Faculty of Resource Science and Technology

Fish Composition and Physicochemical Parameters at the Upper Stretch of Baram River, Sarawak

Juliana Sambai anak Sibat

Master of Science
2018

UNIVERSITI MALAYSIA SARAWAK

Grade: ____________

Please tick (√)

Final Year Project Report ☐

Masters ☑

PhD ☐

DECLARATION OF ORIGINAL WORK

This declaration is made on the ....day of................~~2016~~ 2018.

Student's Declaration:

I Juliana Sambai anak Sibat, 15020821, Faculty of Resource Science and Technology (PLEASE INDICATE STUDENT'S NAME, MATRIC NO. AND FACULTY) hereby declare that the work entitled, Fish Composition and Physicochemical Parameters at the Upper Stretch of Baram River, Sarawak is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

8/10/18

Date submitted

Juliana Sambai anak Sibat (15020821)

Name of the student (Matric No.)

Supervisor's Declaration:

I Prof Dr. Lee Nyanti (SUPERVISOR'S NAME) hereby certifies that the work entitled, Fish Composition and Physicochemical Parameters at the Upper Stretch of Baram River, Sarawak (TITLE) was prepared by the above named student, and was submitted to the "FACULTY" as a * partial/full fulfillment for the conferment of Master of Science (Aquatic Science) (PLEASE INDICATE THE DEGREE), and the aforementioned work, to the best of my knowledge, is the said student's work

Received for examination by: Prof Dr. Lee Nyanti
(Name of the supervisor)

Date: 8 October 2018

I declare this Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*
☑ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirmed with free consent and willingness declared that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abide interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitise the content to for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student's signature ________ 8/10/18
(Date)

Supervisor's signature: ________
(Date)
8/10/2018

Current Address:
Lot 6593, Desa Pujut, Bandar Baru Permyjaya,98000, Miri, Sarawak.

Notes: * If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument was duly prepared by The Centre for Academic Information Services]

Fish Composition and Physicochemical Parameters at the Upper Stretch of Baram River, Sarawak

Juliana Sambai anak Sibat

A thesis submitted

In fulfillment of the requirements for the degree of Master of Science

(Aquatic Science)

Faculty of Resource Science and Technology
UNIVERSITI MALAYSIA SARAWAK

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulation of Universiti Malaysia Sarawak. It is original and is the result of my work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

(JULIANA SAMBAI ANAK SIBAT)

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak

ACKNOWLEDGEMENT

First and above all, I praise God, for His showers of blessings of provision for me when I am in need since the very beginning and granting me the opportunity with full of blessing.

My sincere thanks go to my supervisor, Prof. Dr. Lee Nyanti for giving me an opportunity to do this project. I am fully indebted for the knowledge given throughout the learning process. Thank you for spending your time to encourage, guide and teach me. To my co-supervisor, Prof. Dr. Ling Teck Yee, thank you for your constant support and constructive suggestion throughout the process. I would also like to thank Dr. Jongkar Grinang for his help during the sampling trip. Thanks for being such a good advisor along the journey.

Let me take this opportunity to thank the staff members of FRST, Mr Harris Norman, Mr Richard Toh, Mr Benedict Samling, Mdm Lucy and not to forget Allahyarham Zul for their helping hands throughout the field work. Besides, I would also like to express my sincere gratitude to our boatmen Mr Anyie, Mr Erang, Mr Jeffery, Mr Belawan and Mr Nyipa. Thanks for being such a good friends and cheering me up with your funny stories.

To my batchmates and friends, Jakheus, Fatin, Ainil, Kirol, Nur Ezzaty, Iskandar, Imanina, Abdul Rani, Muzakkir, Jing Jing, Mugilan, Faizul, Angie, Kasturi, Jay, Fakha, Hafida and Ezai; thanks for making my student life so wonderful. Thanks for always sticking by my side in my best and worst times. Our memories will be cherished forever.

I want to extend my deepest appreciation to my backbones, Mr Sibat and Mdm Bernadette, for their encouragement and support in everything I do. Without them I would not be who I am today. Besides, I also would like to thank my brothers and sister for their motivation throughout my adventures. Last but not least, the financial support from Sarawak Energy Berhad (SEB) through grant GL (F07)/SEB/3A/2013 (20) and facilities and transportation from Universiti Malaysia Sarawak for are greatly appreciated.

ABSTRACT

This present study aimed to investigate the diversity and distribution of freshwater fish from four areas (Lio Mato, Long Apu, Long San and Long Kesseh) in the upper stretch of Baram River, which has not been studied before. Studies were undertaken from August 2015 to July 2016. Sampling was done along 60 to 100 m reach of each tributary using an electro-shocker. The fish were also caught using 3 layered net, cast net and gill nets of various mesh sizes (2.54 cm, 5.08 cm, 7.06 cm, 10.16 cm, and 12.7 cm). Triplicates of selected water parameters were obtained *in situ* at each sampling site using Sonde Multiparameters YSI 6920 V2.2 while the standard method of APHA (2005) was used to measure the *ex situ* water quality parameters. A total of 1,376 fishes belonging to 13 families and 58 species were caught. Cyprinidae is the most abundant freshwater family in Baram River with 63.37% of the total number of individuals caught. *Kryptopterus macrocephalus* is the most dominant species constituting 12.06% of the total individuals caught (166 individuals). Biological Indices such as Shannon-Weiner, Margalef's Index and Pielou's Index were used to determine the diversity and distribution of fish species. Long Apu (LA) recorded the highest Shannon Diversity Index H = 1.17 and the lowest was at Long San (LS) with H = 0.93. The highest richness Index was recorded at Lio Mato (LM) with D = 12.28 and the lowest was at Long Kesseh (LK) with D = 9.69. This showed that the total number of species at Lio Mato area is higher compared to the other sampling areas. The highest Pielou's evenness index was recorded at Long Apu (LA) with J = 0.36 and the lowest was at Long San (LS) with J = 0.28. This shows that fish species in Long Apu area are equally diverse and comparable to the other three areas in Baram River. Pooled water quality readings recorded throughout the study period showed that conductivity, DO, pH, temperature and BOD_5 were classified as Class I, while TSS and turbidity were categorized as Class III based on NWQS, Malaysia. This showed that the water can be used for irrigation with precaution but extensive treatment is needed before it could be used for domestic purposes. The exponent b value of LWR ranged from 2.316 (*Kryptopterus apogon*) to 3.487 (*Rasbora caudimaculata*). Length-weight relationship (LWR) and condition factor (K) of selected fish species show that only one species (*Barbonymus schwanenfeldii*) exhibited isometric growth, two species (*Pseudolais micronemus* and *Rasbora caudimaculata*) showed positive allometric growth and the remaining two species (*Krytopterus apogon* and *Osteochillus enneaporos*) have negative allometric growth. The highest mean condition factor (K), was recorded in *B. schwanenfeldii* (1.21±0.23) while the lowest value was observed in *K. apogon* (0.35±0.03). Higher K value showed that Baram River provided a much better habitat for this species. HSI values varied from 0.106 for *B. collingwodii* to 0.648 for *R. caudimaculata*. GSI of male varied from 0.39 for *H. planiceps* to 1.17 for *B. collingwodii*. GSI of female varied from 0.80 for *P. waandersii* to 13.04 for *R. caudimaculata*. Study on the feeding habits of fishes in Baram showed that *Barbonymus schwanenfeldii*, *Luciosoma setigerum*, *Pseudolais micronemus* and *Rasbora caudimaculata* are omnivorous while *Krytopterus apogon* is carnivorous. *C. apogon* could be classified as a euryphagous omnivore, feeding on a wide range of food of benthic organisms. *Hemibagrus planiceps* is suggested as euryphagous as they feed on wide ranges of food. The findings of this study are expected to benefit the planning and management towards conservation programs in Baram River.

Keywords: Fish distribution, diversity index, length-weight relationship, Pielou’s index.

Komposisi Ikan dan Parameter-parameter Fiziko-kimia di Ulu Batang Baram, Sarawak

ABSTRAK

Kajian ini bertujuan untuk mengkaji kepelbagaian dan taburan ikan air tawar dari empat kawasan (Lio Mato, Long Apu, Long San dan Long Kesseh) di Ulu Batang Baram, yang belum pernah dikaji sebelum ini. Kajian telah dijalankan dari Ogos 2015 hingga Julai 2016. Persampelan dijalankan pada jarak 60 hingga 100 m pada setiap anak sungai menggunakan teknik kejutan elektrik. Ikan juga ditangkap menggunakan pukat tiga lapis, jala dan pukat insang dari pelbagai saiz (2.54 cm, 5.08 cm, 7.06 cm, 10.16 cm, dan 12.7 cm). Tiga replikat sampel parameter air terpilih diperolehi in situ *di setiap kawasan persampelan menggunakan Sonde Multiparameters YSI 6920 V2.2 manakala kaedah piawai APHA (2005) digunakan untuk mengukur parameter-parameter kualiti air* ex situ. *Sebanyak 1,376 ekor ikan daripada 13 famili dan 58 spesies telah direkodkan.* Cyprinidae *adalah famili ikan air tawar paling banyak di Batang Baram mewakili 63.37% daripada jumlah individu yang ditangkap.* Kryptopterus macrocephalus *adalah spesis paling dominan yang mewakili 12.06% daripada jumlah tangkapan (166 individu). Indeks kepelbagaian seperti Shannon-Weiner, Indeks Margalef dan Indeks Pielou digunakan untuk menganalisis kepelbagaian dan taburan spesis ikan. Long Apu (LA) mencatat nilai indeks kepelbagaian Shannon yang tertinggi, H = 1.17 dan yang paling rendah direkodkan di Long San (LS) dengan H = 0.93. Nilai indeks kekayaan spesis tertinggi dicatatkan di Lio Mato (LM) dengan D = 12.28 dan paling rendah direkodkan di Long Kesseh (LK) dengan D = 9.69. Ini menunjukkan bahawa bilangan spesis di kawasan Lio Mato lebih tinggi berbanding dengan kawasan yang lain. Nilai indeks kesamaan tertinggi dicatatkan di Long Apu (LA) dengan J = 0.36 dan terendah di Long San (LS) dengan J = 0.28. Ini menunjukkan bahawa spesis ikan di kawasan Long Apu adalah sama rata dan setara* *dengan tiga lagi kawasan lain di Baram. Nilai semua kualiti air yang didapati sepanjang kajian menunjukkan bahawa kekonduksian, DO, pH, suhu dan BOD_5 diklasifikasikan sebagai Kelas I, manakala TSS dan kekeruhan sebagai Kelas III berdasarkan NWQS, Malaysia. Ini menunjukkan bahawa air sungai boleh digunakan untuk pengairan dengan terkawal tetapi rawatan yang ekstensif diperlukan sebelum ianya dapat digunakan untuk tujuan domestik. Nilai eksponen b bagi LWR adalah dari 2.316* (Kryptopterus apogon*) hingga 3.487 (*Rasbora caudimaculata). *Hubungan panjang berat (LWR) merekodkan hanya satu spesis yang menunjukkan pertumbuhan isometrik (Barbonymus schwanenfeldii), dua spesis menunjukkan pertumbuhan alometrik positif* (Pseudolais micronemus *dan* Rasbora caudimaculata) *dan dua spesis* (Kryptopterus apogon *dan* Osteochillus enneaporos) *mengalami pertumbuhan alometrik negatif. Purata faktor keadaan (K) yang paling tinggi dicatatkan pada* B. schwanenfeldii *(1.21 ± 0.23) manakala nilai terendah direkodkan pada* K. apogon *(0.35 ± 0.03). Nilai HSI berjulat dari 0.106 untuk* B. collingwodii *kepada 0.648 untuk* R. caudimaculata. *GSI jantan berjulat dari 0.39 untuk* H. planiceps *kepada 1.17 untuk* B. collingwodii. *GSI betina berjulat dari 0.80 untuk* P. waandersii *kepada 13.04 untuk* R. caudimaculata. *Kajian pemakanan ikan di Batang Baram menunjukkan bahawa* B. schwanenfeldii, L. setigerum, P. micronemus *dan* R. caudimaculata *di Batang Baram adalah omnivora, manakala* K. apogon *adalah karnivora. C. apogon boleh diklasifikasikan sebagai omnivora yang memakan makanan organisma bentik.* H. planiceps *dikategorikan sebagai euryphagous kerana memakan pelbagai jenis makanan. Penemuan kajian ini diharapkan dapat memberi manfaat kepada perancangan dan pengurusan ke arah program pemuliharaan Sungai Baram.*

Kata kunci: *Taburan ikan, indeks kepelbagaian, hubungan panjang-berat, indeks Pielou.*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATION

BOD_5	Biochemical Oxygen Demand
D	Margalef’s Species Richness Index
GSI	Gonadosomatic Index
H’	Shannon-Weiner’s Index
HSI	Hepatosomatic Index
J’	Pielou’s Evenness Index
LM	Lio Mato
LA	Long Apu
LS	Long San
LK	Long Kesseh
SL	Standard Length
TL	Total Length
TSS	Total Suspended Solids

CHAPTER 1

INTRODUCTION

1.1 Research Background

Aquatic systems are diverse and they include freshwater, rivers, lakes, swamp, islands, estuaries, coastal area, reefs and the seas (Arthington et al., 2016). Nelson et al., (2016) stated that there are more than 30,000 reported species of fish and posses variations in diet, habitat requirements, body size, geological structure, and life-history.

Freshwater ecosystems support great numbers of species of plants and animals. Those that live fully, or spent part of their life in either freshwater or estuaries are known as freshwater species (Arthington et al., 2016). Freshwater represents only 0.01% of the world's water which is equal to 0.8% of the Earth's surface, yet they provide at least 100,000 species from approximately 1.8 million, which is equal to 6% of all known species (Dudgeon et al., 2006). Freshwater ecosystems offer crucial ecosystem services which are important for global biodiversity (Angeler et al., 2014).

Malaysia is globally known as a mega diversity country blessed with 420 out of 1000 (42%) species of freshwater fish described in the South-East Asian region (Hashim et al., 2012). Malaysia is well endowed with varieties of ecosystems which can afford essential resources such as commercial aquatic resources, water, food, and transportation for its community. Furthermore, aquatic ecosystem in Malaysia also offer other important services for management such as flood and erosion control and shoreline protection, and plays very important role in tourism industry such as recreational activities (Yusoff et al., 2006).

The freshwater ecosystem is one of Malaysia's most important ecosystems which comprises of artificial and natural water bodies. It includes the riverine, lacustrine and palustrine where lacustrine consist of lakes (both natural and oxbow lakes), reservoirs and ex-mining pools while freshwater, wetlands and rice paddy fields habitats are classified as palustrine (WWFM, 2002). In addition, Malaysia has great potential to develop its commercials fisheries activities due to its high diversity and abundance (Kamaruddin et al., 2011).

Study on freshwater fishes in West Malaysia is conventional whereas in East Malaysia, the research is starting to actively grow. Exploration on the freshwater fishes in West Malaysia has improved steadily for the past 15 years where many new species were recorded. According to Zakaria-Ismail (1991), the works on freshwater fishes in Malaysia started in mid-19th century.

Studies on freshwater fish fauna of Malaysia have received little attention since the earliest days of ichthyological exploration in the region (Roberts, 1989) with work on freshwater fishes started in mid-19th century in Peninsular Malaysia (Zakaria-Ismail, 1991). An earlier study by Lim et al. (1993) recorded a total of 261 species representing 40 families of indigenous freshwater fish in Peninsular Malaysia. Meanwhile Lee et al. (1993) did a more comprehensive compilation of freshwater fish found in Peninsular Malaysia based on existing literature and recorded 43 families of freshwater fish with a total number of 292 species which includes thirteen introduced species found in the wild or natural freshwater habitats. To date, Peninsular Malaysia has probably one of the most comprehensively studied ichthyofauna diversity in the Southeast Asia region due to the easy access to various inland habitats (Ahmad & Khairul-Adha, 2005). In general, the fish diversity listed in Peninsular Malaysia shows the peninsula's close similarity with mainland Asiatic icthyofauna and the Sundaic component (Ahmad & Khairul-Adha, 2005).

Sabah and Sarawak have perhaps over 100 and 200 species, respectively. It is difficult to provide a close estimate of the diversity as many studies are still in progress or about to begin (Ahmad & Khairul-Adha, 2005). Therefore, the data presently available for Sabah and Sarawak are poor estimates. This low number basically reflects the lack of inventory studies. Sabah is better known for its freshwater fish diversity based on the work of (Inger & Chin, 2002).

In Sarawak, focus study was given to major rivers in the state with the earliest ichthyofaunal surveys conducted by the Department of Agriculture in three major river systems, namely, Sungai Rajang, Batang Ai and Sungai Baram (Salam & Gopinath, 2006). A status report was made in 1985 regarding the freshwater fish of Sarawak, which listed 59, 31 and 43 fish species found in Batang Rajang, Batang Ai and Batang Baram, respectively (Salam & Gopinath, 2006). The listing of species that occurred in the river drainage including those that occurred in Batang Rajang can be found in Parenti & Lim (2005) while Watson & Balon (1984) conducted a survey along the Baram River which was associated with taxonomic work.

In addition, several fish fauna studies have also been carried out within the watershed of Baram River, including Watson and Balon (1984) in Baram River, Nyanti et al. (1999) in Kelabit Highlands, Nyanti et al. (2006) in Loagan Bunut National Park.

1.2 Problem Statement

Although many surveys have been done on Sarawak freshwater fishes, there are only few studies carried out especially in the watershed of the uppermost catchment of the Baram River. Information on the documented fish species in the uppermost catchment of Baram River River is still limited. Therefore, more studies are required to provide detailed and specific information on the fish diversity, the distribution and abundance of freshwater fish in this region.

Besides, human settlement along Baram River may also contribute to the deterioration of water quality as the river supports economic activities of local communities such as fishery, transportations and domestic use. Several studies showed fish abundance is highly affected by water quality. Thus, a continuous assesment of water quality in Baram River is important in order to study their relationship with fish fauna composition as water quality provides latest information and state of pollution in the river.

The length-weight relationship of fishes can be used as an indicator of environmental changes and fish ecological health for freshwater fishes in this area. Condition and state of the well-being of fish can be determined by their length-weight relationship and condition factor. Knowledge of length-weight relationships (LWR) is also an important tool for adequate management of any fish species which have been applied in the assessment of fish stocks and populations (King, 2007). However, there is still lack of assessment on important fish study highlighting the Baram River which is the 2nd longest river in Sarawak after Rajang River.

On the other hand, it is essential to collect data on fish community which includes the knowledge of their stomach contents in order to manage and conserve freshwater fish resource. Food is the main source of energy and plays an important role in determining the population level, rates of growth and condition of fishes (Begum et al., 2008). Proper growth of fish depends mainly on the quantity and quality of food having all the essential nutrients. However, there is no such detailed works to date that has been done on food and feeding habit of fishes in Baram River and its tributaries.

1.3 Research Objective

Thus, the objectives of this research were to (a) determine the fish composition, biological indices and the latest status of water quality in Baram River, (b) study the relationship between the length and body weight (LWR) of fishes, condition factor (K), hepatosomatic index (HSI) and gonadomatic index (GSI) of fishes caught in the whole study area in Baram, and lastly (c) to identify the food items and stomach content of selected fish species in Baram.

CHAPTER 2

LITERATURE REVIEW

2.1 Freshwater Fish Fauna Composition in Malaysian Water

Highly diverse streams in Malaysia inhabit wide range of fish diversity. Zakaria-Ismail (1991) reported that Peninsular Malaysia and Borneo Island, which is located in Southeast Asia region is regarded as having one of the utmost diversity of freshwater fish in the world. Malaysia is listed in the top 10 countries in the world for the highest freshwater fish diversity with more than 600 species that have been recorded (Kottelat & Whitten, 1996).

Research conducted by Chong et al. (2010) in Malaysia came up with 521 freshwater fish species found in Malaysia freshwater ecosystem. For east Malaysia, the most well-known research on freshwater fish was conducted by Kottelat and Lim (1995) and Inger and Chin (1962) which carried out a study on ichthyofaunal survey in Sabah. The earliest itchyofaunal study in Sarawak was carried out at Rajang River with 59 species, Batang Ai with 31 species, while Baram River recorded 43 fish species (Salam & Gopinath, 2006).

According to Hasyimah et al. (2013), with more than 1,000 species listed in several parts of Asia, cyprinids appeared to be the most abundance fish family in this region. Mohsin and Ambak (1983) reported that Cyprinidae constitutes a major proportion of stream fishes in Peninsular Malaysia. For comparison, Cyprinidae is the most dominant family at Nanga Merit comprising 59.5% of the total fish caught (Hassan et al. 2010). In addition, research by Khairul Adha et al. (2009) showed that Jempol and Serting water bodies are also dominated by cyprinids with 79.7% of the total fish caught, and similar result was obtained by Izzati & Samat (2010) in Pulau Langkawi where the community of stream fishes was dominated by Cyprinids with 29.63% of the total number of individuals caught.

The same phenomenon was observed for Sarawak water bodies. For example, in Dappur River in Bario Highlands, the most common family caught was Cyprinidae, comprising 57.9% of the total number of fish caught (Nyanti et al., 1999). Khairul Adha et al. (2009) reported that Batang Kerang was also dominated by Cyprinidae which comprised 63.8% of total fish collected and a research conducted in Layar River and Spak River, Betong, Sarawak by Jeffrine et al. (2009) showed that the freshwater fish communities was also dominated by Cyprinidae, comprising approximately 94.3% and 74% of the total individuals caught, respectively.

The most common cyprinids that inhibit the Malaysian water are sebarau scientifically known as Hampala macrolepidota, kelah or Malaysian Mahseer comprising of Tor spp., and temoleh (*Probarbus jullieni*). Meanwhile, sultan fish (*Leptobarbus hoevennii*), tenggalan (*Puntioplites bulu*), kelah (*Tor tambroides*) and tinfoil barb (*Barbonymus schwanenfeldii*) are among the commercially important freshwater fish as reported by Salam & Gopinath (2006).

In studies of fish composition and diversity, it is very important to evaluate the factors that influence the assemblages of the fish in ecosystem (Galactos et al., 2004). There are several factors such as breeding sites, water current, depth, food availability, and physicochemical characteristics of water and topography which influence the distribution and composition of fish species in each habitat (Harris, 1995). Apart from that, both the abundance and species composition of stream fishes is influence by the physical habitat structure (Finger, 1982).

2.2 Effects of Water Quality on Freshwater Fish

Freshwater is an essential requirement for mankind, since it is directly linked to human welfare (Yogendra & Puttaiah, 2008) and is considered as one of the most sensitive parts of the environment (Das & Acharya, 2003). However, the most important sources of water for human activities, the surface water bodies, are unfortunately under severe environmental stress and are vulnerable as a consequence of developmental activities (Yogendra & Puttaiah, 2008).

Water quality gives most recent data about the status of various solutes at a given place and time. According to Iqbal et al. (2004), water quality parameters are indicators used to determine the suitability of water for its selected uses and to improve the current conditions. Random distribution of water on the surface of the earth and fast deteriorating availability of freshwater are the main concerns in terms of water quantity and quality (Boyd & Tucker, 1998).

Rivers are vital resources for life. Water quality does affect the fish composition in the rivers. Physico-chemical parameters such as water temperature, the amount of dissolved oxygen in the water bodies, pH, and chlorophyll-α and TSS level all influence the suitability of water for fish (Amneera et al., 2013). Besides, there are several factors that lead to deteroration of water quality in Malaysia including sediment run-off, industrial waste, domestic waste and heavy metals (Amneera et al., 2013).

Rivers play a very important part of our daily life. For example, Baram River is still an essential means of transportation for many of the people living in the region and they also depend on the river for their daily livelihood such as agricultural, fishing and for domestic use.

Alterations in the water and habitat quality are mostly due to the embankment, forest removal, urbanization and diversions for irrigation (May & Brown, 2002). The deterioration of water quality has been recognized as a possible challenge which directly impacts the aquatic organisms leading to deterioration in diversity.

Past study by Negi and Mamgain (2013) showed that the physical habitat variables play a very crucial role where habitat alteration cause a threat to freshwater fish fauna and it was revealed that temperature, DO and pH are directly associated with fish composition distribution in River Ton (Negi & Mamgain, 2013). In addition, a continuous assesement of water quality is very important to determine the state of pollution in our rivers. This information is vital to be communicated to the general public and the government in order to improve policies for the conservation of the precious fresh water resources (Ali et al., 2000).

2.2.1 Dissolved Oxygen

Most of the organisms that live in natural waters continuously consume dissolved oxygen (DO) to live. Generally, oxygen becomes dissolved in surface waters as a result of diffusion from the atmosphere and photosynthesis carried out by the aquatic plant (Al-Badaii et al., 2013). Water with low dissolved oxygen produces distinct smell because of various pollutants in the water and waste product produced by organism that live in such low oxygen environment (Gosomji & Okooboh, 2013).

The concentration of DO that will trigger avoidance behavior varies among species and life stages, depending on their tolerances to low DO concentrations. For example, Sharma and Gupta (2014) reported on the effect of oxygen on fish where fish that are exposed to low DO concentration tend to change in behavior thus resulting in changes in distribution, habitat use, activity, and respiration mode. Low DO concentrations also lead to reduction of energy available which is very useful for the production of viable eggs and larvae, thus affecting their spawning activities (Sharma & Gupta, 2014). Another observation showed that fishes are prone to some diseases called asphyxiation which lead to suffocation due to low DO level in water (Sharma and Gupta, 2014). In addition, dissolved oxygen also affects feeding behavior of fish. Fishes that is exposed to low DO concentration becomes lethargic as they do not have enough energy to swim and hunt for food (Sharma & Gupta, 2014). The same phenomenon was observed in a study by Abdel-Tawwab et al. (2015) where DO significantly affected fish growth and feed utilization. Freshwater streams ideally should have dissolved oxygen level ranging between 7-11 mg/L in order to support diverse aquatic life (Behar, 1997). DO is therefore acting as an indicator for the health of an aquatic ecosystem and the best sign to show ability of the water body to support aquatic life (Gosomji & Okooboh, 2013).

2.2.2 pH

Ngueku (2014) reported that low pH leads to fish death, retard the growth of natural food organisms and increase toxic ammonia at higher levels. Generally, photosynthetic algae activities that consume carbon dioxide tend to increase pH concentration (Ngueku, 2014). A study by Al-Badaii et al. (2013) on water quality based on the physicochemical and biological parameters in Semenyih River showed that the range of pH from 6.5 to 9 is most appropriate for aquatic organisms.

2.2.3 Temperature

Climate change could cause changes in species behavior because temperature has a prominent effect on biological and chemical processes. Water temperature is one of the most essential physical aspects affecting fish growth and production. Changes in temperatures are lethal to individual organism of a species affecting the distribution and abundance of populations (Walberg, 2011). Fluctuation in temperature below optimum levels can affect food conversion, oxygen production and toxic ammonia production (Ngueku, 2014).

Every species can be active, grow, reproduce, and function best at optimal temperature range (Dodson, 2005). Fish individuals are restricted in their movements by water systems due to climate change thus, preventing the migration to more thermally suitable locations (Walberg, 2011). Fish are vulnerable because their body temperature varies with the ambient temperature due to their ectothermic nature and this will affect their physiological processes (Pang et al., 2011). Pang et al. (2011) also reported that an increase in body temperature within a certain range usually results in higher respiratory and digestive process. Fish dissipate excess body heat by moving to different locations of favorable water temperature because they are unable to perform perspiration (Pough et al., 2009).

2.2.4 Turbidity

Turbidity is a parameter of the optical properties in a sample, and is a measure of the light rays being scattered and absorbed rather than transmitted in straight lines through the sample (Kjelland, 2015). Turbidity values within the standard permissible limits of NWQS for Malaysian rivers are between 5 NTU to 50 NTU. Turbidity affects dissolved oxygen levels in water bodies by reducing aquatic plant photosythesis due to low light transmission through the water (Berry et al., 2003). High turbidity leads to poor light penetration which in turn decreases the rate of photosynthesis and oxygen production as well as the production of natural food organisms (Ngueku, 2014). It can also affect fish directly by clogging the gills and impair visibility (Ngueku, 2014). As reported by Coen (1995), high turbidity in a waterbody may affect the biological activities such as restriction in migrations and spawning, movement patterns, sublethal effects (e.g., disease vulnerability, growth, and development) and cause death to aquatic organism.

2.2.5 BOD_5

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen taken by microorganisms during the oxidation of reduced substances in waters and wastes (Penn et al., 2006). This also is supported by Rajan (2015) who mentioned that biological oxygen demand is a semi-quantitative measure of biodegradable organic waste contained in any water/waste water. Organic material from decaying plants and animal wastes are the natural sources of BOD in surface water (Penn et al., 2006).

According to Penn et al. (2006), organic strength of wastewater can be determined by conducting the BOD5 test. Kwak et al. (2013) also reported that determination of BOD5 is the most commonly standardize test to monitor the water quality of surface waters and the wastewater. BOD has been used as an indicator for the amount of organic load in water body, which is used to check the status and pollution of water (Rajan, 2015). Waters is considered as clean when BOD level is less than 4 mg/L while BOD level more than 10 mg/L are considered as polluted as they contain huge amounts of degradable organic matter (Mc Neely et al., 1979). According to Bhatnagar et al., (2004) the BOD level between 3.0-6.0 mg/L is optimum for normal activities of fishes whereas 6.0-12.0 mg/L is sublethal to fishes.

2.2.6 Total Suspended Solids

The term suspended solids (SS) refers to the mass (mg) or concentration (mg/L) of inorganic and organic matter, which is held in the water column of a stream, river, lake or reservoir by turbulence (Bilotta & Brazier, 2008). TSS concentration within the standard acceptable levels of NWQS for Malaysia are 25 to 150 mg/L. Total suspended solids (TSS) is both a significant part of physical and aesthetic degradation and a good indicator of other pollutants, like nutrients and metals that are carried on the surfaces of sediment in suspension (Packman et al., 1999). Over the last 50 years, the effects of total suspended solids (TSS) on fish and aquatic life have been studied intensively throughout the world (Bilotta & Brazier, 2008). It is now proved that TSS are essential cause of water quality deterioration leading to aesthetic issues, higher costs of water treatment, a deterioration in the fisheries resource, and severe ecological degradation of aquatic environments (Bilotta & Brazier, 2008).

2.3 Feeding Habit of Fishes

Freshwater reservoir fishery was recognised by the Malaysian government as an important sector which deserves special attention for development (Mustafa-Kamal et al., 2012). In order to manage and conserve freshwater fish resources, it is important to collect basic information on the fish population in the area. The main factor is to study both the biological and fundamental processes of individual fish species, which includes the knowledge of their feeding habits (Mustafa-Kamal et al., 2012). In addition, as reported by Nyunja et al. (2002), other than growth, feeding habit of fishes also plays a vital role in fish abundance, distribution and migration. Thus, knowledge on the feeding interaction and feeding habit among species are critically important for a better conservation programme (Balik et al., 2003).

Food is any substance consumed to provide nutritional support for the body (Iyabo, 2016). Food is the main staple source of energy and plays a very important role to determine the population levels, rate of growth and condition of fishes (Iyabo, 2016). Alam et al. (2011) claimed that availability of food found in the fish habitat determine the variation in the food and feeding habits of different fishes. Understanding feeding habits of fish is useful to all scientists who are concerned with any aspect of fisheries.

Nikol'skii (1963) categorized food of fishes into four groups based on the relationships between the fishes and their food. They are: i) Basic food, which represent the common groups found in the gut of this fish species; ii) Secondary food, which is commonly found in the stomach of fishes but in minor quantities; iii) Incidental food, which only rarely enters the gut, and iv) Obligatory food, which the fish consumes in the absence of basic food.

Royle (2001) reported that potential food resources of fish consist of all materials present in its environment. Lagler (1949) reported that the gut contents only show what the fish would consumed. Fishes have been known to feed on a wide variety of items ranging from sand particles, phytoplankton, zooplanktons, crustaceans, roots, worms, insects, insect larvae, leaves and fishes (Omodi et al., 2011). Studies on stomach content of fishes provides crucial information on feeding patterns of the fish and data on quantitative assessment of food habits is very useful in fisheries management. The natural habitats provide a wide range of organisms that are consumed by fish as their food, which varied in body sizes and comes from various taxonomy groups (Olojo, 2003). The stomach content analysis of fish in their natural habitats enriches the understanding of growth, abundance, productivity and distribution of organisms (Fagade & Olaniyan, 1972).

The study on food and feeding habits of fish species is a subject of continuous research because it is the basis for the development of a successful fisheries management program on fish capture and culture (Oronsaye & Nakpodia, 2005) and because the aquatic ecosystem is dynamic. The gut content is a reflection of the water quality, all other factors being constant (Ekpo et al., 2014).

Studies on the feeding habits of fishes have been done in several localities in Malaysia such as by Azfar et al. (2015) on fishes in Pahang River, Mustafa-Kamal et al. (2012) in Pengkalan Gawi-Pulau Dula, and Zakeyyudin et al. (2017) in Sungai Kerian tributaries. From these studies, various kinds of food items consumed by the different sizes of fishes included insects, crustaceans, phytoplankton, zooplankton, unidentified materials, fish parts, plant part, mollusk and detritus.

2.4 Length-weight Relationship

Knowledge on length-weight relationship and condition factor (K) of fishes is an important tool in fisheries biology and assessments. According to Isa et al. (2010), the length-weight relationship indicates the degrees of stabilization of taxonomic characters in fish species and is very crucial in the management and exploitation of fish population. Length-weight relationship of fish is necessary to transform to the length structure obtained into the weight of fish captured (Victor et al., 2014). In addition, length-weight relationship data can be used in fisheries study as they provide crucial information on population parameters and also very useful in comparative growth study (Victor et al., 2014) caused by environmental factors because the growth of the fish is dependent on the availability of food and habitat. Generally, fish tend to grow and experience heavier than normal body weight at certain length if they consumed enough food in their ecosystem (Victor et al., 2014). The length-weight relationship parameters allow the estimation of fish condition.

The three types of growth experienced by fish are isometric growth, negative allometric growth or positive allometric growth. Isometric growth indicates that no change in body shape as an organism grows (Nehemia et al., 2012). Negative allometric growth implies the fish becomes slimmer as it increases in weight, while positive allometric growth suggests the fish body becomes heavier as it increases in length (Riedel et al., 2007).

The condition factor shows the degree of well-being of the fish in their habitat is expressed by ‘coefficient of condition’ also known as length-weight factor (Nehemia et al., 2012). In addition, condition factor is a quantitative parameter of the well-being of the fish which reflects on the current feeding condition that will determine present and future population success by its influence on growth, reproduction and survival. In another word, condition factor refers to the factor of well-being and the degree of fatness of fish (Victor et al., 2014). This factor is a measure of various ecological and biological factors such as degree of fitness, gonad development and the suitability of the environment with regard to the feeding condition (Mac Gregoer, 1959). The condition factor value reflects a better condition of the fish. Several factors that affect condition factor of fish are the food availability, sex, season, and condition of water quality (Khallaf et al., 2003).

Nowadays, many researchers used condition factors to get information about the biological status of fish. Among all the fish with the same length, the heaviest will be in better condition (Bagenal & Tesch, 1998).

The relationships between length and weight were calculated by the method of least squares to fit a linear regression as: $Y = a + bX$, where Y is the body length, a is proportionality constant, X is the total length and b is regression coefficient (Le Cren, 1951). The length-weight relationship was calculated using the expression: $W= aL^b$, where W is the body weight (g), L is the total length (cm), “a” is the intercept of the regression and b is the regression coefficient or slope (Froese, 2006). Also, Fulton’s condition factor

(K) was calculated according to the equation of K= w/aL^b (Le cren, 1951), where W is the whole body weight (g), L is the total length (cm), and a and b are the parameters of length-weight relationship (Le cren, 1951).

2.5 Hepatosomatic Index

The hepatosomatic index (HSI) is widely known as bioindicator of contaminant exposure (Sadekarpawar & Parikh, 2013). This term is usually used in fisheries science as an indicator of energy reserves in the liver (Cerda et al., 1996). Hepatosomatic index is important because it describes the fish's stored energy and is a good indicator of recent feeding activity (Tyler & Dunns, 1976). In poor environment condition, fish usually have a smaller live due to less energy reserve in the liver. Studies evaluating the relative liver size of fishes from contaminated sites and the least disturbed sites often utilize the HSI, which expresses liver size as a percentage of total body weight (Sadekarpawar & Parikh, 2013).

2.6 Gonadosomatic Index

GSI is the percentage of gonad weight and fish weight ratio, including gonads that expressed gonadal changes quantitatively (Wootton, 1991). To understand the gonadal capacity of any fish, gonadosomatic index is a scientifically approved indicator because it gives a correct time span regarding the season of spawning (Pimple & Kharat, 2014). Spawning time is often identified from the changes in gonadosomatic index which determines reproductive season (Arruda et al., 1993).

2.7 Threat to Freshwater Fish

As reported by Chow et al. (2016), Malaysia has 189 river systems, with 100 are located in East Malaysia and the rest are in Peninsular Malaysia. However, anthropogenic activities such land clearing activities, discharge of sewage and industrial effluent disturbed the ecosystem where 42% of the rivers systems have been classified as polluted (Juahir et al., 2011). According to Rosnani (2001), the main pollution sources affecting rivers in Malaysia comes from sewage disposal, discharges of waste from small and medium sized industries that are still not equipped with proper effluent treatment facilities and deforestation.

Freshwater species are defined as those that live fully, or spent part of their life in either freshwater or estuaries (Arthington et al., 2016). Freshwater fish biodiversity is a valuable natural asset in terms of cultural, economics and scientific importance. And yet, the inland freshwater ecosystem in Malaysia is declining at a far greater rate than terrestrial ecosystems in the tropics (Keat-Chuan et al., 2017).

Headwater stream fish communities are increasingly becoming isolated in headwater that are often cut off from other metapopulations within a river network as a result of non-native fish invasions, pollution, water abstraction and habitat degradation downstream (Ellender & Weyl, 2015). Besides, variations in the distribution and diversity of bottom substrates are important factors influencing fish community structures in these systems (Kemenes & Forsberg, 2014). This range restriction and isolation therefore makes them vulnerable to extinction. In addition, headwater streams are considered particularly vulnerable to floods because they have smaller catchments and are easily influenced by relatively minor changes in local conditions (Meyer et al., 2007). Unpredictable, infrequent and catastrophic floods can result in slope failures, bank erosion, substrate scouring, and loss of habitat and biota (Resh et al., 1988). Understanding threats to isolated fish populations is consequently important for their conservation.

CHAPTER 3

FISH FAUNA COMPOSITION AND PHYSICOCHEMICAL PARAMETERS OF UPPER BARAM RIVER

3.1 Introduction

Sarawak, which is located in Borneo, is blessed with the unique fish fauna compared with adjacent regions (Kottelat & Whitten, 1996). Baram River and Rajang River are the two main river systems in Sarawak. Baram River is considered as one of the major eastern drainage for this state and the earliest study on freshwater fish composition was documented by Watson & Balon (1984) which listed 24 species.

Understanding distribution of fishes and compositions change over time has long been an ultimate interest of aquatic ecologists and has progressively become recognized as an important element in fisheries science and management. The study on diversity and distribution of fish fauna could be used as an indicator for fish and fisheries management that provide information on the response to the quality of the environment.

Research on diversity and assemblages of freshwater fish need certain dimensions to be documented to monitor the current state of the habitat condition (Azmir & Samat, 2010). It could be a typical characteristic of fish community composition, but the type of species that occurred may differ for different locations in the river although they are within the same geographical region (Azmir & Samat, 2010). Anthropogenic activities have the capability of changing habitat condition that could potentially change the fish abundance and distribution (Zakaria-Ismail, 1999).

Information on fish fauna and water quality in the upper river system of Baram River are still limited. Therefore, the objectives of this chapter were to determine the fish composition, biological indices and the latest status of water quality in Baram River.

