UNIVERSITI PUTRA MALAYSIA

DIVERSITY AND DISTRIBUTION OF FRESHWATER GASTROPODS (CAENOGASTROPODA) AT SELECTED AREA IN BINTULU, SARAWAK

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By

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A Project Report Submitted in Partial Fulfilment of the Requirement
for the Degree of Bachelor of Bioindustrial Science in the
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DEDICATION

This thesis is dedicated to,

My lovely parents,

Syed Azmai bin Syed Yeop and Hairun binti Jamaluddin

Family members and relatives

Hariz, Hazwan, Muhammad, Alias, Kamil, Sakinah, Aqilah, Afiqah

My close friends

Norfadila, Nazihah, Ezwin, Fatin, Norsyafiqah, Syifaq, Erra, Norsidah, Hidayah

And all my loved ones

ABSTRACT

Gastropoda communities are the most diverse class of mollusc and considered as important component in the freshwater ecosystems. Gastropods were found significantly important in the terms of ecology and economy. However, there were no clear information reported and lack of conservation effort and management of freshwater gastopods (Caenogastropoda) in Malaysia particularly in Sarawak. Therefore, this study was conducted to identify the species composition and to determine the diversity and abundance of freshwater gastropods communities from selected Bintulu freshwater systems. The environmental variables of water sample in the selected areas were also statistically analyzed. Present study discovered a total of 5 species from Pachychilidae and Thiaridae families were observed and identified. Snails were obtained by randomly placing a 1 m x 1 m quadrat at each location from five different stations in Bintulu, Sarawak. *Melanoides tuberculata* was the most abundance species indicated by its existence in almost every quadrat at each selected area. Shannon indices and Simpson's indices revealed the species diversity and richness were maximum at Station 3 compared to the other four study locations. Based on Bray-Curtis, two separate groups was formed at 40% similarities and supported by ordination of Principal Component Analysis. Jaccard similarity index showed that gastopods community from Station 4 and Station 5 were most similar. The value of environmental parameters indicates that there was a positive relation with the population of gastropods. The freshwater gastropods population showed a significant correlation ($p<0.05$) with the temperature, pH, turbidity, dissolved oxygen but no correlation with conductivity, chlorophyll *a* and TSS.

ABSTRAK

Komuniti Gastropoda adalah kelas moluska yang paling pelbagai dan dianggap sebagai komponen penting dalam ekosistem air tawar. Siput didapati sangat penting dari segi ekologi dan ekonomi. Walau bagaimanapun, tiada maklumat jelas yang dilaporkan dan kurang usaha pemuliharaan dan pengurusan siput air tawar (Caenogastropoda) di Malaysia khususnya di Sarawak. Oleh itu, kajian ini dijalankan untuk mengenal pasti komposisi spesies dan menentukan kepelbagaian dan kepadatan komuniti siput air tawar daripada sistem air tawar Bintulu yang terpilih. Pembolehubah persekitaran dari sampel air di kawasan kajian juga dianalisis secara statistik. Kajian mendapati sejumlah 5 spesies daripada famili Pachychilidae dan Thiaridae telah direkodkan dan dikenal pasti. Siput telah diperoleh secara rawak mengunakan 1 m x 1 m kuadrat pada setiap lokasi daripada lima stesen yang berlainan di Bintulu, Sarawak. *Melanoides tuberculata* merupakan spesies paling dominan ditunjukkan oleh kewujudannya pada hampir setiap kuadrat di setiap kawasan kajian. Indeks Shannon dan indeks Simpson menunjukkan kepelbagaian dan kekayaan spesies adalah maksimum di Stesen 3 berbanding dengan empat lokasi kajian yang lain. Berdasarkan Bray-Curtis, dua kumpulan berbeza terbentuk pada persamaan 40% dan disokong oleh hasil ordinat PCA. Indeks persamaan Jaccard menunjukkan bahawa komuniti siput di Stesen 4 dan Stesen 5 adalah yang paling sama. Nilai parameter persekitaran menunjukkan bahawa terdapat hubungan positif dengan populasi Gastropoda. Populasi siput air tawar menunjukkan korelasi yang ketara (p<0.05) dengan suhu, pH, kekeruhan, oksigen terlarut tetapi tidak berkorelasi dengan konduktiviti, klorofil *a* dan TSS.

ACKNOWLEDGEMENTS

First of all, I would like to Praise be to Allah S.W.T for His guidance, bless and for giving me the strength to perform my responsibilities and completed this final year research project report within the stipulated time. In performing my research project, it was a successful one I had to take with the help and guidance of some respected people. I would like to take this opportunity to express my endless appreciation and sincere gratitude to my supervisor, Dr. Hadi bin Hamli for giving me the chance to conduct my final year project (CFP 4999) under his supervision. I considered myself fortunate to have had him as my supervisor, since he would always find time to answer my questions and be willing to help. His willingness to assist me contributed tremendously to my final year project. In addition, there were more people who also played important roles – Mr Awangku Nizam, Mrs Maini, Mrs Eleena whom I was working with during laboratory works and always guided me in doing my tasks. My grateful thanks to Dr. Noorasmah as the coordinator of CFP 4999 that had taken responsibility to organize this final year research project because she really worked hard to make sure that my final year project went well. Not to forget my special thanks to all my friends for sharing their experiences, time and strength especially within the struggled period during this final year project. I am grateful because I have a lot of friends that helped and supported me throughout the course of completing this final year research project.

APPROVAL SHEET

I certify that this research project report entitled "Diversity and Distribution of Freshwater Gastropods (Caenogastropoda) at Selected Area in Bintulu, Sarawak" has been examined and approved as a partial fulfillment of the requirement for the degree of Bachelor of Bioindustrial Science in the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

DO	Dissolved oxygen
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
PCA	Pricipal Component Analysis
TSS	Total suspended solid
UPMKB	Universiti Putra Malaysia Kampus Bintulu

CHAPTER 1

INTRODUCTION

1.1 Background

Mollusca are the most diverse phylum and the most named species in the animal kingdom after Arthropoda. Gastropoda is the most abundance class of mollusc in the world that can be found in aquatic and terrestrial area. Lydeard *et al.* (2004) estimated that there are approximately 31,000 non–marine mollusc species with valid descriptions existed and probably 3000 to 40,000 undescribed non–marine mollusc species.

Freshwater gastropods can be classified into two groups which are Prosobranchia or gilled gastropods and Pulmonata or lunged gastropods. There are approximately 20 families of freshwater Prosobranchia and 7 families of freshwater Pulmonata are found all over the world (Mandaville 1999). Nevertheless, habitats of freshwater gastropods are taxonomically inadequate compared to the marine gastropod habitats.

