silt. Form this study, it showed that the highest percentage of weight retained in the different size of sieve opening was from, 0.71mm and 0.25mm which represented sand in type of sand coarse and sand fine respectively. *C. fluminea* was lower density when the substrate was from pebbles and the sand of very coarse. The percentage for both type of sand was highest collected from both downstream and middle stream which maybe the one factor that contribute to no present of this species.

5.2 RECOMMENDATIONS

There are several recommendation can be made in order to improve the quality and accuracy of this study.

1. Increase the number of sampling to cover up all the river area.
2. Increase the chemical parameter of water quality such as BOD, COD in order to gain more information with the habitat characteristic of *C. fluminea*.
3. Include analysis of organic material in the sediment as it is one of the preferred habitat of *C. fluminea* and they feed on the organic materials.
4. Include the study of phytoplankton as *C. fluminea* feed on phytoplankton also.
5. Include the gut content analysis of this species to determine what their feeding selectivity is.
6. Sampling must be done frequently and continuous to know the ecology of this species in more detail.

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APPENDICES

APPENDIX A

```
FREQUENCIES VARIABLES=length
  /NTILES=4
  /STATISTICS=VARIANCE RANGE MEAN MEDIAN MODE SKEWNESS
SESKEW
  /BARCHART FREQ
  /ORDER=ANALYSIS.
```

Statistics

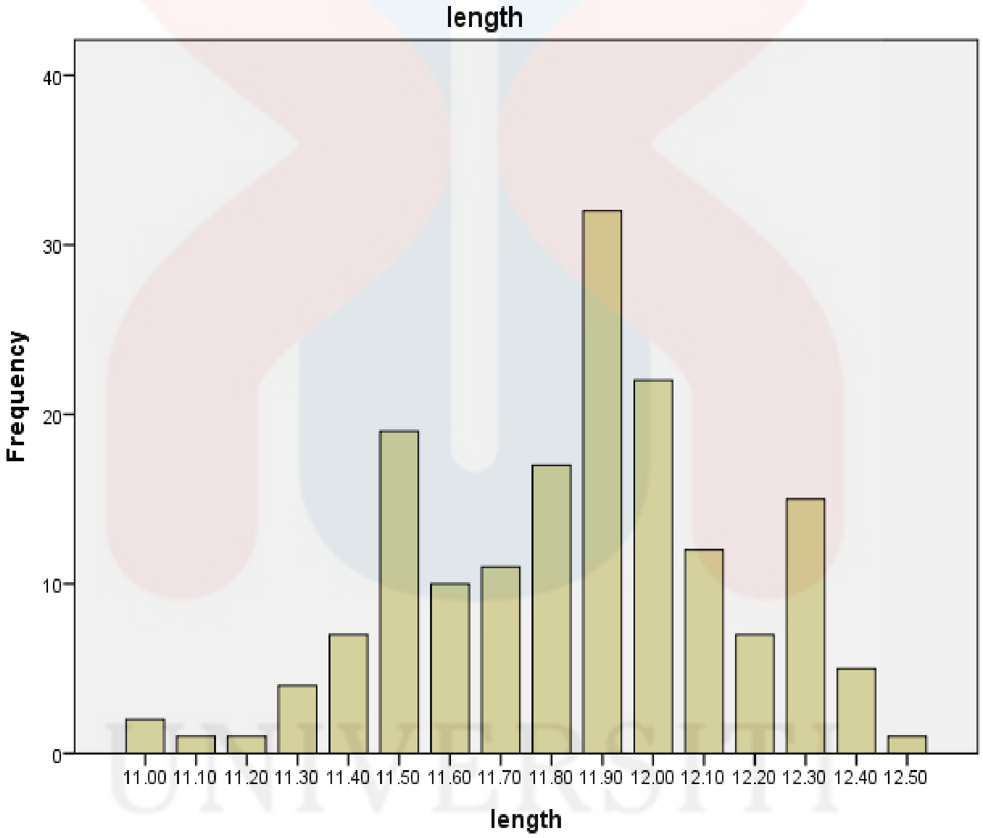
length

N	Valid	166
	Missing	0
Mean		11.8524
Median		11.9000
Mode		11.90
Variance		.094
Skewness		-.281
Std. Error of Skewness		.188
Range		1.50
Percentiles	25	11.6000
	50	11.9000
	75	12.0000

length

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	11.00	2	1.2	1.2	1.2
	11.10	1	.6	.6	1.8
	11.20	1	.6	.6	2.4
	11.30	4	2.4	2.4	4.8
	11.40	7	4.2	4.2	9.0
	11.50	19	11.4	11.4	20.5
	11.60	10	6.0	6.0	26.5
	11.70	11	6.6	6.6	33.1
	11.80	17	10.2	10.2	43.4

11.90	32	19.3	19.3	62.7
12.00	22	13.3	13.3	75.9
12.10	12	7.2	7.2	83.1
12.20	7	4.2	4.2	87.3
12.30	15	9.0	9.0	96.4
12.40	5	3.0	3.0	99.4
12.50	1	.6	.6	100.0
Total	166	100.0	100.0	