3.2 Materials and Methods

3.2.1 Study Sites

This study was carried out at Baram River, which originates in the Kelabit Highlands, a watershed demarcated by the Iran Mountains of East Kalimantan, which form a natural border with Sarawak. Baram River is located at latitude of 4.5883° N and longitude of 113.9703° E. Baram River is the second longest river in Sarawak after Rajang River with a length of 402 km and catchment of 22,325 km^2 (Yusoff et al., 2006). Rivers in Baram is a life for rural communities as they use this river for transportation, domestic use and source of protein and it is rightly called the rice bowl of the communities.

The study on diversity and distribution of freshwater fishes at Baram River was carried out from August 2015 to July 2016. A total of 29 sampling stations were selected along the four sampling areas starting from Long Kesseh area and all the way up to Lio Mato with the aimed to document the fish fauna composition and diversity and water quality. The location of the stations at each study area is shown in Figure 3.1, while the coordinates of the stations are shown in Table 3.1. The physicochemical characteristics of water quality at each station were recorded.

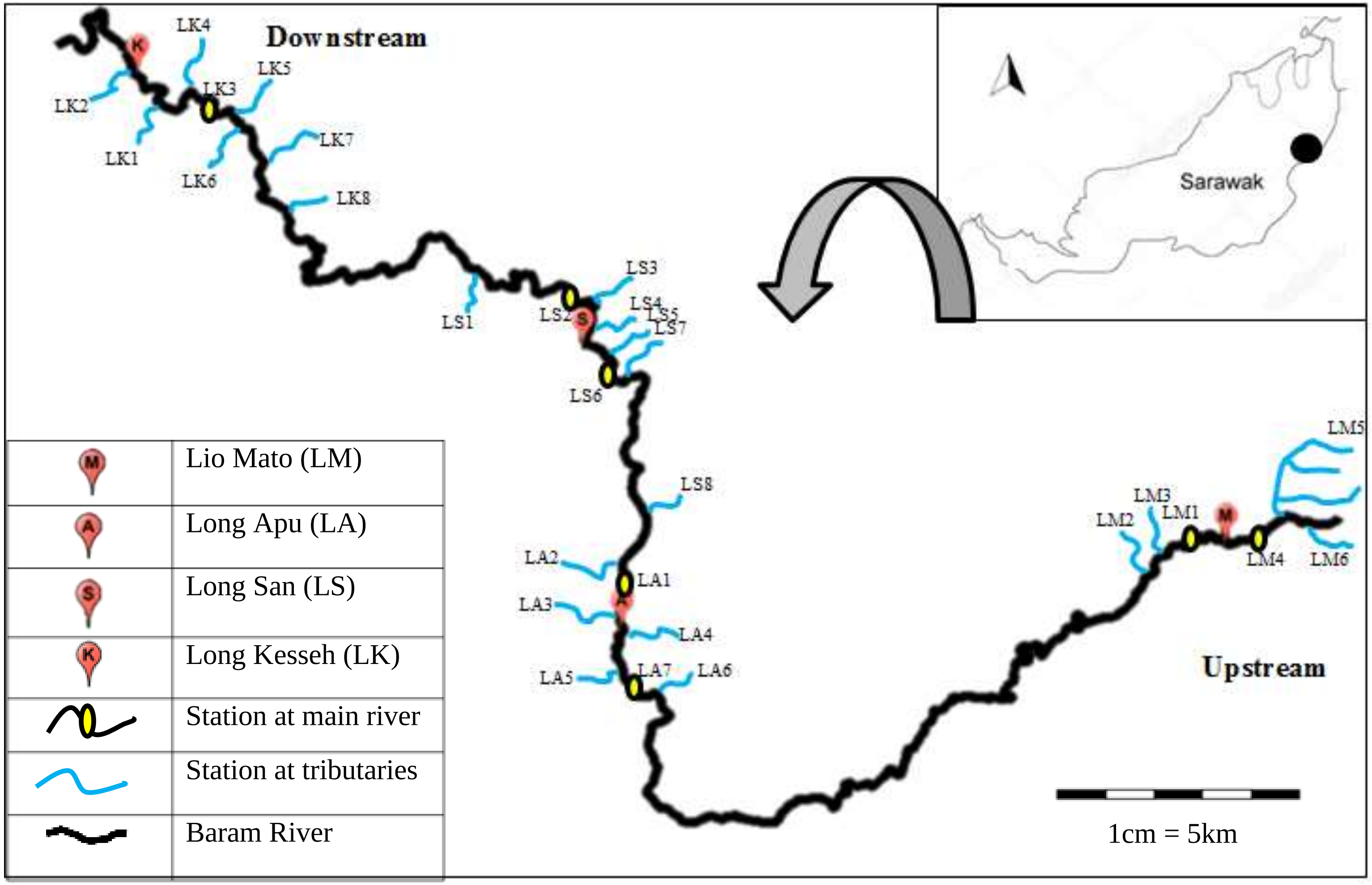


Figure 3.1: Location of the four sampling areas at upper Baram River and its tributaries.

Table 3.1: The sampling stations, coordinates and mean depth of each station.

Date & Time	Location	Coordinates	Mean Depth ± SD (m)	Mean Width ± SD (m)	Habitat Condition
31 July 2015 10.47 am	Baram River (LM 1)	N03°10’17.1’’ E115°11’59.5’’	2.00±0.28	6.7±0.25	Bank was dominated by big tree and shrubs, fast flowing water with boulder
31 July 2015 10.27 am	Sungai Serupa (LM 2)	N03°10’7.7’’ E115°11’59.1’’	1.85±0.64	4.57±0.51	Dominant vegetation was shrubs and herbs, canopy cover 50% shaded, running water with gravel
31 July 2015 11.22 am	Sungai Serebu (LM 3)	N03°10’34.5’’ E115°12’27.4’’	2.05±0.49	2.93±0.21	Dominant vegetation was shrubs and herbs, canopy cover 50% shaded, running water with gravel, peeble and boulder
31 July 2015 11.30 am	Baram River 2 (LM4)	N03°10’10.1’’ E115°13’27.3’’	2.60±1.41	6.40±0.38	Bank was dominated by big tree and shrubs, Moderate flowing water
31 July 2015 11.41 am	Lio Samleng (LM 5)	N03°10’19.3’’ E115°13’28.2’’	0.40±0.14	3.40±0.36	Dominated by big trees and shrubs, 90% shaded by riparian cover vegetation, riffle and pools with peebles and gravels, fast flowing
31 July 2015 12.10 pm	Sungai Sepula (LM 6)	N03°10’6.3’’ E115°13’28.6’’	0.20±0.00	0.90±0.15	Dominated by big trees and shrubs, 90% shaded by riparian cover vegetation, riffle and pools with peebles and gravels
22 June 2016 1.51 pm	Baram River (LA 1)	N03°9’874’’ E114°49’452’’	0.50±0.12	9.40±0.35	Fast flowing water interspaced by large rocks, bank was dominated by big tree
21 June 2016 8.20 am	Sungai Lasa (LA 2)	N03°8’719’’ E114°48’611’’	0.40±0.13	7.40±0.29	Shrubs, herbs and grasses, riffle with dominant substrate, gravel, peeble, cobble and boulder
21 June 2016 3.38pm	Sungai Julan (LA 3)	N03°6’44’’ E114°48’386’’	0.30±0.10	5.40±0.32	Dominant vegetation was shrubs and herbs,70% shaded by canopy cover, riffle, running water with gravel, cobble and boulder
21 June 2016 1.53 pm	Sungai Plutan (LA 4)	N03°6’249’’ E114°48’671’’	2.80±0.00	4.20±0.21	Dominated by shrubs and herbs, canopy cover 50% shaded, riffle, running water with gravel, peeble, cobble and boulder
21 June 2016 11.45am	Sungai Menapun (LA 5)	N03°5’618’’ E114°48’396	0.30±0.12	5.40±0.38	Dominated by shrubs and herbs, canopy cover 50% shaded, riffle, running water with gravel, peeble,

Table 3.1 continued

Date & Time	Location	Coordinates	Mean Depth ± SD (m)	Mean Width ± SD (m)	Habitat Condition
22 June 2016 9.03 am	Sungai Beraan (LA 6)	N03°3'435'' E114°50'5''	0.54±0.13	5.50±0.25	Dominated by shrubs and herbs, canopy cover 50% shaded, riffle, running water with gravel, peeble, cobble and boulder.
22 June 2016 3.29 pm	Baram River (LA 7)	N03°5'949'' E114°48'741''	0.60±0.14	9.10±0.1	Bank dominated by grass and shrubs, low gradient bank slope.
19 July 2016 8.45 am	Sungai Kluan (LS 1)	N03°20'219'' E114°42'395''	0.50±0.10	6.70±0.25	Dominanted by shrubs, herbs and grasses, main habitat was riffle with dominant substrate, gravel, peeble, cobble and boulder.
16 July 2016 11.06 am	Baram River (LS 2)	N03°19'132'' E114°46'769''	0.80±0.12	7.70±0.21	Moderate flowing river, low gradient bank slope.
19 July 2016 11.19 am	Sungai Akah (LS 3)	N03°19'218'' E114°47'331''	6.50±0.14	6.60±0.15	Canopy cover is almost 100% open with riparian vegetation, fast flowing water.
19 July 2016 1.40 pm	Sungai Kelameh (LS 4)	N03°18'184'' E114°47'10''	1.00±0.14	7.60±0.21	Canopy cover is almost 100% open with riparian vegetation, fast flowing water, riffle with gravel.
19 July 2016 3.06 pm	Sungai Sabop (LS 5)	N03°16'688'' E114°48'20''	0.90±0.15	5.20±0.26	Dominanted by shrubs, herbs and grasses, riffles area with dominant substrates are gravel, peeble, cobble and boulder.
20 July 2016 8.16 am	Baram River (LS 6)	N03°16'105'' E114°48'539''	0.90±0.00	9.33±0.35	Canopy cover was almost 100% open with riparian vegetation, fast flowing
19 July 2016 4.51 pm	Sungai Benuang (LS 7)	N03°16'377'' E114°49'196''	0.30±0.00	8.10±0.28	Fast flowing water, interspaced with large rocks, canopy cover is almost 100% open with riparian vegetation.
20 July 2016 10.07 am	Sungai Pelet (LS 8)	N03°10'653'' E114°49'509''	0.30±0.12	1.50±0.20	Dominanted by shrubs and herbs, 70% shaded by canopy cover, running water with gravel, peeble, cobble and boulder.
14 January 2016 10.09 am	Sungai Nakan (LK 1)	N03°28'19.1'' E114°23'29.7''	0.51±0.00	8.10±0.28	Canopy cover is almost 100% open with riparian vegetation, bank populated by grasses, moderate flowing water.

Table 3.1 continued

Date & Time	Location	Coordinates	Mean Depth ± SD (m)	Mean Width ± SD (m)	Habitat Condition
14 January 2016 8.32 am	Sungai Kemenyih (LK 2)	N03°28’20.1’’ E114°25’30.7’’	0.09±0.00	3.90±0.1	90% shaded riparian cover, vegetation dominated by bigger trees and shrubs, riffle, pools with peebles
13 January 2016 9.04 am	Baram River (LK 3)	N03°27’30.0’’ E114°30’49’	1.14±0.00	12.47±0.21	Canopy cover is almost 100% open with riparian vegetation, bank dominated by shrubs, fast flowing water.
13 January 2016 8.28 am	Sungai Kesseh (LK 4)	N03°27’22.2’’ E114°30’39.5’’	0.35±0.00	9.30±0.35	Bank dominated by shrubs, herbs and grasses, riffle with gravel.
13 January 2016 9.32 am	Sungai Liseng (LK 5)	N03°26’25.9’’ E114°31’58.2’’	0.09±0.00	5.30±0.20	Dominated by shrubs and herbs, 50% shaded by canopy cover, riffle, running water with gravel, peeble cobble and boulder, fast flowing.
13 January 2016 10.23 am	Sungai Jertang (LK 6)	N03°26’21.5’’ E114°32’17.2’’	0.05±0.00	6.23±0.21	Dominated by shrubs and herbs, 50% shaded by canopy cover, riffle, running water with gravel, peeble cobble and boulder.
13 January 2016 11.18 am	Sungai Piping (LK 7)	N03°24’46.1’’ E114°33’29.6’’	0.50±0.00	6.43±0.32	Dominated by shrubs and herbs, 50% shaded by canopy cover, riffle, running water with gravel, peeble cobble and boulder, moderate flowing water.
14 January 2016 11.50 am	Sungai Kahah (LK 8)	N03°23’49’’ E114°33’16.2’’	0.50±0.00	7.30±0.35	Dominant vegetation are shrubs and herbs, 50% shaded by canopy cover, riffle, gravel and peeble.

3.2.2 Fish Fauna

3.2.2.1 Fish Sampling

Monofilament gill net, three-layered net, cast net and electroshocking devices were used to collect the fish samples. Monofilament gill net of various mesh sizes of 2.54 cm, 5.08 cm, 7.60 cm and three-layered net with mesh sizes of 15.00 cm, 2.00 cm and 7.50 cm were used at each station. These nets were set at each sampling site and were left overnight. Each net was inspected every day for three days from morning until late afternoon. Cast net with a mesh size of 2.5 cm was also employed where 8 throws were made at each station. At the tributaries, electro-shocker device powered by 100-watt portable AC generator fully equipped with two copper electrodes on wooden handles was used to collect the fish. The stunned fish was collected using scoop net while the nets were placed and left overnight. At each sampling point, electro-shocking was carried out for about 25 minutes, covering a distance of about 100 metres, including pools and riffles. Permission to carry out electrofishing in the study area was obtained from the headman of every village.

3.2.2.2 Fish Preservation

For fish preservation, the fish samples were kept in sample bottles and were fixed in 10% formalin and later transfered to 70% ethanol for long term preservation and further identifications. All important data such as name of station, date, and mesh size of net, as well as location of sampling site were labeled.

3.2.2.3 Fish Species Identification

The specimens were collected and sorted out according to species during the field work. The samples were identified at the sampling site and samples that could not be identified in the field were identified in the Aquatic Vertebrate laboratory. Species identification was based on standard taxonomic keys suggested by Mohsin and Ambak (1983), Roberts (1989), Kotellat et al. (1993), Inger and Chin (2002), and Tan (2006).

3.2.2.4 Fish Measurement

Fish measurement such as standard length, total length and body weight of each individual caught were recorded to study the growth and population of the species inhabiting the rivers. The standard length and total length were measured using plastic ruler and measuring board (Wildeo Model no.118).

3.2.3 Water Quality Parameters

3.2.3.1 *In-situ* Water Quality

Triplicates of selected water parameters such as temperature, pH, turbidity, conductivity and dissolved oxygen (DO) were obtained *in situ* at each sampling site using Multi-parameter Sonde Model YSI 6920 V2. Water transparency was measured using a secchi disk and measuring tape in triplicate. The Secchi disk was lowered into water and the depth at which it become invisible was recorded.

3.2.3.2 *Ex-situ* Water Quality

3.2.3.2.1 Total Suspended Solids (TSS)

The glass fibre filter (GF/C, 47 mm diameter) was soaked in distilled water, wrapped in the aluminum foil and dried in oven under 103-105 °C temperature. The filter paper was taken out from the oven and was allowed to cool for about 10 minutes to avoid the fluctuation of weight. Each filter paper that was already wrapped with aluminium foil was weighed using the calibrated analytical balanced (ACCULAB, ALC-210). The process of drying, cooling and weighing were repeated until a constant weight was achieved. The initial weight of each filter paper was recorded on the aluminium foil by using permanent marker.

The filtration system was set up and the prepared filter paper was placed using forceps on the glass inter plate of the filter funnel. For each replicate, 1 litre of the water sample was filtered. The filter paper was removed and folded back to its original aluminium foil and dried in the oven at 103-105 °C overnight. The filter paper was taken out from the oven and allowed to cool in the dissector, before being weighed. The standard method of APHA (2005) was used to measure the total suspended solids.

The formula that was used to calculate TSS is presented below:

$$\text{TSS (mg/L)} = \frac{\text{B - A}}{\text{C}}$$

A= Initial weight (mg)

B= Final weight of filter paper (mg)

C= Volume of water sample used (L)

3.2.3.2.2 Chlorophyll-*a*

Triplicates water sample were collected in 1000 ml bottle and placed in cooler box filled with ice blocks during transportation. All works with chlorophyll-α extract was conducted in subdued light or a semi-darkened room. The glass fibre filter (WHATMAN GF/C, 47 mm diameter with 45 µm pore size) was placed on the funnel between the top and bottom sections of the vacuum filter unit using forceps, with the ‘rough’ side on top. The water sample was filled into the top section of the filter unit. For each replicate, 1 litre of water sample was filtered as soon as possible to prevent degradation of pigments. The receiving conical flask below the filter unit was removed to discard the water. After the filtration, the filter paper on the top section was removed using forceps and fold with aluminium foil with the rough side on the inside. The sample was kept in the refrigerator. The volume of water sample being filtered, date and station name were recorded before the extraction process in the laboratory.

Sample extraction process was done as soon as possible. The filter paper was grounded by using mortar and pestle in approximately 5 to 6 mL of 90% aqueous acetone. The grounded filter paper was transferred into a capped test tube. The total volume of the solution was adjusted to 10 mL with 90 % aqueous acetone. The test tube was wrapped using aluminium foil and was put in refrigerator for about 18 to 24 hours to facilitate complete extraction of the pigments. The liquid extract was transferred into a centrifuge tube before being transferred into centrifuge machine (Gyrozen, 406) for 10 minutes under 3000 rpm.

The spectrophotometer (DR2800) was turned on approximately 30 minutes before scheduled use. Blank solution was prepared by filling a quartz cuvette with 90% aqueous acetone and the spectrophotometer was turned to zeros to calibrate. The supernatant was extracted to obtain the optical density in a spectrophotometer. The supernatant was transferred into a spectrophotometer cuvette (1 cm path length). The extraction at 750 nm, 664 nm, 647 nm and 630 nm was measured. The standard method of APHA (2005) was used to calculate Chlorophyll-α.

Chlorophyll-α concentrations (μg/mL) in water samples was calculated using:

$$\text{Chl } a \text{ (Ca)} = 11.85 * E_{664}\_C - 1.54 * E_{647}\_C - 0.08 * E_{630}\_C$$

$$E_{664}\_C = E_{664} - E_{750}$$

$$E_{647}\_C = E_{647} - E_{750}$$

$$E_{630}\_C = E_{630} - E_{750}$$

where,

Chl-*a* concentration in μg/mL if 1 cm light path cuvette was used

The chlorophyll-*a* concentration in μg/mL is converted to mg/m^3 in water by using this formula:

$$\text{Chl-}a\ (mg/m^3) = \frac{C\alpha \times v}{V}$$

where:

$C\alpha$ = Concentration of chlorophyll-a in mg/mL

v= Volume of acetone used for the extraction (L)

V= Volume of water filtered (m^3)

3.2.3.2.3 BOD_5

Dissolved oxygen was measured by using DO meter (HANNA Instrument, HI 9146). At each station, the initial DO reading was recorded and water sample was collected using 300 mL BOD glass bottle. The bottle was completely filled without trapping any bubbles and the stopper was inserted into the bottle to avoid trapping any bubbles. The bottles were wrapped using aluminium foil to avoid direct sunlight and placed in cooler box for 5 days. The reading was recorded on the 5th day. BOD_5 was calculated by using the formula based on APHA (2005):

$$BOD_5\ (mg/L) = D1 - D5$$

Where:

D1= Initial *in-situ* DO reading (mg/L)

D5= Day 5 DO reading (mg/L)

3.2.4 Biological Indices

The indices that were used are Shannon-Weiner's Diversity index, Margalef's Species Richness Index and Pielou's Evenness Index. Shannon-weiner index is used because it provides more complex information and is based on the number of species. In addition, it serves as a valuable tool in monitoring ecological change (Fedor & Spellerberg, 2013). One of the advantages of Shannon-Wiener index is that it is not greatly affected by sample size.

Margalef index was used to explain the changes occurring in the structure of fish community from Lio Mato area to Long Kesseh, Baram. This index was used due to its sensitivity to changes in the fish community structure and is therefore a good indicator of biodiversity (Iglesias-Rios & Mazzoni, 2014).

According to Magurran (1988), richness of the species is considered lower when the index value is less than 3.5, moderate richness when the value is between 3.5 to 5, and an index that is more than 5 indicates high species richness. Pielou index is a good measure of distribution of relative abundance in a community (Jost, 2010). Evenness expresses how evenly the individuals in the community are distributed over the different species.

- Shannon- Weiver's Diversity index (H') (Shannon & Weaver, 1963).

  The formula use is:

$$H' = n \log \quad \frac{n - \Sigma \text{ fi} \log \text{fi}}{n}$$

n = sample size

fi = number of individual for each species

- Margalef's Species Richness Index (D) (Margalef, 1958).

$$D = \frac{S - 1}{\ln n}$$

Where,

S = no. of species

N = total no. of organisms in samples

- Pielou's Evenness Index (J') (Pielou, 1966)

$$J' = \frac{H'}{\ln S}$$

Where,

H' = Species diversity value

S = no. of species

3.2.5 Statistical Analysis

Statistical Package for Social Sciences (SPSS) software version 23.0 was used to analyze all statistics to determine the significant differences of water quality parameters among stations for each sampling area. One-way analysis of variance (ANOVA) was used to determine the significant difference of each test. Post hoc test using Tukey was used to explain among the means. Level of significance was set at 5% ($p < 0.05$) to reject null hypothesis. In order to identify the relationship between water quality variables with fish assemblages in the study area, eight parameters were taken into consideration namely, turbidity, pH, temperature, dissolved oxygen, BOD_5, TSS, chlorophyll-α and conductivity. The relationship between water quality parameters with the number of fish individuals were analyzed using Canonical Correspondence Analysis (CCA). The CCA was examined using PAST 3.14. The significance of each variable was tested using CCA in PAST 3.14 with 5000 permutations at a significance level of 5% (Ikhwanuddin et al., 2016). The results are presented using canonical biplots.

3.3 Results

3.3.1 Fish Fauna Composition

3.3.1.1 Lio Mato, Baram

A total of 487 fishes from 34 species belonging to 5 families from the main river and 4 tributaries namely, Sungai Serupa (LM2), Sungai Serebu (LM3), Lio Samleng (LM5), Sungai Sepula (LM6) and 2 stations at main rivers (LM1 & LM4) were caught at Lio Mato.

Fish fauna composition in Lio Mato was dominated by Siluridae, which comprised 52.57% (N=256) of the total number of individuals caught, followed by the family Cyprinidae representing 41.89% (N=204), Pangasiidae representing 3.08% (N=15), Bagridae representing 1.85% (N=9) and Mastacembelidae representing 0.62% (N=3) as shown in Figure 3.2.

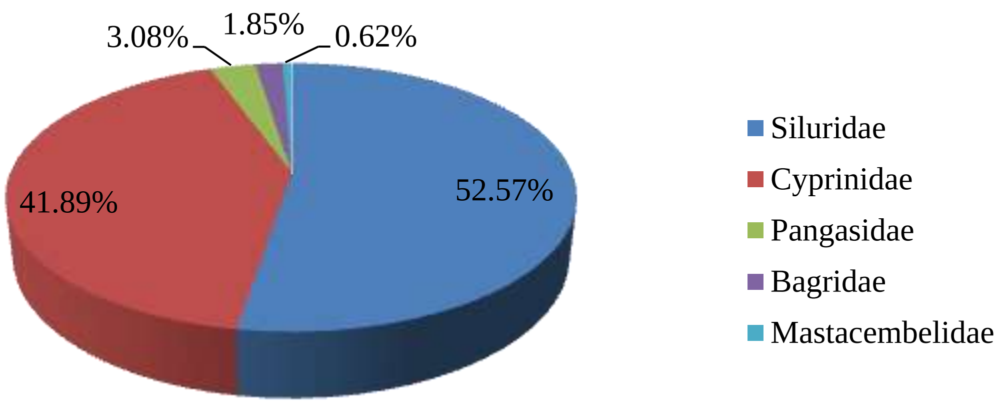


Figure 3.2: Percentage of fish family caught in all six stations at Lio Mato.

The family Siluridae was represented by *Kryptopterus apogon*, *Kryptopterus lumholtzi* and *Kryptopterus macrocephalus*. Family Cyprinidae is comprised of *Barbonymus collingwoodii*, *Barbonymus schwanenfeldii*, *Cirrhinus chinensis*, *Cyclocheilichthys apogon*, *Hampala bimaculata*, *Hampala macrolepidota*, *Leptobarbus hoevenii*, *Lobocheilos hispidus, Luciosoma setigerum, Luciosoma spilopleura, Nematabramis everetti, Osteochilus enneaporos, Osteochilus schlegelii, Osteochilus triporos, Osteochilus vittatus, Osteochilus waandersii, Parachela hypophthalmus, Parachela oxygastroides, Puntioplites waandersii, Rasbora argyrotaenia, Rasbora borneensis, Rasbora caudimaculata, Tor douronensis* and *Tor tambroides*. Family Pangasiidae is consisted of *Pangasius macronema, Pangasius micronema* and *Pseudolais micronemus*. Family Bagridae is comprised of *Bagrichthys micranodus, Hemibagrus planiceps* and *Nanobagrus armatus* while *Mastacembelus unicolor* is from the family Mastacembelidae.

The top five dominant species by number of individuals caught throughout this study were (in decreasing order) *Krytopterus macrocephalus* which recorded 166 individuals (34.09%), followed by *Krytopterus apogon* with 89 individuals (18.28%), *Luciosoma spilopleura* representing 7.60% or 37 individuals, *Barbonymus collingwoodii* with 24 individuals (4.93%) and *Rasbora argyrotaenia* with 16 individuals (3.29%) caught (Figure 3.3).

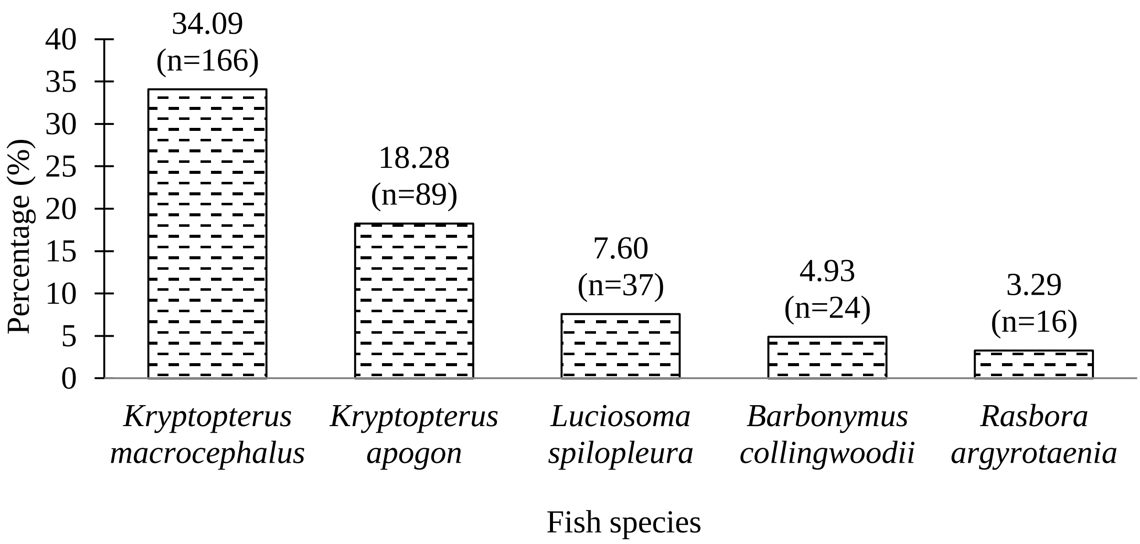


Figure 3.3: Percentages of the five dominant fish species caught at Lio Mato.

At Main River (LM1), the dominant species is *Rasbora argyrotaenia* with a total of 5 individuals and representing 25% of the total number of individuals caught. *Kryptopterus macrocephalus* has the highest number of individuals caught at both Sungai Serupa (LM2) and Sungai Serebu (LM3) with 154 individuals (40.63%) and 6 individuals (35.29%), respectively. At the main River (LM4), *Pseudolais micronemus* representing 28.21% or 11 individuals was caught. Lio Samleng (LM5) was dominated by *Lobocheilos hispidus* with a total of 5 individuals representing 41.67%, while Sungai Sepula (LM6) was dominated by *Rasbora caudimaculata* with 9 individuals (45%) caught (Table 3.2).

Table 3.2: List of fish family, species, number of individuals (N) and percentage (%) caught from all sampling stations at Lio Mato.

Station	Family	Species	N	(%)
Main River (LM1)	Bagridae	*Bagrichthys micranodus*	1	5
		Cyclocheilichthys apogon	1	5
		Luciosoma setigerum	1	5
		Luciosoma spilopleura	1	5
		Osteochilus triporos	2	10
		Osteochilus vittatus	2	10
		Puntioplites waandersii	2	10
		Rasbora argyrotaenia	5	25
	Pangasiidae	*Pangasius micronema*	2	10
	Siluridae	*Kryptopterus macrocephalus*	3	15
Sg Serupa (LM2)	Bagridae	*Hemibagrus planiceps*	4	1.06
		Nanobagrus armatus	3	0.79
	Cyprinidae	*Barbonymus collingwoodii*	23	6.07
		Barbonymus schwanenfeldii	4	1.06
		Cirrhinus chinensis	4	1.06
		Cyclocheilichthys apogon	3	0.79
		Hampala bimaculata	2	0.53
		Hampala macrolepidota	4	1.06
		Leptobarbus hoevenii	6	1.58
		Lobocheilos hispidus	1	0.26
		Luciosoma setigerum	5	1.32
		Luciosoma spilopleura	35	9.23
		Osteochilus schlegelii	4	1.06
		Osteochilus triporos	12	3.17
		Osteochilus vittatus	2	0.53
		Osteochilus waandersii	1	0.26
		Parachela hypophthalmus	1	0.26
		Parachela oxygastroides	9	2.37

Table 3.2 continued

Station	Family	Species	N	(%)
		Rasbora argyrotaenia	6	1.58
		Tor douronensis	3	0.79
		Tor tambroides	1	0.26
	Mastacembelidae	*Mastacembelus notophthalmus*	3	0.79
	Siluridae	*Kryptopterus apogon*	89	23.48
		Kryptopterus macrocephalus	154	40.63
		Rasbora argyrotaenia	6	1.58
Sg Serebu (LM3)	Cyprinidae	*Barbonymus collingwoodii*	1	5.88
		Hampala bimaculata	1	5.88
		Hampala macrolepidota	1	5.88
		Luciosoma spilopleura	1	5.88
		Osteochilus vittatus	4	23.53
		Rasbora argyrotaenia	2	11.76
		Tor duoronensis	1	5.88
	Siluridae	*Kryptopterus macrocephalus*	6	35.29
Main River (LM4)	Cyprinidae	*Barbonymus schwanenfeldii*	1	2.56
		Cyclocheilichthys apogon	5	12.82
		Luciosoma setigerum	5	12.82
		Nematabramis everetti	2	5.13
		Osteochilus enneaporos	5	12.82
		Puntioplites waandersii	1	2.56
		Rasbora argyrotaenia	3	7.69
	Pangasiidae	*Pangasius macronema*	2	5.13
		Pseudolais micronemus	11	28.21
	Siluridae	*Kryptopterus lumholtzi*	1	2.56
		Kryptopterus macrocephalus	3	7.69
Lio Samleng (LM5)	Bagridae	*Hemibagrus planiceps*	1	8.33
	Cyprinidae	*Barbonymus schwanenfeldii*	1	8.33
		Lobocheilos hispidus	5	41.67
		Osteochilus vittatus	4	33.33
		Tor duoronensis	1	8.33
Sg Sepula (LM6)	Cyprinidae	*Hampala bimaculata*	2	10
		Hampala macrolepidota	1	5
		Rasbora borneensis	7	35
		Rasbora caudimaculata	9	45
		Tor duoronensis	1	5

The fish fauna composition caught at each station in Lio Mato and their biological indices are presented in Table 3.3. The number of individuals caught from each station ranged from 12 to 379 individuals, with the lowest number of individuals was recorded from Lio

Samleng (LM5), while the highest number of individuals was from Sungai Serupa (LM2). Number of species caught from each station ranged from 5 to 10 species with the lowest number of individuals was from Lio Samleng (LM5) and Sungai Sepula (LM6), while the highest number of species was from Main River (LM1). Meanwhile, the number of family of fish caught ranged from 1 to 4 families. The lowest number of family was recorded at Sungai Sepula (LM6) and the highest was recorded at Main River (LM1) and Sungai Serupa (LM2).

Table 3.3: Fish composition at each station at Lio Mato, Baram River, Sarawak and their biological indices.

Sampling Area	Family	Species	Sampling Station					
			LM1	LM2	LM3	LM4	LM5	LM6
Lio Mato	Bagridae	*Bagrichthys micranodus*	1	-	-	-	-	-
		Hemibagrus planiceps	-	4	-	1	-	-
		Nanobagrus armatus	-	3	-	-	-	-
	Cyprinidae	*Barbonymus collingwoodii*	-	23	1	-	-	-
		Barbonymus schwanenfeldii	-	4	-	1	1	-
		Cirrhinus chinensis	-	4	-	-	-	-
		Cyclocheilichthys apogon	1	3	-	-	5	-
		Hampala bimaculata	-	2	1	-	-	2
		Hampala macrolepidota	-	4	1	-	-	1
		Leptobarbus hoevenii	-	6	-	-	-	-
		Lobocheilos hispidus	-	1	-	5	-	-
		Luciosoma setigerum	1	5	-	-	5	-
		Luciosoma spilopleura	1	35	1	-	-	-
		Nematabramis everetti	-	-	-	-	2	-
		Osteochilus enneaporos	-	-	-	-	5	-
		Osteochilus schlegelii	-	4	-	-	-	-
		Osteochilus triporos	2	12	-	-	-	-
		Osteochilus vittatus	2	2	4	4	-	-
		Osteochilus waandersii	-	1	-	-	-	-
		Parachela hypophthalmus	-	1	-	-	-	-
		Parachela oxygastroides	-	9	-	-	-	-
		Puntioplites waandersii	2	-	-	-	1	-
		Rasbora argyrotaenia	5	6	2	-	3	-
		Rasbora borneensis	-	-	-	-	-	7
		Rasbora caudimaculata	-	-	-	-	-	9

Table 3.3 continued

Sampling Area	Family	Species	Sampling Station					
			LM1	LM2	LM3	LM4	LM5	LM6
		Tor douronensis	-	3	1	1	-	1
Lio Mato		*Tor tambroides*	-	1	-	-	-	-
	Mastacembelidae	*Mastacembelus notophthalmus*	-	3	-	-	-	-
	Pangasidae	*Pangasius macronema*	-	-	-	-	2	-
		Pangasius micronema	2	-	-	-	-	-
		Pseudolais micronemus	-	-	-	-	11	-
	Siluridae	*Kryptopterus apogon*	-	89	-	-	-	-
		Kryptopterus lumholtzi	-	-	-	-	1	-
		Kryptopterus macrocephalus	3	154	6	-	3	-
		Number of individual	20	379	17	12	39	20
		Number of family	4	4	2	2	3	1
		Number of species	10	24	8	5	11	5
		Shannon-Weiner Index (H’)	1.090	1.064	0.848	0.587	1.048	0.546
		Pielou’s Index (J’)	0.413	0.272	0.386	0.365	0.387	0.339
		Margalef’s Index (D)	4.340	8.253	2.824	3.821	1.610	1.335

*(LM1, Main River; LM2, Sungai Serupa; LM3, Sungai Serebu; LM4, Lio Samleng; LM5, Main River and LM6, Sungai Sepula).

The occurrence of fish species from the six sampling sites caught in Lio Mato based on tributaries and the main river, total individuals caught, their standard length (SL), total length (TL), body weight (BW) and standard deviation are shown in (Table 3.4).

The top three dominant fish species in Lio Mato have TL range of 13.8 to 33.8 cm with a mean of 28.8±2.80 cm, and a BW range of 15.63 to 115.4 g with a mean of 81.36±17.22 g for *Kryptopterus macrocephalus*, TL range of 25.7 to 55.6 cm with a mean of 28.63±3.25 cm, and a BW range of 56.32 to 735 g with a mean of 86.52±70.27 g for *Kryptopterus apogon*, and TL range of 17.7 to 28.8 cm with a mean of 24.08±2.39 cm, and a BW range of 29.8 to 145.02 g with a mean of 85.60±24.17 g for *Luciosoma spilopleura*.

The values of Shannon-Weiner's Index (H') among the streams surveyed varied and its value ranged between 0.546 and 1.090. The lowest diversity index was recorded in Sungai Sepula (LM6), while the highest was recorded at Main River (LM1). The Margalef's Species Richness (D) ranged from 1.335 to 8.253. The lowest species richness was recorded at Sungai Sepula (LM6), while the highest was at Sungai Serupa (LM2). Meanwhile, Pielou's Evennes Index (J) ranged from 0.272 to 0.413. The lowest was recorded at Sungai Serupa (LM2), while the highest was recorded at Main River (LM1).

Table 3.4: Fish family, species, number of individual (N) caught from main river (LMMR) and its tributaries (LMTR) at each station at Lio Mato, Baram and their standard length, total length and body weight.

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LMMR	LMTR			
Lio Mato	Bagridae	*Bagrichthys micranodus*	0	1	1	18.1	59.98
		Hemibagrus planiceps	5	0	5	18.8±6.2	66.93±57.86
		Nanobagrus armatus	3	0	3	17.3±3.0	46.43±19.81
	Cyprinidae	*Barbonymus collingwoodii*	24	0	24	16.0±4.1	46.07±22.15
		Barbonymus schwanenfeldii	5	1	6	17.3±6.2	80.02±93.28
		Cirrhinus chinensis	4	0	4	22.6±2.9	71.20±36.94
		Cyclocheilichthys apogon	3	6	9	20.4±4.8	102.01±67.70
		Hampala bimaculata	5	0	5	19.2±2.2	73.43±31.54
		Hampala macrolepidota	6	0	6	20.5±1.6	86.45±22.57
		Leptobarbus hoevenii	6	0	6	20.5±4.9	103.92±57.02
		Lobocheilos hispidus	6	0	6	17.0±3.0	50.61±34.78
		Luciosoma setigerum	5	6	11	22.3±2.8	70.15±36.85
		Luciosoma spilopleura	36	1	37	24.2±2.4	86.60±24.17
		Nematabramis everetti	0	2	2	12.1±0.1	13.66±0.08
		Osteochilus enneaporos	0	5	5	19.5±2.0	76.61±30.43
		Osteochilus schlegelii	4	0	4	18.1±1.5	50.20±13.30
		Osteochilus triporos	12	2	14	14.8±3.7	36.88±26.44
		Osteochilus vittatus	10	2	12	15.1±4.2	39.71±37.48
		Osteochilus waandersii	1	0	1	19.4	56.93
		Parachela hypophthalmus	1	0	1	21.9	51.34
		Parachela oxygastroides	9	0	9	12.3±0.9	12.41±2.81
		Puntioplites waandersii	0	3	3	25.8±5.3	112.16±74.14
		Rasbora argyrotaenia	8	8	16	13.7±2.8	20.84±17.59
		Rasbora borneensis	7	0	7	13.6±1.1	17.50±4.89

Table 3.4 continued

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LMMR	LMTR			
Lio Mato		*Rasbora caudimaculata*	9	0	9	13.4±2.9	20.27±18.56
		Tor douronensis	6	0	6	17.8±4.0	57.08±31.10
		Tor tambroides	1	0	1	23.9	120.54
	Mastacembelidae	*Mastacembelus notophthalmus*	3	0	3	28.0±8.3	78.28±53.68
	Pangasidae	*Pangasius macronema*	0	2	2	33.5±2.8	307.50±31.82
		Pangasius micronema	0	2	2	23.4±4.5	86.06±43.15
		Pseudolais micronemus	0	11	11	22.1±3.4	70.77±33.67
	Siluridae	*Kryptopterus apogon*	89	0	89	28.6±3.3	86.52±70.27
		Kryptopterus lumholtzi	0	1	1	310	101.53
		Kryptopterus macrocephalus	160	6	166	28.8±2.8	81.36±17.22

*($N_{T,}$total number of individual caught; - , absence; SL, standard length, TL, total length, BW, body weight and SD, standard deviation).