Currently in Malaysia, there are few studies done on the freshwater gastropod (Ng *et al.* 2017; Supian and Ikhwanuddin 2002). In Sarawak, little study has been conducted on the diversity and abundance of gastropod. Some of the studies were abundance of marine gastropod and bivalves in Sampadi Island, Lundu, Sarawak by Shabdin *et al.* (2014), diversity of edible mollusc (gastropod and bivalvia) at selected division in Sarawak by Hamli *et al.* (2012) and distribution of macrofauna including gastropod in Rajang River, Sarawak carried out by Shabdin (2010).

Gastropods form a significant role in the ecology and promote the worldwide economy. In ecology, gastropods are reliable water quality indicators and the abundance of some species may tell the current status of any water impoundment (Galan *et al.* 2015). In economy, some of edible molluscs are found as economically important (Sarwade *et al.* 2015).

Despite their ecological and economic importance, the world freshwater gastropods battle with loss and decline in number. Freshwater gastropods encounter threats from habitat loss and degradation (Strong *et al.* 2008). In fact, a total number of the 279 extinct and 1794 threatened Gastropoda species were listed in the Red List of Threatened Species by IUCN (2017). However, the overall diversity of freshwater gastropods in Malaysia, particularly in Sarawak remains poorly documented in comparison to other part of Southeast Asia region. This situation is worsened as there are lack of information, conservation effort and management on freshwater Caenogastropoda in Malaysia particularly in Sarawak.

1.2 Objectives

The specific objectives of this study are:

i. To identify species of freshwater Caenogastropoda at selected area in Bintulu, Sarawak.

ii. To determine diversity and abundance of freshwater Caenogastropoda at selected area in Bintulu, Sarawak.

CHAPTER 2

LITERATURE REVIEW

2.1 Caenogastropoda

Caenogastropoda is the most dominant group of gastropod in term of number of species, abundance and distribution and including their ecology and commercial importance. Among the living snails, Caenogastropoda encompass almost 60% of the discovered species (Ponder *et al.* 2008). They are the largest and diverse group of gastropod, thus they can be found at wide array of habitats as some can be found in marine, freshwater, brackish water and terrestrial areas. Furthermore, they also have diverse habits as they can be benthic epifaunal or burrowers, pelagic drifters or active swimmers; detritus or sedentary suspension feeders, herbivores or grazing or active carnivores, ectoparasites or shell-less internal parasites (Colgan *et al.* 2006).

2.2 Taxonomy

The taxonomy classifications of Caenogastropoda are shown as below:

Domain : Eukaryota

Kingdom : Animalia

Phylum : Mollusca

Class : Gastropoda

Subclass : Caenogastropoda

(Source: Bandel 2007)

2.3 Morphology of Gastropod

Gastropod possesses soft body covered by a coiled univalved shell that provide protection. Normally, that shell are composed of several layers with a thick layer of calcium carbonate and outermost periostracum with organic composition mostly protein (Brown 2001). Their body consist of twisted 90–180° nervous systems that developed since embryonic stage, head-foot and mantle. Their head possess tentacles, eyes and mouth and broad muscular flat foot used for creeping over the surface.

Generally, shell length of gastropod is measured from the end point of the shell (apex) to the basal lip of the opening of the shell called aperture. The suture separates the spire into several whorls. The most apical whorl is the nepionic whorl or protoconch, the initial shell of the young snail. Part of the aperture is often reflected over the body whorl at the columella to form an inner lip. The initial opening of the shell base that moved inward into the columella is referred to the umbilicus. Shell thickness varies among the gastropod as some pulmonates had thin and fragile shell while some prosobranch had thick and resistant to crushed shell. Body whorl is the final and largest whorl that indicates the most recent shell growth, ending in the aperture (Poutiers 1998). The general features of freshwater gastropod shell are shown in Figure 2.1.

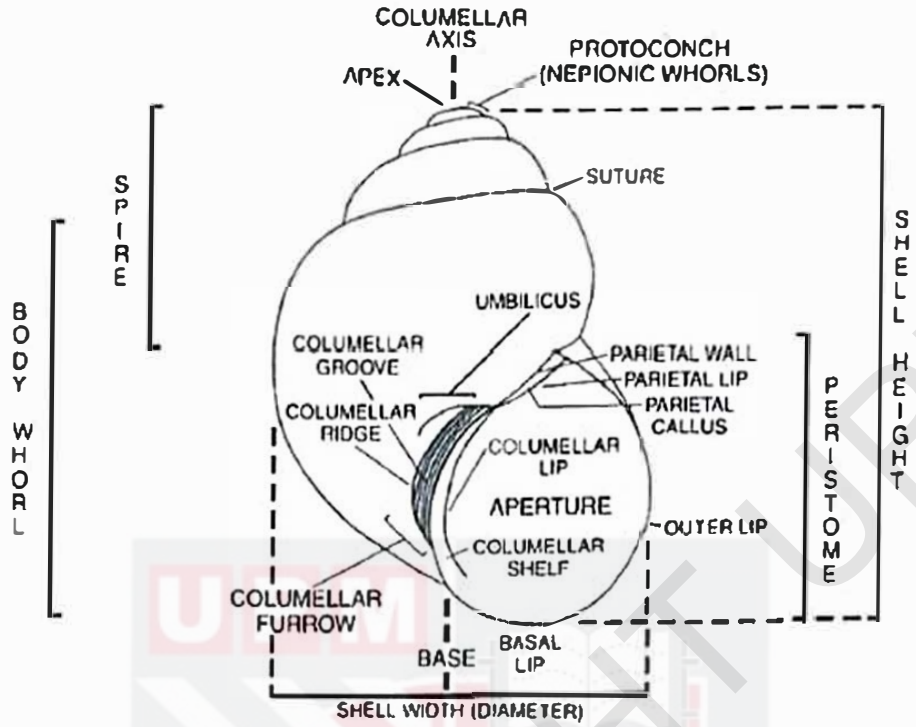

Figure 2.1 General features of freshwater gastropod shell (Frest and Johannes 1999)

2.4 Habitat and Preference

Gastropods have the widest range of ecological niches among the molluscs. Freshwater gastropods can be found in nearly all aquatic habitats including rivers, lakes, swamps, springs, ponds, drainage and other seasonal water. Most of freshwater gastropods lived submerged and some have specialized particular habitats like aquatic vegetation, stones, wood, dead leaves and soft sediment (Strong *et al.* 2008). Pulmonate snails commonly preferred calmer waters, while prosobranchs normally favoured lotic environments (Dillon 2000). Snail's shell exhibits some structural features in response towards their habitat preferences.