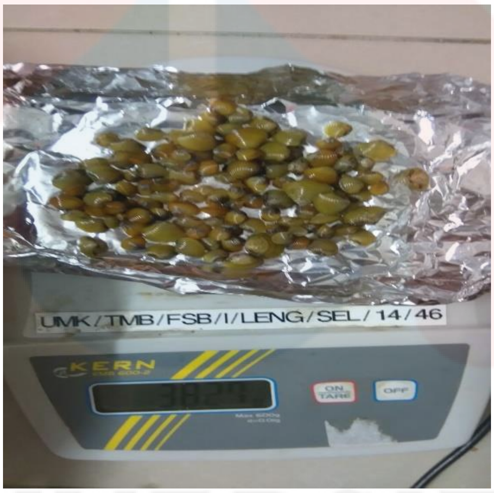
APPENDIX B

Appendix B (1): Substrates for substrate analysis

Appendix B (2): Chemical parameter of water quality recorded using YSI instrument

Appendix B (3): Turbidity concentration of river water using Turbidity meter.

Appendix B (4): The measurement of *C.fluminea* shell. From left the height of shell and the right side shows the height of *C. fluminea*



Appendix B (5): Measure the weight of *C. fluminea* using weighing balance.

APPENDIX C

PARAMETER	UNIT	CLASS				
		I	IIA/IIB	III#	IV	V
Al	mg/l	NATURAL LEVELS OR ABSENT	-	(0.06)	0.5	LEVELS ABOVE IV
As	mg/l		0.05	0.4 (0.05)	0.1	
Ba	mg/l		1	-	-	
Cd	mg/l		0.01	0.01* (0.001)	0.01	
Cr (IV)	mg/l		0.05	1.4 (0.05)	0.1	
Cr (III)	mg/l		-	2.5	-	
Cu	mg/l		0.02	-	0.2	
Hardness	mg/l		250	-	-	
Ca	mg/l		-	-	-	
Mg	mg/l		-	-	-	
Na	mg/l		-	-	3 SAR	
K	mg/l		-	-	-	
Fe	mg/l		1	1	1 (Leaf) 5 (Others)	
Pb	mg/l		0.05	0.02* (0.01)	5	
Mn	mg/l		0.1	0.1	0.2	
Hg	mg/l		0.001	0.004 (0.0001)	0.002	
Ni	mg/l		0.05	0.9*	0.2	
Se	mg/l		0.01	0.25 (0.04)	0.02	
Ag	mg/l		0.05	0.0002	-	
Sn	mg/l		-	0.004	-	
U	mg/l		-	-	-	
Zn	mg/l		5	0.4*	2	
B	mg/l		1	(3.4)	0.8	
Cl	mg/l		200	-	80	
Cl_2	mg/l		-	(0.02)	-	
CN	mg/l		0.02	0.06 (0.02)	-	
F	mg/l		1.5	10	1	
NO_2	mg/l		0.4	0.4 (0.03)	-	
NO_3	mg/l		7	-	5	
P	mg/l		0.2	0.1	-	
Silica	mg/l		50	-	-	
SO_4	mg/l		250	-	-	
S	mg/l		0.05	(0.001)	-	
CO_2	mg/l		-	-	-	
Gross-α	Bq/l		0.1	-	-	
Gross-β	Bq/l		1	-	-	
Ra-226	Bq/l		< 0.1	-	-	
Sr-90	Bq/l		< 1	-	-	
CCE	µg/l		500	-	-	-
MBAS/BAS	µg/l		500	5000 (200)	-	-
O & G (Mineral)	µg/l		40; N	N	-	-
O & G (Emulsified Edible)	µg/l		7000; N	N	-	-
PCB	µg/l		0.1	6 (0.05)	-	-
Phenol	µg/l		10	-	-	-
Aldrin/Dieldrin	µg/l		0.02	0.2 (0.01)	-	-
BHC	µg/l		2	9 (0.1)	-	-
Chlordane	µg/l		0.08	2 (0.02)	-	-
t-DDT	µg/l		0.1	(1)	-	-
Endosulfan	µg/l		10	-	-	-
Heptachlor/Epoxide	µg/l		0.05	0.9 (0.06)	-	-
Lindane	µg/l		2	3 (0.4)	-	-
2,4-D	µg/l		70	450	-	-
2,4,5-T	µg/l		10	160	-	-
2,4,5-TP	µg/l		4	850	-	-
Paraquat	µg/l		10	1800	-	-

Notes :

* = At hardness 50 mg/l $CaCO_3$
# = Maximum (unbracketed) and 24-hour average (bracketed) concentrations
N = Free from visible film sheen, discolouration and deposits

Appendix C (1): National Water Quality Standards for Malaysia

NATIONAL WATER QUALITY STANDARDS FOR MALAYSIA

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	μS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Notes :

N : No visible floatable materials or debris, no objectional odour or no objectional taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

WATER CLASSES AND USES

CLASS	USES
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

Appendix C (2): National Water Quality Standards for Malaysia

DOE WATER QUALITY INDEX CLASSIFICATION

PARAMETER	UNIT			CLASS		
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1 – 3	3 – 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 – 5	1 – 3	< 1
pH	-	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	> 5.0
Total Suspended Solid	mg/l	< 25	25 – 50	50 – 150	150 – 300	> 300
Water Quality Index (WQI)		> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Appendix C (3): DOE Water Quality Index Classification.