3.3.1.2 Long Apu, Baram

A total of 279 fishes from 27 species belonging to 8 families from 5 tributaries namely, Sungai Lasa (LA2), Sungai Julan (LA3), Sungai Plutan (LA4), Sungai Menapun (LA5), Sungai Beraan (LA6) and 2 stations at main rivers (LA1 & LA7) were caught at Long Apu.

Fish fauna composition in Long Apu was dominated by Cyprinidae, which comprised 64.87% (N=181) of the total number of individuals caught, followed by the family Bagridae and Siluridae representing 8.60% (N=24), Gastromyzontidae and Pangasiidae each representing 7.89% (N=22), Balitoridae representing 1.08% (N=3), Mastacembelidae representing 0.72% (N=2), and Tetraodontidae representing 0.36% with only one individual caught as shown in Figure 3.4.

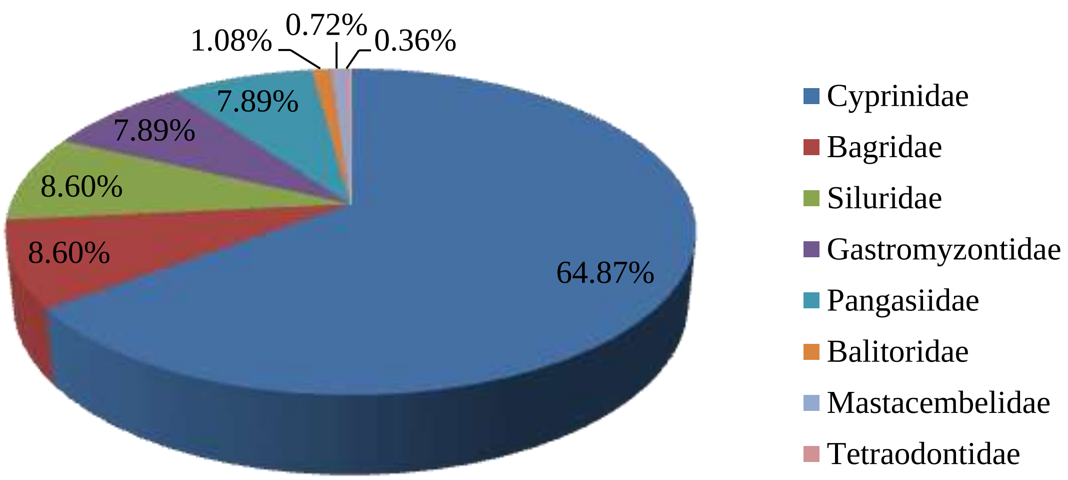


Figure 3.4: Percentage of fish family caught in all seven stations at Long Apu.

The family Cyprinidae represented by B*arbonymus schwanenfeldii*, *Cyclocheilichthys apogon*, *Hampala bimaculata*, *Hampala macrolepidota*, *Leptobarbus hoevenii*, *Lobocheilos bo*, *Lobocheilos hispidus*, *Luciosoma setigerum*, *Luciosoma spilopleura*, *Osteochilus enneaporos, Osteochilus kahajanensis, Parachela oxygastroides, Puntioplites wandersii, Rasbora caudimaculata,* and *Tor duoronensis.* Family Bagridae is comprised of *Hemibagrus planiceps* and *Hemibagrus wyckii* while family Siluridae is represented by *Ceratoglanis schelonema, Krytopterus apogon* and *Krytopterus Limpok.* Family Pangasiidae is represented by only one species which is *Pseudolais micronemus.* Family Gastromyzontidae consisted of *Gastromyzon fasciatus* and *Gastromyzon punctulatus.* Family Mastacembelidae are comprised of *Mastacembelus unicolor* and *Mastacembelus notophthalmus* while *Auriglobus silus* from the family Tetraodontidae.

The top five dominant species by number of individuals caught throughout this study are *Lobocheilos bo* which recorded 54 individuals (19.35%), followed by *Barbonymus schwanenfeldii* with 32 individuals (11.47%), *Osteochilus enneaporos* representing 9.68% or 27 individuals, *Hemibagrus planiceps* with 23 individuals (8.24%) and *Rasbora argyrotaenia* with 22 individuals (7.89%) (Figure 3.5).

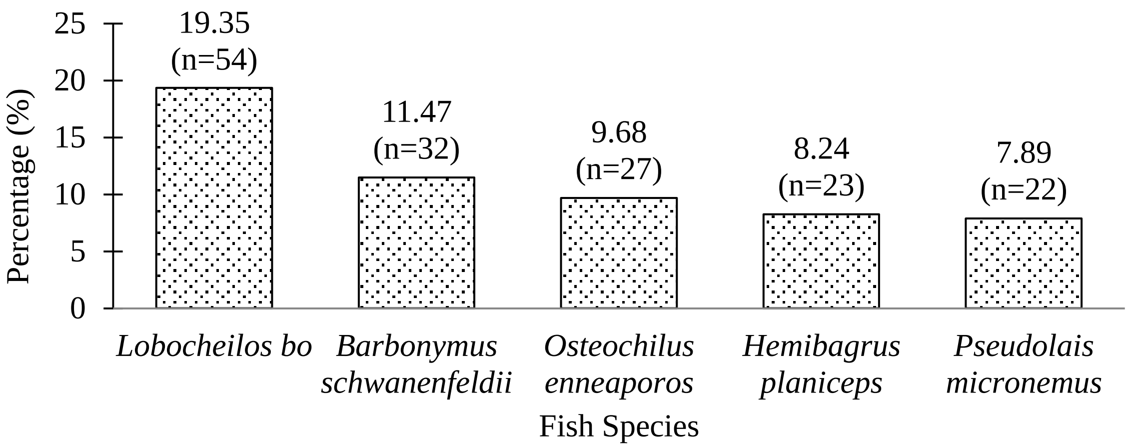


Figure 3.5: Percentages of the five dominant fish species caught at Long Apu.

The list of fish species, the number and percentage caught from all sampling stations are shown in Table 3.5. At Main River (LA1), the dominant species is *Pseudolais micronemus,* with a total of 13 individuals and representing 52% of the total number of individuals caught. *Barbonymus schwanenfeldii* has the highest number of individuals caught at both Sungai Lasa (LA2) and Sungai Julan (LA3) with 14 individuals (29.79%) and 11 individuals (20.75%), respectively. Sungai Plutan (LA4), Sungai Menapun (LA5) and Sungai Beraan (LA6) were dominated by *Lobocheilos bo* with a total number of 24 individuals representing 40.68%, 6 individuals (18.18%) and 8 individuals (30.77%), respectively. At the main River (LA7), *Kryptopterus apogon* representing 27.78% or 10 individuals caught.

Table 3.5: List of fish family, species, number of individuals (N) and percentage (%) caught from all sampling stations at Long Apu.

Station	Family	Species	N	(%)
Main River (LA1)	Cyprinidae	*Cyclocheilichthys apogon*	4	16
		Osteochilus enneaporos	1	4
		Tor duoronensis	1	4
	Siluridae	*Ceratoglanis scleronema*	2	8
		Kryptopterus apogon	4	16
	Pangasiidae	*Pseudolais micronemus*	13	52
Sg Lasa (LA2)	Bagridae	*Hemibagrus planiceps*	7	14.89
	Cyprinidae	*Barbonymus schwanenfeldii*	14	29.79
		Cyclocheilichthys apogon	2	4.26
		Hampala bimaculata	1	2.12
		Lobocheilos bo	7	14.89
		Luciosoma setigerum	2	4.26
		Osteochilus enneaporos	8	17.02
		Parachela oxygastroides	1	2.12
		Puntioplites wandersii	1	2.12
		Rasbora caudimaculata	2	4.26
	Pangasiidae	*Pseudolais micronemus*	2	4.26
Sg Julan (LA3)	Bagridae	*Hemibagrus planiceps*	2	3.77
	Balitoridae	*Homaloptera orthogoniata*	3	5.66
	Cyprinidae	*Barbonymus schwanenfeldii*	11	20.75
		Cyclocheilichthys apogon	2	3.77
		Hampala bimaculata	2	3.77
		Hampala macrolepidota	1	1.89
		Leptobarbus hoevenii	1	1.89
		Lobocheilos bo	9	16.98
		Lobocheilos hispidus	5	9.43
		Luciosoma spilopleura	4	7.55
		Osteochilus enneaporos	2	3.77
		Tor duoronensis	1	1.89
	Gastromyzontidae	*Gastromyzon fasciatus*	3	5.66

Table 3.5 continued

Station	Family	Species	N	(%)
		Gastromyzon punctulatus	3	5.66
	Mastacembelidae	*Mastacembelus unicolor*	1	1.89
		Mastacembelus notophthalmus	1	1.89
	Siluridae	*Krytopterus Limpok*	1	1.89
	Tetraodontidae	*Auriglobus silus*	1	1.89
Sg Plutan (LA4)	Bagridae	*Hemibagrus planiceps*	2	3.39
	Cyprinidae	*Barbonymus schwanenfeldii*	1	1.69
		Lobocheilos bo	24	40.68
		Osteochilus enneaporos	5	8.47
		Rasbora caudimaculata	12	20.34
		Tor duoronensis	2	3.39
	Gastromyzontidae	*Gastromyzon fasciatus*	13	22.03
Sg Menapun (LA5)	Bagridae	*Hemibagrus planiceps*	4	12.12
		Hemibagrus wyckii	1	3.03
	Cyprinidae	*Barbonymus schwanenfeldii*	1	3.03
		Cyclocheilichthys apogon	3	9.09
		Hampala bimaculata	1	3.03
		Lobocheilos bo	6	18.18
		Osteochilus enneaporos	3	9.09
		Osteochilus kahajanensis	1	3.03
		Puntioplites wandersii	4	12.12
	Gastromyzontidae	*Gastromyzon punctulatus*	1	3.03
	Pangasiidae	*Pseudolais micronemus*	4	12.12
	Siluridae	*Krytopterus apogon*	4	12.12
Sg Beraan (LA6)	Bagridae	*Hemibagrus planiceps*	6	23.08
	Cyprinidae	*Hampala macrolepidota*	1	3.85
		Lobocheilos bo	8	30.77
		Lobocheilos hispidus	2	7.69
		Osteochilus enneaporos	4	15.38
		Parachela oxygastroides	1	3.85
		Rasbora caudimaculata	2	7.69
	Gastromyzontidae	*Gastromyzon fasciatus*	2	7.69
Main River (LA7)	Bagridae	*Hemibagrus planiceps*	2	5.56
	Cyprinidae	*Barbonymus schwanenfeldii*	5	13.87
		Cyclocheilichthys apogon	5	13.87
		Hampala bimaculata	1	2.78
		Hampala macrolepidota	1	2.78
		Osteochilus enneaporos	4	11.11
		Puntioplites wandersii	2	5.56
	Siluridae	*Ceratoglanis schleronema*	2	5.56
		Krytopterus apogon	10	27.78
		Krytopterus limpok	1	2.78
	Pangasiidae	*Pseudolais micronemus*	3	8.33

The fish fauna composition caught at each station in Long Apu and their biological indices are presented in Table 3.6. The number of individuals caught from each station ranged from 19 to 59 individuals, with the lowest number of individual was recorded from Main River (LA1) while the highest number of individual was from Sungai Plutan (LA4). The number of fish species caught from each station ranged from 6 to 18 species, with the lowest number of species was from Main River (LA1) while the highest number of species was from Sungai Julan (LA3). Meanwhile, the number of fish family caught ranged from 3 to 7 families. The lowest number of family was recorded at Main River (LA1), Sungai Lasa (LA2), Sungai Plutan (LA4) and Sungai Beraan (LA6) while the highest was recorded at Sungai Julan (LA3).

Table 3.6: Fish composition at each station at Long Apu, Baram, Sarawak and their biological indices.

Sampling Area	Family	Species	Sampling Station						
			LA1	LA2	LA3	LA4	LA5	LA6	LA7
Long Apu	Bagridae	*Hemibagrus planiceps*	-	7	2	2	4	6	2
		Mystus wyckii	-	-	-	-	1	-	-
	Balitoridae	*Homaloptera orthogoniata*	-	-	3	-	-	-	-
	Cyprinidae	*Barbonymus schwanenfeldii*	-	14	11	1	1	-	5
		Cyclocheilichthys apogon	4	2	2	-	3	-	5
		Hampala bimaculata	-	1	2	-	1	-	1
		Hampala macrolepidota	-	-	1	-	-	1	1
		Leptobarbus hoevenii	-	-	1	-	-	-	-
		Lobocheilos bo	-	7	9	24	6	8	-
		Lobocheilos hispidus	-	-	5	-	-	2	-
		Luciosoma setigerum	-	2	-	-	-	-	-
		Luciosoma spilopleura	-	-	4	-	-	-	-
		Osteochilus enneaporos	1	8	2	5	3	4	4
		Osteochilus kahajanensis	-	-	-	-	1	-	-
		Parachela oxygastroides	-	1	-	-	-	1	-
		Puntioplites wandersii	-	1	-	-	4	-	2
		Rasbora caudimaculata	-	2	-	12	-	2	-
		Tor duoronensis	1	-	1	2	-	-	-
	Gastromyzontidae	*Gastromyzon fasciatus*	-	-	3	13	-	2	-
		Gastromyzon punctulatus	-	-	3	-	1	-	-
	Mastacembelidae	*Mastacembelus unicolor*	-	-	1	-	-	-	-
		Mastacembelus notophthalmus	-	-	1	-	-	-	-
	Pangasidae	*Pseudolais micronemus*	13	2	-	-	4	-	3
	Siluridae	*Ceratoglanis scleronema*	2	-	-	-	-	-	2
		Kryptopterus apogon	4	-	-	-	4	-	10
		Kryptopterus limpok	-	-	1	-	-	-	1

Table 3.6 continued

Sampling Area			Sampling Station						
			LA1	LA2	LA3	LA4	LA5	LA6	LA7
	Tetraodontidae	*Auriglobus silus*	-	-	1	-	-	-	-
		Number of individual	35	47	53	59	33	26	36
		Number of family	3	3	7	3	5	3	4
Long Apu		Number of species	6	11	18	7	12	8	11
		Shannon-Weiner Index (H’)	0.602	1.076	1.188	0.665	1.053	0.795	0.928
		Pielou’s Index (J’)	0.336	0.388	0.384	0.342	0.399	0.383	0.387
		Margalef’s Index (D)	1.553	3.896	5.289	1.471	3.718	2.148	2.791

*(LA1, Main River; LA2, Sungai Lasa; LA3, Sungai Julan; LA4, Sungai Plutan; LA5, Sungai Menapun; LA6, Sungai Beraan, and LA7, Sungai Pelet).

The occurrence of fish species from the seven sampling stations caught in Long Apu based on tributaries and the main river, total individuals caught, their standard length (SL), total length (TL), body weight (BW) and standard deviation are shown in Table 3.7.

The top three dominant fish species in Long Apu have TL range of 4.2 to 28.6 cm with a mean of 12.33±5.33 cm, and a BW range of 0.7 to 204.4 g with a mean of 25.01±37.52 g for *Lobocheilos bo*, TL range of 6.7 to 21.6 cm with a mean of 14.98±3.88 cm, and a BW range of 3.8 to 142.2 g with a mean of 53.31±39.24 g for *Barbonymus schwanenfeldii* and TL range of 5.4 to 24.5 cm with a mean of 14.52±5.93 cm, and a BW range of 1.9 to 168.1 g with a mean of 46.28±53.68 g for *Osteochilus enneaporos*.

The values of Shannon-Weiner's Index (H') of fish among the streams surveyed ranged between 0.602 and 1.188. The lowest diversity index was recorded at Main River (LA1), while the highest was recorded at Sungai Julan (LA3). The Margalef's Species Richness (D) ranged from 1.471 to 5.289. The lowest species richness was recorded at Sungai Plutan (LA4), while the highest was recorded in Sungai Julan (LA3). Meanwhile, the Pielou's Evennes Index (J) ranged from 0.336 to 0.399. The lowest evenness index was recorded at Main River (LA1), while the highest was recorded in Sungai Plutan (LA5).

Table 3.7: Fish family, species, number of individual (N) caught from main river (LAMR) and its tributaries (LATR) at each station at Long Apu, Baram and their standard length, total length and body weight.

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LAMR	LATR			
Long Apu	Bagridae	*Hemibagrus planiceps*	2	21	23	17.6±10.3	111.80±186.15
		Mystus wyckii	-	1	1	26.5	160.30
	Balitoridae	*Homaloptera orthogoniata*	-	3	3	6.7±2.0	3.06±2.09
	Cyprinidae	*Barbonymus schwanenfeldii*	5	27	32	15.0±3.9	53.31±39.24
		Cyclocheilichthys apogon	9	7	16	15.7±3.7	47.23±24.13
		Hampala bimaculata	1	4	5	30.1±9.7	352.96±338.5
		Hampala macrolepidota	1	2	3	21.5±5.6	105.27±69.27
		Leptobarbus hoevenii	-	1	1	22.6	106.40
		Lobocheilos bo	-	54	54	12.3±5.3	25.01±37.52
		Lobocheilos hispidus	-	7	7	5.3±1.0	1.62±0.79
		Luciosoma setigerum	-	2	2	20.0±0.1	47.72±9.45
		Luciosoma spilopleura	-	4	4	16.9±8.0	40.95±57.24
		Osteochilus enneaporos	5	22	27	14.5±6.0	46.28±53.68
		Osteochilus kahajanensis	-	1	1	19.3	71.30
		Parachela oxygastroides	-	2	2	7.5±0.2	3.30±0.57
		Puntioplites wandersii	2	5	7	24.6±6.9	210.51±252.0
		Rasbora caudimaculata	-	16	16	9.9±2.4	9.69±9.23
		Tor duoronensis	1	3	4	19.1±6.9	95.13±85.43
	Gastromyzontidae	*Gastromyzon fasciatus*	-	18	18	5.7±1.6	2.11±1.28
		Gastromyzon punctulatus	-	4	4	4.9±1.0	2.67±1.28
	Mastacembelidae	*Mastacembelus unicolor*	-	1	1	14	11.88
		Mastacembelus notophthalmus	-	1	1	15	7.93
	Pangasidae	*Pseudolais micronemus*	16	6	22	21.4±4.5	73.11±45.00

Table 3.7 continued

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LAMR	LATR			
	Siluridae	*Ceratoglanis scleronema*	4	-	4	34.1±2.2	139.50±28.97
		Kryptopterus apogon	14	4	18	25.0±3.0	60.76±20.97
		Kryptopterus limpok	1	1	2	29.6±1.3	103.75±13.08
	Tetraodontidae	*Auriglobus silus*	-	1	1	5.5	4.80

3.3.1.3 Long San, Baram

A total of 424 fishes from 27 species belonging to 10 families from 2 stations at main rivers (LS1 & LS6) and 6 tributaries namely, Sungai Kluan (LS1), Sungai Akah (LS3), Sungai Kelameh (LS4), Sungai Sabop (LS5), Sungai Benuang (LS7), Sungai Pelet (LS8) were caught at Long San.

Fish fauna composition in Long San was dominated by Cyprinidae, which comprised 85.38% (N=362) of the total number of individuals caught, followed by the family Gastromyzontidae representing 4.01% (N=17). Sisoridae representing 2.83% (N=12), Bagridae representing 2.59% (N=11), Pangasiidae representing 2.12% (N=9) and Siluridae representing 1.65% (N=7). Channidae and Mastacembelidae representing 0.47% (N=2), whereas Balitoridae and Osphronemidae representing 0.24% or only one individual caught (Figure 3.6).

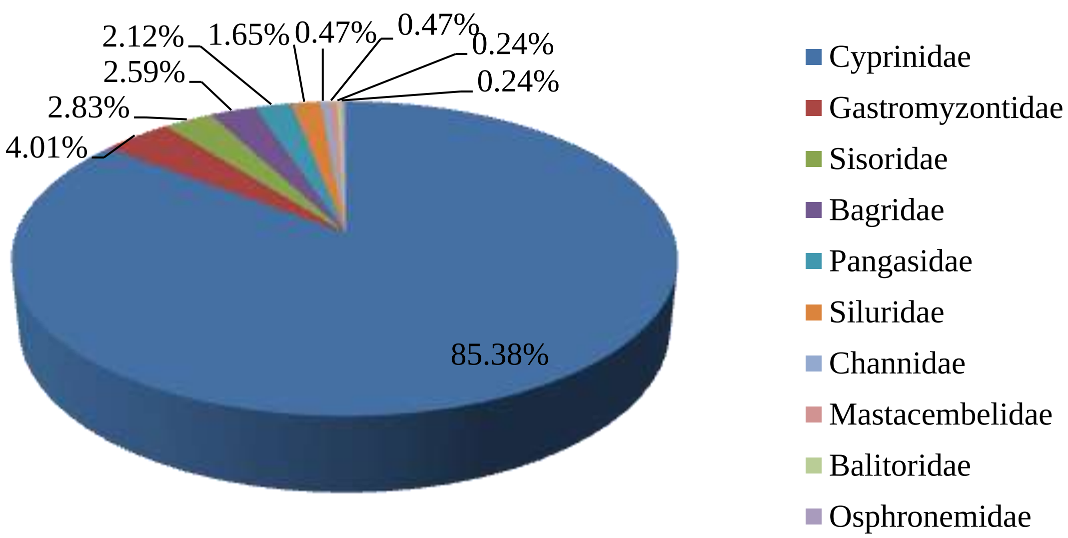


Figure 3.6: Percentage of fish family caught in all eight stations at Long San.

The family Cyprinidae represented by *Barbonymus schwanenfeldii Cyclocheilichthys apogon*, *Hampala bimaculata*, *Hampala macrolepidota*, *Leptobarbus hoevenii*, *Lobocheilos hispidus, Osteochilus enneaporos, Osteochilus vittatus, Osteochilus schlegelii, Parachela oxygastroides, Paracrossochilus vittatus, Puntioplites waandersii, Puntius vittatus, Rasbora caudimaculata* and *Tor duoronensis. Gastromyzon fasciatus* and *Glyptothorax major* from the family Gastromyzontidae and Sisoridae, respectively. Family Bagridae is comprised of *Mystus nigriceps* and *Hemibagrus planiceps* while family Pangasiidae is represented by *Pseudolais micronemus.* Family Siluridae is consisted of *Krytopterus apogon, Krytopterus crytopterus* and *Ompok bimaculatus*. Family Channidae is represented by only one species which is *Channa lucius*. Family Mastacembelidae, Balitoridae and Osphronemidae are consisted of *Macrognathus maculatus, Homaloptera orthogoniata* and *Osphronemus septemfasciatus,* respectively.

The top five dominant species by number of individuals caught throughout this study are *Lobocheilos hispidus* which recorded 145 individuals (34.20%), followed by *Puntius vittatus* with 103 individuals (26.65%), *Osteochilus enneaporos* representing 8.96% or 38 individuals, *Barbonymus schwanenfeldii* with 32 individuals (7.55%) and *Paracrossochilus vittatus* with 21 individuals (4.95%) (Figure 3.7).

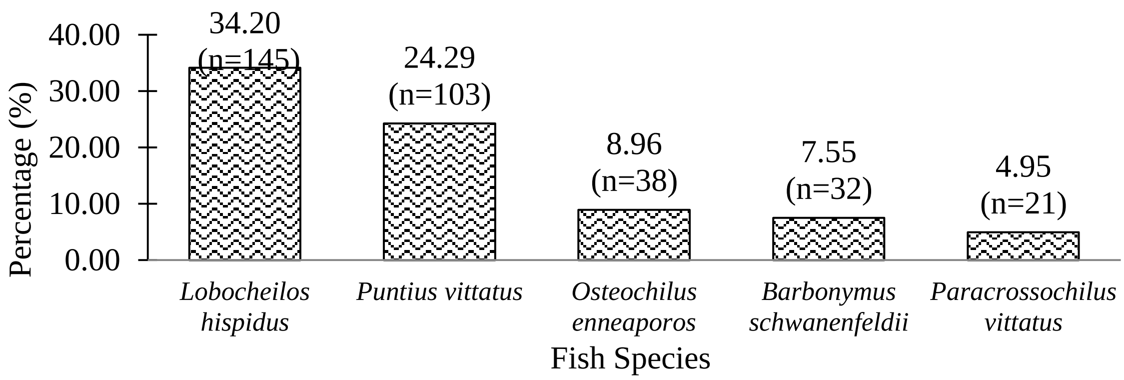


Figure 3.7: Percentages of the five dominant fish species caught at Long San.

At Sungai Kluan (LS1), the dominant species is *Barbonymus schwanenfeldii* with 5 individuals and comprised 33.3% of the total number of individuals caught. *Puntioplites* *waandersii* has the highest number of individuals caught (7 individuals) at main river (LS2) comprising 31.82%. *Lobocheilos hispidus* has the highest number of individuals at three tributaries namely, Sungai Akah (LS3), Sungai Sabop (LS5) and Sungai Pelet (LS8) with a total number of 24 individuals representing 44.4%, 13 (25%) and 71 (48.63%), respectively. Sungai Kelameh (LS4) was dominated by *Osteochilus enneaporos* with a total number of 17 individuals representing 27.42% whereas the main river (LA7) was dominated by *Pseudolais micronemus* representing 30% or 6 individuals. *Puntius vittatus* comprised 37.74% or 20 individuals caught at Sungai Benuang (LS7) (Table 3.8).

Table 3.8: List of fish family, species, number of individuals (N) and percentage (%) caught from all sampling stations at Long San.

Station	Family	Species	N	(%)
Sg Kluan (LS1)	Bagridae	*Mystus nigriceps*	1	6.67
	Cyprinidae	*Barbonymus schwanenfeldii*	5	33.33
		Hampala bimaculata	1	6.67
		Lobocheilos hispidus	3	20
		Paracrossochilus vittatus	1	6.67
		Rasbora caudimaculata	2	13.33
	Matacembelidae	*Macrognathus maculatus*	1	6.67
	Osphronemidae	*Osphronemus septemfasciatus*	1	6.67
Main River (LS2)	Cyprinidae	*Barbonymus schwanenfeldii*	6	27.27
		Leptobarbus hoevenii	1	4.55
		Lobocheilos hispidus	1	4.55
		Osteochilus enneaporos	4	18.18
		Puntioplites waandersii	7	31.82
	Pangasiidae	*Pseudolais micronemus*	2	9.09
	Siluridae	*Ompok bimaculatus*	1	4.55
Sg Akah (LS3)	Balitoridae	*Homaloptera orthogoniata*	1	1.85
	Bagridae	*Mystus nigriceps*	1	1.85
	Cyprinidae	*Barbonymus schwanenfeldii*	1	1.85
		Lobocheilos hispidus	24	44.4
		Osteochilus enneaporos	5	9.25
		Puntius vittatus	6	11.1
	Gastromyzontidae	*Gastromyzon fasciatus*	13	24.05
	Pangasiidae	*Pseudolais micronemus*	1	1.85
	Sisoridae	*Glyptothorax major*	2	3.70
Sg Sabop (LS5)	Bagridae	*Hemibagrus nigricep*	1	1.92
		Hemibagrus planiceps	3	5.77
	Channidae	*Channa lucius*	2	3.85
	Cyprinidae	*Barbonymus schwanenfeldii*	5	9.62

Table 3.8 continued

Station	Family	Species	N	(%)
		Hampala bimaculata	3	5.77
		Hampala macrolepidota	1	1.92
		Leptobarbus hoevenii	2	3.85
		Lobocheilos hispidus	13	25
		Osteochilus enneaporos	3	5.77
		Osteochilus vittatus	4	7.69
		Osteochilus schlegelii	1	1.92
		Parachela oxygastroides	1	1.92
		Puntius vittatus	1	1.92
		Rasbora caudimaculata	8	15.38
	Siluridae	*Krytopterus crytopterus*	3	5.77
	Sisoridae	*Glyptothorax major*	1	1.92
	Gastromyzontidae	*Gastromyzon fasciatus*	13	24.05
	Pangasiidae	*Pseudolais micronemus*	1	1.85
	Sisoridae	*Glyptothorax major*	2	3.70
Main River (LS6)	Bagridae	*Barbonymus schwanenfeldii*	5	25
		Hampala macrolepidota	1	5
		Lobocheilos hispidus	5	25
		Osteochilus enneaporos	1	5
		Puntioplites waandersii	1	5
	Pangasiidae	*Pseudolais micronemus*	6	30
	Siluridae	*Krytopterus apogon*	1	5
Sg Benuang (LS7)	Cyprinidae	*Barbonymus schwanenfeldii*	5	9.43
		Lobocheilos hispidus	15	28.30
		Osteochilus enneaporos	8	15.09
		Puntius vittatus	20	37.74
	Gastromyzontidae	*Gastromyzon fasciatus*	4	7.55
	Sisoridae	*Glyptothorax major*	1	1.89
Sg Pelet (LS8)	Bagridae	*Mystus nigriceps*	1	0.68
	Cyprinidae	*Barbonymus schwanenfeldii*	3	2.05
		Cyclocheilichthys apogon	1	0.68
		Hampala macrolepidota	1	0.68
		Lobocheilos hispidus	71	48.63
		Puntius vittatus	59	40.41
		Tor duoronensis	1	0.68
	Siluridae	*Krytopterus apogon*	1	0.68
		Krytopterus crytopterus	1	0.68
	Sisoridae	*Glyptothorax major*	7	4.79

The fish fauna composition caught at each station in Long San and their biological indices are presented in Table 3.9. The number of individuals caught from each station ranged from 15 to 146 individuals, with the lowest number of individuals was recorded from

Sungai Kluan (LS1) while the highest number was from Sungai Pelet (LS8). The number of species caught from each station ranged from 6 to 16 species, with the lowest number of species was from Sungai Benuang (LS7) while the highest was from Sungai Sabop (LS5). Meanwhile, the number of fish family caught ranged from 3-6 families. The lowest number of family was recorded at both main river (LS2 and LS6) and Sungai Benuang (LS7), while the highest was recorded at Sungai Akah (LS3).

The values of Shannon-Weiner's Index (H') of fish among the streams varied and its value ranged between 0.498 and 1.096. The lowest diversity index was recorded in Sungai Pelet (LS8), while the highest was recorded at Sungai Kelameh (LS5). The Margalef's Species Richness (D) ranged from 1.511-4.302. The lowest species richness was recorded in Sungai Benuang (LS7), while the highest was recorded in Sungai Sabop (LS5). Meanwhile, the Pielou's Evennes Index (J) ranged from 0.216 to 0.388. The lowest evenness index was recorded in Sungai Pelet (LS8), while the highest was recorded in Sungai Kluan (LS1) (Table 3.9).

The occurrence of fish species from the eight sampling sites caught in Long San based on tributaries and the main river, total individual caught, their standard length (SL), total length (TL), body weight (BW) and standard deviation are shown in Table 3.10.

The top three dominant fish species in Long San recorded TL range of 5.8 to 22.1 cm with a mean of 12.2±3.7 cm, and a BW range of 1.9 to 91.3 g with a mean of 18.85±17.32 g for *Lobocheilos hispidus*, TL range of 3.1 to 9.3 cm with a mean of 6.0±1.3 cm, and a BW range of 0.3 to 7.0 g with a mean of 2.17±1.36 g for *Puntius vittatus* and TL range of 6.9 to 21.4 cm with a mean of 12.71±4.34 cm, and a BW range of 4.0 to 91.5 g with a mean of 28.46±27.19 g for *Osteochilus enneaporos*.

Table 3.9: Fish composition at each station at Long San of midstream Baram River, Sarawak and their biological indices.

Sampling Area	Family	Species	Sampling Station							
			LS1	LS2	LS3	LS4	LS5	LS6	LS7	L8
Long San	Bagridae	*Mystus nigriceps*	1	-	1	1	1	-	-	1
		Hemibagrus planiceps	-	-	-	3	3	-	-	-
	Balitoridae	*Homaloptera orthogoniata*	-	-	1	-	-	-	-	-
	Channidae	*Channa lucius*	-	-		-	2	-	-	-
	Cyprinidae	*Barbonymus schwanenfeldii*	5	5	1	2	5	6	5	3
		Cyclocheilichthys apogon	-	-	-	-	-	-	-	1
		Hampala bimaculata	1	-	-	-	3	-	-	-
		Hampala macrolepidota	-	-	-	-	1	1	-	1
		Leptobarbus hoevenii	-	1	-	-	2	-	-	-
		Lobocheilos hispidus	3	1	24	13	13	5	15	71
		Osteochilus enneaporos	-	1	5	17	3	4	8	-
		Osteochilus schlegelii	-	-	-	-	1	-	-	-
		Osteochilus vittatus	-	-	-	4	4	-	-	-
		Parachela oxygastroides	-	-	-	-	1	-	-	-
		Paracrossochilus vittatus	1	-	-	-	-	-	-	-
		Puntioplites waandersii	-	7	-	-	-	1	-	-
		Puntius vittatus	-	-	6	17	1	-	20	59
		Rasbora caudimaculata	2	-	-	3	8	-	-	-
		Tor duoronensis	-	-	-	-	-	-	-	1
	Gastromyzontidae	*Gastromyzon fasciatus*	-	-	13	-	-	-	4	-
	Mastacembelidae	*Macrognathus maculatus*	1	-	-	1	-	-	-	-
	Osphronemidae	*Osphronemus septemfasciatus*	1	-	-	-	-	-	-	-
	Pangasiidae	*Pseudolais micronemus*	-	2	1	-	-	6	-	-
	Siluridae	*Ompok bimaculatus*	-	1	-	-	-	-	-	-
		Kryptopterus apogon	-	-	-	-	-	1	-	1
		Kryptopterus crytopterus	-	-	-	-	3	-	-	1

Table 3.9 continued

Sampling Area			Sampling Station							
			LS1	LS2	LS3	LS4	LS5	LS6	LS7	L8
	Sisoridae	*Glyptothorax major*	-	-	2	1	1	-	1	7
		Number of individual	15	18	54	62	52	24	53	146
		Number of family	4	2	6	4	5	2	3	4
Long San		Number of species	8	7	9	10	16	7	6	10
		Shannon-Weiner Index (H’)	0.808	0.718	0.688	0.812	1.096	0.724	0.673	0.498
		Pielou’s Index (J’)	0.388	0.369	0.313	0.327	0.379	0.372	0.346	0.216
		Margalef’s Index (D)	2.585	2.003	2.006	2.665	4.302	1.941	1.511	1.806

*(LS1, Sungai Kluan, LA2; Main River, LS3; Sungai Akah, LS4; Sungai Kelameh, LS5; Sungai Sabop, LS6; Main River, LS7; Sungai Benuang and LS8, Sungai Pelet)

Table 3.10: Fish family, species, number of individual (N) caught from main river (LSMR) and its tributaries (LSTR) at each station at Long San, Baram and their standard length, total length and body weight.

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LSMR	LSTR			
Long San	Bagridae	*Mystus nigriceps*	-	5	5	13.0±3.0	22.02±12.96
		Hemibagrus planiceps	-	6	6	24.9±1.7	122.22±31.02
	Balitoridae	*Homaloptera orthogoniata*	-	1	1	11.1	11.5
	Channidae	*Channa Lucius*	-	2	2	22.6±1.3	104.15±29.91
	Cyprinidae	*Barbonymus schwanenfeldii*	11	21	32	12.7±5.8	39.31±46.74
		Cyclocheilichthys apogon	-	1	1	9.2	7.6
		Hampala bimaculata	-	4	4	15.38.4	51.75±54.63
		Hampala macrolepidota	1	2	3	20.0±4.6	85.47±62.00
		Leptobarbus hoevenii	1	2	3	24.6±5.1	172.67±107.55
		Lobocheilos hispidus	6	139	145	12.2±3.7	18.85±17.32
		Osteochilus enneaporos	5	33	38	12.7±4.3	28.46±27.19
		Osteochilus schlegelii	-	1	1	18.2	73.4
		Osteochilus vittatus	-	8	8	10.2±3.0	12.36±7.63
		Parachela oxygastroides	-	1	1	9.7	5.7
		Paracrossochilus vittatus	-	1	1	8.9	5.3
		Puntioplites waandersii	8	-	8	26.4±4.8	217.60±112.54
		Puntius vittatus	-	103	103	6.0±1.3	2.17±1.36
		Rasbora caudimaculata	-	13	13	8.3±2.8	5.23±4.08
		Tor duoronensis	-	1	1	35	435.2
	Gastromyzontidae	*Gastromyzon fasciatus*	-	17	17	5.0±1.1	1.78±1.08
	Mastacembelidae	*Macrognathus maculatus*	-	2	2	26.7±18.6	96.87±124.64
	Osphronemidae	*Osphronemus septemfasciatus*	-	1	1	4.9	2.7
	Pangasiidae	*Pseudolais micronemus*	8	1	9	23.0±6.2	91.43±53.31
	Siluridae	*Ompok bimaculatus*	1	-	1	17.6	32.8

Table 3.10 continued

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LSMR	LSTR			
Long San		*Kryptopterus apogon*	1	1	2	26.0±0.6	67.05±6.01
		Kryptopterus crytopterus	-	4	4	29.9±3.2	109.30±22.56
	Sisoridae	*Glyptothorax major*	-	12	12	5.4±0.6	1.43±0.43

3.3.1.4 Long Kesseh, Baram

A total of 186 fishes from 22 species belonging to 8 families from 7 tributaries namely, Sungai Nakan (LK1), Sungai Kemenyih (LK2), Sungai Kesseh (LK4), Sungai Liseng (LK5), Sungai Jertang (LK6), Sungai Piping (LK7), Sungai Kahah (LK8) and 1 station at main river (LK3) were caught at Long Kesseh.

Fish fauna composition in Long Kesseh was dominated by Cyprinidae, which comprised 67.20% (N=125) of the total number of individuals caught, followed by the family Pangasiidae representing 25.81% (N=48). Siluridae representing 3.76% (N=7) whereas Ambassidae representing 1.08% (N=2). Bagridae, Cynoglossidae, Mastacembelidae and Osphronemidae representing 0.54% with only one individual caught as shown in Figure 3.8.

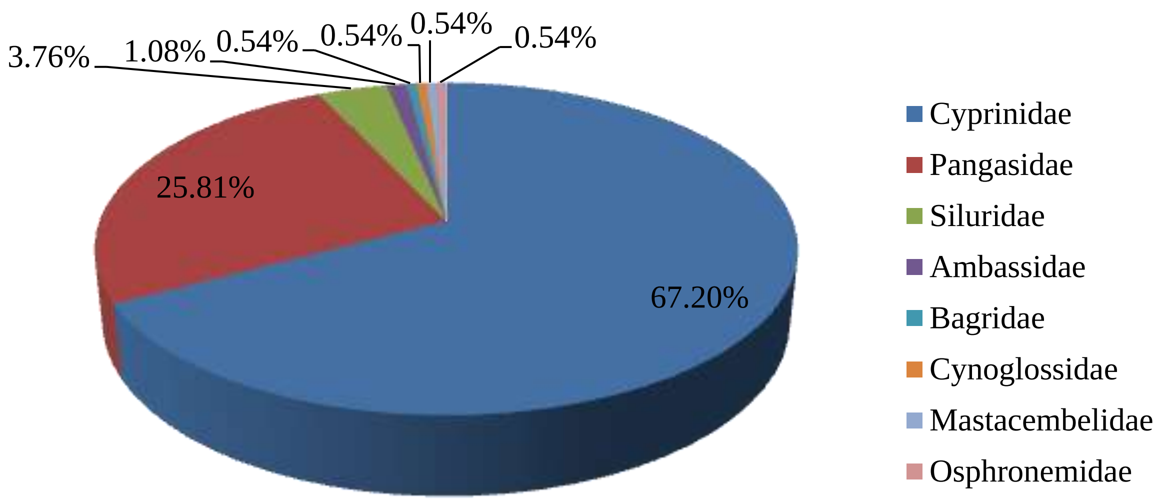


Figure 3.8: Percentage of fish family caught in all eight stations at Long Kesseh.