2.5 Diversity and Distribution

Gastropods are the largest group of molluscs and can be found worldwide except in the Antarctica. Their 40,000 species comprise over 80% of living molluscs. Gastropods are distributed in many habitats with high adaptabilities with the surrounding. Hence, their high capabilities resulted in wide range distribution of area. Throughout the world specifically in Southeast Asia, numerous studies had been carried out on the abundance of freshwater gastropod comprising 14 species found in Khek River, Thailand (Dechruksa *et al* 2007), 9 species from 8 families have been recorded in Brunei (Ng *et al.* 2015), 6 genus of freshwater snails were documented in South Kalimantan (Hidayat *et al.* 2015), 5 species were identified in Agusan del Sur, Philippines (Cundrado 2015), 7 species representing 5 families were discovered in Bukidnon, Philippines (Galan *et al.* 2015) and 7 species found in Bogor, Indonesia (Priawandiputra *et al.* 2017). Meanwhile in Malaysia, there is significant number of freshwater gastropod species found from the diversity studies (Table 2.5).

Table 2.5 Number of freshwater gastropod species found in Malaysia

Location	No. of species	References
Kuala Klawang, Negeri Sembilan	6	Ismail (1994)
Sungai Semenyih, Selangor	2	Yap *et al.* (2003)
Sungai Rajang, Sarawak	5	Shabdin (2010)
Padawan Limestone, Sarawak	11	Grinang (2013)
East and west coast of Sabah	18	Ng *et al.* (2017)

2.6 Feeding Habits

Most freshwater gastropods are herbivorous or detrital feeders. They grazed on any small organic particles: macrophytic vegetation (living or dead), litter from the bank of the river or pond, algal filaments, fungal hyphae, detritus, bacteria, and even carrion. Some larger snail species are more likely consuming rougher foodstuffs and filter feeding has evolved in the Viviparidae and the Bithyniidae (Dilllon 2000). Likewise, the composition of gastropod radulae and stomach, together with other parts of the digestive system, exhibits their distinct feeding habits either herbivory, detritivory, carnivory, or parasitism (Fryda 2013). Both herbivorous and carnivorous snails use a radula for feeding while some species even use their radula as a "drill" to bore into the shells of other mollusks before consuming their prey (Smith and Kershaw 1979).

Freshwater snails actively scraped their food with the help of a specially modified "tongue" called a radula which is covered with tiny, hard, blade-like projections that graze and tear into small pieces of algae and organic material from the surfaces. The ingested food enters the mouth by mixing it with mucus. As their feet glide most easily across firm surfaces, the snails feed directly on top of the surface on which they are crawling. Snails may feed by lying on their shells and turning their foot up into the water column in heavy amounts of suspended organic matter river. Thus, snails can be suspension feeders, directly collecting food from the water column (Johnson 2009).

2.7 Gastropods as Bioindicator

Gastropods are sensitive to certain chemicals, thus they are excellent water quality indicators within a given ecosystem. Gastropods have limited movement patterns and particularly well suited for assessing site-specific impacts. According to Sharma *et al.* (2013), freshwater molluscs were able to respond to nutrient inputs, discharge of sewage and excreta produced by animals and humans. Hence, Ali and Fishar (2005) observed the highest concentrations of most trace metals measured in mollucsa as compared to some other benthic invertebrate and fish species in Lake Qarun, Egypt.

Another study done by Vukašinović-Pešić *et al.* (2017) revealed that freshwater snail, *Viviparus mamillatus* can be used for biomonitoring of Cd, Cu, Zn and Fe in the aquatic environment at Motenegro. The study also stated that accumulation of metal by *V. mamillatus* might affect its growth rate as they found negative relations between Pb, Cd, Cu and Zn in different tissues and allometric parameters. Studies on heavy metal accumulation in *Melanoides tuberculata* was conducted by Al-Qarooni *et al.* (2012), Shuhaimi-Othman *et al.* (2012) and Tyokumbur and Okorie (2014).

2.8 Environmental Parameter

2.8.1 Physico-chemical of Water Parameter

Water quality often significantly affects the relationship between habitat area and freshwater mollusc diversity. Freshwater gastropods composition and abundance depends on their abilities to colonize and survive in a habitat. Colonisation success is not attained by the specialised species that are typical of stable habitats, but rather by species with a tolerance to a wide range of environmental conditions (Spyra and

Strzelec 2014). Survival of gastropods is regulated by various physico-chemical factors that influenced the ecological traits associated with a particular species. Water bodies, pollution, diseases and vegetation are aspects that significantly affected the distribution and abundance of gastropods (Saddozai *et al.* 2013). The freshwater snails can easily survive in temperature between 10°C and 35°C (Rozendaal 1997) and water temperature gave influence on their growth rate and development (Smitha and Mustak 2017).

Sarwade *et al.* 2015 stated the suitable pH for molluscs habitat is between 7.1 until 8.4 and greater mollusean population in alkaline lakes as compared to acidic lake in Maharashta, India has been observed by Sakhare and Joshi (2003). In addition, influence of physico-chemical parameters on individual species abundance shows that temperature was significant for *Bulinus globosus*, pH was significant for *Bulinus forskalii*, *Biomphalaria pfeifferi* and *Lymnaea natalensis* while pH and dissolved oxygen were significant for *Indoplanorbis exutus* abundance in the sampled water bodies across Nasawara state, Nigeria (Abe *et al.* 2017).

2.8.2 Chlorophyll *a*

Chlorophyll *a* is a major pigment in plants that act as a biomass indicator of aquatic mirco-algae which support food webs in the aquatic area. It is the most useful method to measure biochemical parameter in oceanography (Aminot and Rey 2000). Chlorophyll *a* content shown to correlate positively with benthic macrofaunal species richness in the northern Gulf of Mexico (Haedrich *et al.* 2008). Other study done by Lewin (2006) also obtained a statistically significant correlation between *Viviparus viviparus* density and the chlorophyll *a* level in the rivers of the

Ciechanowska Upland, Poland. The study also discovered the level of chlorophyll *a* in water is dependent on the concentration of either nitrate nitrogen or phosphates.

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Bintulu, Sarawak (Figure 3.1). Samplings on gastropods were carried out at five selected stations in Bintulu. Global Positioning System (GPS) was used in order to determine the precise location (coordinates) of the study area. These locations were chosen due to the abundance of freshwater gastropod species at that particular location. A short description and GPS readings of each sampling location were shown in Table 3.1.

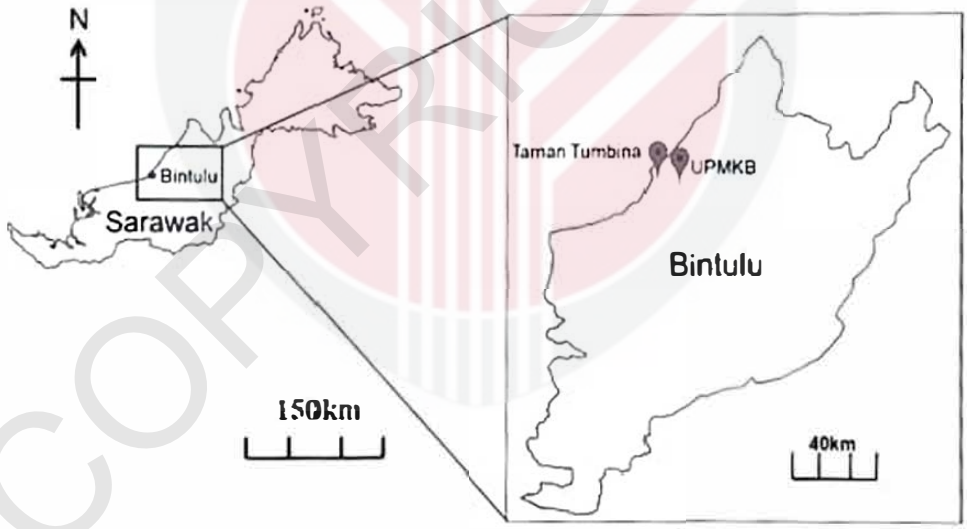

Figure 3.1 Location of selected sampling sites at Bintulu, Sarawak

Table 3.1 Coordinates and brief description of each selected area in Bintulu, Sarawak

Site	Station No	GPS coordinates	Site description
Taman Tumbina	1	N 03° 12.280' E 113° 03.108'	Shaded rocky stream with clear water.
	2	N 03° 12.237' E 113° 03.008'	Partially shaded rocky stream with clear water.
	3	N 03° 12.096' E 113° 02.978'	Exposed sandy stream with clear water.
Hutan Nirwana UPMKB	4	N 03°12'55.3" E113°04'04.8"	Partly sheltered stream with clear water.
Air Terjun UPMKB	5	N 03°12.469' E 113°04.498'	Exposed rocky and sandy stream with clear water.

3.2 Sampling Technique

Gastropods were sampled by using 1 m x 1 m quadrat which randomly placed at each station. The total number of individuals of each species within the quadrat was identified, counted and recorded. The samples were collected randomly at each station and placed in the zip bags for further analysis. Each sample collected was photographed using a digital camera and redraw to reveal any dim characters on the shell. The water sample at each station was also taken for laboratory analysis. Water parameter such as water temperature, pH, conductivity, turbidity and dissolved oxygen (DO) were obtained *in situ*. Water parameters were measured at every station by using multi-parameter water quality checker (Model WQC-24).

3.3 Laboratory Analysis

3.3.1 Chlorophyll *a* Analysis

The chlorophyll *a* analysis (Eaton *et al.* 2005) was determined by filtering the water sample using filter paper with additional 3–5 drops of magnesium carbonate into the water sample. Then the filter papers were transferred into the centrifuge tube filled with 10 mL of 90% of acetone and left overnight in the incubator before being centrifuged for 10 minutes at 4000 rpm. The reading of chlorophyll *a* at wavelength 664 nm, 647 nm and 630 nm were recorded. The recorded data were used in the calculation.

The equations involved were as follows:

$Ca = 11.85\ A_{664} - 1.54\ A_{647} - 0.08\ A_{630}$

$mg\ Ca/\ m^3 = (Ca \times V_{acetone}) / (V_{sample} \times 1)$

Where,

Ca = Chlorophyll *a*

A = Absorbance of wavelength

$V_{acetone}$ = Volume of acetone used in mL

V_{sample} = Volume of water sample in liters

3.3.2 Total Suspended Solid Analysis

The Total Suspended Solid (TSS) analysis (Eaton *et al.* 2005) was done by heating the filter paper with aluminium foil that was shaped like a dish in the oven at 103–105°C for 15 minutes. Then the dish was cooled down in a desiccator and weighed for the initial weight before the water samples were filtered using the filter paper and put in the oven at temperature 103–105°C for 1 hour. Then the filter paper was

cooled down at room temperature for 20 minutes before the final weight was recorded.

The calculation involves were as follows:

TSS (mg / L) = (A – B) x 1000 / C

Where,

A = final weight of dish

B = initial weight of dish

C = volume of water sample

3.4 Species Identification

The identification of the gastropods species were done based on the taxonomy characteristics by referring the shell features such as shell shape, marks, body whorl, columella and aperture shape. The identification was done by referring to Subba Rao (1989), Perez *et al.* (2004), von Rintelen and Glaubrecht (2005), Köhler and Glaubrecht (2006), Köhler and Dames (2009), von Rintelen *et al.* (2007), Marwoto and Isnaningsih (2012) and Madsen and Hung (2014).

3.5 Data Analysis

Data on number of species and individual per species of each site were analysed using Plymouth Routines In Multivariate Ecological Research (PRIMER) version 5.2.8. PRIMER was used to determine the Shannon diversity index (H'), Pielou's evenness index (J') and Margalef's richness index (D). The Pearson's correlation relationship between physico-chemical parameter with diversity indices was

analysed using Statistical Package for Social Science (SPSS) to test the Pearson correlation.

Shannon-Weiner Diversity Index

$H' = -Sum(P_i * log(P_i))$

Where,

$P_i = n_i / N$

n_i = Number of each individual species

Pielau's Evenness Index

$J' = H' / log(S)$

Where,

J' = Evenness Index

H' = Shannon-Weiner Diversity Index

S = Total Species

Margalef's Richness Index

$D = (S-1) / log\ N$

Where,

D = Richness Index

N = Total of individual number

S = Total species

Jaccard's Similarity Index

$S_J = A / (A + B + C)$

Where,

A = Total number of species present in both communities

B = Number of species present in community 1 but not in community 2

C = Number of species present in community 2 but not community 1

Cluster Analysis

The species distribution between each station was hierarchically clustered based on Bray-Curtis similarity matrix after the fourth root transformed. An average similarity within a group and dissimilarity between groups were calculated. The dissimilarity average produced based on the contribution of all species distribution mean data and the percentage contributions of each station were also displayed.

CHAPTER 4

RESULTS

4.1 Taxonomy and Classification of Gastropods

A) *Melanoides tuberculata* (Müller, 1774)

Family : Thiaridae

Genus : Melanoides

Species : *Melanoides tuberculata* (Müller, 1774)

Synonyms : *Melanoides fasciolata* Olivier, 1804

Habitat : Submerged on soft sediment, shallow and calm to less turbulent zone of water stream.

No. of specimen : 339

Description : The shell is elongate and conical shape with light to dark brown colour. Axial reddish-brown band and vertical sculpture form on the whorl. Aperture is oval shape. The total length ranges are between 17.79 mm–19.54 mm. The mean widths are between 6.43 mm–7.97 mm (Plate 4.1).