The family Cyprinidae consisted of *Barbonymus schwanenfeldii, Cyclocheilichthys apogon, Hampala bimaculata, Hampala macrolepidota, Leptobarbus hoevenii, Lobocheilos bo, Lobocheilus hispidus, Luciosoma setigerum, Osteochilus vittatus,* *Osteochilus melanopleurus*, *Puntioplites waandersii*, *Rasbora caudimaculata* and *Tor tambroides*. *Ambassis kopsii, Hemibagrus planicep, Cynoglossus waandersii, Mastacembelus unicolor, Osphronemus scptemfasciatus* and *Pseudolais micronemus* are represented by Ambassidae, Bagridae, Cynoglossidae, Mastacembelidae, Osphronemidae and Pangasidae, respectively. *Krytopterus apogon*, *Krytopterus lais* and *Krytopterus micronema* are from the family Siluridae.

The top five dominant species by number of individuals caught throughout this study were *Barbonymus schwanenfeldii* which recorded 53 individuals (28.49%), followed by *Pseudolais micronemus* with 48 individuals (25.81%), *Luciosoma setigerum* representing 8.60% or 16 individuals, *Osteochilus vittatus* with 15 individuals (8.06%) and *Leptobarbus hoevenii* with 11 individuals (5.91%) (Figure 3.9).

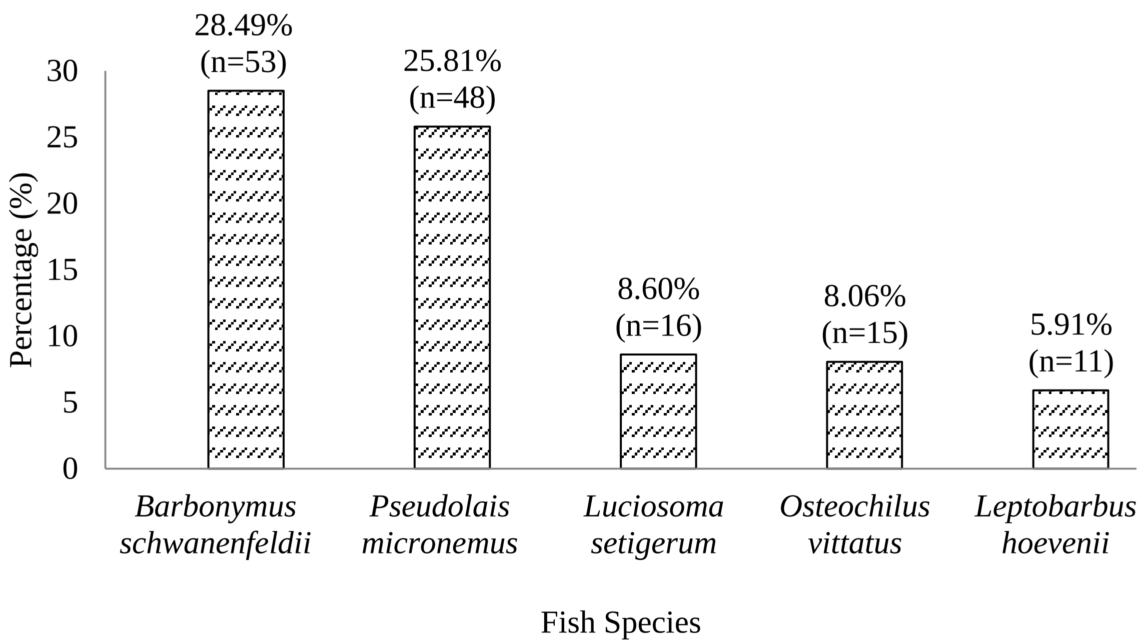


Figure 3.9: Percentages of the five dominant fish species caught at Long Kesseh.

The list of fish species, number and percentage caught from all sampling stations are shown in Table 3.11. At Sungai Nakan (LK1) and Main River (LK3), the dominant species is *Barbonymus schwanenfeldii* with a total of 8 individuals representing 88.89% and 13 individuals (54.17%), respectively. All four species in Sungai Kemenyih (LK2) namely, *Barbonymus schwanenfeldii*, *Osphronemus scptemfasciatus*, *Kryptopterus apogon* and *Pseudolais micronemus* recorded the same number of individual caught (1 individual) representing 25% of the total caught. *Leptobarbus hoevenii* has the highest number of individuals caught with 5 individuals at Sungai Kesseh (LK5) representing 29.41%. Sungai Liseng (LK5) was dominated by *Osteochilus vittatus* with a total number of 7 individuals representing 35%, whereas Sungai Jertang (LK6) was dominated by *Luciosoma setigerum* representing 42.86% from 12 individuals was caught (Table 3.11).

Table 3.11: List of fish family, species, number of individuals (N) and percentage (%) caught from all sampling stations at Long Kesseh.

Station	Family	Species	N	(%)
Sg Nakan	Cyprinidae	*Barbonymus schwanenfeldii*	8	88.89
(LK1)		*Puntioplites waandersii*	1	11.11
Sg Kemenyih	Cyprinidae	*Barbonymus schwanenfeldii*	1	25
(LK2)	Osphronemidae	*Osphronemus scptemfasciatus*	1	25
	Pangasidae	*Pseudolais micronemus*	1	25
	Siluridae	*Krytopterus apogon*	1	25
Main River	Cyprinidae	*Barbonymus schwanenfeldii*	13	54.17
(LK3)		*Hampala macrolepidota*	1	4.17
		Leptobarbus hoevenii	5	20.83
		Puntioplites waandersii	2	8.33
	Pangasiidae	*Pseudolais micronemus*	3	12.5
Sg Kesseh	Ambassidae	*Ambassis kopsii*	1	5.88
(LK4)	Cynoglossidae	*Cynoglossus waandersii*	1	5.88
	Cyprinidae	*Barbonymus schwanenfeldii*	4	23.53
		Hampala bimaculata	1	5.88
		Hampala macrolepidota	1	5.88
		Leptobarbus hoevenii	5	29.41
		Lobocheilos bo	1	5.88
		Lobocheilus hispidus	1	5.88
		Osteochilus vittatus	1	5.88
	Siluridae	*Krytopterus micronema*	1	5.88
Sg Liseng	Bagridae	*Hemibagrus planicep*	1	5
(LK5)	Cyprinidae	*Barbonymus schwanenfeldii*	5	25
		Hampala bimaculata	2	10

Table 3.11: continued

Station	Family	Species	N	(%)
		Luciosoma setigerum	2	10
		Osteochilus vittatus	7	35
		Tor tambroides	1	5
	Pangasidae	*Pseudaolais micronemus*	1	5
	Siluridae	*Krytopterus lais*	1	5
Sg Jertang (LK6)	Cyprinidae	*Barbonymus schwanenfeldii*	2	7.14
		Cyclocheilichthys apogon	1	3.57
		Hampala macrolepidota	4	14.29
		Lobocheilos bo	2	7.14
		Luciosoma setigerum	12	42.86
		Osteochilus vittatus	6	21.43
		Puntioplites waandersii	1	3.57
Sg Piping (LK7)	Ambassidae	*Ambassis kopsii*	1	2.04
	Cyprinidae	*Barbonymus schwanenfeldii*	11	22.45
		Cyclocheilichthys apogon	1	2.04
		Puntioplites waandersii	1	2.04
	Pangasidae	*Pseudolais micronemus*	32	65.31
	Siluridae	*Krytopterus apogon*	2	4.08
		Krytopterus lais	1	2.04
Sg Kahah (LK8)	Cyprinidae	*Barbonymus schwanenfeldii*	9	25.71
		Cyclocheilichthys apogon	1	2.86
		Leptobarbus hoevenii	1	2.86
		Lobocheilos bo	1	2.86
		Luciosoma setigerum	2	5.71
		Osteochilus vittatus	1	2.86
		Osteochilus melanopleurus	1	2.86
		Puntioplites waandersii	1	2.86
		Rasbora caudimaculata	3	8.57
		Tor tambroides	2	5.71
	Mastacembelidae	*Mastacembelus unicolor*	1	2.86
	Pangasidae	*Pseudolais micronemus*	11	31.43
	Siluridae	*Krytopterus apogon*	1	2.86

The fish fauna composition caught at each station in Long Kesseh and their biological indices are presented in Table 3.12. The number of individuals caught from each station ranged from 4 to 49 individuals, with the lowest number of individual was recorded from Sungai Kemenyih (LK2) while the highest number was from Sungai Piping (LK7). The number of species caught from each station ranged from 2 to 13 species with the lowest number of species was from Sungai Nakan (LK1) while the highest number was from

Sungai Kahah (LSK8). Meanwhile, the number of fish family caught ranged from 1 to 4 families. The lowest number of family was recorded at Sungai Nakan (LK1) and Sungai Jertang (LK6), while the highest was recorded at five tributaries namely, Sungai Kemenyih, Sungai Kesseh (LK4), Sungai Liseng (LK5), Sungai Piping (LK7) and Sungai Kahah (LK8).

The values of Shannon-Weiner's Index (H') of fish among the streams surveyed varied and its value ranged between 0.151 and 0.896. The lowest diversity index was recorded in Sungai Nakan (LK1), while the highest was recorded at Sungai Kahah (LK8). The Margalef's Species Richness (D) ranged from 0.455-3.375. The lowest species richness was recorded in Sungai Nakan (LK1), while the highest was recorded in Sungai Kahah (LK8). Meanwhile, the Pielou's Evennes Index (J) ranged from 0.219 to 0.434. The lowest evenness index was recorded in Sungai Nakan (LK1), while the highest was recorded in Sungai Kemenyih (LK2) (Table 3.12).

Table 3.12: Fish composition at each station at Long Kesseh of downstream Baram River, Sarawak and their biological indices.

Sampling Area	Family	Species	Sampling Station							
			LK1	LK2	LK3	LK4	LK5	LK6	LK7	LK8
Long Kesseh	Ambassidae	*Ambassis kopsii*	-	-	-	1	-	-	1	-
	Bagridae	*Hemibagrus planicep*	-	-	-	-	1	-	-	-
	Cynoglossidae	*Cynoglossus waandersii*	-	-	-	1	-	-	-	-
	Cyprinidae	*Barbonymus schwanenfeldii*	8	1	13	4	5	2	11	9
		Cyclocheilichthys apogon	-	-	-	-	-	1	1	1
		Hampala bimaculata	-	-	-	1	2	-	-	-
		Hampala macrolepidota	-	-	1	1	-	4	-	-
		Leptobarbus hoevenii	-	-	5	5	-	-	-	1
		Lobocheilus bo	-	-	-	1	-	2	-	1
		Lobocheilus hispidus	-	-	-	1	-	-	-	-
		Luciosoma setigerum	-	-	-	-	2	12	-	2
		Osteochilus vittatus	-	-	-	1	7	6	-	1
		Puntioplites waandersii	1	-	2	-	-	1	1	1
		Rasbora caudimaculata	-	-	-	-	-	-	-	3
		Osteochilus melanopleurus	-	-	-	-	-	-	-	1
		Tor tambroides	-	-	-	-	1	-	-	2
	Mastacembelidae	*Mastacembelus unicolor*	-	-	-	-	-	-	-	1
	Pangasidae	*Pseudolais micronemus*	-	1	3	-	1	-	32	11
	Siluridae	*Kryptopterus micronema*	-	-	-	1	-	-	-	-
		Kryptopterus apogon	-	1	-	-	-	-	2	1
		Kryptopterus lais	-	-	-	-	1	-	1	-
	Osphronemidae	*Osphronemus scptemfasciatus*	-	1	-	-	-	-	-	-
		Number of individual	9	4	24	17	20	28	49	35
		Number of family	1	3	2	4	4	1	4	4
		Number of species	2	4	5	10	8	7	7	13

Table 3.12 continued

Sampling Area	Family	Indices	Sampling stations							
			LK1	LK2	LK3	LK4	LK5	LK6	LK7	LK8
		Shannon-Weiner Index (H')	0.151	0.602	0.546	0.883	0.77	0.689	0.637	0.896
Long		Pielou's Index (J')	0.219	0.434	0.340	0.384	0.396	0.354	0.306	0.349
Kesseh		Margalef's Index (D)	0.455	2.164	1.259	3.177	2.003	1.801	1.799	3.375

*(LK1, Sungai Nakan; LK2, Sungai Kemenyih; LK3, Main River; LK4, Sungai Kesseh; LK5, Sungai Liseng; LK6, Sungai Jertang; LK7, Sungai Piping and LK8, Sungai Kahah)

The occurrence of fish species from the eight sampling sites caught in Long Kesseh based on tributaries and the main river, total individual caught, their standard length (SL), total length (TL), body weight (BW) and standard deviation are shown in Table 3.13.

The top three dominant fish species in Long Kesseh recorded TL range of 10.7 to 31.8 cm with a mean of 19.6±5.4 cm, and a BW range of 13.7 to 445.43 g with a mean of 105.71±89.62 g for *Barbonymus schwanenfeldii*, TL range of 16.7 to 38.4 cm with a mean of 23.7±4.6 cm, and a BW range of 8.44 to 365.6 g with a mean of 102.28±77.96 g for *Pseudolais micronemus* and TL range of 13.1 to 21.6 cm with a mean of 18.7±2.5 cm, and a BW range of 13.8 to 64.7 g with a mean of 42.16±14.66 g for *Luciosoma setigerum*.

Table 3.13: Fish family, species, number of individual (N) caught from tributaries (LKTR) and main river (LKMR) at each station at Long Kesseh, Baram and their standard length, total length and body weight.

Sampling Area	Family	Species	N		N_T	TL±SD (cm)	BW±SD(cm)
			LKMR	LKTR			
Long Kesseh	Ambassidae	*Ambassis kopsii*	-	2	2	11.6±1.3	20.45±0.92
	Bagridae	*Hemibagrus planiceps*	-	1	1	15.6	29.50
	Cynoglossidae	*Cynoglossus waandersii*	-	1	1	20.1	40.90
	Cyprinidae	*Barbonymus schwanenfeldii*	13	40	53	19.6±5.4	105.71±89.62
		Cyclocheilichthys apogon	-	3	3	14.2±4.8	21.07±10.98
		Hampala bimaculata	-	3	3	16.7±5.8	42.90±29.40
		Hampala macrolepidota	1	5	6	16.4±7.3	34.58±22.07
		Leptobarbus hoevenii	5	6	11	21.8±5.3	102.43±44.92
		Lobocheilus bo	-	4	4	16.8±2.5	42.20±4.78
		Lobocheilus hispidus	-	1	1	21.20	72.70
		Luciosoma setigerum	-	16	16	18.7±2.5	42.16±14.66
		Osteochilus vittatus	-	15	15	15.2±2.1	31.05±15.67
		Puntioplites waandersii	2	4	6	22.8±9.3	222.42±254.37
		Rasbora caudimaculata	-	3	3	12.2±0.4	12.80±0.72
		Osteochilus melanopleurus	-	1	1	20.2	84.30
		Tor tambroides	-	3	1	15.7±4.9	46.47±33.23
	Mastacembelidae	*Mastacembelus unicolor*	-	1	1	45.4	219.8
	Pangasidae	*Pseudolais micronemus*	3	45	48	23.7±4.6	102.28±77.96
	Siluridae	*Kryptopterus micronema*	-	1	1	28	71.40
		Kryptopterus lais	-	2	2	25.4±0.4	65.15±5.02
		Kryptopterus apogon	-	4	4	31.9±12.2	212.38±208.80
		Osphronemus scptemfasciatus	-	1	1	61	> 5kg

*($N_{T,}$total number of individual caught; - , absence; SL, standard length, TL, total length, BW, body weight and SD, standard deviation.

3.3.1.5 Overall Fish Fauna Composition in Baram River

Figure 3.10 shows the list of fish family caught and the percentage composition for fish population in the upper stretch of Baram River. Overall, a total of 1376 individuals from 58 species belonging to 13 families of freshwater fish were recorded in whole area of Baram River throughout the entire study period (Appendix 1). On the basis of percentage composition, family Cyprinidae was dominant, where it formed 63.37% of the individuals present. Family Siluridae make up about 21.44% of individuals caught, followed by Pangasiidae with 6.83%, Bagridae with 3.27% and Gastromyzontidae representing 2.83% of all individuals caught. For the remaining eight families, each comprised approximately about less than 1% of the total fish caught. They were Sisoridae (0.87%), Mastacembelidae (0.58%), Balitoridae (0.29%), Ambassidae (0.15%), Channidae (0.15%), Cynoglossidae (0.07%), Osphronemidae (0.07%) and Tetraodontidae (0.07%).

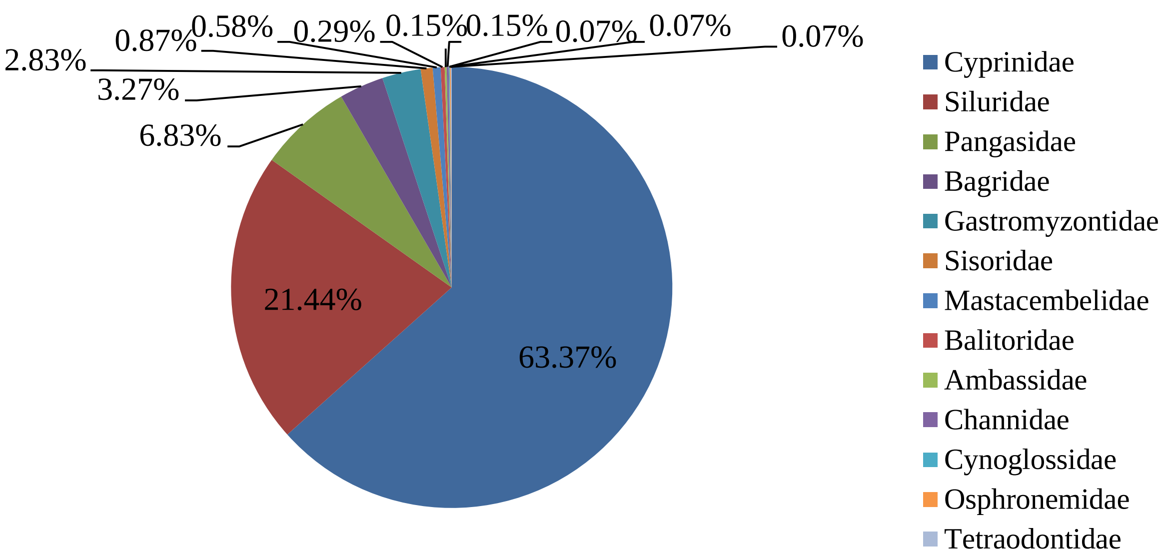


Figure 3.10: Percentage of each fish family caught from the whole study area.

The number of fish family in the whole study area ranged from 5 to 10 families, with the lowest number of family caught was at Lio Mato, while the highest number was at Long San (Figure 3.11).

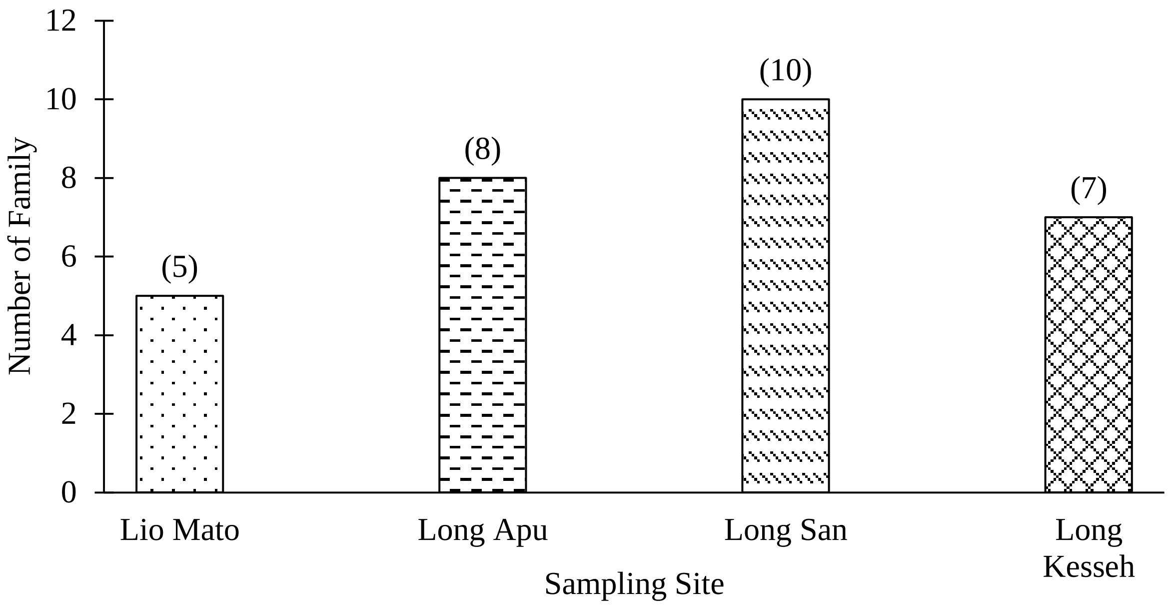


Figure 3.11: Number of fish family caught in all sampling sites in Baram River.

The family Cyprinidae was consisted of *Barbonymus collingwoodii, Barbonymus schwanenfeldii, Cirrhinus chinensis, Cyclocheilichthys apogon, Hampala bimaculata, Hampala macrolepidota, Leptobarbus hoevenii, Lobocheilos bo, Lobocheilos hispidus, Luciosoma setigerum, Luciosoma spilopleura, Nematabramis everetti, Osteochilus enneaporos, Osteochilus kahajanensis, Osteochilus melanopleurus, Osteochilus schlegelii, Osteochilus triporos, Osteochilus vittatus, Osteochilus waandersii, Parachela hypophthalmus, Parachela oxygastroides, Paracrossochilus vittatus, Puntioplites waandersii, Puntius vittatusRasbora argyrotaenia, Rasbora borneensis, Rasbora caudimaculata, Tor douronensis* and *Tor tambroides*. Family Siluridae was represented by *Ceratoglanis scleronema, Kryptopterus apogon, Kryptopterus crytopterus, Kryptopterus lais, Kryptopterus limpok, Kryptopterus lumholtzi, Kryptopterus macrocephalus, Kryptopterus micronema*, and *Ompok bimaculatus. Pangasius macronema, Pangasius micronema* and *Pseudolais micronemus* are from the family Pangasiidae while *Mystus nigriceps*, *Bagrichthys micanodus, Hemibagrus planiceps, Mystus wyckii* and *Nanobagrus* *armatus* are from family Bagridae. Family Gastromyzontidae was consisted of *Gastromyzon fasciatus* and *Gastromyzon punctulatus* whereas *Macrognathus maculatus, Mastacembelus notophthalmus* and *Mastacembelus unicolor* are from the family Mastacembelidae. *Ambassis kopsii, Homaloptera orthogoniata, Channa Lucius, Cynoglossus waandersii, Osphronemus septemfasciatus, Glyptothorax major, Auriglobus silus* are from the family Ambassidae, Balitoridae, Channidae, Cynoglossidae, Osphronemidae, Sisoridae and Tetraodontidae, respectively.

The number of fish species caught in the whole area ranged from 23 to 34 species, with the lowest number of species caught was at Long Kesseh while the highest number was at Lio Mato (Figure 3.12).

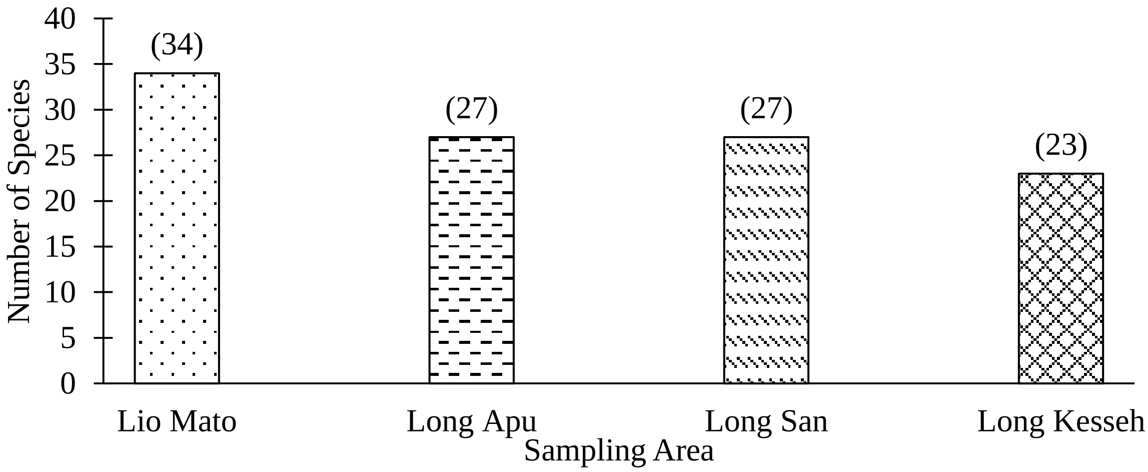


Figure 3.12: Number of fish species caught in all sampling sites in Baram River.

The top ten fish species of Baram River was dominated by *Kryptopterus macrocephalus* constituting 12.06% of the total catch. The remaining nine dominant species by number of individuals caught throughout this study were *Lobocheilos hispidus* with 159 individuals caught representing 11.56%, *Barbonymus schwanenfeldii* which recorded 123 individuals (8.94%), followed by *Kryptopterus apogon* with 113 individuals (8.21%), *Puntius vittatus* representing 7.49% from 103 individuals, *Pseudolais micronemus* with 90 individuals (6.54%), *Osteochilus enneaporos* with 70 individuals (5.09%) and *Lobocheilos bo* with 58 individuals (4.22%) caught. *Luciosoma spilopleura* and *Rasbora caudimaculata* recorded the same number of individuals caught representing 2.98% (41 individuals) (Figure 3.13).

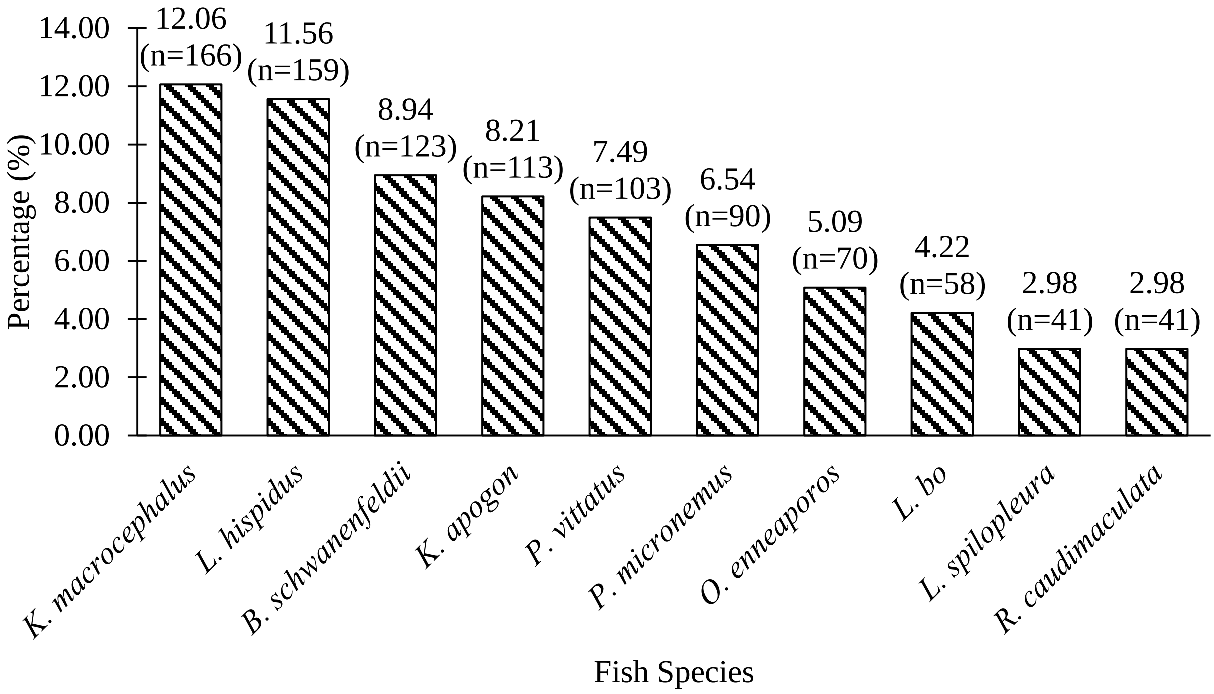


Figure 3.13: Percentage of the ten dominant species caught at all sampling sites in Baram River.

The number of fish individuals caught in the whole area ranged from 186 to 487 individuals, with the lowest number of individuals caught was at Long Kesseh while the highest was at Lio Mato (Figure 3.14).

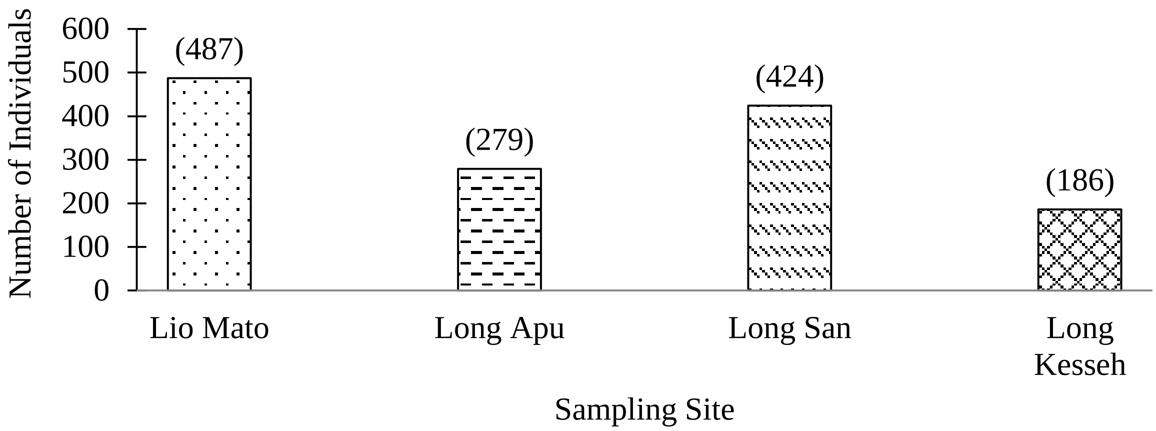


Figure 3.14: Number of fish individual caught in all sampling sites in upper Baram River.

At Lio Mato (LM), the dominant species is *Kryptopterus macrocephalus* with a total number of 166 individuals representing 34.09%, while Long Apu (LA) it was dominated by *Lobocheilos bo* with 54 individuals representing 19.35% of the total number caught. *Lobocheilos hipidus* has the highest number of individuals caught with 145 individuals at Long San (LS) representing 34.20%, whereas Long Kesseh was dominated by *Pseudolais micronemus* representing 25.81% from 48 individuals caught (Table 3.14).

Table 3.14: List of fish family, species, number of individual (N) and percentage (%) caught from all sampling stations in Baram River.

Sampling site	Family	Species	N	(%)
Lio Mato	Bagridae	*Bagrichthys micranodus*	1	0.21
		Hemibagrus planiceps	5	1.03
		Nanobagrus armatus	3	0.62
	Cyprinidae	*Barbonymus collingwoodii*	24	4.93
		Barbonymus schwanenfeldii	6	1.23
		Cirrhinus chinensis	4	0.82
		Cyclocheilichthys apogon	9	1.85
		Hampala bimaculata	5	1.03
		Hampala macrolepidota	6	1.23
		Leptobarbus hoevenii	6	1.23
		Lobocheilos hispidus	6	1.23
		Luciosoma setigerum	11	2.26
		Luciosoma spilopleura	37	7.60
		Nematabramis everetti	2	0.41
		Osteochilus enneaporos	5	1.03
		Osteochilus schlegelii	4	0.82

Table 3.14 continued

Sampling site	Family	Species	N	(%)
		Osteochilus triporos	14	2.87
		Osteochilus vittatus	12	2.46
		Osteochilus waandersii	1	0.21
		Parachela hypophthalmus	1	0.21
		Parachela oxygastroides	9	1.85
		Puntioplites waandersii	3	0.62
		Rasbora argyrotaenia	16	3.29
		Rasbora borneensis	7	1.44
		Rasbora caudimaculata	9	1.85
		Tor douronensis	6	1.23
		Tor tambroides	1	0.21
	Mastacembelidae	*Mastacembelus notophthalmus*	3	0.62
	Pangasiidae	*Pangasius macronema*	2	0.41
		Pangasius micronema	2	0.41
		Pseudolais micronemus	11	2.26
	Siluridae	*Kryptopterus apogon*	89	18.28
		Kryptopterus lumholtzi	1	0.21
		Kryptopterus macrocephalus	166	34.09
Long Apu	Bagridae	*Hemibagrus planiceps*	23	8.24
		Mystus wyckii	1	0.36
	Balitoridae	*Homaloptera orthogoniata*	3	1.08
	Cyprinidae	*Barbonymus schwanenfeldii*	32	11.47
		Cyclocheilichthys apogon	16	5.73
		Hampala bimaculata	5	1.79
		Hampala macrolepidota	3	1.08
		Leptobarbus hoevenii	1	0.36
		Lobocheilos bo	54	19.35
		Lobocheilos hispidus	7	2.51
		Luciosoma setigerum	2	0.72
		Luciosoma spilopleura	4	1.43
		Osteochilus enneaporos	27	9.68
		Osteochilus kahajanensis	1	0.36
		Parachela oxygastroides	2	0.72
		Puntioplites wandersii	7	2.51
		Rasbora caudimaculata	16	5.73
		Tor duoronensis	4	1.43
	Gastromyzontidae	*Gastromyzon fasciatus*	18	6.45
		Gastromyzon punctulatus	4	1.43
	Mastacembelidae	*Mastacembelus unicolor*	1	0.36
		Mastacembelus notophthalmus	1	0.36
	Pangasiidae	*Pseudolais micronemus*	22	7.89
	Siluridae	*Ceratoglanis scleronema*	4	1.43
		Kryptopterus apogon	18	6.45
		Kryptopterus limpok	2	0.72

Table 3.14 continued

Sampling site	Family	Species	N	(%)
	Tetraodontidae	*Auriglobus silus*	1	0.36
Long San	Bagridae	*Mystus nigriceps*	5	1.18
		Hemibagrus planiceps	6	1.42
	Balitoridae	*Homaloptera orthogoniata*	1	0.24
	Channidae	*Channa lucius*	2	0.47
	Cyprinidae	*Barbonymus schwanenfeldii*	32	7.55
		Cyclocheilichthys apogon	1	0.24
		Hampala bimaculata	4	0.94
		Hampala macrolepidota	3	0.71
		Leptobarbus hoevenii	3	0.71
		Lobocheilos hispidus	145	34.20
		Osteochilus enneaporos	38	8.96
		Osteochilus schlegelii	1	0.24
		Osteochilus vittatus	8	1.89
		Parachela oxygastroides	1	0.24
		Paracrossochilus vittatus	1	0.24
		Puntioplites waandersii	8	1.89
		Puntius vittatus	103	24.29
		Rasbora caudimaculata	13	3.07
		Tor douronensis	1	0.24
	Gastromyzontidae	*Gastromyzon fasciatus*	17	4.01
	Mastacembelidae	*Macrognathus maculatus*	2	0.47
	Osphronemidae	*Osphronemus septemfasciatus*	1	0.24
	Siluridae	*Ompok bimaculatus*	1	0.24
	Pangasidae	*Pseudolais micronemus*	9	2.12
		Kryptopterus apogon	2	0.47
	Pangasidae	*Kryptopterus crytopterus*	4	0.94
	Sisoridae	*Glyptothorax major*	12	2.83
Long Kesseh	Ambassidae	*Ambassis kopsii*	2	1.08
	Bagridae	*Hemibagrus planicep*	1	0.54
	Cynoglossidae	*Cynoglossus waandersii*	1	0.54
	Cyprinidae	*Barbonymus schwanenfeldii*	53	28.49
		Cyclocheilichthys apogon	3	1.61
		Hampala bimaculata	3	1.61
		Hampala macrolepidota	6	3.23
		Leptobarbus hoevenii	11	5.91
		Lobocheilus bo	4	2.15
		Lobocheilus hispidus	1	0.54
		Luciosoma setigerum	16	8.60
		Osteochilus melanopleurus	1	0.54
		Osteochilus vittatus	15	8.06
		Puntioplites waandersii	6	3.23
		Rasbora caudimaculata	3	1.61
		Tor douronensis	2	1.08

Table 3.14 continued

Sampling site	Family	Species	N	(%)
		Tor tambroides	1	0.54
	Mastacembelidae	*Mastacembelus unicolor*	1	0.54
	Pangasiidae	*Pseudolais micronemus*	48	25.81
	Siluridae	*Kryptopterus apogon*	4	2.15
		Kryptopterus micronema	1	0.54
		Kryptopterus lais	2	1.08
	Osphronemidae	*Osphronemus scptemfasciatus*	1	0.54

The presence of each species from Lio Mato, Long Apu, Long San and Long Kesseh is shown in Table 3.14. *Bagrichthys micranodus, Nanobagrus armatus, Barbonymus collingwoodii, Cirrhinus chinensis, Nematabramis everetti, Osteochilus triporos, Osteochilus waandersii, Parachela hypophthalmus, Rasbora argyrotaenia, Rasbora borneensis, Pangasius macronema, Pangasius micronema, Kryptopterus lumholtzi* and *Kryptopterus macrocephalus* were only caught from Lio Mato of upstream Baram while *Auriglobus silus, Ceratoglanis scleronema, Gastromyzon punctulatus, Kryptopterus limpok, Mastacembelus notophthalmus, Mystus wyckii* and *Osteochilus kahajanensis* were only caught from Long Apu of midstream Baram. *Mystus nigriceps, Channa lucius, Macrognathus maculatus, Ompok bimaculatus, Kryptopterus crytopterus* and *Glyptothorax major* were only caught from Long San of midstream Baram whereas *Ambassis kopsii, Cynoglossus waandersii, Osteochilus melanopleurus, Kryptopterus micronema* and *Kryptopterus lais* were only caught from Long Kesseh of downstream Baram.

3.3.1.6 Biological Indices

The fish abundance from all four areas in Baram ranged from 186 individuals at Long Kesseh to 487 individuals at Lio Mato. The Shannon-Wiener's diversity Index (H) in Long Apu shows a higher value at 1.17 and was lowest at Long San with 0.93. The Margalef's species richness index (D) from all study areas ranged from 3.91 at Long Apu to 5.33 at Lio Mato. The Pielou's evenness index (J) for Long San is lowest with a value of 0.28 and highest value of evenness index was recorded at Long Apu with 0.36 (Table 3.15).

Table 3.15: Fish diversity indices for each sampling area.

Sampling Sites	Lio Mato	Long Apu	Long San	Long Kesseh
Shannon-wiener's Diversity Index (H)	1.08	1.17	0.93	0.98
Margalef's Species Richness Index (D)	5.33	3.91	4.30	4.21
Pielou's Evenness Index (J)	0.31	0.36	0.28	0.31

3.3.2 Physicochemical Parameters

3.3.2.1 Lio Mato, Baram

3.3.2.1.1 Conductivity

The mean conductivity of water ranged from 24.0 µS/cm to 61.3 µS/cm (Figure 3.15). Conductivity was found to be within the recommended level by NWQS, Malaysia, and fell into Class I (Appendix 2). The highest mean conductivity was recorded at LM 3 (Sungai Serebu) with a mean value of 61.3 µS/cm and was significantly higher than all the other stations ($p<0.05$). The lowest value of 24.0 µS/cm was recorded at LM6 (Sungai Sepula) and was significantly lower than all stations in Lio Mato ($p<0.05$). There was no significant difference in the mean conductivity of water between LM1 (Main River) and LM4 (Main River) ($p>0.05$), but both were significantly different from the other stations ($p<0.05$).