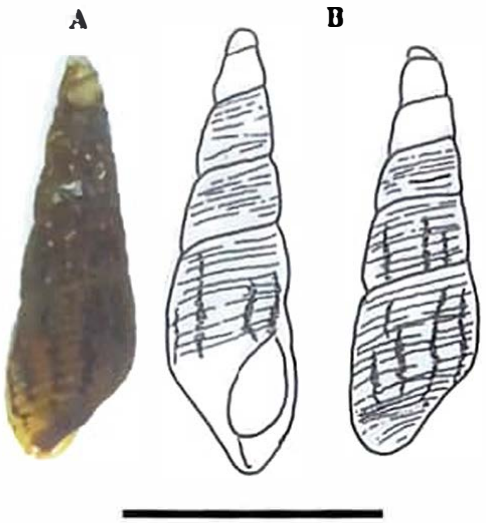

Plate 4.1 Morphological structure of *Melanoides tuberculata* (Müller, 1774). (A) Photo diagram. (B) Drawing diagram front and back view.

B) *Tylomelania masapensis* (Kruimel, 1913)

Family : Pachychilidae

Genus : Tylomelania

Species : *Tylomelania masapensis* (Kruimel, 1913)

Synonyms : -

Habitat : Submerged in shallow and calm zone at the river bank on soft substrate.

No. of specimen : 82

Description : The shell is small and turriculate in shape. Spiral ribs formed on body whorl. Spire whorls smooth. Black to dark brown shell colour. The total length ranges are between 14.47 mm–14.92 mm. The mean widths are between 4.81 mm–6.03 mm (Plate 4.2).

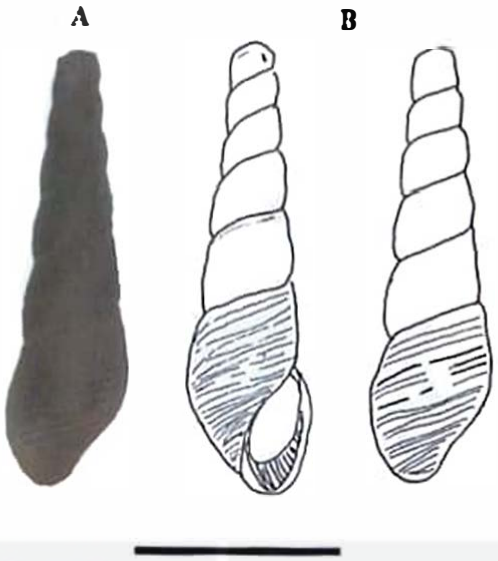

Plate 4.2 Morphological structure of *Tylomelania masapensis* (Kruimel. 1913). (A) Photo diagram. (B) Drawing diagram front and back view.

C) *Brotia siamensis* (Brot, 1886)

Family : Pachychilidae

Genus : Brotia

Species : *Brotia siamensis* (Brot, 1886)

Synonyms : *Brotia peninsularis* (Brandt,1974), *Melania hamonvillei* (Brot, 1887), *Antimelania siamensis* (Brot, 1886)

Habitat : Submerged in shallow and low to mild turbulent water stream on soft sediment.

No. of specimen : 52

Description : The shell is small and elongately conic. Sculptures with both radial and spiral ribs. Shell colour light to dark brown. The total length ranges are between 11.75 mm–12.82 mm. The mean widths are between 4.14 mm–4.66 mm (Plate 4.3).

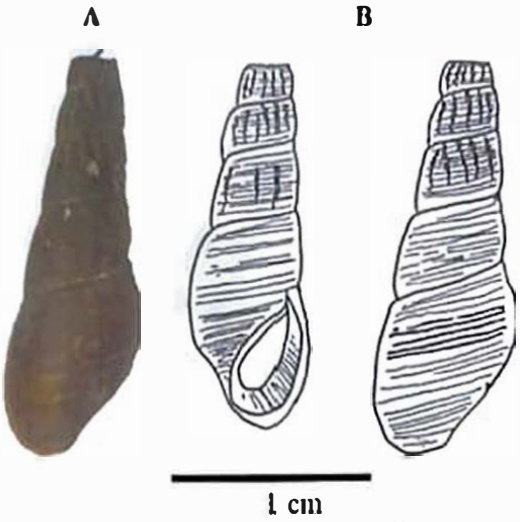

Plate 4.3 Morphological structure of *Brotia siamensis* (Brot, 1886). (A) Photo diagram. (B) Drawing diagram front and back view.

D) *Melania biconica* (Brot, 1886)

Family	:	Pachychilidae
Genus	:	Melania
Species	:	*Melania biconica* (Brot, 1886)
Synonyms	:	*Melania hainanensis* (Brot, 1872)
Habitat	:	Submerge in soft sediment or attached on rock, wood and dead leaves. Found at shallow and calm water current.
No. of specimen	:	67
Description	:	The shell is elongate and conical shape. Dark brown shell colour. Fine vertical and horizontal ribs formation on body whorl. The aperture is ovate. The total length ranges are between 26.73 mm–26.73 mm. The mean widths are between 10.10 mm–11.41 mm (Plate 4.4).

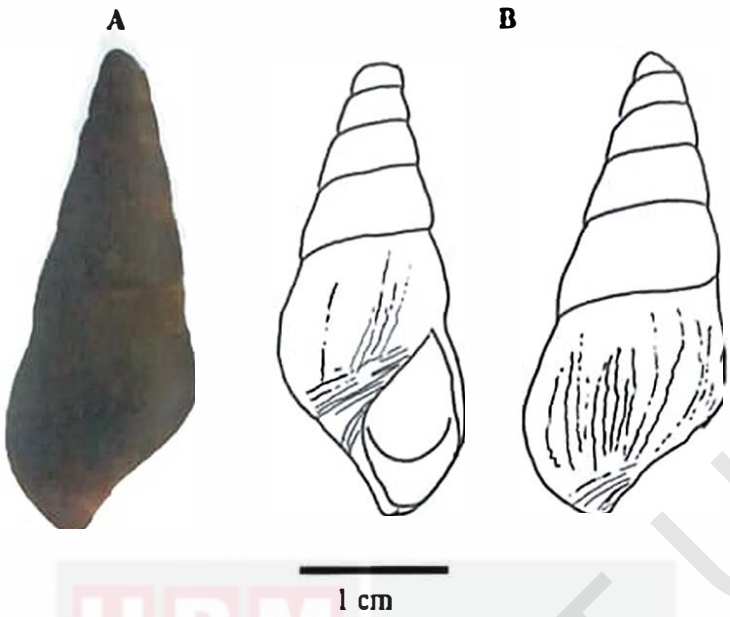

Plate 4.4 Morphological structure of *Melania biconica* (Brot, 1886). (A) Photo diagram. (B) Drawing diagram front and back view.

E) *Sulcospira testudinaria* (von dem Busch, 1842)

Family : Pachychilidae

Genus : Sulcospira

Species : *Sulcospira testudinaria* (von dem Busch, 1842)

Synonyms : *Melania foeda* (Lea,1850), *Melania jughuhni* (Schepmann, 1896), *Melania martini* (Schepmann,1898)

Habitat : Submerge in soft sediment and some attached on rock, wood and dead leaves. Found at shallow and calm water current.

No. of specimen : 11

Description : The shell is elongate and conical shape. Black to dark brown shell colour. Fine spiral ribs formed at basal lip of aperture. The total length ranges are between 39.13 mm–52.80 mm. The mean widths are between 15.19 mm–19.95 mm (Plate 4.5).

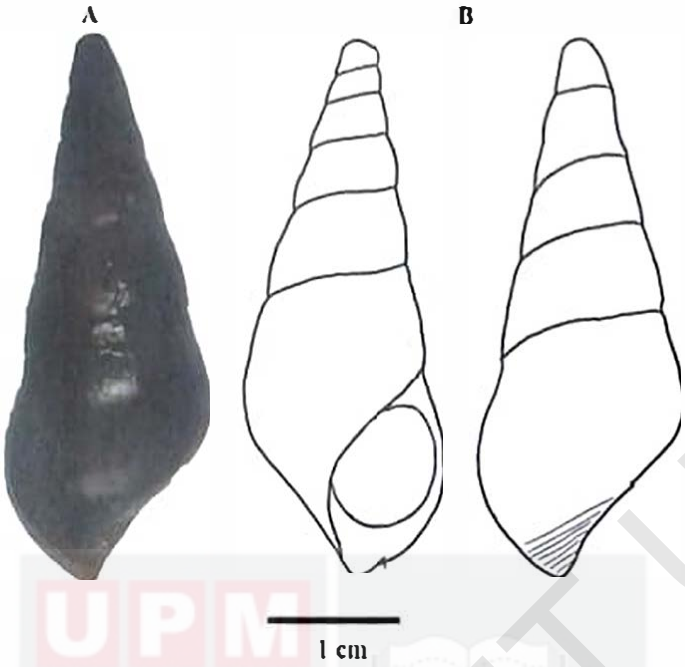

Plate 4.5 Morphological structure of *Sulcospira testudinaria* (von dem Busch, 1842). (A) Photo diagram. (B) Drawing diagram front and back view.

4.2 Species Distribution

In total, 551 numbers of individual were recorded with 5 species from 2 families were identified from selected area in Bintulu, Sarawak. The existing gastropods species presented in Table 4.1 showed that *Melanoides tuberculata* was recorded at all the selected stations. Species that located at Station 1, Station 2 and Station 3 was *Tylomelania masapensis*. Other species such as *Brotia siamensis* and *Melania biconica* were distributed at the same two stations (Station 2 and Station 3). Meanwhile, the least distributed species was *Sulcospira testudinaria* and only can be found at Station 1.

Table 4.1 Species distribution of gastropod at selected areas in Bintulu, Sarawak

Family/ Genus/ Species	Station				
	S1	S2	S3	S4	S5
Thiaridae					
Melanoides tuberculata	+	+	+	+	+
Pachychilidae					
Tylomelania masapensis	+	+	+	-	-
Brotia siamensis	-	+	+	-	-
Melania biconica	-	+	+	-	-
Sulcospira testudinaria	-	-	+	-	-

Note: (+) = Present, (-) = Absent

4.3 Species Diversity, Richness and Evenness

Station 4 and Station 5 showed the lowest diversity, richness and evenness indices (0) presented in Table 4.2. Meanwhile, Station 3 showed the highest diversity index (1.264) followed by Station 2 (1.108) and Station 1 (0.5865). For richness index value, Station 3 have the highest value (0.7467) followed by Station 2 (0.5933) and Station 1 (0.1996). In spite of this, Station 1 presented the highest evenness index value (0.8462) and Station 2 has the second highest value (0.7991) followed by Station 3 (0.7852).

Table 4.2 Univariate analysis on diversity, richness and evenness indices of freshwater gastropod of each station in Bintulu, Sarawak

Station	No of Species (S)	No. of Individual (N)	Margalef's Richness Index (d)	Pielou's Evenness Index (J')	Shannon-Weiner Diversity Index (H')
S1	2	150	0.1996	0.8462	0.5865
S2	4	157	0.5933	0.7991	1.108
S3	5	212	0.7467	0.7852	1.264
S4	1	4	0	0	0
S5	1	28	0	0	0

4.4 Similarity Index

Result on similarity index analysis was presented in Figure 4.1 shown that Station 4 versus Station 5 has highest similarity value (1.0) as compared to other selected area. The following highest similarity value was Station 2 versus Station 3 (0.8). The lowest similarities were Station 3 versus Station 4 and Station 3 versus Station 5 with 0.2 similarities value. Other station similarities were 0.5 (Station 1 versus Station 2), (Station 1 versus Station 4), (Station 1 versus Station 5). 0.4 (Station 1 versus Station 3), 0.25 (Station 2 versus Station 4) and (Station 2 versus Station 5).

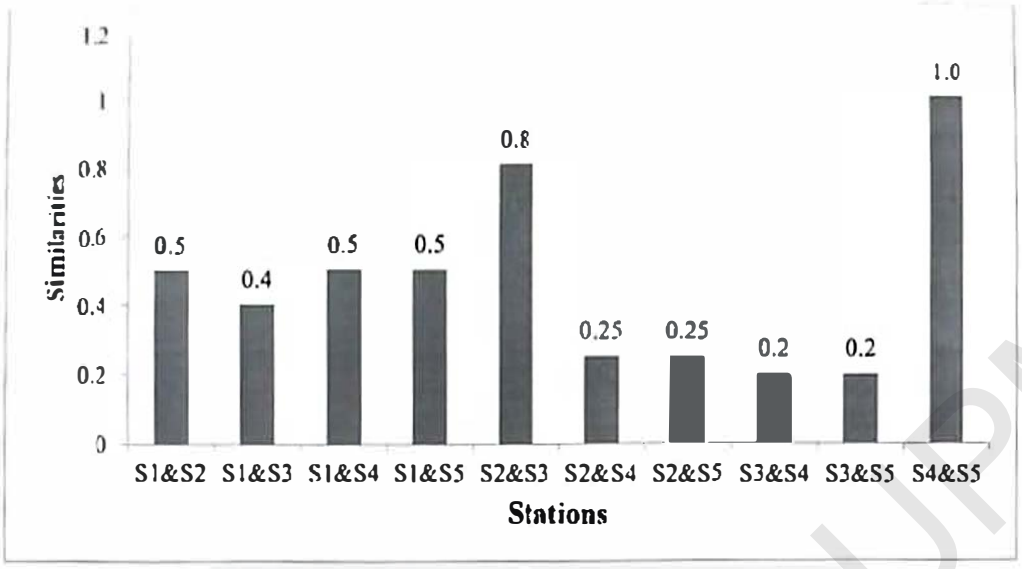

Figure 4.1 Jaccard's Similarity Index of recorded gastropods among each station at selected areas in Bintulu, Sarawak

4.5 Cluster Analysis

The result of cluster analysis was shown in Figure 4.2. At 40% similarity, there were 2 groups comprising group 1 that consists of Station 1, Station 2 and Station 3 whereas group 2 consists of Station 4 and Station 5. Meanwhile at 60% similarity, only group 1 has high similarity whereas group 2 are independent. However at 90% similarity, both group 1 and group 2 were independent.