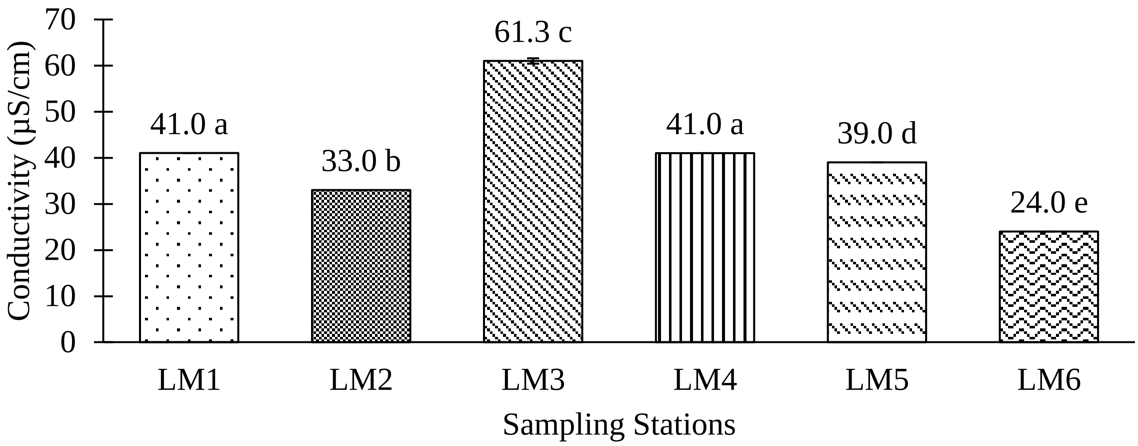


Figure 3.15: Mean conductivity at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.2 Dissolved Oxygen

The mean DO values recorded at the stations ranged from 6.66 mg/L to 7.89 mg/L, with the lowest mean was recorded at LM2 (Sungai Serupa) and the highest at LM6 (Sungai Sepula) (Figure 3.16). The mean DO in Sungai Sepula (LM6) was significantly higher than the other sampling stations in Lio Mato ($p<0.05$). DO at LM2 (Sungai Serupa) was significantly lower than DO value of the other stations ($p<0.05$) except LM1 (Main River) and LM3 (Sungai Serebu) ($p>0.05$). There was no significant difference in means of DO among LM1 (Main River), LM2 (Sungai Serupa) and LM3 (Sungai Serebu) ($p>0.05$), but they were significantly different from LM4 (Main River), LM5 (Lio Samleng) and LM6 (Sungai Sepula) ($p<0.05$). Overall, LM5 and LM6 were classified under Class I of NWQS, whereas LM1, LM2, LM3 and LM4 were classified as Class II.

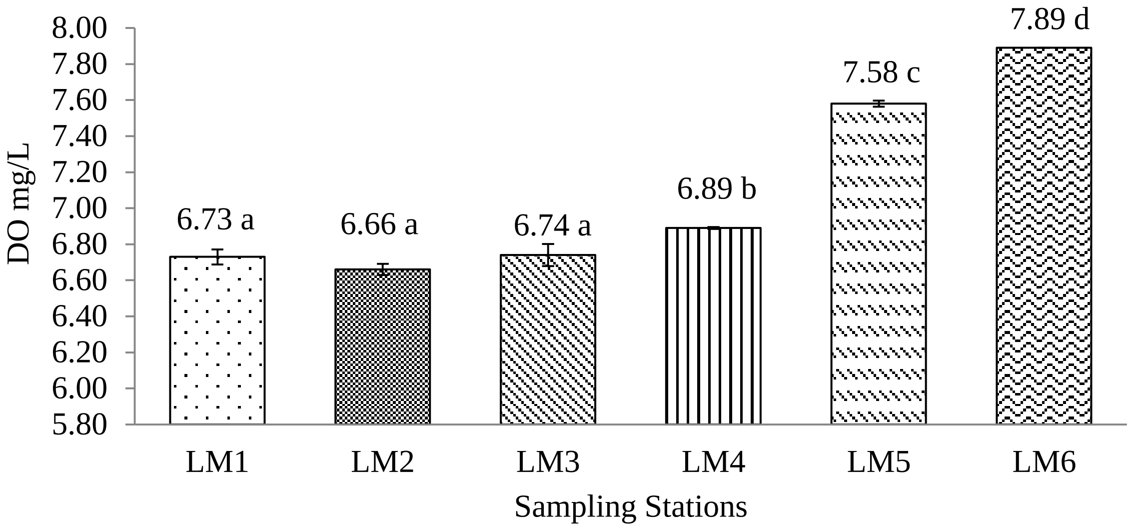


Figure 3.16: Mean DO at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.3 pH

The mean pH values recorded at the stations ranged from 6.81 to 7.26 and most of the stations at Lio Mato area showed slightly acidic condition with mean pH lower than 7 except for LM3 (Sungai Serebu) and LM4 (Main River) (Figure 3.17). The pH level was found to be within the recommended level by NWQS, Malaysia and fell into Class I. Values of mean pH recorded showed no significant difference between LM3 (Sungai Serebu) and LM4 (Main River) ($p>0.05$). Similar results were also shown between LM2 (Sungai Serupa) and LM6 (Sungai Sepula) ($p>0.05$) while the LM1 (Main River) was significantly different from LM5 (Lio Samleng) ($p<0.05$). The lowest pH was recorded in LM5 (Lio Samleng) with a mean value of 6.81 which was significantly lower than the other stations ($p<0.05$) except for LM2 (Sungai Serupa) and LM6 (Sungai Sepula) ($p>0.05$). Meanwhile, LM3 (Sungai Serebu) was significantly less acidic than other stations with a mean pH of 7.26 and was significantly higher than the other stations ($p<0.05$) except for LM4 (Main River) ($p>0.05$).

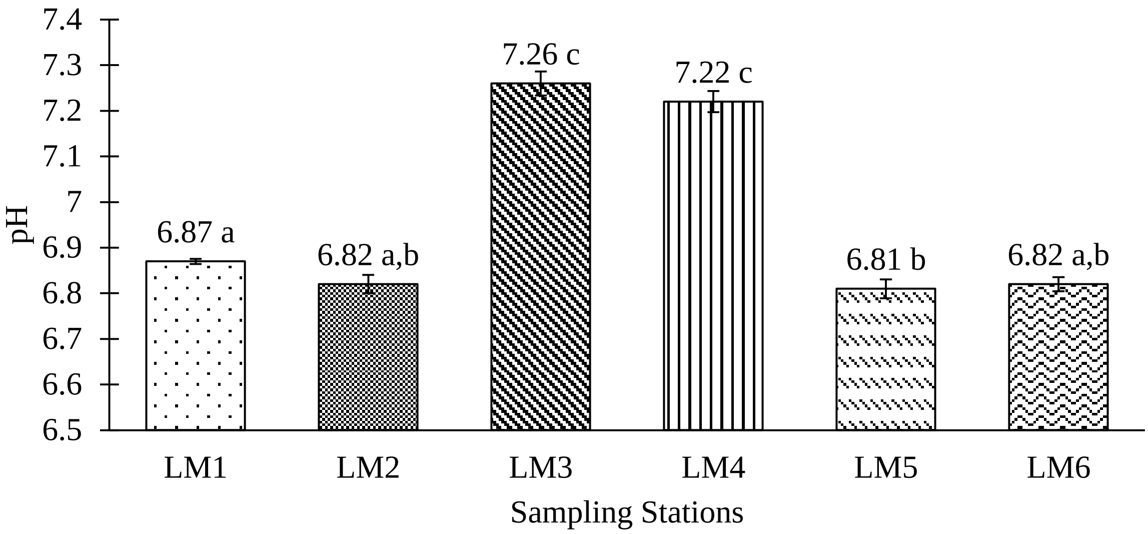


Figure 3.17: Mean pH at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.4 Temperature

The means temperature recorded at the stations ranged from 24.08 °C to 25.88 °C (Figure 3.18), with the lowest was recorded at LM6 (Sungai Sepula). The highest mean temperature was recorded at Main River (LM1) with a mean value of 25.88 °C and was significantly higher than the other stations ($p<0.05$). Temperature at LM6 (Sungai Sepula) was significantly lower than other stations ($p<0.05$) except for LM2 (Sungai Serupa) and LM5 (Lio Samleng) ($p>0.05$). There was no significant difference in means of temperature among LM2 (Sungai Serupa), LM5 (Lio Samleng) and LM6 (Sungai Sepula) ($p>0.05$), but they were significantly different from LM1 (Main River), LM3 (Sungai Serebu) and LM4 (Main River) ($p<0.05$).

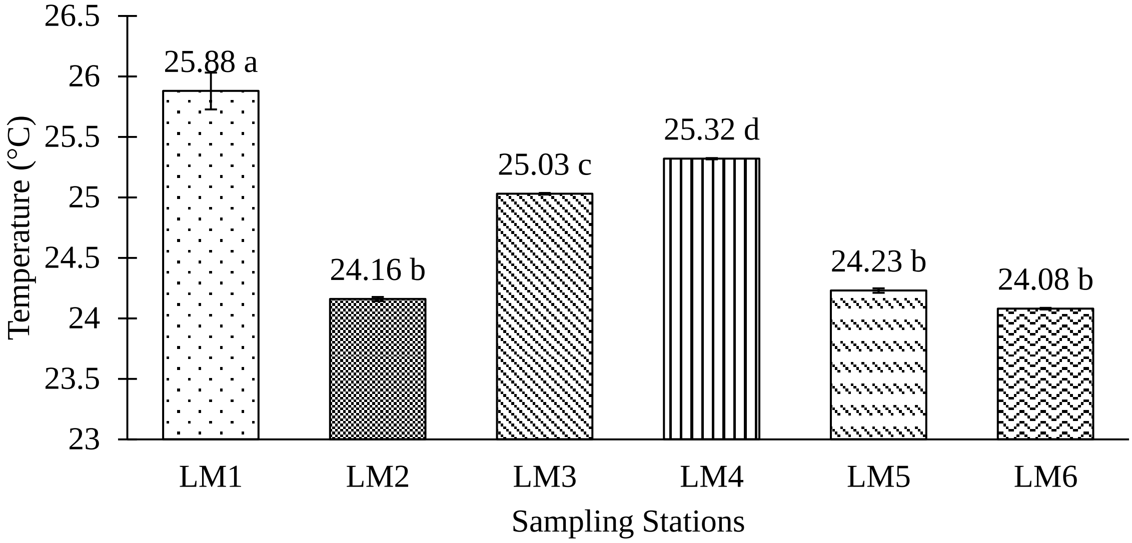


Figure 3.18: Mean temperature at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.5 Turbidity

The mean of turbidity recorded at the stations ranged from 1.3 NTU to 123.8 NTU (Figure 3.19), with the lowest mean was recorded at LM6 (Sungai Sepula). These values generally exceeded the normal level of NWQS for Malaysian rivers which is 50 NTU, hence they falled into Class III. Turbidity values at all stations in Lio Mato was significantly different among each other ($p<0.05$). The highest mean turbidity was recorded at LM2 (Sungai Serupa) with a mean value of 123.8 NTU and was significantly higher than other stations in Lio Mato ($p<0.05$). Turbidity at LM6 (Sungai Sepula) was significantly lower than all other stations in Lio Mato ($p<0.05$).

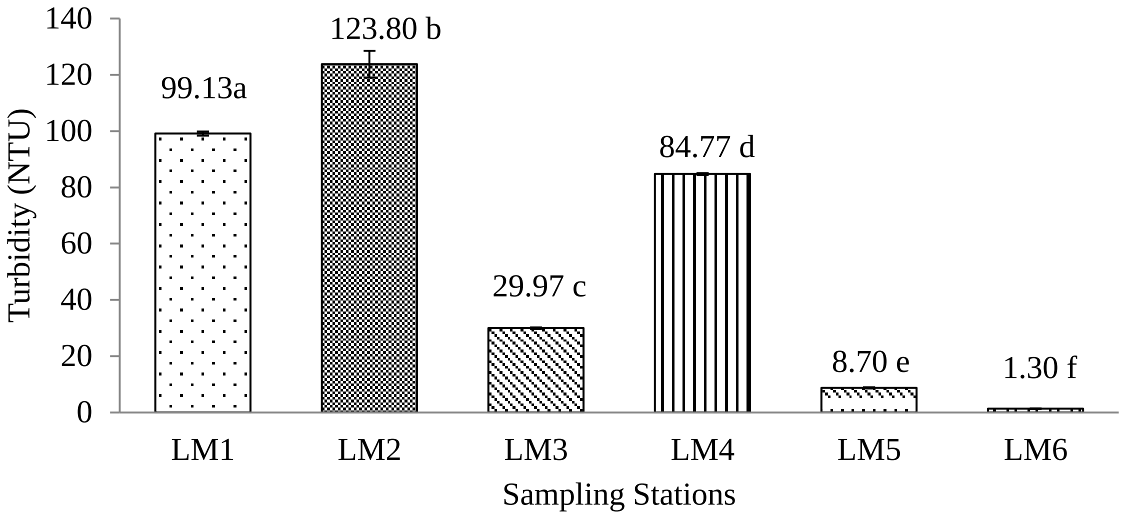


Figure 3.19: Mean turbidity at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.6 BOD_5

The mean biochemical oxygen demand values recorded at the stations ranged from 1.57 mg/L to 3.27 mg/L (Figure 3.20). These concentrations were within the standard permissible limits of NWQS for Malaysian rivers and categorized as Class II. The highest mean BOD_5 concentration was recorded at LM6 (Sungai Sepula) with a mean value of 3.27 mg/L and was significantly higher ($p<0.05$) than other stations except LM2 (Sungai Serupa), LM4 (Main River) and LM6 (Sungai Sepula) ($p>0.05$). The lowest mean of BOD_5 concentration was recorded at LM3 (Sungai Serebu) and was significantly lower than all other stations in Lio Mato area ($p<0.05$).

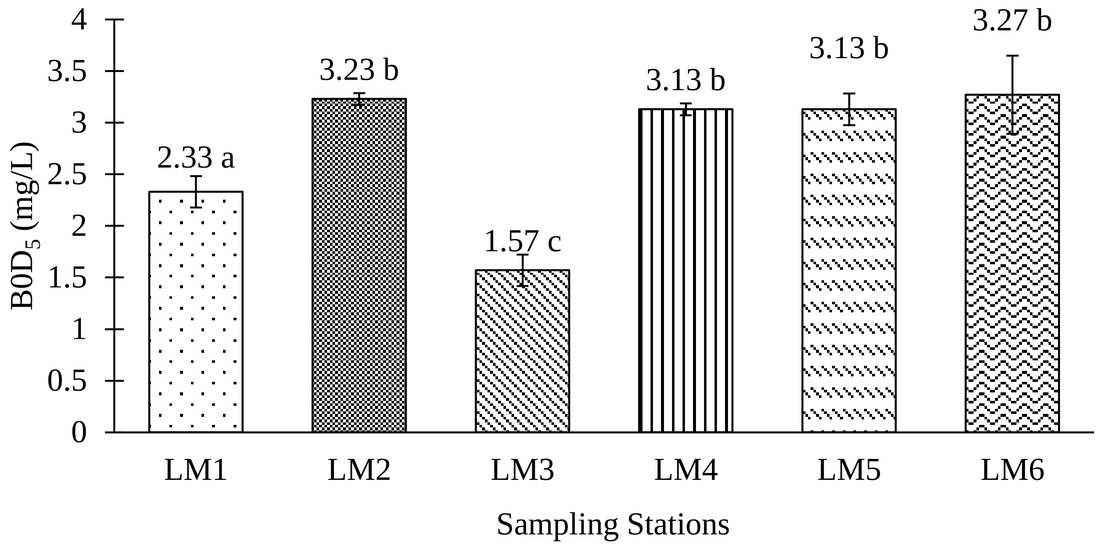


Figure 3.20: Mean BOD_5 at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.7 Chlorophyll-*a*

The mean of chlorophyll-*a* recorded at the stations ranged from 0.81 mg/m^3 to 6.97 mg/m^3 (Figure 3.21). The lowest mean of chlorophyll-*a* concentration was recorded at LM5 (Lio Samleng) with a mean value of 0.81 mg/m^3 and was significantly lower than the other stations ($p<0.05$) except LM3 (Sungai Serebu) ($p>0.05$). The highest mean chlorophyll-α concentration was recorded at LM1 (Main River) with a mean value of 6.97 mg/m^3 and was significantly higher than other stations ($p<0.05$) except LM6 (Sungai Sepula) ($p>0.05$). The mean chlorophyll-*a* concentration at LM6 (Sungai Sepula) was not significantly different from LM1 (Main River), LM2 (Sungai Serupa) and LM4 (Main River) ($p>0.05$). However, it was significantly different from LM3 (Sungai Serebu) and LM5 (Lio Samleng) ($p<0.05$).

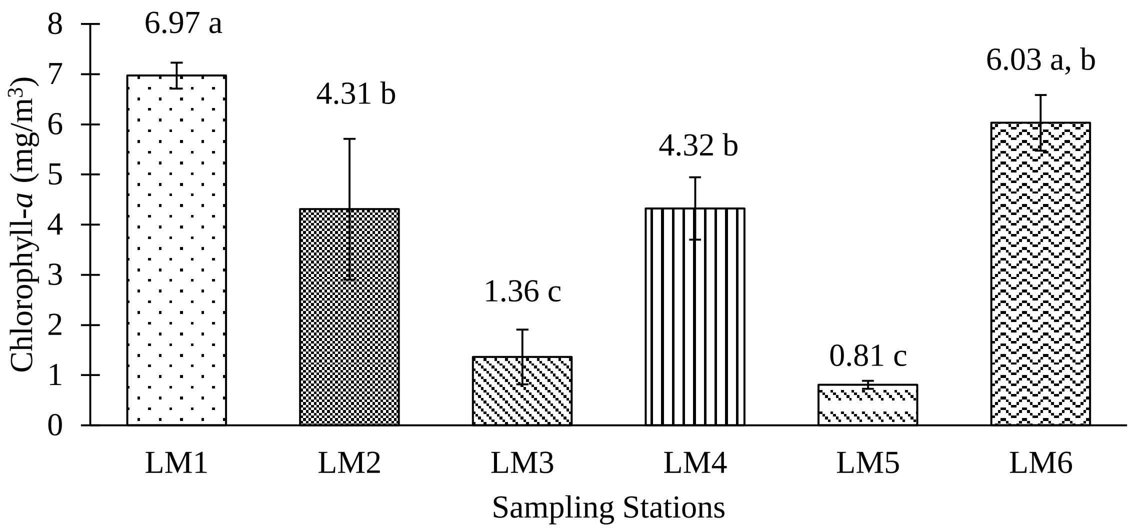


Figure 3.21: Mean chlorophyll-*a* at the six stations in Lio Mato, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.1.8 Total Suspended Solids

The mean of concentration of total suspended solids ranged from 16.9 mg/L to 298.6 mg/L (Figure 3.22). TSS values in this study were within the maximum permissible limit set by NWQS, Malaysia, which is 300 mg/L and is classified as Class IV. The lowest mean of TSS concentration was recorded at LM3 (Sungai Serebu) and was significantly lower than the other stations ($p<0.05$) except LM1 (Main River), and LM6 (Sungai Sepula) ($p>0.05$). The highest mean TSS concentration was recorded at LM2 (Sungai Serupa) with a mean value of 298.6 mg/L and was significantly higher than the other stations ($p<0.05$). The mean TSS was not significantly different among LM1 (Main River), LM3 (Sungai Serebu), and LM6 (Sungai Sepula) ($p>0.05$), but significantly different from LM2 (Sungai Serupa) and LM4 (Main River) ($p<0.05$).

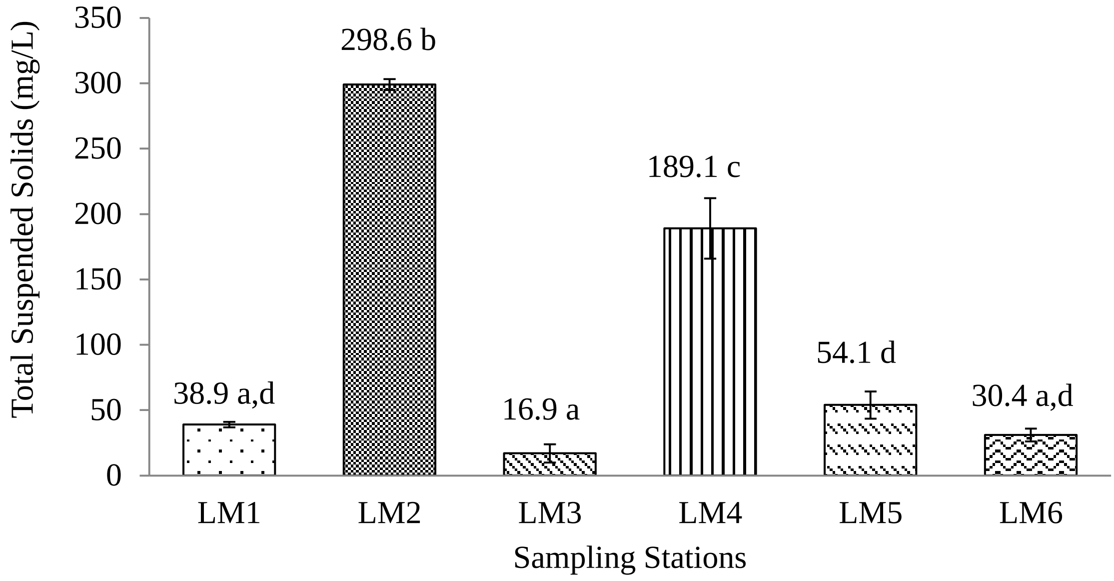


Figure 3.22: Mean total suspended solids at the six stations in Lio Mato, Baram. Mean with the same superscript were not significantly different at 5% significant.

3.3.2.2 Long Apu, Baram

3.3.2.2.1 Conductivity

The mean conductivity of water ranged from 27.0 µS/cm to 72.0 µS/cm (Figure 3.23). Conductivity results are within the standard allowable levels of Malaysian rivers and are classified as Class I by NWQS. The lowest value of 27.0 µS/cm was recorded at LA6 (Sungai Beraan) and was significantly lower than the other stations in Long Apu ($p<0.05$). The highest mean conductivity was recorded at LA2 (Sungai Lasa) and was significantly ($p<0.05$) higher than the other stations.

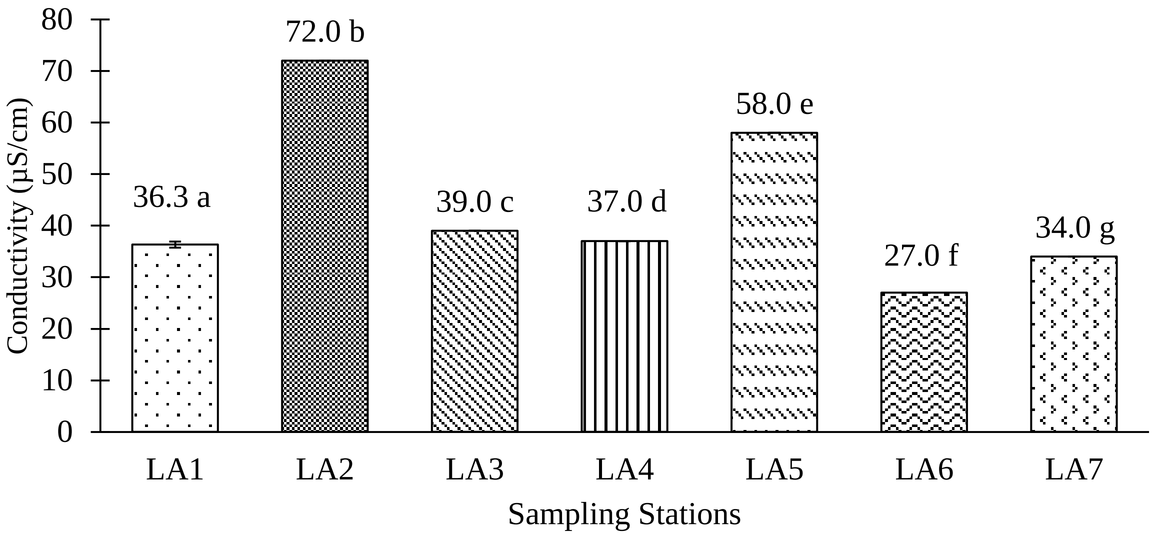


Figure 3.23: Mean conductivity at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.2 Dissolved Oxygen

The mean DO concentration recorded at the stations ranged from 7.79 mg/L to 8.03 mg/L (Figure 3.24). These results are categorized under Class I of the NWQS for Malaysian river, which is more than 7 mg/L. The lowest mean DO concentration was recorded at LA7 (Main River) and was significantly lower than the other stations in Long Apu ($p<0.05$). The highest mean DO concentration was recorded at LA6 (Sungai Beraan) with a mean value of 8.03 mg/L and was significantly higher than the other stations in Long Apu ($p<0.05$). The mean value of DO concentrations showed no significant difference between LA1 (Main River) and LA2 (Sungai Lasa) ($p>0.05$), but was significantly different from LA3 (Sungai Julan), LA4 (Sungai Plutan), LA5 (Sungai Menapun), LA6 (Sungai Beraan) and LA7 (Main River) ($p<0.05$).

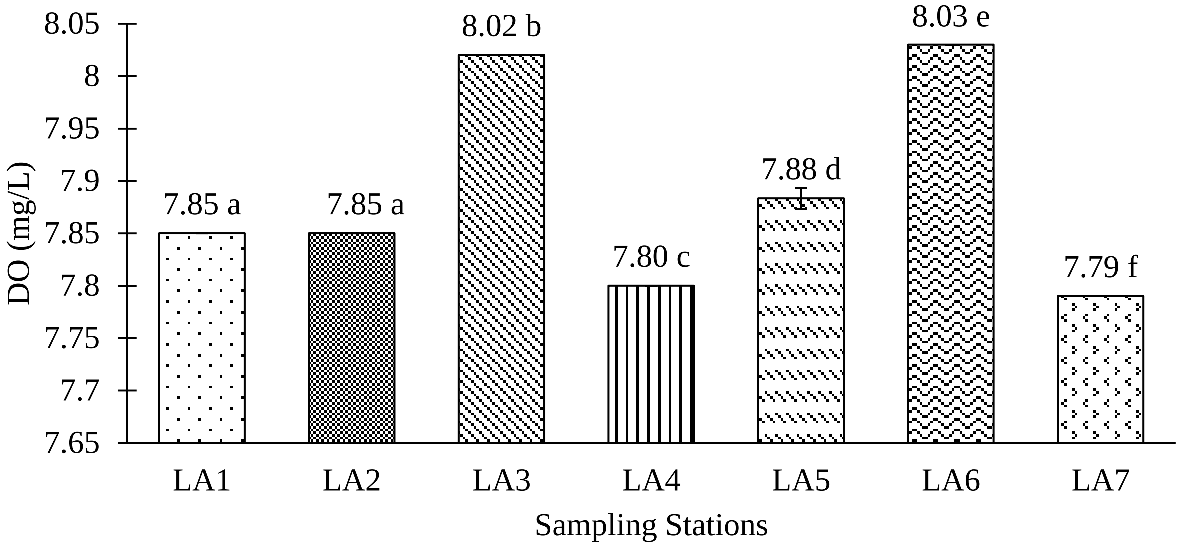


Figure 3.24: Mean DO at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.3 pH

The mean pH recorded at the stations in Long Apu ranged from 6.76 to 7.38 (Figure 3.25). The pH levels are classified as Class I by NWQS, Malaysia. The highest mean pH value was recorded at LA2 (Sungai Lasa) and LA5 (Sungai Menapun) with a mean of 7.38 and was significantly higher than the other stations in Long Apu area ($p<0.05$). LA3 (Sungai Julan) was significantly more acidic than the other stations in Long Apu with a mean value of 6.76 ($p<0.05$). Only one station in Long Apu was slightly acidic with pH less than 7 which is LA3 (Sungai Julan). Mean value of pH recorded showed no significant difference between LA1 (Main River) and LA7 (Main River) ($p>0.05$). Similar results were also shown between LA2 (Sungai Lasa) and LA5 (Sungai Menapun) ($p>0.05$), but was significantly different from the other stations like LA3 (Sungai Julan), LA4 (Sungai Plutan) and LA6 (Sungai Beraan) ($p<0.05$).

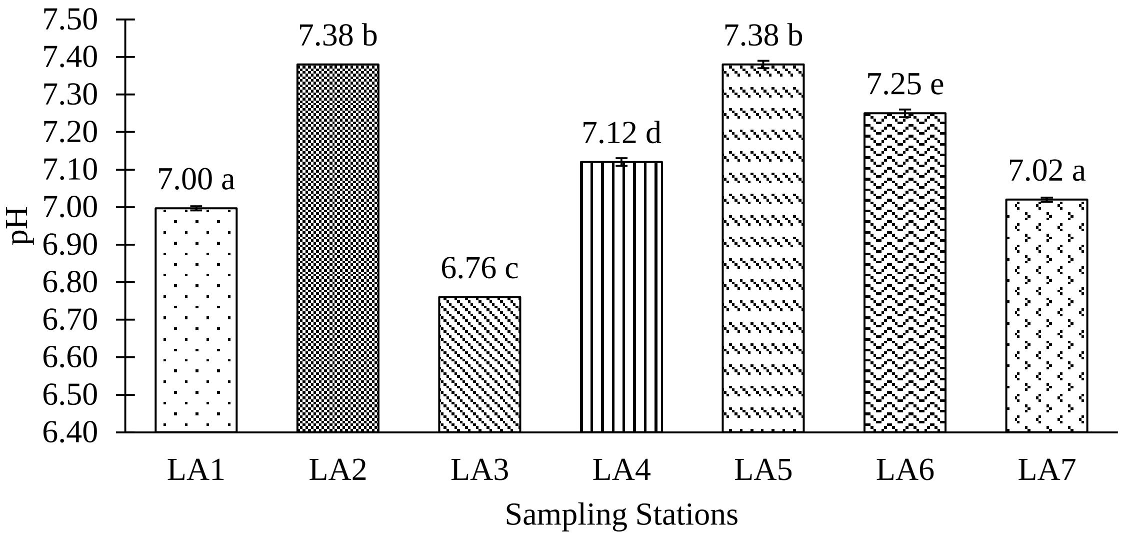


Figure 3.25: Mean pH at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.4 Temperature

The mean of temperature recorded at the stations ranged from 23.84 °C to 26.28 °C with the lowest mean was recorded at LA6 (Sungai Beraan) (Figure 3.26). The highest mean temperature was recorded at LA4 (Sungai Plutan) with a mean of 26.28 °C and was significantly higher than the other stations ($p<0.05$). Temperature at LA6 (Sungai Beraan) was significantly lower than other stations (Figure 26) ($p<0.05$). There was no significant difference in mean temperature between LA1 (Main River) and LA3 (Sungai Julan) ($p>0.05$), but they were significantly different from LA2 (Sungai Lasa), LA4 (Sungai Plutan), LA5 (Sungai Menapun), LA6 (Sungai Beraan) and LA7 (Main River) ($p<0.05$).

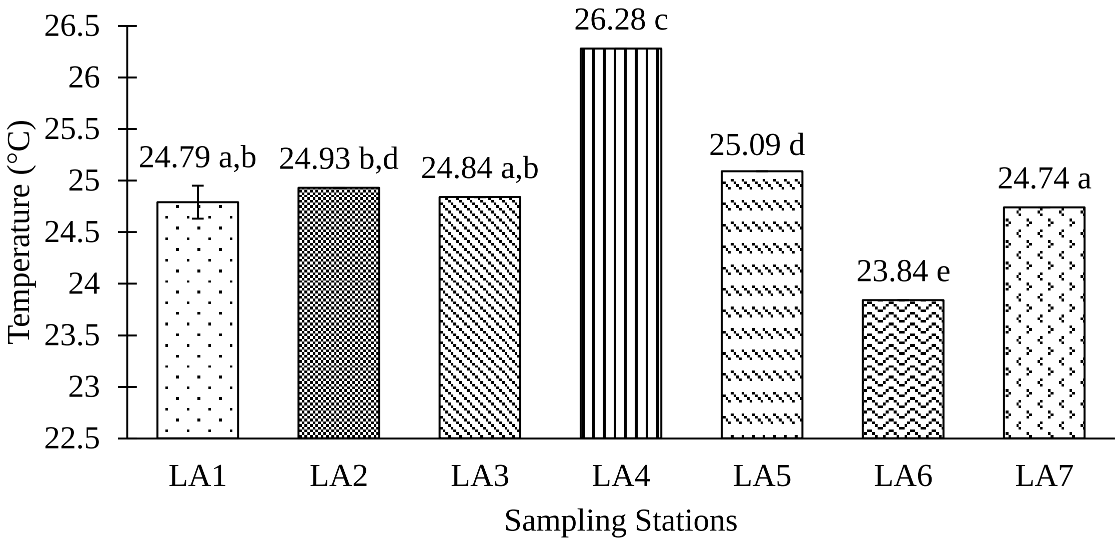


Figure 3.26: Mean temperature at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.5 Turbidity

The mean turbidity values in Long Apu ranged from 1.20 NTU to 86.50 NTU (Figure 3.27). Turbidity values were within the maximum permissible limit set by NWQS (50 NTU), and is categorized as Class III. The highest turbidity value was recorded at LA6 (Sungai Beraan) with a mean value of 86.50 NTU and was significantly higher compared to all the other stations in Long Apu ($p<0.05$). The lowest mean of turbidity was recorded at LA3 (Sungai Julan) and was significantly lower than the other stations ($p<0.05$). Mean value of turbidity recorded showed no significant difference between two stations LA1 and LA7, at main river at Long Apu ($p>0.05$). Similar results were also shown between LA4 (Sungai Plutan) and LA5 (Sungai Menapun) ($p>0.05$), but was significantly different from other stations, namely LA2 (Sungai Lasa), LA3 (Sungai Julan) and LA6 (Sungai Beraan) ($p<0.05$).

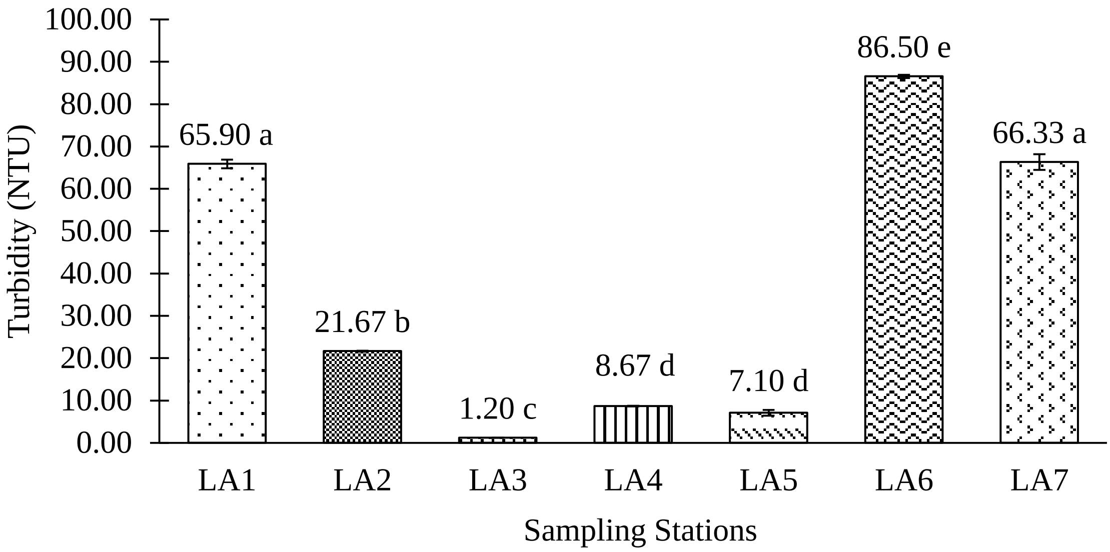


Figure 3.27: Mean turbidity at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.6 BOD_5

The mean biochemical oxygen demand recorded at the stations ranged from 1.63 mg/L to 4.07 mg/L (Figure 3.28). These results are within the standard acceptable level of NWQS for Malaysian river, which is categorized under Class III. The highest BOD_5 concentration was recorded at LA4 (Sungai Plutan) with a mean value of 4.07 mg/L and was significantly higher than all the other stations ($p<0.05$). The lowest mean BOD_5 concentration was recorded at LA3 (Sungai Julan) and was significantly lower than other stations ($p<0.05$) except LA1 (Main River) ($p>0.05$). The concentration of (BOD_5 at LA1 (Main River) was significantly different from LA2 (Sungai Lasa), LA4 (Sungai Plutan), LA6 (Sungai Beraan) and LA7 (Main River) ($p<0.05$), but showed no significant difference with LA3 (Sungai Julan) and LA5 (Sungai Menapun) ($p>0.05$).

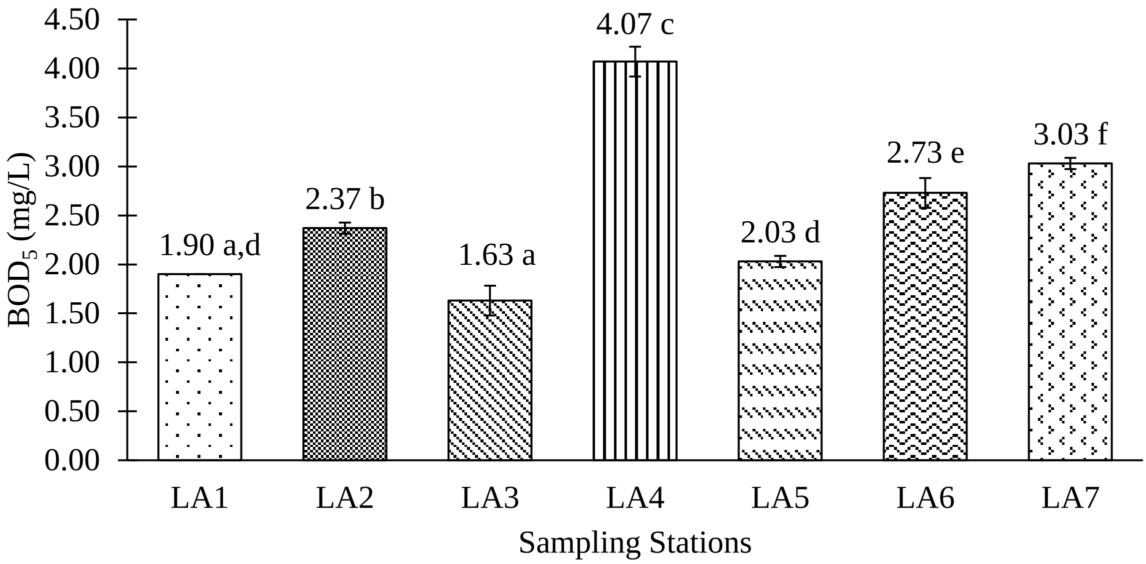


Figure 3.28: Mean BOD_5 at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.7 Chlorophyll-*a*

The mean of chlorophyll-*a* recorded at the stations ranged from 0.13 mg/m^3 to 3.34 mg/m^3 (Figure 3.29). The highest chlorophyll-*a* concentration was recorded at LA1 (Main River) with a mean value of 3.34 mg/m^3 and was significantly higher than other stations ($p<0.05$) except LA7 (Main River) ($p>0.05$). The lowest mean of chlorophyll-*a* concentration was recorded at LA4 (Sungai Plutan) with a mean value of 0.13 mg/m^3 and was significantly lower than other stations ($p<0.05$) except LA2 (Sungai Lasa), LA3 (Sungai Julan), LA5 (Sungai Menapun) and LA6 (Sungai Beraan) ($p>0.05$). Mean chlorophyll-*a* concentration in LA2 (Sungai Lasa), LA3 (Sungai Julan), LA4 (Sungai Plutan), LA5 (Sungai Menapun) and LA6 (Sungai Beraan) ($p>0.05$) showed no significant difference, but they were significantly different with two main rivers in Long Apu (LA1 and LA7) ($p<0.05$).