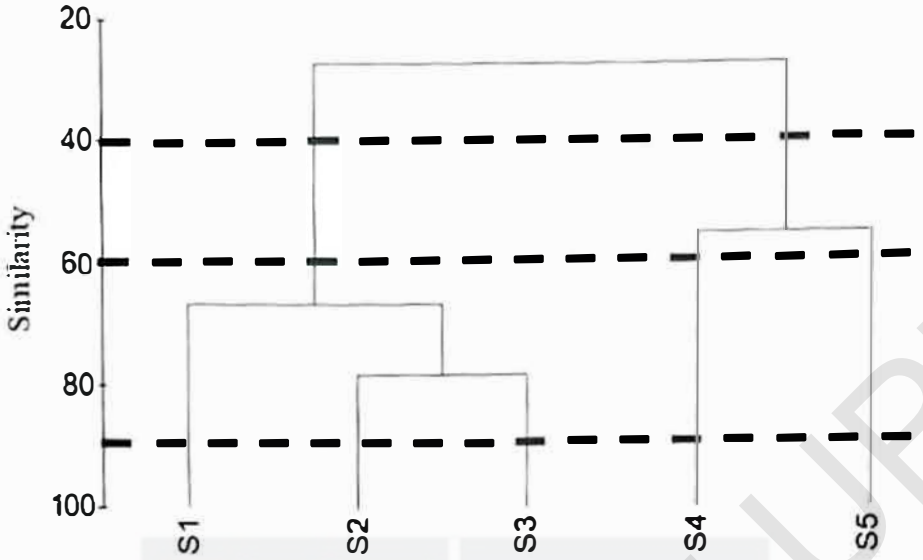

Figure 4.2 Cluster of gastropods assemblage based on Bray–Curtis similarity matrix at selected areas in Bintulu, Sarawak

4.6 Principal Component Analysis

Ordination by Principal Component Analysis (PCA) presented in Figure 4.3 shown that there were two groupings among the stations. Group 1 consisted of Station 1, Station 2 and Station 3 while Station 4 and Station 5 was grouped together. The result had supported 40% similarity of Bray-Curtis hierarchical cluster analysis given in Figure 4.2. Principal component 1 (x-axis) shown 58.53% of the variation and principal component 2 (y-axis) revealed 30.40% of the variations, both component represent the abundance and distribution of freshwater gastropods at the given selected study areas in Bintulu, Sarawak.

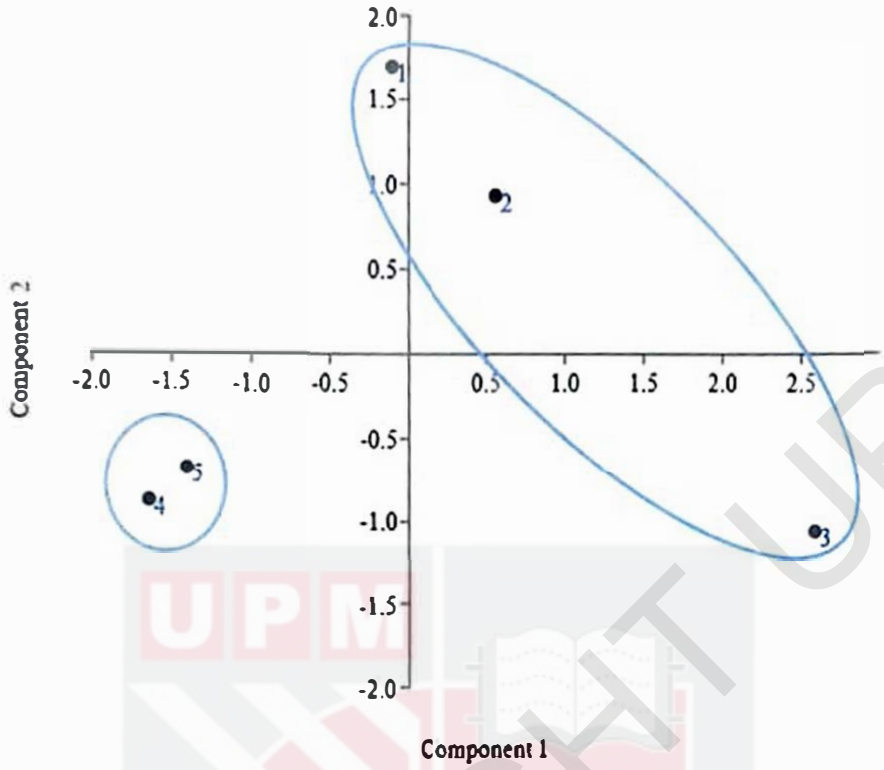

Figure 4.3 Principal Components Analysis (PCA) of selected areas in Bintulu, Sarawak

4.7 Environmental Parameters

The environmental parameters of water from selected area in Bintulu were presented in Table 4.3. There was significant difference at level 0.05 among environmental variables between five study areas except for chlorophyll *a* and TSS. The conductivity and DO value between Station 2 and Station 3 were similar but different with other three stations. Besides, the temperature in Station 1 and Station 2 did not differ significantly between each other but significantly differ with other study locations. Moreover, pH value in Station 5 shown a dissimilarity with Station 1, Station 2 and Station 4, however, Station 3 shown a similarity with all the study area. The result for turbidity shown that Station 2, Station 3 and Station 5; and Station 1 and Station 4 having no significant difference.

Table 4.3 Environmental parameters (Mean ± SD) of each station at selected areas in Bintulu, Sarawak

Station	Parameters						
	Conductivity (µS/cm)	Temperature (°C)	pH	Tubidity (NTU)	DO (mg/L)	Chlorophyll *a* (mg/m^3)	TSS (mg/L)
1	11.700a ± 0.000	26.330a ± 0.058	7.190a ± 0.345	35.030a ± 8.727	4.500a ± 0.482	0.574a ± 0.994	0.015a ± 0.007
2	5.900b ± 0.100	26.330a ± 0.058	7.000a ± 0.164	12.300b ± 1.473	5.977b ± 0.051	0.000a ± 0.000	0.495a ± 0.686
3	5.330b ± 0.493	26.630b ± 0.058	6.817ab ± 0.096	12.467b ± 1.656	5.813b ± 0.035	0.000a ± 0.000	0.040a ± 0.042
4	2.800c ± 0.520	25.330c ± 0.058	7.010a ± 0.546	36.267a ± 7.457	3.740c ± 0.367	3.751a ± 6.497	0.100a ± 0.071
5	0.700d ± 0.000	27.030d ± 0.058	6.093b ± 0.248	9.433b ± 0.153	1.390d ± 0.010	7.158a ± 12.399	0.035a ± 0.007

Note: Means in the same column followed by the same letter do not differ significantly according to the Tukey test ($\alpha = 0.05$).