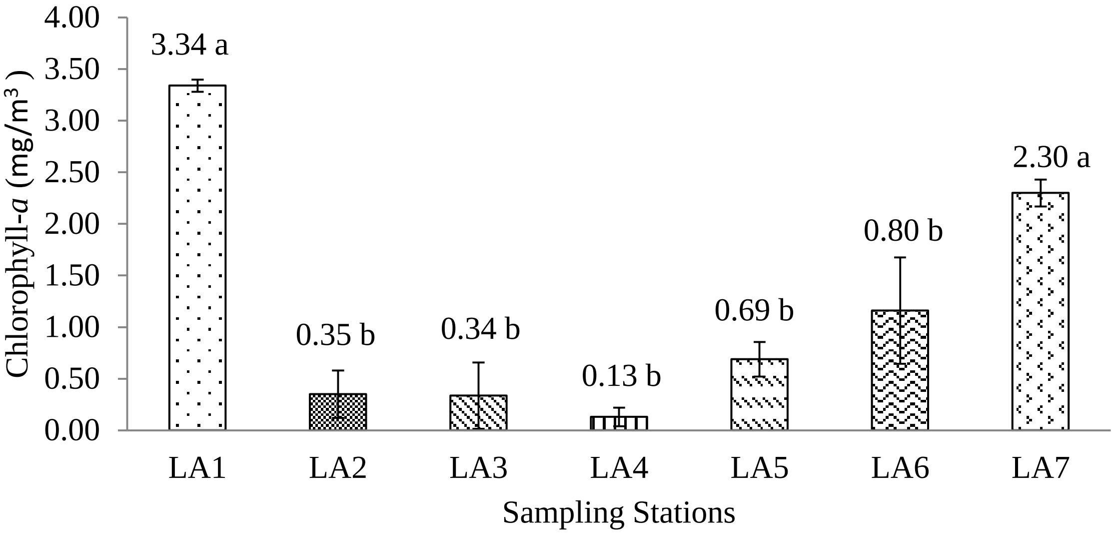


Figure 3.29: Mean chlorophyll-*a* at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.2.8 Total Suspended Solids

The mean concentration of total suspended solids ranged from 2.17 mg/L to 102.11 mg/L (Figure 3.30). Based on the NWQS, the maximum threshold limit of TSS for Malaysian rivers which can support aquatic life is 150 mg/L. Therefore, the TSS values in this study were within this limit and are categorized as Class III. The highest TSS concentration was recorded at LA1 (Main River) with a mean value of 102.11 mg/L and was significantly higher than all the other stations ($p<0.05$). The lowest mean of TSS concentration was recorded at LA6 (Sungai Beraan) and was significantly lower than other stations except LA3 (Sungai Julan), ($p>0.05$). The value of TSS recorded showed no significant difference between LA3 (Sungai Julan) and LA6 (Sungai Beraan) ($p>0.05$). Similar results were also shown between LA4 (Sungai Plutan) and LA5 (Sungai Menapun) ($p>0.05$), but was significantly different from other stations namely, LA1 (Main River), LA2 (Sungai Lasa) and LA7 (Main River) ($p<0.05$).

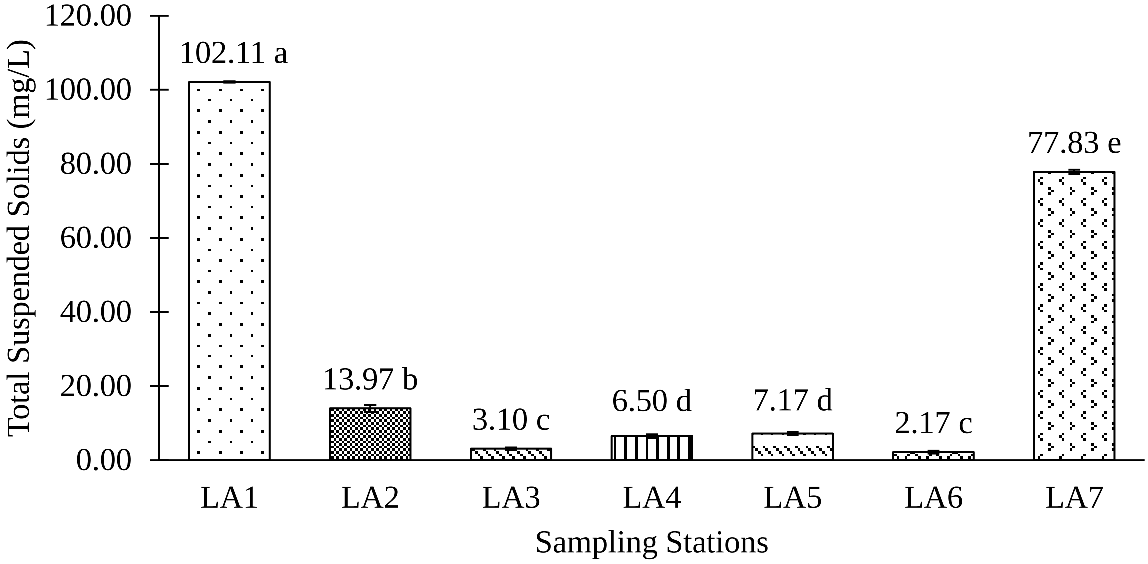


Figure 3.30: Mean total suspended solids at the seven stations in Long Apu, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3 Long San, Baram

3.3.2.3.1 Conductivity

The mean conductivity of water ranged from 32.0 µS/cm to 107.0 µS/cm (Figure 3.31). Conductivity results are classified as Class I as determined by NWQS, Malaysia and are within the standard allowable levels for Malaysian rivers. The mean conductivity recorded at Baram River was significantly different among each other ($p<0.05$). The highest mean conductivity was recorded at LS4 (Sungai Kelameh) with a mean value of 107.0 µS/cm and was significantly higher than other stations ($p<0.05$). The lowest mean of 32.0 µS/cm was recorded at LS2 (Main River) and was significantly lower than the other stations in Long San ($p<0.05$).

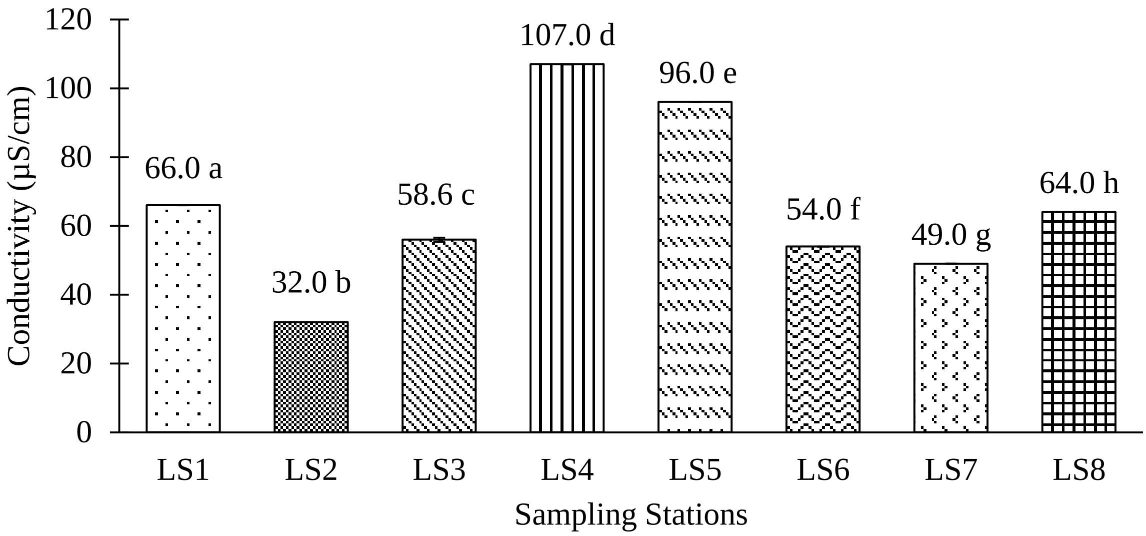


Figure 3.31: Mean conductivity at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3.2 Dissolved Oxygen

The mean DO concentration recorded at the stations ranged from 7.33 mg/L to 7.88 mg/L (Figure 3.32). DO level was found to be within the recommended level by NWQS, Malaysia, and fell into Class I. The lowest mean of DO concentration was recorded at LS5 (Sungai Sabop) and LS6 (Main River) with a mean value of 7.33 mg/L. Mean DO at LS5 (Sungai Sabop) and LS6 (Main River) was significantly lower than all stations in Long San ($p<0.05$). The highest DO concentration was recorded at LS8 (Sungai Pelet) with a mean value of 7.88 mg/L and was significantly higher than the other stations in Long San ($p<0.05$). The mean value of DO concentrations showed no significant difference between LS5 (Sungai Sabop) and LS6 (Main River) ($p>0.05$), but they were significantly different from LS1 (Sungai Kluan), LS2 (Main River), LS3 (Sungai Akah), LS4 (Sungai Kelameh), LS7 (Sungai Benuang) and LS8 (Sungai Pelet) ($p<0.05$).

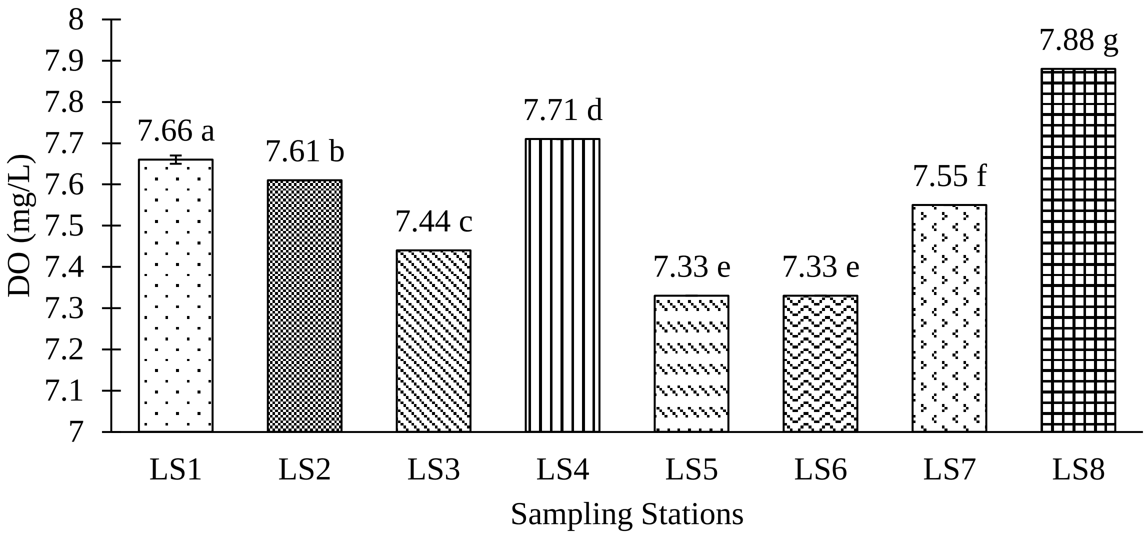


Figure 3.32: Mean DO at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3.3 pH

The mean of pH recorded at the stations in Long San ranged from 7.21 to 7.92 (Figure 3.33). pH results are within the standard allowable levels of Malaysian rivers and are classified as Class I by NWQS, Malaysia. All stations in Long San were less acidic with mean pH of more than 7. Mean value pH recorded showed no significant difference between LS4 (Sungai Kelameh) and LS8 (Sungai Pelet) ($p>0.05$), but significantly different with LS1 (Sungai Kluan), LS2 (Main River), LS3 (Sungai Akah), LS5 (Sungai Sabop), LS6 (Main River) and LS7 (Sungai Benuang) ($p<0.05$). DO at LS7 (Sungai Benuang) was significantly lower than the other stations in Long San with a mean value of 6.76 ($p<0.05$). Meanwhile, the highest pH was recorded at LS6 (Main River) and was significantly higher than all other stations in Long San area ($p<0.05$).

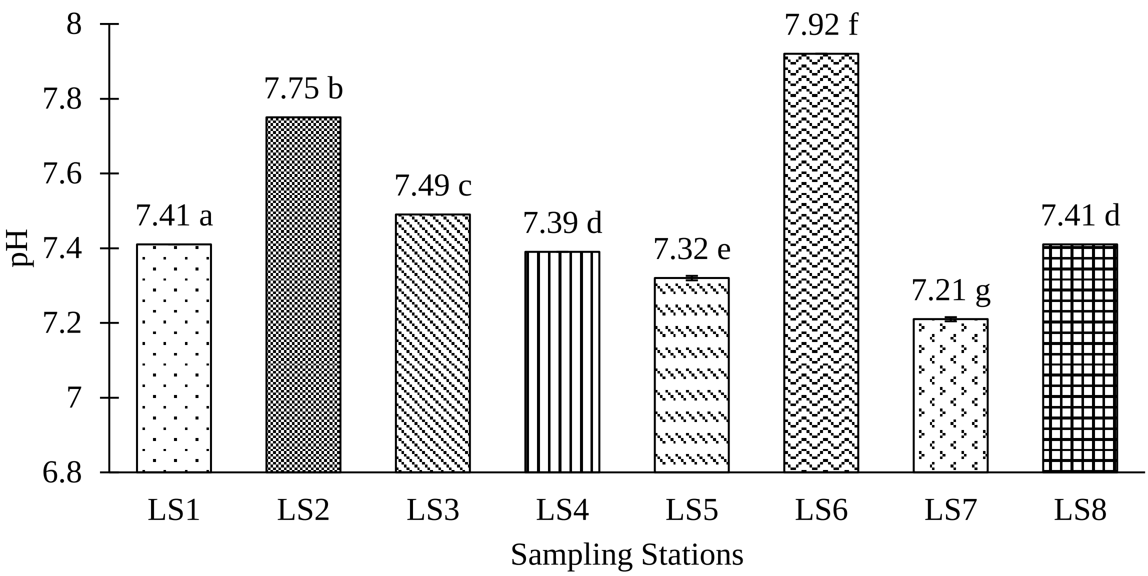


Figure 3.33: Mean pH at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3.4 Temperature

The mean temperature recorded at the stations ranged from 25.27 °C to 30.44 °C with the lowest temperature was recorded at LS8 (Sungai Pelet) (Figure 3.34). Temperature at LS8 (Sungai Pelet) was significantly lower than the other stations ($p<0.05$). Mean temperature in Long San was significantly difference among all stations ($p>0.05$). The highest temperature was recorded at LS3 (Sungai Akah) with a mean of 30.44 °C and was significantly higher than the other stations ($p<0.05$).

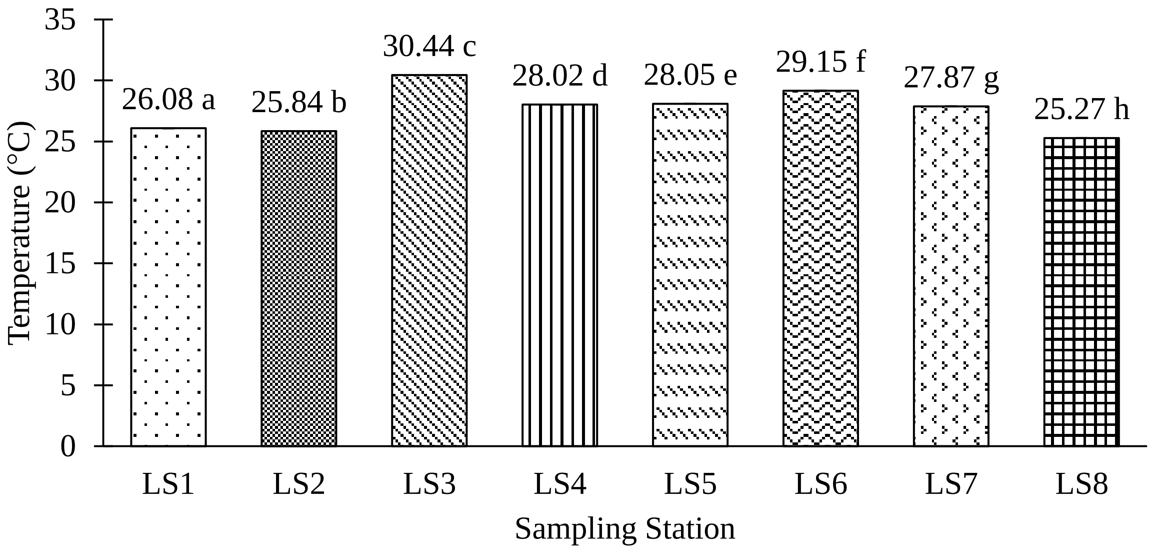


Figure 3.34: Mean temperature at the eight stations in Long San, Baram. Mean with the same superscript were not significantly different at 5% significant level.

3.3.2.3.5 Turbidity

The mean values of turbidity in Long San ranged from 23.9 NTU to 222.2 NTU (Figure 3.35). These values generally exceeded the threshold limit of NWQS for Malaysian rivers which is 50 NTU, hence categorized into Class III. Mean value of turbidity in Long San was significantly different among all stations ($p<0.05$). The highest mean value of turbidity was at LS2 (Main River) with a mean of 222.2 NTU and was significantly higher than the other stations in Long San ($p<0.05$). The lowest mean turbidity was recorded at LS5 (Sungai Sabop) with a mean value of 23.9 NTU and was significantly lower than other stations ($p<0.05$).

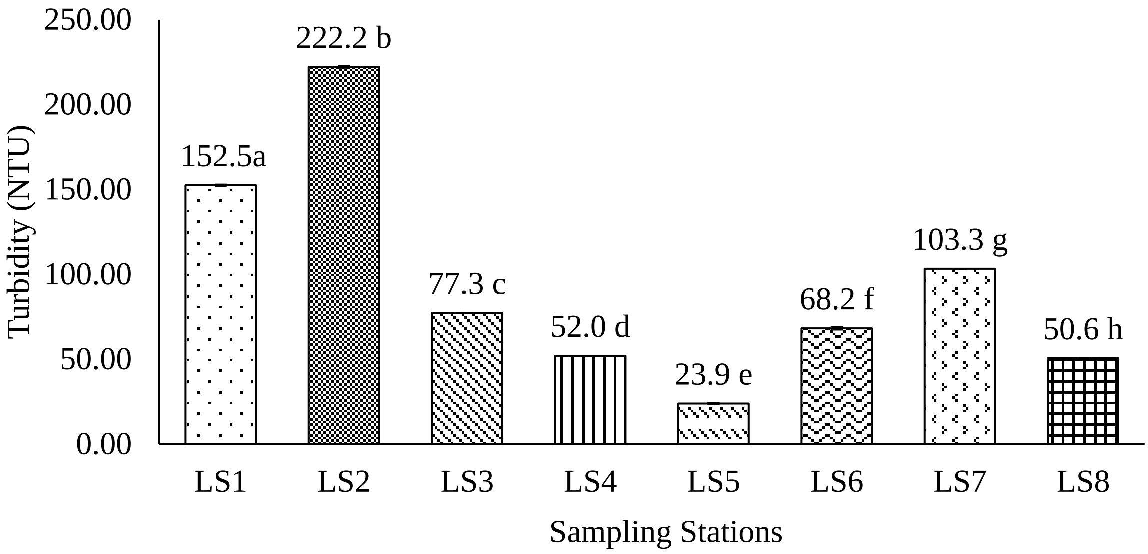


Figure 3.35: Mean turbidity at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3.6 BOD_5

The mean biochemical oxygen demand recorded at the stations ranged from 0.23 mg/L to 2.07 mg/L (Figure 3.36). The BOD_5 was found to be within the recommended level by NWQS, Malaysia, and is categorized as Class I. The highest mean BOD_5 concentration was recorded at LS1 (Sungai Kluan) with a mean value of 2.07 mg/L and was significantly higher than the other sampling stations in Long San ($p<0.05$). The lowest BOD_5 concentration of was recorded at LS8 (Sungai Pelet) and was significantly lower than the other stations ($p<0.05$) except LS4 (Sungai Kelameh), LS6 (Main River), and LS7 (Sungai Benuang) ($p>0.05$). The mean value BOD_5 at LS8 (Sungai Pelet) showed no significant difference with LS4 (Sungai Kelameh), LS6 (Main River), and LS7 (Sungai Benuang) ($p>0.05$), but was significantly different from LS1 (Sungai Kluan), LS2 (Main River), LS3 (Sungai Akah) and LS5 (Sungai Sabop) ($p<0.05$).

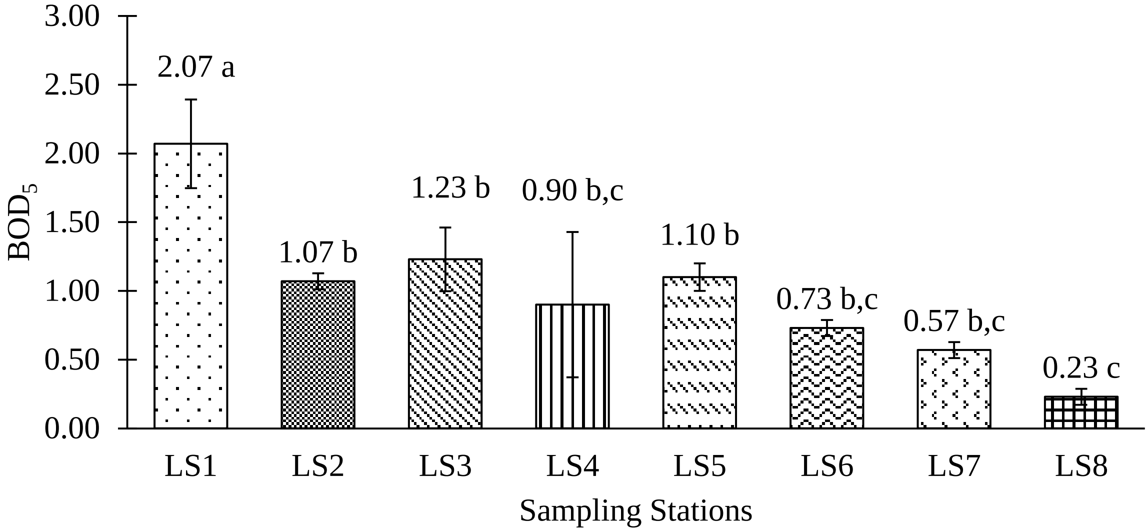


Figure 3.36: Mean BOD_5 at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3.7 Chlorophyll-*a*

The mean chlorophyll-*a* recorded at the stations ranged from 0.39 mg/m^3 to 1.10 mg/m^3 (Figure 3.37). Chlorophyll-*a* concentration in Long San showed no significant difference among all stations ($p>0.05$). The highest mean of chlorophyll-*a* concentration was recorded at LS4 (Sungai Kelameh) with a mean value of 1.10 mg/m^3 but showed no significant different with all stations in Long San ($p>0.05$). The lowest mean of chlorophyll-*a* concentration was recorded at LS7 (Sungai Benuang) with a mean of 0.39 mg/m^3 but was not significantly lower than other stations ($p>0.05$).

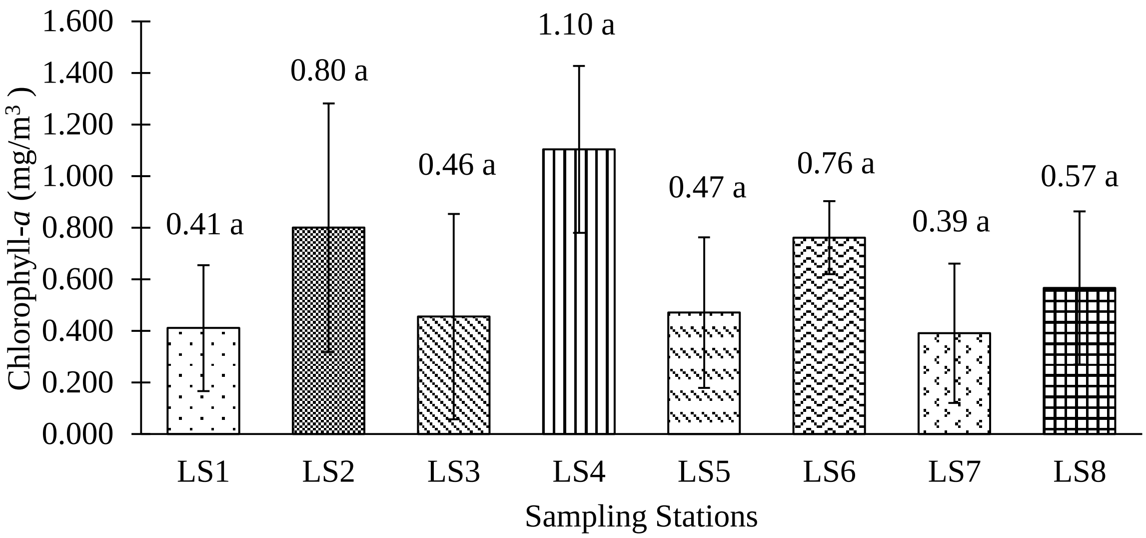


Figure 3.37: Mean chlorophyll-*a* at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.3.8 Total Suspended Solids

The mean concentration total suspended solids ranged from 21.25 mg/L to 89.85 mg/L (Figure 3.38). These results are within the standard acceptable levels of NWQS for Malaysian river, which can be categorized under Class III. The highest mean TSS concentration was recorded at LS7 (Sungai Benuang) with a mean value of 89.85 mg/L and was significantly higher than the other stations in Long San ($p<0.05$). The lowest mean of TSS concentration was recorded at LS5 (Sungai Sabop) and was significantly lower than the other stations ($p<0.05$). Mean value of TSS recorded showed no significant difference between LS4 (Sungai Kelameh) and LS8 (Sungai Pelet) ($p>0.05$). Similar results were also shown between LS1 (Sungai Kluan) and LS6 (Main River) ($p>0.05$), but they were significantly different with LS2 (Main River), LS3 (Sungai Akah), LS5 (Sungai Sabop) and LS7 (Sungai Benuang) ($p<0.05$).

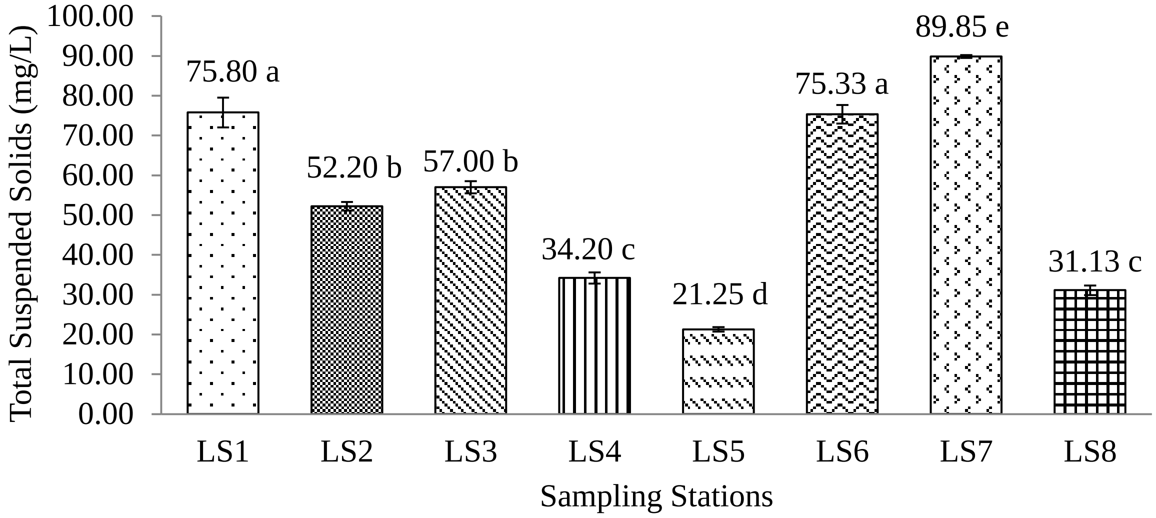


Figure 3.38: Mean total suspended solids at the eight stations in Long San, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4 Long Kesseh, Baram

3.3.2.4.1 Conductivity

The mean conductivity of water ranged from 40.0 µS/cm to 86.7 µS/cm (Figure 3.39). Conductivity was found to be within the recommended level by NWQS, Malaysia, and fell into the Class I. The mean conductivity of water in Long Kesseh showed significant differences among all stations ($p<0.05$). The highest mean conductivity was recorded at Sungai Nakan (LK1) with a mean value of 86.7 µS/cm and was significantly higher than other stations ($p<0.05$). The lowest value of 40.0 µS/cm was recorded at LK3 (Main River) and was significantly lower than all stations in Long Kesseh ($p<0.05$).

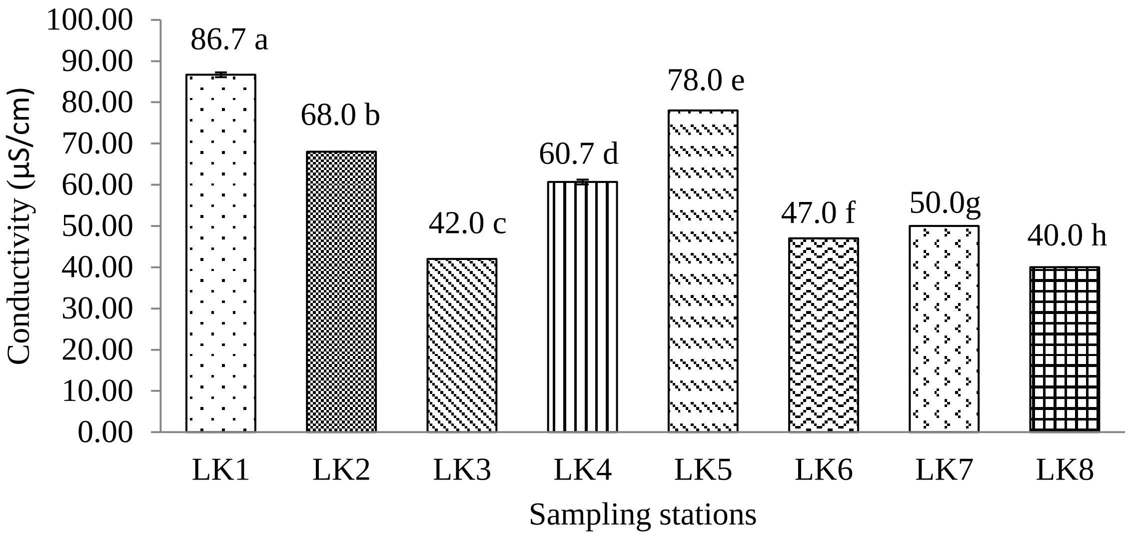


Figure 3.39: Mean conductivity at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4.2 Dissolved Oxygen

The mean DO concentration recorded at the stations ranged from 7.40 mg/L to 8.01 mg/L (Figure 3.40). The DO level in this area fell into the Class I which is the recommended level by NWQS, Malaysia. The highest mean DO concentration was recorded at LK7 (Sungai Piping) and LK8 (Sungai Kahah) with the mean value of 8.01 mg/L and was significantly higher than the other stations in Long Kesseh ($p<0.05$). The lowest mean of DO concentration was recorded at LK2 (Sungai Kemenyih) and LK5 (Sungai Liseng) and was significantly lower than the other stations in Long Kesseh ($p<0.05$). Mean value of dissolved oxygen concentration recorded showed no significant difference between LK2 (Sungai Kemenyih) and LK5 (Sungai Liseng) ($p>0.05$). Similar results were shown between LK7 (Sungai Piping) and LK8 (Sungai Kahah) ($p>0.05$), but they were significantly different from LK1 (Sungai Nakan), LK3 (Main River), LK4 (Sungai Kesseh) and LK6 (Sungai Jertang) ($p<0.05$).

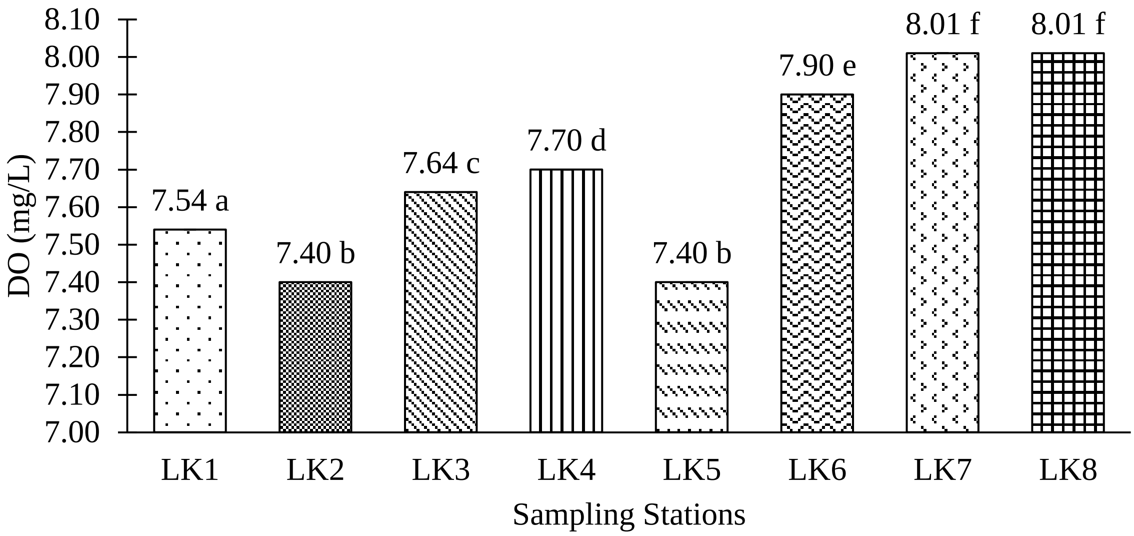


Figure 3.40: Mean DO at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4.3 pH

The mean of pH recorded at the stations in Long Kesseh ranged from 7.14 to 7.36 (Figure 3.41). These levels were categorized as Class I of NWQS for Malaysian rivers. All stations in Long Kesseh were less acidic with mean pH more than 7. The highest mean pH was recorded at LK1 (Sungai Nakan) with a mean value of 7.36 and was significantly higher than the other stations in Long Kesseh area ($p<0.05$). Mean pH at LK2 (Sungai Kemenyih) and LK5 (Sungai Liseng) was significantly lower than the other stations in Long Kesseh with a mean value of 7.14 ($p<0.05$). Mean value of pH recorded showed no significant difference between LK2 (Sungai Kemenyih) and LK5 (Sungai Liseng) ($p>0.05$). Similar results were also shown between LK7 (Sungai Piping) and LK8 (Sungai Kahah) ($p>0.05$), but were significantly different from LK1 (Sungai Nakan), LK3 (Main River), LK4 (Sungai Kesseh) and LK6 (Sungai Jertang) ($p<0.05$).

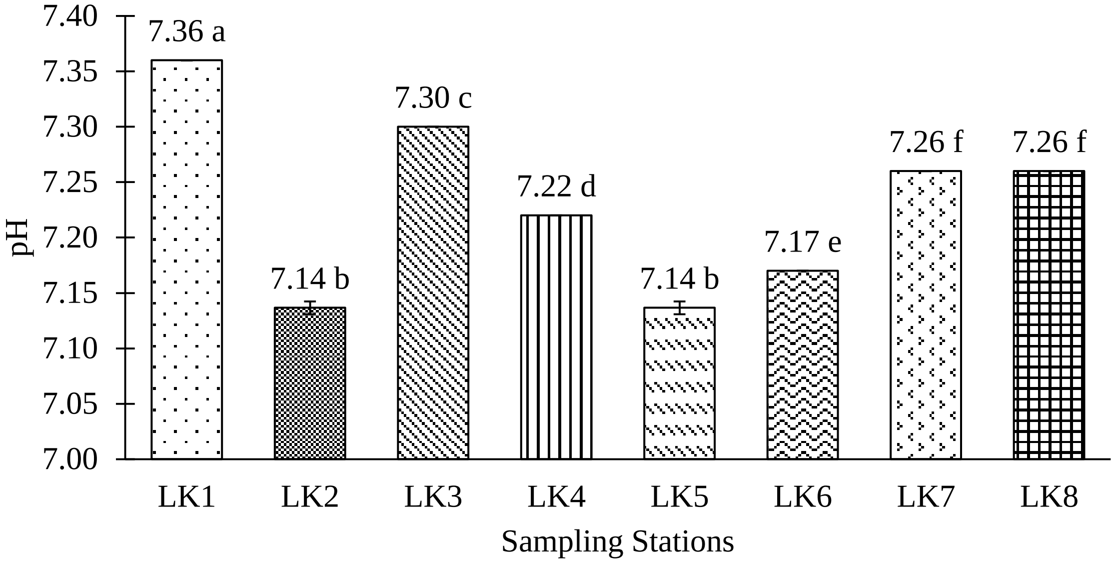


Figure 3.41: Mean pH at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4.4 Temperature

The mean temperature recorded at the stations ranged from 25.67 °C to 27.74 °C, with the lowest mean was recorded at LK7 (Sungai Piping) (Figure 3.42). The highest mean temperature was recorded at LK1 (Sungai Nakan) with a mean value of 27.74 °C and was significantly higher than the other stations ($p<0.05$). Temperature at LK7 (Sungai Piping) was significantly lower than the other stations ($p<0.05$). Mean value of temperature recorded showed no significant difference between LK2 (Sungai Kemenyih) and LK5 (Sungai Liseng) ($p>0.05$), but they were significantly different from LK1 (Sungai Nakan), LK3 (Main River), LK4 (Sungai Kesseh), LK6 (Sungai Jertang), LK7 (Sungai Piping) and LK8 (Sungai Kahah) ($p<0.05$).

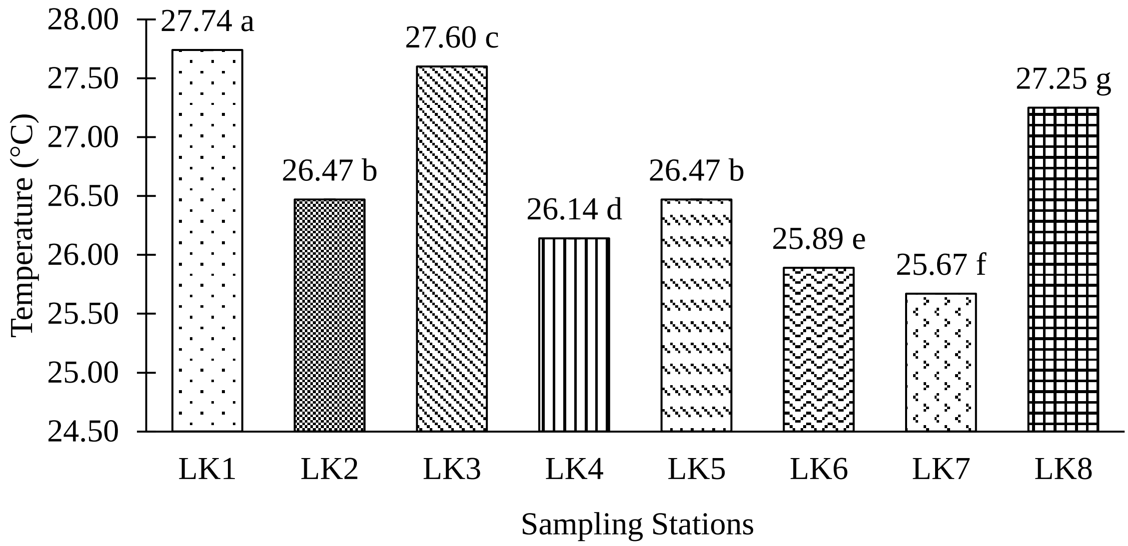


Figure 3.42: Mean temperature at the eight stations in Long Kesseh, Baram. Mean with the same letters was not significantly different at 5% significant level.

3.3.2.4.5 Turbidity

The mean turbidity values in Long Kesseh ranged from 2.67 NTU to 36.83 NTU (Figure 3.43). These results are within the standard acceptable levels of NWQS for Malaysian river and can be categorized under Class II. The highest mean turbidity was recorded at LK3 (Main River) with a mean value of 36.83 NTU and was significantly higher than the other stations in Long Kesseh ($p<0.05$). The lowest mean turbidity was recorded at LK1 (Sungai Nakan) and was significantly lower than the other stations ($p<0.05$). Mean value of turbidity in Long Kesseh showed no significant difference among LK2 (Sungai Kemenyih), LK4 (Sungai Kesseh), LK5 (Sungai Liseng) and LK8 (Sungai Kahah) ($p>0.05$). There was no significant difference between LK6 (Sungai Jertang) and LK7 (Sungai Benuang) ($p>0.05$), but were significantly different from LK1 (Sungai Nakan) and LK3 (Main River) ($p<0.05$).

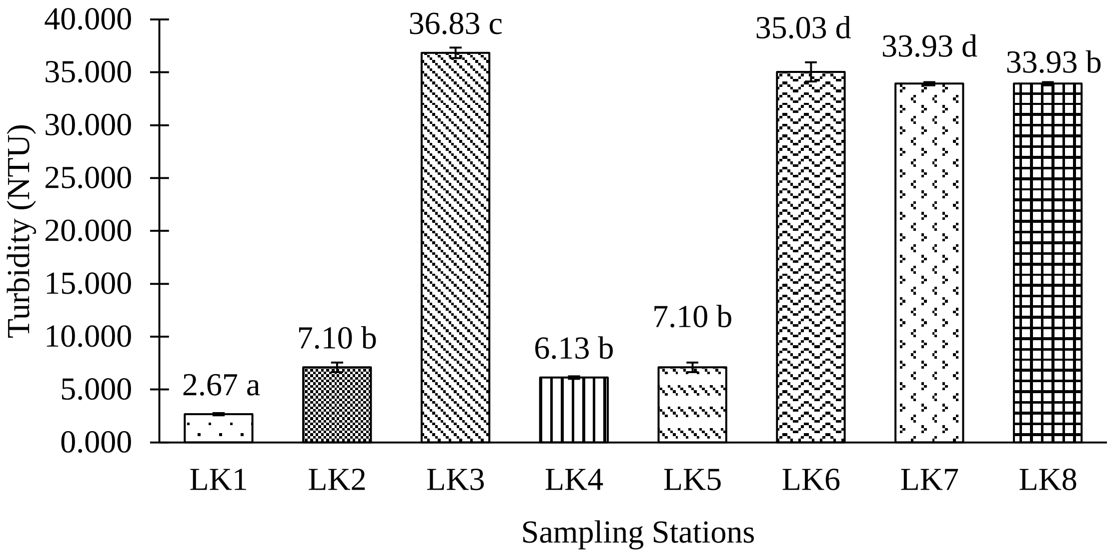


Figure 3.43: Mean turbidity at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4.6 BOD_5

The mean biochemical oxygen demand recorded at the stations ranged from 0.83 mg/L to 2.47 mg/L (Figure 3.44). These results are the recommended level by NWQS, Malaysia, and were categorized under Class I. The highest mean BOD_5 concentration was recorded at LK4 (Sungai Kesseh) with a mean value of 2.47 mg/L and showed no significant different with the other sampling stations in Long Kesseh ($p>0.05$) except LK1 (Sungai Nakan) ($p<0.05$). The lowest mean BOD_5 concentration was recorded at LK1 (Sungai Nakan) and was significantly lower than the other stations ($p<0.05$) except LK2 (Sungai Kemenyih), LK6 (Sungai Jertang) and LK8 (Sungai Kahah) ($p>0.05$). The mean BOD_5 concentration at LK1 (Sungai Nakan) showed no significant difference with LK2 (Sungai Kemenyih), LK6 (Sungai Jertang) and LK8 (Sungai Kahah) ($p>0.05$), but was significantly different from LK3 (Main River), LK4 (Sungai Kesseh), LK5 (Sungai Liseng) and LK7 (Sungai Piping) ($p<0.05$).

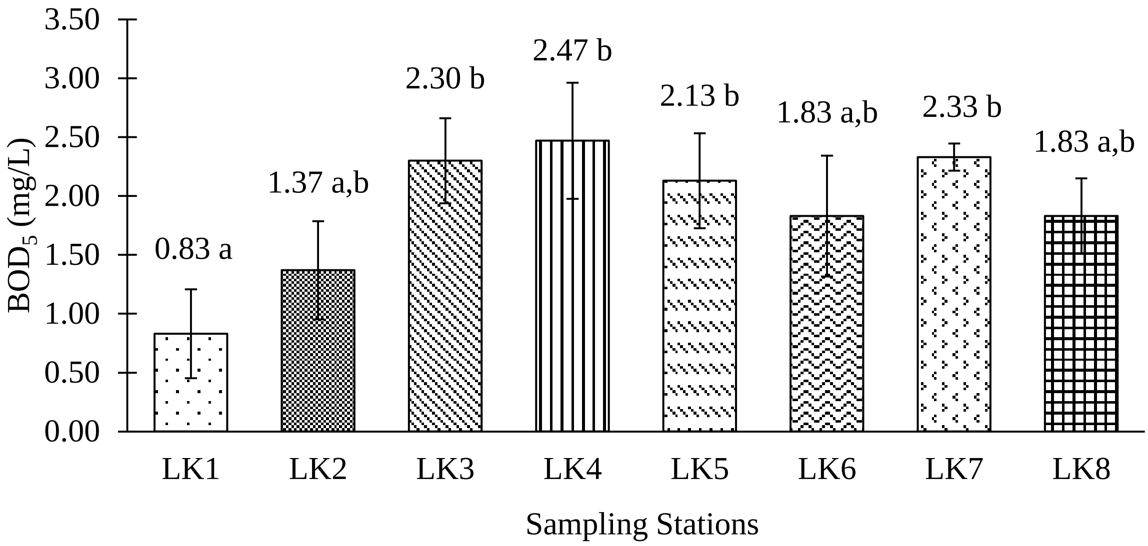


Figure 3.44: Mean BOD_5 at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4.7 Chlorophyll-*a*

The mean chlorophyll-*a* recorded at the stations ranged from 0.09 mg/m^3 to 0.40 mg/m^3 (Figure 3.45). Chlorophyll-*a* concentration in Long Kesseh showed significant differences among all stations ($p>0.05$). The lowest chlorophyll-*a* concentration was recorded at LK4 (Sungai Kesseh) with a mean value of 0.09 mg/m^3 but showed no significant difference with other stations ($p>0.05$). Meanwhile, the highest chlorophyll-*a* concentration was recorded at LK8 (Sungai Kahah) with a mean value of 0.40 mg/m^3 but was not significantly higher than other stations ($p>0.05$).

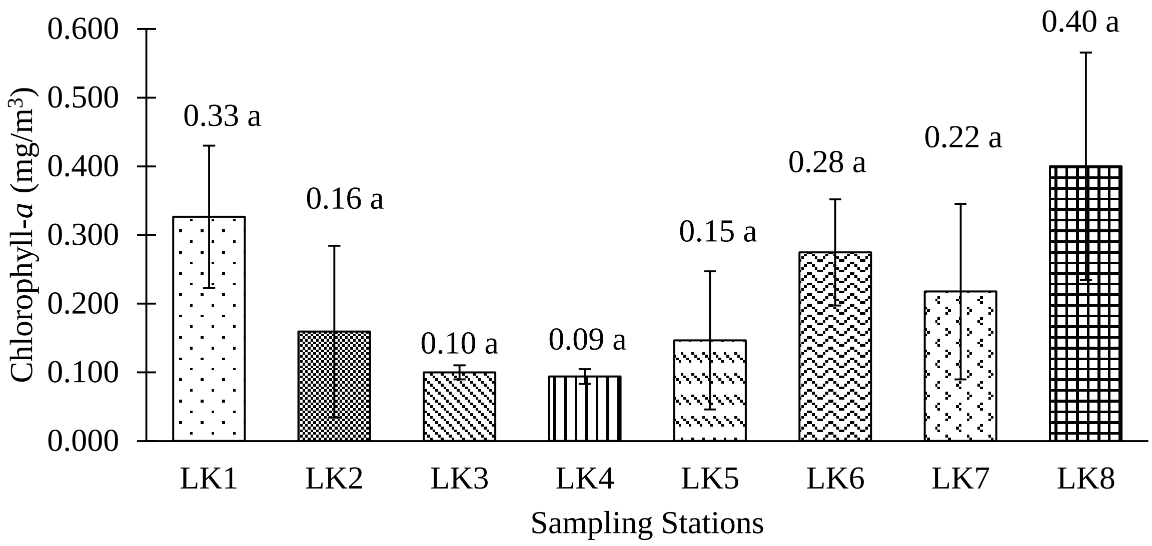


Figure 3.45: Mean total chlorophyll-*a* at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.4.8 Total Suspended Solids

The mean concentration of total suspended solids ranged from 5.17 mg/L to 46.30 mg/L (Figure 3.46). TSS results are within the standard allowable level of Malaysian rivers and are classified as Class II by NWQS, Malaysia. The highest mean of TSS concentration was recorded at LK6 (Sungai Jertang) with a mean value of 46.30 mg/L and was significantly higher than the other stations ($p<0.05$) except at LK7 (Sungai Piping) ($p>0.05$). The lowest mean of TSS concentration was recorded at LK4 (Sungai Kesseh) and was significantly lower than the other stations except LK1 (Sungai Nakan) ($p>0.05$). Mean of TSS concentration at LK1 (Sungai Nakan) showed no significant difference with LK2 (Sungai Kemenyih) and LK4 (Sungai Kesseh) ($p>0.05$) but was significantly different from LK3 (Main River), LK5 (Sungai Liseng), LK6 (Sungai Jertang), LK7 (Sungai Benuang) and LK8 (Sungai Pelet) ($p<0.05$).

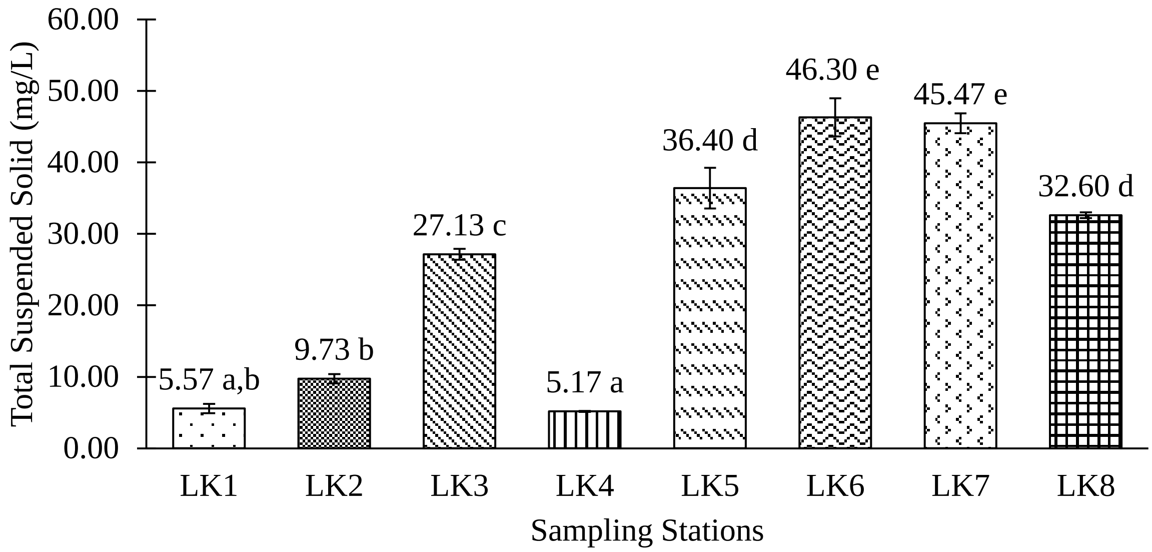


Figure 3.46: Mean total suspended solids at the eight stations in Long Kesseh, Baram. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5 Physicochemical Parameter at the Whole Study Area

3.3.2.5.1 Conductivity

The mean conductivity of water ranged from 39.9 µS/cm to 65.8 µS/cm (Figure 3.47). Overall, the conductivity was found to be within the recommended level by NWQS, Malaysia and fell into Class I. The highest mean of conductivity was recorded at LS (Long San) with a mean value of 65.8 µS/cm and was significantly higher than other stations ($p<0.05$) except LK (Long Kesseh) ($p>0.05$). The lowest mean of 39.9 µS/cm was recorded at LM (Lio Mato) and was significantly lower than all stations ($p<0.05$) except LA (Long Apu) ($p>0.05$).

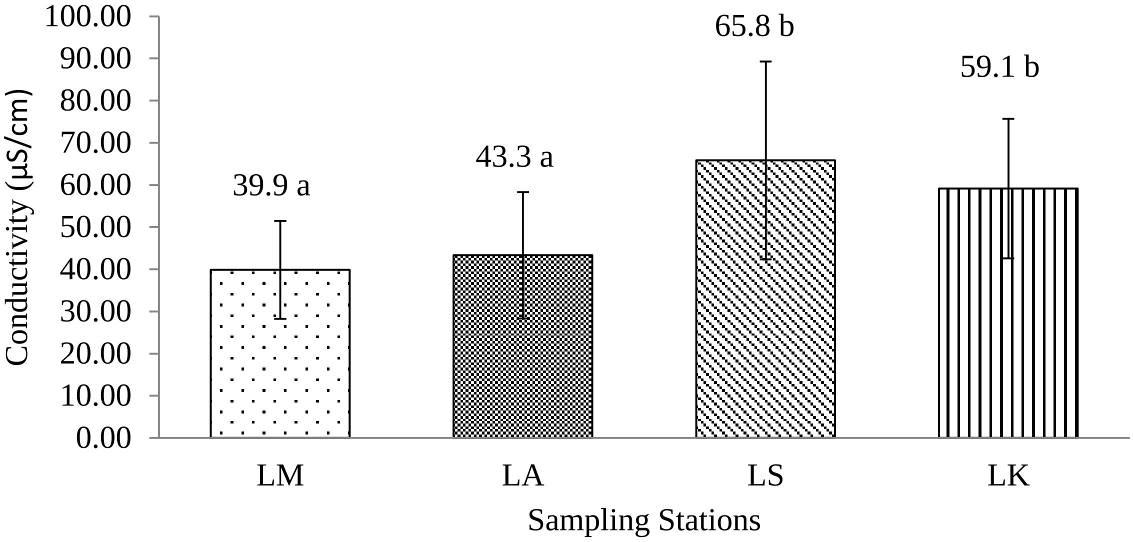


Figure 3.47: Mean conductivity for the sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.2 DO

The mean DO concentration recorded at the stations ranged from 7.08 mg/L to 7.89 mg/L (Figure 3.48). The concentrations are within the standard range and are classified under Class I based on NWQS for Malaysian rivers. The highest mean of DO concentration was recorded at LA (Long Apu) with a mean value of 7.89 mg/L and was significantly higher than the other stations ($p<0.05$) except in LK (Long Kesseh) ($p>0.05$). The lowest mean DO concentration was recorded at LM (Lio Mato) and was significantly lower than the other sampling stations in Baram River ($p<0.05$). Mean DO at LK (Long Kesseh) showed no significant difference with LA (Long Apu) and LS (Long San) ($p>0.05$) but was significantly different from LM (Lio Mato) ($p<0.05$).

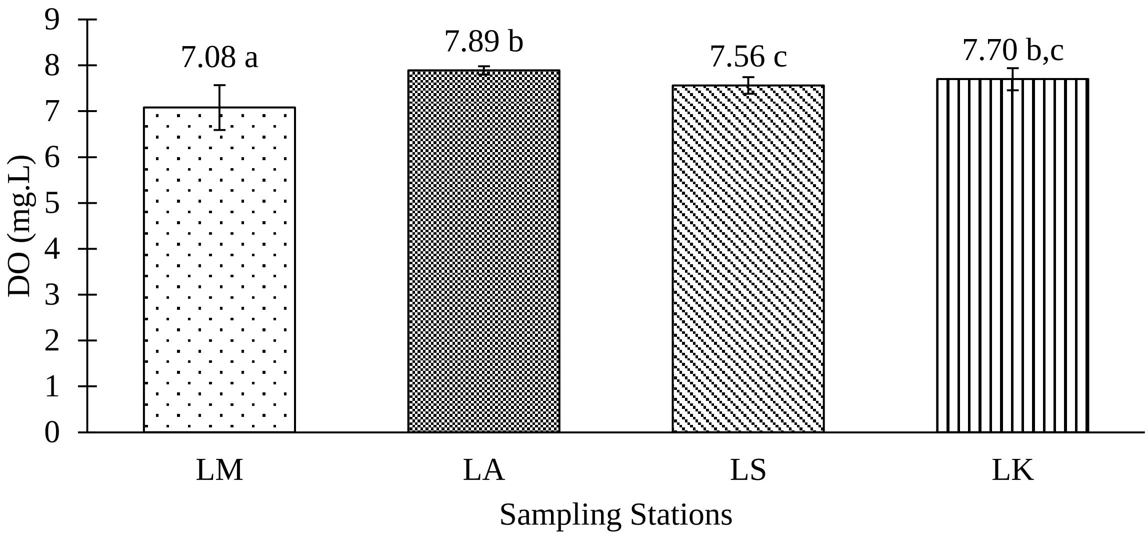


Figure 3.48: Mean DO for the sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.3 pH

The mean value of pH recorded at the stations ranged from 6.97 to 7.49 (Figure 3.49). The pH levels are within the recommended range and are classified under Class I based on NWQS for Malaysian rivers. The highest mean of pH was recorded at Long San (LS) with a mean value of 7.49 and was significantly higher than all other stations ($p<0.05$). The lowest mean of pH was recoded at Lio Mato (LM) with a mean value of 6.97 and was significantly lower than other stations ($p<0.05$) Mean value of pH recorded at Long Kesseh (LK) showed no significant difference with Long Apu (LA) but was significantly different with Lio Mato (LM) and Long San (LS) ($p<0.05$).

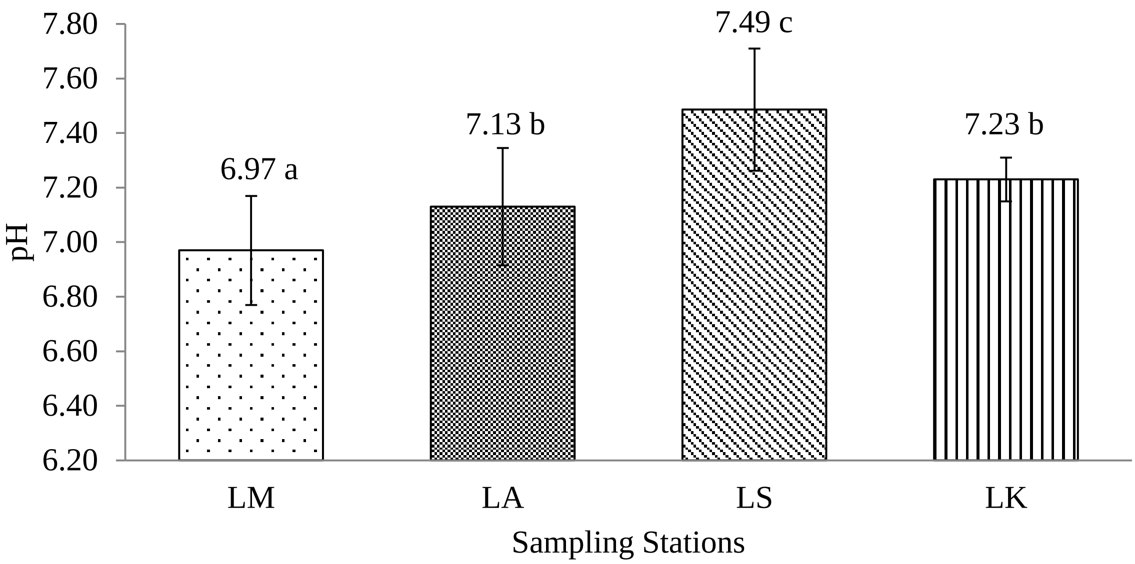


Figure 3.49: Mean pH for the sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.4 Temperature

The mean of temperature recorded at the stations ranged from 24.78 °C to 27.59 ° C with the lowest mean temperature was recorded at LM (Lio Mato) (Figure 3.50). The temperature values recorded are within the standard acceptable levels of National Water Quality Standards, Malaysia. The highest temperature was recorded at LS (Long San) with a mean of 27.59 °C and was significantly higher than the other stations ($p<0.05$). Temperature at LM (Lio Mato) was significantly lower than the other stations ($p<0.05$) except LA (Long Apu) ($p>0.05$). Mean value of temperature recorded showed no significant difference between LM (Lio Mato) and LA (Long Apu) ($p>0.05$), but were significantly different from LS (Long San) and LK (Long Kesseh) ($p<0.05$).

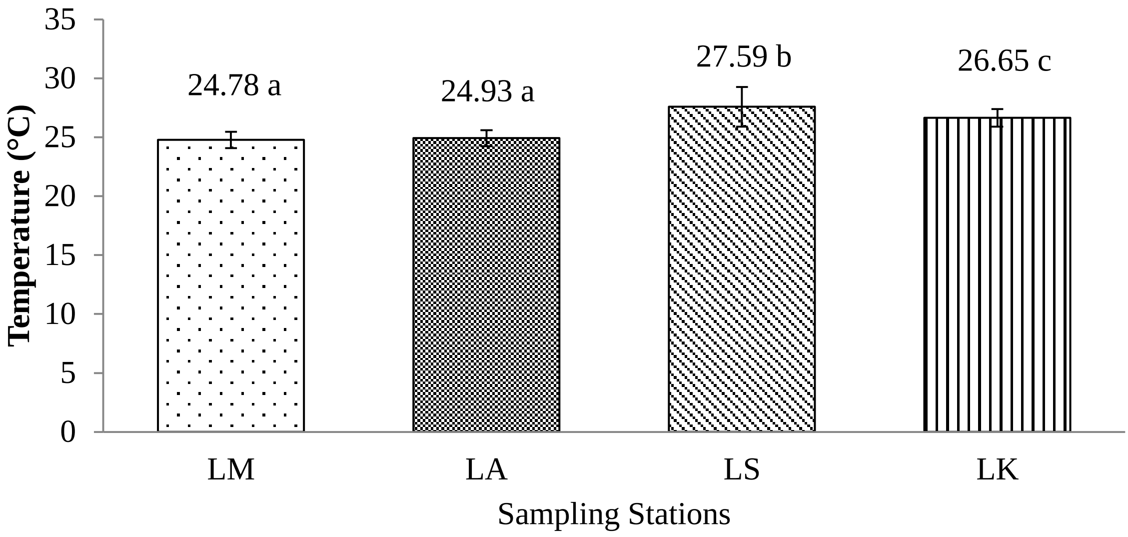


Figure 3.50: Mean temperature for the sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.5 Turbidity

The mean turbidity values in Baram ranged from 17.00 NTU to 93.75 NTU (Figure 3.51). These values exceeded the normal level of NWQS for Malaysian rivers which is 50 NTU, and are categorized into Class III. The highest mean turbidity was recorded at LS (Long San) with a mean value of 93.75 NTU and was significantly higher than the other stations ($p<0.05$). The lowest mean of turbidity was recorded at LK (Long Kesseh) with a mean value of 17.0 NTU and was significantly lower than other the stations ($p<0.05$) except LA (Long Apu) ($p>0.05$). Mean of turbidity value at LA (Long Apu) showed no significant difference with LM (Lio Mato) and LK (Long Kesseh) ($p>0.05$), but was significantly different with Long San (LS) ($p<0.05$).

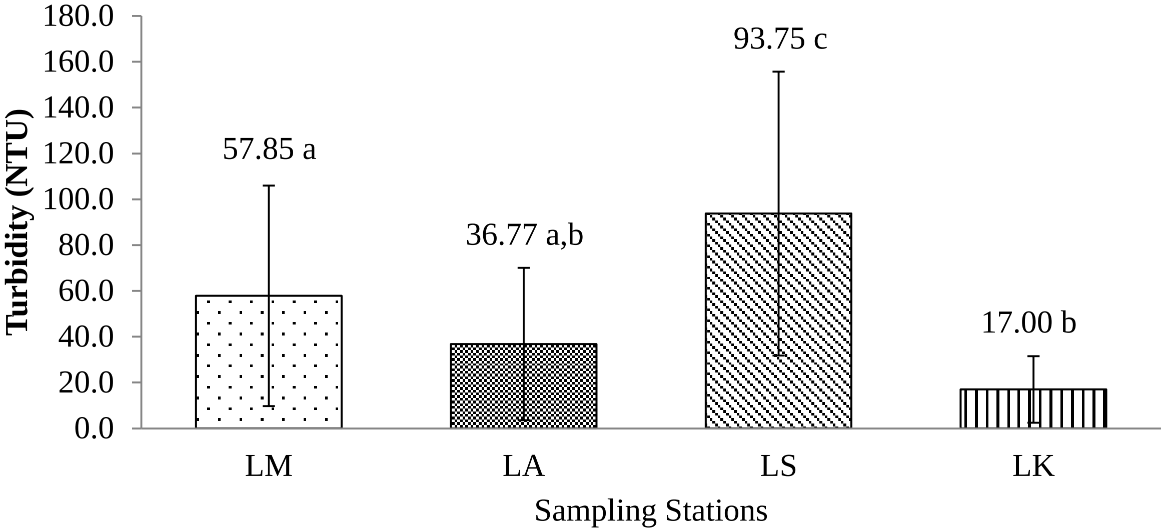


Figure 3.51: Mean turbidity for the sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.6 BOD_5

The mean of BOD_5 recorded at the stations ranged from 0.99 mg/L to 2.78 mg/L (Figure 3.52). The results are within the standard range and are classified under Class I based on NWQS for Malaysian rivers. The highest BOD_5 concentration was recorded at LM (Lio Mato) with a mean value of 2.78 mg/L and was significantly higher than the other sampling stations ($p>0.05$) except LA (Long Apu) ($p>0.05$). The lowest BOD_5 concentration was recorded at LS (Long San) with a mean value of 0.99 mg/L and was significantly lower than the other stations ($p<0.05$). The mean of BOD_5 concentration showed no significant difference between LM (Lio Mato) and LA (Long Apu) ($p>0.05$), but they were significantly different from LS (Long San) and LK (Long Kesseh) ($p<0.05$).

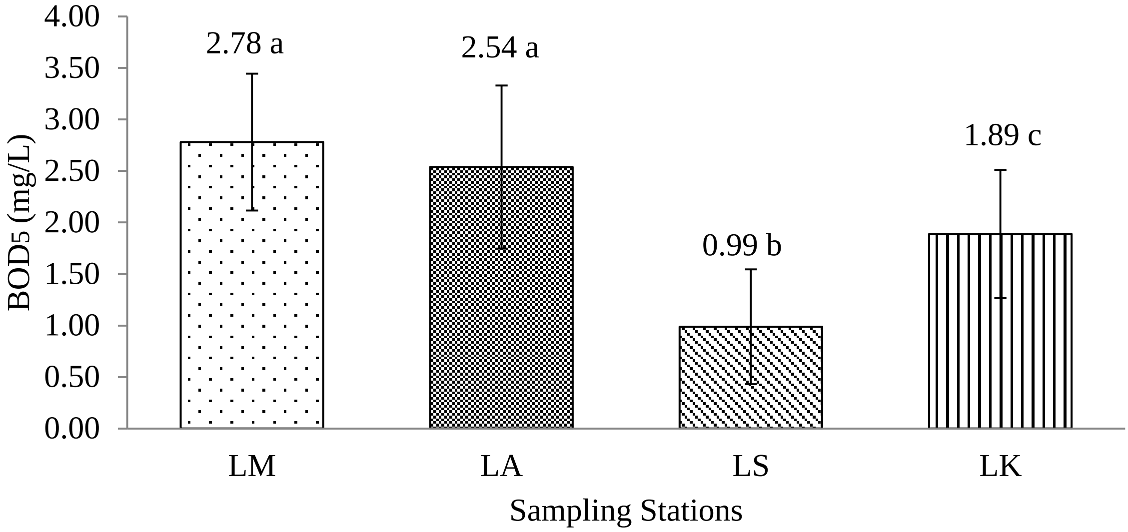


Figure 3.52: Mean BOD_5 for all sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.7 Chlorophyll-*a*

The mean value of chlorophyll-*a* recorded at the stations ranged from 0.21 mg/m^3 to 3.97 mg/m^3 (Figure 3.53). The highest chlorophyll-*a* concentration was recorded at LM (Lio Mato) with a mean value of 3.97 mg/m^3 and was significantly higher than other stations ($p<0.05$). The lowest mean of chlorophyll-*a* concentration was recorded at LK (Long Kesseh) with a mean of 0.21 mg/m^3 and showed no significant difference with other stations ($p>0.05$) except LM (Lio Mato) ($p<0.05$). Mean of chlorophyll-*a* concentration in Long Apu (LA) showed no significant difference with LS (Long San) and LK (Long Kesseh) ($p>0.05$), but was significantly different with LM (Lio Mato) ($p<0.05$).

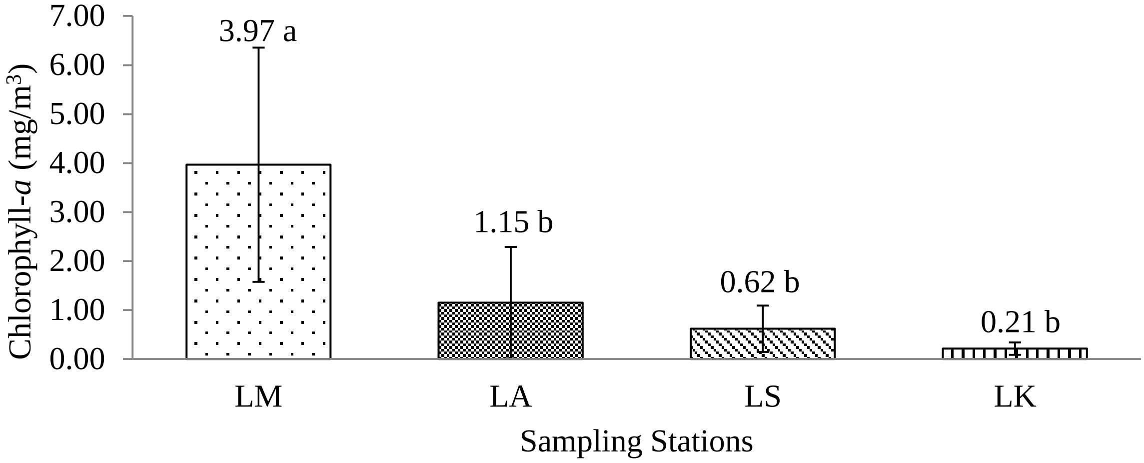


Figure 3.53: Mean chlorophyll-*a* for all sampling stations in Baram River. Mean with the same letters were not significantly different at 5% significant level.

3.3.2.5.8 Total Suspended Solids

The mean concentration of total suspended solids ranged from 26.0 mg/L to 98.7 mg/L (Figure 3.54). These concentrations are within the standard permissible limits of NWQS for Malaysian rivers and are categorized as Class III. The highest TSS concentration was recorded at LM (Lio Mato) with a mean value of 98.7 mg/L and was significantly higher than other stations in Baram River ($p<0.05$). The lowest mean of TSS concentration was recorded at LK (Long Kesseh) with a mean value of 26.0 mg/L and was significantly lower than other stations ($p<0.05$) except LA (Long Apu) and LS (Long San) ($p>0.05$). Mean of TSS concentration at LA (Long Apu) showed no significant difference with LS (Long San) and LK (Long Kesseh) ($p>0.05$) but was significantly different with LM (Lio Mato) ($p<0.05$).

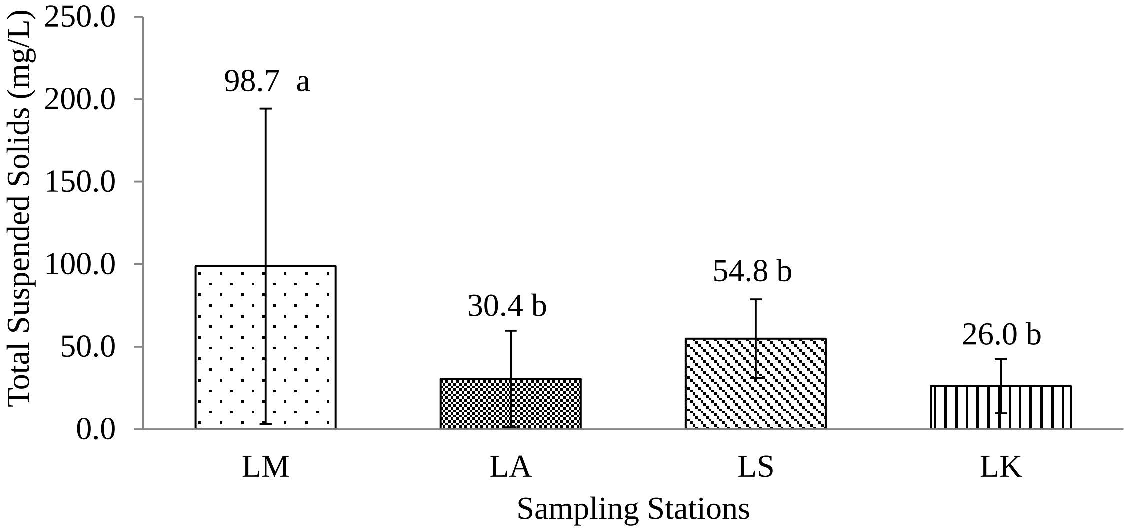


Figure 3.54: Mean total suspended solids for the sampling stations in Baram River. Mean with the same letters was not significantly different at 5% significant level.

3.3.3 Correlation between Fish Fauna Abundance and Water Quality Parameters

The CCA results on the water quality and fish species is best explained by Axis 1 and 2 with a total variance of 64.94% (Table 3.16). The results of the permutation test of 999 showed that the test of axis 1 and axis 2 canonical eigenvalues was 0.676 and 0.464, respectively and the *p*-value was less than 0.05, indicating that both canonical axis was statistically singnificant at $p<0.05$. Figure 1.55 shows the CCA ordination diagram on the relationship between the fish assemblages with the environmental variables in Baram River. The position of a species on the CCA biplot is a reflection of the environmental conditions where it was found.

Table 3.16: Canonical correspondence analysis summary statistics for composition of fish species in Baram River.

Axes	1	2	
Eigenvalue	0.676	0.464	
Species-environment correlations	0.051	0.009	
Cumulative percentage variance;			
a) Of species data	20.87	14.32	
b) Of fish species-environment relation	38.51	26.43	
Sum of all unconstrained eigenvalues			1.484
Sum of all canonical eigenvalues			1.756

The longest CCA vector was for BOD_5, followed by DO, TSS, water temperature, conductivity, pH, turbidity and chlorophyll-α. The distribution of fishes is related to some specific physicochemical parameters. Eleven species, *Kryptopterus lumholtzi*, *Nematabramis everetti*, *Pangasius macronema*, *Rasbora argyrotaenia, Luciosoma setigerum, Leptobarbus hoevenii*, *Cyclocheilichthys apogon, Tor duoronensis, Ceratoglanis scleronema, Pangasius micronema* and *Rasbora borneensis* were associated with sites with high chlorophyll-α and BOD_5, while nine species, *Puntius vittatus, Glyptothorax major, Lobocheilos hispidus, Mystus nigriceps, Kryptopterus crytopterus, Macrognathus maculatus, Ompok bimaculatus, Channa Lucius* and *Paracrossochilus vittatus*, are associated with habitats having higher temperature, pH and high conductivity, but with low chlorophyll-α and $BOD_{5.}$ These species were mainly found in Long San area. Twelve species, *Mastacembelus notophthalmus, Parachela oxygastroides*, *Kryptopterus apogon, Luciosoma spilopleura, Osphronemus scptemfasciatus, Barbonymus collingwoodii, Osteochilus triporos, Parachela hypophthalmus, Kryptopterus macrocephalus, Cirrhinus chinensis, Osteochilus waandersii* and *Nanobagrus armatus* are positively associated with habitat in Lio Mato with high tubidity and TSS values, but lower dissolved oxygen, while the remaining 26 species namely, *Osphronemus scptemfasciatus,* *Osteochilus enneaporos, Hampala macrolepidota, Puntioplites waandersii, Barbonymus schwanenfeldii, Tor tambroides, Osteochilus vittatus, Pseudolais micronemus, Hampala bimaculata, Auriglobus silus, Mastacembelus unicolor, Homaloptera orthogoniata, Osteochilus melanopleurus, Gastromyzon punctulatus, Mystus wyckii, Kryptopterus lais, Osteochilus kahajanensis, Hemibagrus planiceps, Gastromyzon fasciatus, Kryptopterus limpok, Ambassis kopsii, Bagrichthys micranodus, Rasbora caudimaculata, Cynoglossus waandersii, Kryptopterus micronema* and *Lobocheilos bo* are associated with high dissolved oxygen, low turbidity and TSS values. These species are widely distributed in Long Apu and Long Kesseh area.

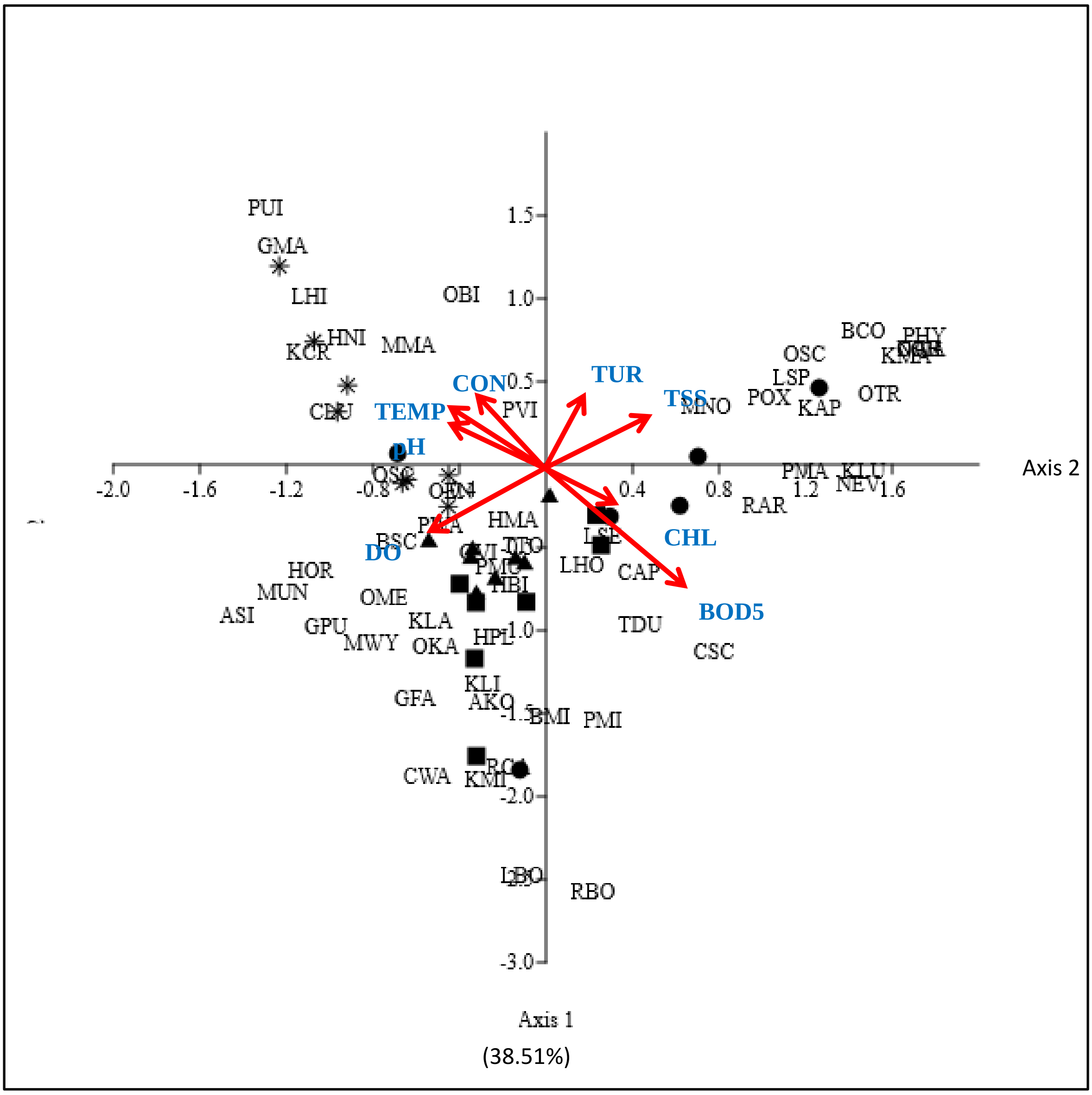


Figure 3.55: Triplot diagram of CCA showing relationship between abundance of fish species in Baram with 8 environmental variables in Lio Mato, Long Apu, Long San and Long Kesseh. Symbols: Dots (Lio Mato), square (Long Apu), star (Long San) and triangle (Long Kesseh); Red arrows represent the environmental parameters such as pH, TEMP (temperature), CON (conductivity), TUR (turbidity), TSS (total suspended solids), CHL (chlrorophyll-a), BOD_5 and DO (dissolved oxygen). The fish species codes are listed by the first letter of the genus and the first two letters of the fish species name (Table 3.17).