4.8 Correlation of Environmental Parameters with Diversity

The diversity of freshwater Caenogastropoda showed positive and negative correlation with environmental parameters of the study areas presented in Table 4.4. Among the seven environmental factors, there was a significant correlation ($p<0.05$) between diversity of gastropods with the temperature (r = 0.253268), pH (r = 0.398592), turbidity (r = -0.39295) and DO (r = 0.885432). Other environmental variables such as conductivity, chlorophyll *a* and TSS were not significantly correlated between freshwater gastropods diversity ($p>0.05$) with correlation coefficient r = 0.455471, r = -0.86522 and r = 0.419513, respectively.

Table 4.4 Pearson's correlation coefficient (r) between environmental parameters and diversity of gastropods at selected areas in Bintulu, Sarawak

Parameters	**r**	**Sig. (2-tailed)**
Conductivity (µS/cm)	0.455471	0.0549665
Temperature (°C)	0.253268*	0.0000002*
pH	0.398592*	0.0000177*
Turbidity (NTU)	-0.39295*	0.0279218*
DO (mg/L)	0.885432*	0.0037857*
Chlorophyll *a* (mg/m^3)	-0.86522	0.3564751
TSS (mg/L)	0.419513	0.1342800

Note: *Marked correlation was significant ($p<0.05$)

CHAPTER 5

DISCUSSION

5.1 Species Composition

In the present study, 2 families with 5 species in total of 551 individual of freshwater gastropod has been identified. *Melanoides tuberculata* was recorded the highest distribution because this species had existed in every quadrat as compared to other species. Station 3 recorded the highest number of species with 5 species presented and the lowest was Station 4 and Station 5 with only 1 species presented during this study. *Melanoides tuberculata* is the most widespread member of the family Thiaridae that commonly found in freshwater system (Supian and Ikhwanuddin 2002) and being discovered in northern and southern Africa, eastern Mediterranean countries, the Arabian Peninsula, south and southeast Asia, southern China, Japan, Malaysia, and northern Australia (Gimnich 2015).

The findings of Minton *et al.* (2008) documented a total of 13 gastropod species representing three orders and seven genera at Bayou Bartholomew drainage, Arkansas, U.S.A. Ponce *et al.* (2014) studied six genera of gastropods has been found in the wetland ponds of Turnbull National Wildlife Refuge, Eastern Washington and was dominated by *Radix auricularia*. According to Lange *et al.* (2013) there were 15 species belonging to 8 families recorded in Lake Victoria, Kenya The study also showed that dominancy of some snail species in Lake Victoria, especially *Biomphalaria choanomphala* and *Melanoides tuberculata*

occurred due to biological changes impact from anthropogenic disturbance, while other species cannot endure towards the changes.

5.2 Diversity, Richness and Evenness Analysis

The species diversity index reflects on both the total number of species and how equally individuals were distributed among the species in a given study area. Result shown that Station 4 and Station 5 recorded the lowest diversity indices value (0) compared to other study areas. The numbers indicated the dominancy of only one gastropod species (*Melanoides tuberculata*) at Station 4 and Station 5 in comparison to other selected study areas. The highest diversity index value (1.264) belonged to Station 3. The amount of individual found in Station 3 ranged from 11-113 from 5 species existed there. Callisto *et al.* (2005) observed an increase in diversity and richness of benthic macroinvertebrates with substrate diversification and high biomass of aquatic macrophytes in São Francisco River, northeastern Brazil.

The total number of species in the particular area influenced the richness index value. Richness index was measured by totalling up the number of different species in a given area. Among the study area chosen, Station 3 showed the highest richness index value with 0.7467. Anthropogenic activities including constructions, agricultural activities, urbanization and industrializations along the river could have influenced the density and abundance of macrobenthic invertebrates at the downstream of Sungai Semenyih (Yap *et al.* 2003, 2008).

Evenness index was based on species abundance distribution in a community's diversity. Station 1 has the highest evenness index value with 0.8462. It signified

that the uniformity of distribution of various species at that area was high. According to Esenowo and Ugwumba (2010) the high diversity index in Majidun River, Nigeria was a reflection of less anthropogenic disturbance, stress-free and stable environment for macrobenthos habitat.

5.3 Relationship of Environmental Parameters with Diversity

The freshwater gastropods population showed a significant correlation with the temperature, pH, turbidity, DO presented in Table 4.4. On the other hand, the rest of environmental parameter such as conductivity, chlorophyll *a* and TSS showed no correlation with population density of freshwater gastropods in the selected study area.

Water temperature exhibited a positive correlation with the abundance of molluscs in the study done by Sahin (2012) and Smitha and Mustak (2017). The study showed that increase in temperature within the observed range helps the growth and development of molluscs. Temperature and pH was found by Gutiérrez *et al.* (1997) to exert the main factor influencing the abundance of *Melanoides tuberculata* and *Tarebia granifera* in central region of Cuba. Environmental variables such as pH and turbidity were found by Lamptey and Armah (2008) being the major significant variables structuring the macrobenthic faunal assemblage in Keta Lagoon, Ghana. Ponce *et al.* (2014) discovered that chlorophyll *a* did not significantly impact snail richness in wetland of Turnbull National Wildlife Refuge, WA.

CHAPTER 6

CONCLUSION

From the present study, a total of 5 species from 2 families of freshwater gastropods had been recorded. *Melanoides tuberculata* was the most abundance species as compared to other species in the study areas denoting by its existence in almost every quadrat at each selected area in Bintulu, Sarawak. The dominancy of species was also related to the total number of individual in which 339 individual of *Melanoides tuberculata* has been identified. The presence of this species could be the biological indicator for the steam water quality.

The diversity indices shown that Station 3 has the highest diversity and richness index value in comparison to Station 4 and Station 5 which has the lowest diversity index value. The indices value reflected that Station 3 has the most stable and highly favourable condition for freshwater gastropod to colonize and survive with the present water quality.

The relationship between environmental parameter with freshwater gastropods was statistically significant. Among seven environmental factors, only chlorophyll *a* and TSS were not significantly correlated to the freshwater Caenogastropoda distribution. Therefore, any changes of both chlorophyll *a* and TSS does not affect the abundance and diversity of freshwater snails species in the given study areas.

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PUBLICATION OF THE PROJECT UNDERTAKING

This is to certify that I have no objection to publish the project entitled "Diversity and Distribution of Freshwater Gastropods (Caenogastropoda) at Selected Area in Bintulu, Sarawak" by the supervisor in a joint authorship. However, it has to be evaluated by the Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus and published in the form approved by the Faculty.

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Date: 12 JUNE 2018