Table 3.17: The abbreviation codes for fish species used in CCA ordination.

Species	Code	Species	Code
Ambassis kopsii	AKO	*Luciosoma spilopleura*	LSP
Auriglobus silus	ASI	*Macrognathus maculatus*	MMA
Bagrichthys micranodus	BMI	*Mastacembelus notophthalmus*	MNO
Barbonymus collingwoodii	BCO	*Mastacembelus unicolor*	MUN
Barbonymus schwanenfeldii	BSC	*Mystus wyckii*	MWY
Ceratoglanis scleronema	CSC	*Nanobagrus armatus*	NAR
Channa Lucius	CLU	*Nematabramis everetti*	NEV
Cirrhinus chinensis	CCH	*Ompok bimaculatus*	OBI
Cyclocheilichthys apogon	CAP	*Osphronemus scptemfasciatus*	OSC
Cynoglossus waandersii	CWA	*Osteochilus enneaporos*	OEN
Gastromyzon fasciatus	GFA	*Osteochilus kahajanensis*	OKA
Gastromyzon punctulatus	GPU	*Osteochilus melanopleurus*	OME
Glyptothorax major	GMA	*Osteochilus schlegelii*	OSC
Mystus nigriceps	MNI	*Osteochilus triporos*	OTR
Hemibagrus planiceps	HPL	*Osteochilus vittatus*	OVI
Hampala bimaculata	HBI	*Osteochilus waandersii*	OWA
Hampala macrolepidota	HMA	*Pangasius macronema*	PMA
Homaloptera orthogoniata	HOR	*Pangasius micronema*	PMI
Kryptopterus apogon	KAP	*Pseudolais micronemus*	PMU
Kryptopterus crytopterus	KCR	*Parachela hypophthalmus*	PHY
Kryptopterus lais	KLA	*Parachela oxygastroides*	POX
Kryptopterus limpok	KLI	*Paracrossochilus vittatus*	PVI
Kryptopterus lumholtzi	KLU	*Puntioplites waandersii*	PWA
Kryptopterus macrocephalus	KMA	*Puntius vittatus*	PUI
Kryptopterus micronema	KMI	*Rasbora argyrotaenia*	RAR
Leptobarbus hoevenii	LHO	*Rasbora borneensis*	RBO
Lobocheilos bo	LBO	*Rasbora caudimaculata*	RCA
Lobocheilos hispidus	LHI	*Tor douronensis*	TDU
Luciosoma setigerum	LSE	*Tor tambroides*	TTO

3.4 Discussion

The composition and assemblages of species in each ecosystem was linked to various aspects such as food availability, spawning sites, water current, depth, topography and water chemistry (Ali et al., 1988). Generally, fishes in Baram are dominated by cyprinids, which accounts for 63.37% of the total number of species recorded. The remaining families were represented by only a few species. The family Cyprinidae had the utmost number of species as they are found in all sampling sites in Baram due to their high adaptive variability. The highly adapted body forms and mouth structures of the cyprinids explained the abundance of this family and inhabit all habitats throughout their distributions (Ward-Campbell et al., 2005). This is supported by the fact that the dominance of cyprinids in the tropical river is due to their high adaptive variability and the avaibility of extensive hetereogenous habitat structure (Bhat, 2004). This result is in line with documented studies from several types of water bodies and geographical locations in Malaysia (Chong et al., 2010). This is also a common pattern of species distribution for the Southeast Asian region, which is the focus of cyprinid evolution with at least 1600 species reported to date (Samat et al., 2005). The same phenomenon was observed in Sungai Dappur, Bario Highlands where the most common family caught was cyprinidae (Nyanti et al., 1999), in Brown river at Batang Kerang which were dominated by the Cyprinidae (63.8%) (Khairul-Adha et al., 2009), and in Perak River where 43 species of the fish caught was represented by this family (Hashim et al., 2012).

Different fish species occupied different stretch of the river. In the upper stretch (Lio Mato), strong current represents favorable conditions for fishes such as *Lobocheilos* sp. and *Kryptopterus macrocephalus.* A similar observation was reported by Jefferine et al. (2009), where *Lobocheilos* sp. was found dominant and anatomically adapted to live in fast flowing current area. This could be due to the type of habitat and substrate in the area where *Lobocheilos* sp. were found dominant in the sandy, gravels and rocky substrates. Lio Mato was dominated by *Kryptopterus macrocephalus,* whereas *Lobocheilos bo* in Long Apu, and *Lobocheilos hispidus* in Long San and *Barbonymus schwanenfeldii* is mainly found in Long Kesseh. Although the fish fauna composition in Lio Mato was dominated by the Cyprinid fish, the numbers of fish species were mainly dominated by *Kryptopterus macrocephalus* from the family Siluridae and this species was found dominant in Lio Mato throughout the study period. Generally, the rivers in Lio Mato were fast flowing with lower temperature ranging from 24.08°C to 25.95°C with a mean of 25.16°C for all the stations. *Kryptopterus macrocephalus* is mainly found in shady spots in running water (Fishbase, http://www.fishbase.) and this explained its abundance in Lio Mato.

Furthermore, the occurrence of fish species such as *Tor duoronensis* which is indigenous to Sarawak (Nguyen, 2008) indicates the good water quality of the area. Some species especially the cyprinids are known for their aesthetics and might have the potential of being commercialised as ornamental fish. As reported by Taylor (1989), species from the genus *Nematabramis* and *Puntius* were already being traded as ornamental fish. In addition, according to Ng (2016), some ornamental fish species are valued for their transparency, such as the *Kryptopterus* spp. which can be found abundance in Lio Mato since these species prefer rocky running water.

However, there are fish families which were represented by few species in each family, including Channidae that was represented by *Channa lucius* and *Osphronemus septemfasciatus* from family Ospheronemidae with only two individuals each. The low number of individuals may contribute disproportionately to the overall biomass due to their large body size (Northcote & Hartman, 2004).

Species diversity of fish among the areas varied and its value ranged between 0.93 in Long San to 1.17 in Long Apu. The evenness index values ranged from 0.28 to 0.36. In this study, all areas show high species richness with index of more than 5. The highest species richness was recorded in Lio Mato with 5.33 and the lowest was recorded in Long Apu with 3.91. The higher species diversity and richness at Lio Mato and Long Apu may be associated to the rivers morphology and hydrology. The river in both areas are characterized by a rocky bedrock interspaced by large rocks, shallow short pools, and rapid riffles which influenced its habitat heterogeneity resulting in better habitat niches (Mwagi et al., 2012). Zakaria et al. (1999) suggested that species diversity, species richness and species endurance in aquatic ecosystems are dependent on some environmental factors including the physico-chemical characteristics of the water quality, topography and habitat destruction. This is supported by Gophen (1998) that suggested both biotic and abiotic factors in aquatic ecosystem including oxygen content and source of food affect the composition and structure of fish community.

Water quality changed over time due to both anthropogenic and natural factors (Ahmad et al., 2009). Effects of environmental variable on species distributions in Baram area were tested by CCA analysis. In the CCA ordination, axes 1 and 2 together described a high percentage of variance of the species-environment biplot, with BOD_5, DO, TSS, water temperature, conductivity, pH, turbidity and chlorophyll-α, as the most significant variables influencing the variation of number of fish individuals in Baram area.

Biochemical Oxygen Demand (BOD) is an important parameter of water, which act as an indicator on the health status of freshwater ecosystem (Bhatti & Latif, 2011). The BOD_5 values ranged from 0.99 mg/L in Long San area to 2.78 mg/L in Lio Mato. The values of BOD_5 obtained can be classified into Class II of the National Water Quality Standard

(NWQS) and is able to support sensitive aquatic life. Bhatnagar *et al.*, (2004) also reported that the optimum BOD_5 level for normal activities of fishes is between 3.0 - 6.0 mg/L. Higher BOD values were also recorded at study area which was shaded and contained leaves and branches in the streams. The leaves and branches that fall into the stream will undergo aerobic respiration and are readily to be degraded by microorganisms in the stream resulting in low dissolved oxygen (Addy & Green, 1997). Based on the arrow length of the CCA vector in ordination diagram, the BOD_5 was recorded as the main variable in influencing fish distribution in Baram River. Eleven species, *K. lumholtzi*, *N. everetti*, *P. macronema*, *R. argyrotaenia*, *L. setigerum*, *L. hoevenii*, *C. apogon*, *T. duoronensis*, *C. scleronema*, *P. micronema* and *R. borneensis* were associated with sites with high chlorophyll-*a* and BOD_5. Other than increasing in nutrients in water bodies, natural plant decaying process also can contributes to higher BOD_5 level in water bodies (Al-Badaii et al., 2013). Level of BOD concentration is linked with DO concentrations where higher BOD level shows a decline in DO level.

Fishes need dissolved oxygen for their survival in an ecocystem. Different organisms have different optimal oxygen concentrations requirement thus, the amount of DO determines which organisms an ecosystem can support (Addy & Green, 1997). In Baram area, dissolved oxygen concentration ranged from 7.08 to 7.89 mg/L with Long Apu site showing higher DO values. These results are within the standard range and are classified under Class I based on NWQS for Malaysian rivers. Ideally, freshwater streams should have dissolved oxygen level ranging between 7 - 11 mg/L to support diverse aquatic life (Behar, 1997). Higher DO values recorded in Long Apu is due to the fast flowing water that increases the aeration process. However, all sampling areas meet the optimum requirement for the survival of diverse aquatic organism, which is above 5 mg/L (Poxton and Allouse, 1982).

Fish communities are highly affected by temperature. Temperature is known to limit the distribution of species directly and indirectly (Taylor et al., 1993). A sudden fluctuation in water temperature may cause fish mortality (Blaber, 2000). Throughout this study, water temperature varied among sites and areas where the water temperature recorded ranged from 24.78 °C in Lio Mato to 27.59 °C in Long San area. Water temperature in Baram area especially at the small streams was influenced by riparian cover as it reduced the direct penetration from the sun. Water temperature in Long San was much warmer as compared to water temperature at Lio Mato probably due to lack of coverage by riparian vegetation in Long San area. From our observation, most of the tributaries in Lio Mato are located in shady area and covered with riparian vegetation while sampling area in Long San are directly expose to sunlight. The results are in conformity with the study by Lynch et al. (1984) where a slightly increase in stream temperature was caused by the removal of riparian vegetation. This was also supported by Kalny et al. (2017) which stated that riparian shading plays a vital role in inhibiting river warming. CCA bi-plot shows that only 9 fish species can be found in habitat that were positively associated with an increase in temperature namely, *Puntius vittatus, Glypthothorax major, Lobocheilos hispidus, Mystus nigriceps, Kryptopterus crytopterus, Macrognathus maculatus, Ompok bimaculatus, Channa Lucius* and *Paracrossochilus vittatus*. Increase in temperature may be suitable for the reproduction and recruitment of some fish species (Hellmann et al., 2008). It can be concluded that due their greater adaptability behavior, these species were able to sustain their dominance in this area. It is because every fish species has its own optimal temperature range at which they can grow, breed, active, and metabolize (Dodson, 2005).

From the CCA ordination bi-plot, water quality parameters such as turbidity and total suspended solids were associated with Lio Mato area and showed correlation with some of the fish species distribution. Despite higher TSS and turbidity recorded, fish species such as *M. notophthalmus, P. oxygastroides, K. apogon, L. spilopleura, O. scptemfasciatus, B. collingwoodii, O. triporos, P. hypophthalmus, K. macrocephalus, C. chinensis, O. waandersii* and *N. armatus* are positively associated with elevated TSS and turbidity values. In our study, TSS values recorded vary among sampling areas and ranged between 26 mg/L to 98.7 mg/L, while turbidity ranged from 17 NTU to 93.75 NTU. Both TSS and turbidity values were within the standard permissible limits of NWQS for Malaysian rivers and is categorized as Class II eventhough these rivers are affected by human activities such as logging which may affect the growth of some of these fishes. Turbidity values within the standard permissible limits of NWQS for Malaysian rivers are between 5 NTU to 50 NTU, while for TSS, the concentration within the standard acceptable levels of NWQS for Malaysian are 25 to 150 mg/L.

High turbidity level also affects prey-predator interaction since high turbidity impaired their vision while searching for food. This is supported by Rowe and Dean (1998) which reported that feeding rate decline as turbidity level increased because it is hard for the predator to locate their prey in the dark. As reported by Al-Badaii et al. (2013), turbidity is caused by the existence of suspended particles that are deposited in the water including sand particles, plankton, clay, organic matter, and decomposers organisms that affects the clarity of water.

The total suspended solids concentrations were shown to be highly correlated with turbidity in Baram River. TSS in Lio Mato was the highest compared to other areas with 98.7 mg/L. The high TSS value may be due to the soil erosion that occurred at the watershed near and upstream of Lio Mato. As reported by Al-Badaii et al. (2013), soil erosion is one of the factors that contribute to high suspended solids that come from the surrounding area caused by anthropogenic activities. However, while some of the fish species needs clear water to survive, *M. notophthalmus*, *P. oxygastroides*, *K. apogon*, *L. spilopleura*, *O. scptemfasciatus*, *B. collingwoodii*, *O. triporos*, *P. hypophthalmus*, *K. macrocephalus*, *C. chinensis*, *O. waandersii* and *N. armatus* were well-adapted to live in high tubidity and high TSS level habitat such as at Lio Mato.

Dubey et al. (2012) reported that water conductivity is one of the main factors that affects fish composition. Water conductivity in Baram area varied from 39.89 µS/cm to 70.00 µS/cm. This value is common in most of the freshwaters as conductivity normally ranged from 10 to 1000 µS/cm while conductivity value that exceeded 1000 µS/cm indicate that the area received pollutant (Al-Badaii et al., 2013).

pH values were different among areas in Baram in which higher average values of 7.49 were recorded in Long San, whereas lower average values of 6.97 was recorded in Lio Mato. The results were found to be within the recommended level by NWQS, Malaysia, and fell into the Class IIA. Results showed that pH values for all areas in Baram River fall within the acceptable limit of 6 to 8.5 (Cleophas et al., 2013). Al-Badaii et al. (2013) reported the range of pH from 6.5 to 9 is the most suitable for aquatic life. In general, pH values recorded in Baram were almost at neutral, indicating that waste discharge did not affect the water's pH. Thus, it is vital to sustain the aquatic ecosystem within this range because high and low pH can have negative implication to nature (Rosli et al., 2010).

3.5 Conclusions

The present study focused mainly on fish distribution and diversity as well as water quality at four areas from Lio Mato to Long Kesseh along the Baram River. The findings reveal that fish fauna in Baram River is similar to other areas in Sarawak where Cyprinidae is dominant. The total number of species recorded during this study indicates high biodiversity at the area. Cyprinidae can be found in all sampling areas, indicating that they are capable of tolerating and thriving the water conditions in Baram River. Furthermore, the results suggested the importance of water quality influences on the distribution of fish species in each area. CCA bi-plot shows that environmental variables such as BOD_5, DO, TSS, water temperature, conductivity, pH, turbidity and chlorophyll-*a* significantly influenced the distribution of fish composition in Baram area. Overall, this report has contributed to the information on fish distribution at the upper stretch of Baram River. The study can also be used as a guideline to manage and conserve the aquatic ecosystem at Baram River in the future.

CHAPTER 4

LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF SELECTED FISH SPECIES IN UPPER BARAM RIVER, SARAWAK

4.1 Introduction

In fisheries study, length-weight relationship is important for the estimation of weight where only length data are available and as an index on the condition of the fish (Pauly 1993). The condition of a fish reflects recent physical and biochemical circumstances, and fluctuates due to interaction among feeding conditions, parasitic infections and physiological factors (Le Cren, 1951). In addition, the length-weight relationship is useful for conservation and management of fish species (Anene, 2005).

Studies on the length-weight relationship and condition factor have been well documented in many tropical freshwater species including *Mystus vittatus* in Bangladesh (Hossain et al., 2006), *Puntius filamentosus* (Prasad and Ali, 2007), *Labeo bata, Channa punctata, Ompok pabda* and *Mastacembelus armatus* (Khan et al., 2012), *Tor putitora* in India (Khajuria et al., 2014), *Macrognathus aculeatus* (Pathak and Serajuddin, 2015), *Tor tambra* (Muchlisin et al., 2014), and *Hemibagrus* species in Indonesia (Aryani et al., 2016).

Several length-weight relationship studies on fishes in Malaysia have also been done in Lutong River in Sarawak (Nyanti et al., 2012), Pedu Lake in Kedah and Kerian River in Perak (Isa et al., 2010), Zulkafli et al., (2015) in Pahang, *Pterygoplichthys pardalisand* in Langat River and at headwater streams of the Segama River near Danum Valley in Sabah (Martin-Smith, 1996).

Gonadosomatic index of fish is related to spawning and reproduction. Therefore, knowledge about GSI is essential for evaluating the potentials of its stock life histories, practical culture and actual management of the fishery. HSI value provides information about the health condition of fish and also about the quality of water, because higher HSI value means fishes are growing rapidly and have a good aquatic environment (Sadekarpawar & Parikh, 2013). Low HSI value means fish is not growing well and it is facing unhealthy environmental conditions. Thus, both GSI and HSI values give us indications on the development pattern of fishes.

Currently, there are no known published literature on the freshwater fish in Baram which emphasizes on the length-weight relationship, condition factor, hepatosomatic index and gonadosomatic index.

Thus, the objective of this study was to determine the relationship between length and body weight (LWR), condition factor (K), hepatosomatic index (HSI) and gonadomatic index (GSI) of fish caught in the whole study area in Baram.

4.2 Materials and Methods

4.2.1 Length-weight Relationship

A total of 58 fish species from thirteen families, namely Ambassidae, Bagridae, Balitoridae, Channidae, Cynoglossidae, Cyprinidae, Gastromyzontidae, Mastacembelidae, Osphronomidae, Pangasidae, Siluridae, Sisoridae and Tetraodontidae were caught in Baram River. However, the length-weight relationship (LWR) was not carried out for 53 species where the number of individuals was low, that is less than 29 individuals for each species. Thus, only five species were chosen for further examination based on their greater abundance of equal or more than 30 individuals and are also present at two or more study areas for comparison purposes. These species are *Barbonymus schwanenfeldii*, *Rasbora caudimaculata, Pseudolais micronemus, Osteochilus enneaporos* and *Kryptopterus apogon.*

A total of 388 individuals belonging to three families representing Cyprinidae, Pangasidae and Siluridae were analyzed for their LWR. Cyprinidae was represented by three species namely, *Barbonymus schwanenfeldii*, *Osteochilus enneaporos* and *Rasbora caudimaculata,* while the remaining two families, Pangasiidae and Siluridae were represented by only one species each, (*Pseudolais micronemus* and *Kryptopterus apogon*, respectively). The most abundant species caught were *Barbonymus schwanenfeldii* with 117 individuals followed by *Kryptopterus apogon* with 107 individuals, *Pseudolais micronemus* with 70 individuals, *Osteochilus enneaporos* (N=65) and *Rasbora caudimaculata* (N=29).

The total length of the fish was measured from the most forward point of the snout to the tip of the longer lobe of the caudal fin while standard length was measured from the snout to the caudal peduncle (Figure 4.1). Analytical balance (SHIMADZU, BL 3200HL) was used to measure the body weight of the fish (Figure 4.2).

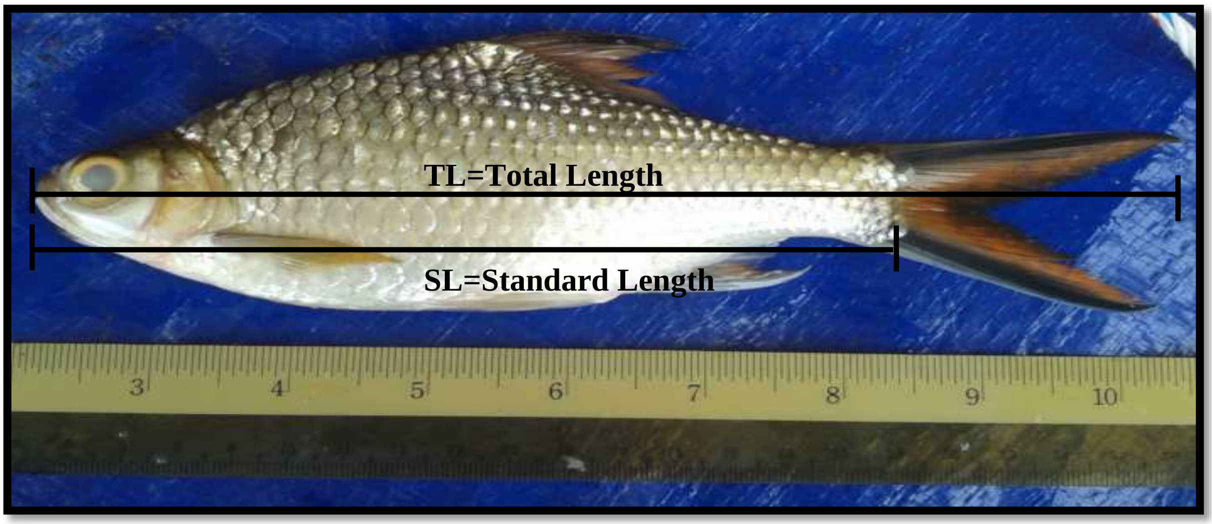


Figure 4.1: Measuring total length (TL) and standard length (SL) for fish sample.

Figure 4.2: Weighing body weight (BW) of fish sample.

The estimation of length-weight relationship was based on the formula $W = aL^b$ by Schneider et al. (2000).

Where,

W = weight of fish (g)

L = length of fish (cm)

a = constant

b = an exponential expressing relationship between length-weight.

Length-weight relationship was estimated by linear regression of the log-transformed length and weight data:

$$\text{LogW} = \text{Log a} + \text{b Log L}$$

where b represents the slope of the line and Log a is a constant.

'b' showed the growth type of the fish where *b* more than 3 signifies positive allometric, negative allometric when *b* is less than 3, and the growth is isometric when *b* is equal to 3. The coefficient of condition factor (K) was computed using the formula $K = 100W/ L^3$ (Pauly, 1983).

where,

W = body weight of fish in gram

L = Total length of fish in cm

100 = Factor to bring the value of K near unity

4.2.2 Hepatosomatic Index (HSI)

Hepatosomatic Index (HSI) is defined as a ratio of liver weight to fish weight. In fisheries science, HSI is as an indicator of energy reserves in the liver (Hismayasari et al., 2015). The body weigth of every fish was weighed and then dissected to determine the weight of the liver. Only fishes that have good liver condition were used for the analysis of Hepatosomatic Index values.

HSI was calculate using the following formula (Parmeshwaren, 1974).

$$HSI = \frac{\text{Weight of Liver (g)}}{\text{Body weight (g)}} \times 100$$

4.2.2.1 Hepatosomatic Index (HSI) of fishes in Lio Mato, Baram

In Lio Mato, hepatosomatic index were carried out for 58 fish individuals from three families and 8 species. *Barbonymus collingwoodii* (N=11), *Cyclocheilichthys apogon* (N=5), *Luciosoma setigerum* (N=8), *Luciosoma spilopleura* (N=6), and *Osteochilus schlegelii* (N=4) from the family Cyprinidae, *Pseudolais micronemus* (N=11) from the family Pangasiidae, *Kryptopterus apogon* (N=4) and *Kryptopterus macrocephalus* (N=9) from the family Siluridae.

4.2.2.2 Hepatosomatic Index (HSI) of fishes in Long Apu, Baram

In Long Apu, hepatosomatic index were carried out for 74 individuals from three families and 7 species, namely *Barbonymus schwanenfeldii* (N=10), *Cyclocheilichthys apogon* (N=12), *Lobocheilos bo* (N=5), *Osteochilus enneaporos* (N=7), and *Puntioplites waandersii* (N=4) from the family Cyprinidae, *Pseudolais micronemus* (N=19) from the family Pangasiidae and *Kryptopterus apogon* (N=17) from the family Siluridae.

4.2.2.3 Hepatosomatic Index (HSI) of fishes in Long San, Baram

In Long San, hepatosomatic index were carried out for 41 fish individuals from two families and 5 species. *Barbonymus schwanenfeldii* (N=11), *Lobocheilos hispidus* (N=7), *Osteochilus enneaporos* (N=7) and *Puntioplites waandersii* (N=8) from the family Cyprinidae, while *Pseudolais micronemus* (N=8) from the family Pangasiidae.

4.2.2.4 Hepatosomatic Index (HSI) of fishes in Long Kesseh, Baram

In Long Kesseh, hepatosomatic index were carried out for 141 fish individuals from three families and 9 species, namely *Barbonymus schwanenfeldii* (N=48), *Hampala* *macrolepidota* (N=5), *Leptobarbus hoevenii* (N=7), *Lobocheilos bo* (N=4), *Luciosoma setigerum* (N=16), *Osteochilus vittatus* (N=15) and *Puntioplites waandersii* (N=6) from the family Cyprinidae, *Pseudolais micronemus* (N=36) from the family Pangasiidae and *Kryptopterus apogon* (N=4) from the family Siluridae.

4.2.3 Gonadosomatic Index (GSI)

Limited information on GSI is mainly due to the less number of individuals having gonads. The Gonadosomatic index was calculated according to Strum (1978):

$$GSI = \frac{\text{Weight of gonad (g)}}{\text{Body weight (g)}} \times 100$$

4.2.4 Data analysis

Data on total length (L) in cm and body weight (W) in g were recorded for each fish. The parameters "a" and "b" of the length to weight relationship were estimated using the logarithmic transformation of the equation: $W= a \times L^b$, where W is body weight in g and L length in cm. The values of the constant "a" and "b" were estimated from the log transformed values of length and weight ($\log W = \log a + \log L$) via the least square linear regression. All statistical analyses were performed using the statistical package SPSS version 23 to estimate the parameters of the length-weight relationship of fish species in Baram.

4.3 Results

4.3.1 Length-weight Relationship

4.3.1.1 Length-weight Relationship of *Barbonymus schwanenfeldii*

Barbonymus schwanenfeldii in Long Kesseh had the highest value of TL that ranged from 10.7 to 32.9 cm, with a mean of 19.62±5.4 cm and a BW ranging from 13.70 to 463.40 g with a mean of 39.31±46.74 g (Table 4.1). This is followed by *B. schwanenfeldii* in Long Apu with TL ranging from 6.7 to 21.6 cm with a mean of 15.0±3.9 cm and a BW ranging from 3.80 to 142.20 g with a mean of 53.31±39.24 g (Table 4.1, appendix 3). In Long San, this species has TL range of 3.2 to 24.5 cm with a mean of 12.7±5.7 cm and a BW range of 0.40 to 185.40 g with a mean of 39.31±46.74 g (Table 4.1). The b values of *B. schwanenfeldii* in Baram ranged from 2.716 to 3.124. In Long Kesseh, this species showed negative allometric growth with the lowest b value of 2.716 , followed by in Long Apu with b=3.039 which exibit isometric growth while *B. schwanenfeldii* in Long San showed positive allometric growth with b= 3.124 (Table 4.2, Figure 4.3). The overall estimated values of condition factor (K) ranged from 1.14 to 1.30 (Table 4.2). In Long San, this species recorded the lowest with 1.14±0.14, followed by *B. schwanenfeldii* in Long Kesseh with K= 1.20±0.24 and *B. schwanenfeldii* in Long Apu recorded the highest condition factor with 1.30±0.26.

Table 4.1: Length and weight of five selected fish species caught in the Baram River.

Family	Sampling Site	Species	N	Length (cm)		Weight (g)	
				min-max	mean±SD	min-max	mean±SD
Cyprinidae	Long Apu	*Barbonymus schwanenfeldii*	32	6.7-21.6	15.0±3.9	3.80-142.20	53.31±39.24
	Long San	*Barbonymus schwanenfeldii*	32	3.2-24.5	12.7±5.7	0.40-185.40	39.31±46.74
	Long Kesseh	*Barbonymus schwanenfeldii*	53	10.7-32.9	19.62±5.4	13.70-463.40	39.31±46.74
	Long Apu	*Osteochilus enneaporos*	27	5.4-24.5	14.52±5.9	1.90-168.10	46.28±53.68
	Long San	*Osteochilus enneaporos*	38	6.9-21.4	12.7±4.3	4.00-91.50	28.46±27.19
	Long Apu	*Rasbora caudimaculata*	16	6.8-13.2	9.9±2.4	2.90-16.90	9.69±9.23
	Long San	*Rasbora caudimaculata*	13	3.4-11.6	8.3±2.8	0.10-12.60	5.23±4.08
Pangasiidae	Long Apu	*Pseudolais micronemus*	22	13.9-29.6	21.4±4.4	18.00-176.10	73.11±45.00
	Long Kesseh	*Pseudolais micronemus*	48	16.7-38.4	23.7±4.4	8.44-365.60	102.27±77.96
Siluridae	Lio Mato	*Kryptopterus apogon*	89	25.7-55.6	28.6±3.3	56.32-735.00	86.65±70.66
	Long Apu	*Kryptopterus apogon*	18	18.7-31.4	25.0±3.0	35.30-107.20	60.71±20.97

Table 4.2: The number of fish individuals (N), length-weight relationship and condition factor (K) for five selected species in Baram River.

Sampling Site	Species	N	A	95% C.L. of a	b	95% C.L. of b	Growth Pattern	R^2	K mean±SD
Long Apu	*Barbonymus schwanenfeldii*	32	0.009	-2.289 to -1.757	3.039	2.883 to 3.339	Isometric	0.963	1.30±0.26
Long San	*Barbonymus schwanenfeldii*	32	0.008	-2.170 to -1.987	3.124	3.039 to 3.029	Positive	0.995	1.14±0.14
Long Kesseh	*Barbonymus schwanenfeldii*	53	0.027	-1.913 to -1.227	2.716	2.448 to 2.983	Negative	0.891	1.20±0.24
Long Apu	*Osteochilus enneaporos*	27	0.011	-2.088 to -1.863	2.973	2.874 to 3.072	Negative	0.994	0.99±0.10
Long San	*Osteochilus enneaporos*	38	0.013	-1.968 to -1.806	2.912	2.838 to 2.986	Negative	0.994	1.04±0.08
Long Apu	*Rasbora caudimaculata*	16	0.010	-2.218 to -1.776	2.927	2.703 to 3.151	Negative	0.982	0.86±0.07
Long San	*Rasbora caudimaculata*	13	0.002	-3.029 to -2.336	3.542	3.159 to 3.926	Positive	0.974	0.66±0.16
Long Apu	*Pseudolais micronemus*	22	0.007	-2.352 to -2.016	3.006	2.879 to 3.133	Isometric	0.992	0.67±0.04
Long Kesseh	*Pseudolais micronemus*	48	0.004	-2.588 to -2.213	3.171	3.034 to 3.307	Positive	0.981	0.67±0.17
Lio Mato	*Kryptopterus apogon*	89	0.005	-2.574 to -1.952	2.866	2.652 to 3.079	Negative	0.892	0.34±0.03
Long Apu	*Kryptopterus apogon*	18	0.015	-2.449 to -1.198	2.570	2.122 to 3.018	Negative	0.902	1.38±0.05

a = intercept of regression line, *b* = slope of regression line, C.L. = Confidence Level, growth pattern, *R*2 = Regressio Coefficient and K= Condition factor)

4.3.1.2 Length-weight Relationship of *Osteochilus enneaporos*

The TL of *O. enneaporos* in Long Apu ranged from 5.4 to 24.5 cm with a mean of 14.52±5.93 cm and a BW ranging from 1.90 to 168.10 g with a mean of 46.28±53.68 g (Table 4.1). In Long San, this species has TL range of 6.9 to 21.4 cm with a mean of 12.7±4.3 cm and a BW ranging from 4.00 to 91.50 g with a mean of 28.46±27.19 g (Table 4.1). The b values of *O. enneaporos* in both areas ranged from 2.912 (Long San) to 2.973 (Long Apu) (Table 4.2, appendix 3). *O. enneaporos* caught in both areas showed negative allometric growth. The overall estimated values of condition factor (K) ranged from 0.99 to 1.04 (Table 4.2). In Long Apu, this species recorded the lowest condition factor with 0.99±0.10, followed by *O. enneaporos* in Long San with K= 1.04±0.08.

4.3.1.3 Length-weight Relationship of *Rasbora caudimaculata*

The TL of *R. caudimaculata* in Long Apu ranged from 6.8 to 13.2 cm with a mean of 9.9±2.4 cm and a BW ranging from 2.90 to 16.90 g with a mean of 9.69±9.23 g (Table 4.1). In Long San, this species recorded TL ranging from 3.4 to 11.6 cm with a mean of 8.3±2.8 cm and a BW ranging from 0.10 to 12.60 g with a mean of 5.23±4.08 g (Table 4.1). The b values of *R. caudimaculata* in Baram ranged from 2.927 to 3.542 (Table 4.2, appendix 3). In Long Apu, this species showed negative allometric growth with the lowest b value of 2.927, while in Long San showed positive allometric growth with b= 3.542. The overall estimated values of condition factor (K) ranged from 0.66 to 0.86 (Table 4.2). In Long San, this species recorded the lowest condition factor with 0.66±0.16, followed by *R. caudimaculata* in Long Apu with K= 0.86±0.07.

4.3.1.4 Length-weight Relationship of *Pseudolais micronemus*

The TL of *P. micronemus* in Long Apu ranged from 13.9 to 29.6 cm with a mean of 21.4±4.4 cm and a BW ranging from 18.00 to 176.10 g with a mean of 73.11±45.00 g (Table 4.1). In Long Kesseh, this species recorded TL ranging from 16.7 to 38.4 cm with a mean of 23.7±4.4 cm and a BW ranging from 8.44 to 365.60 g with a mean of 102.27±77.96 g (Table 4.1, appendix 3). The b values of *P. micronemus* in Baram ranged from 3.006 to 3.171(Table 4.2). In Long Apu, this species showed isometric growth with the lowest b value of 3.006. In Long Kesseh, this species showed positive allometric growth with b= 3.171. The overall estimated values of condition factor (K) ranged from 0.67 (Long Apu) to 0.67 (Long Kesseh) (Table 4.2).

4.3.1.5 Length-weight Relationship of *Kryptopterus apogon*

The TL of *Kryptopterus apogon* in Lio Mato ranged from 25.7 to 55.6 cm with a mean of 28.6±3.3cm and a BW ranging 56.32 to 735.00 g with a mean of 86.65±70.66 g (Table 4.1). This is followed by *K. apogon* in Long Apu with TL ranging from 18.7 to 31.4 cm with a mean of 25.0±3.0 cm and a BW range of 35.30 to 107.20 g with a mean of 60.71±20.97 g (Table 4.1, appendix 3). The b values of *K. apogon* in both areas ranged from 2.570 (Long Apu) to 2.866 (Lio Mato) (Table 4.2,). *K. apogon* caught in both areas showed negative allometric growth. The overall estimated values of condition factor (K) ranged from 0.34±0.03 to 1.38±0.05 (Table 4.2).

4.3.2 Whole Study Area of Baram

Among the five species, only one species (*B. schwanenfeldii*) exhibited isometric growth, two species (*K. apogon* and *O. enneaporos*) showed negative allometric growth and the remaining two species (*P. micronemus* and *R. caudimaculata*) have positive allometric growth. The b values ranged from 2.316 (*K. apogon*) to 3.487 (*R. caudimaculata*). The highest mean condition factor (K) was recorded in *B. schwanenfeldii* (1.21±0.23), while the lowest value was observed in *K. apogon* (0.35±0.03) (Table 2.3). A plot of log body weight (BW) against log total length (TL) yielded a straight line with R^2 ranging from 0.928 to 0.997 (Appendix 3)

Table 4.3: Descriptive statistics and parameters of the length-weight relationship of pooled data from the whole study area in Baram.

Species	N	b value	K factor	R^2	Growth Pattern
Barbonymus schwanenfeldii	117	3.024	1.21±0.23	0.986	Isometric
Kryptopterus apogon	106	2.316	0.35±0.03	0.928	Negative
Osteochilus enneaporos	65	2.935	1.02±0.09	0.997	Negative
Pseudolais micronemus	70	3.117	0.68±0.14	0.992	Positive
Rasbora caudimaculata	29	3.487	0.77±0.16	0.983	Positive

4.3.3 Hepatosomatic Index (HSI)

4.3.3.1 HSI of fishes in Lio Mato, Baram

The mean value of HSI for all samples taken in Lio Mato is shown in Table 4.4. The mean HSI value ranged from 0.054 to 0.448. *Kryptopterus macrocephalus* recorded the highest HSI value with a mean of 0.448, followed by *Luciosoma spilopleura* with 0.175, *Osteochilus schlegelii* with 0.122, *Cyclocheilichthys apogon* with 0.121, *Luciosoma* *setigerum* with 0.119, *Barbonymus collingwoodii* with 0.106, *Pseudolais micronemus* with 0.090 and *Kryptopterus apogon* with 0.054.

Table 4.4: Descriptive statistics and mean of hepatosomatic index for selected fish species caught from Lio Mato, Baram.

Family	Species	N_D	N_I	(%)	HSI (Lio Mato)		
					Min	Max	Mean±SD
Cyprinidae	*B. collingwodii*	14	11	78.57	0.057	0.181	0.106±0.050
	C. apogon	9	5	55.56	0.050	0.193	0.121±0.065
	L. setigerum	11	8	72.7	0.064	0.179	0.119±0.051
	L. spilopleura	6	6	100	0.048	0.274	0.175±0.084
	O. schlegelli	4	4	100	0.085	0.163	0.122±0.032
Pangasiidae	*P. micronemus*	11	11	100	0.023	0.159	0.090±0.049
Siluridae	*K. apogon*	7	4	57.14	0.011	0.089	0.054±0.034
	K. macrocephalus	11	9	81.82	0.014	1.189	0.448±0.419

(*ND; Number of samples dissected; NL; Number of good liver condition; Percentage of good liver condition.

4.3.3.2 HSI of fishes in Long Apu, Baram

The mean value of HSI for all samples taken in Long Apu is shown in Table 4.5. The mean HSI value ranged from 0.107 to 0.266. *Cyclocheilichthys apogon* recorded the highest HSI value with a mean of 0.266, followed by *Pseudolais micronemus* with 0.216, *Barbonymus schwanenfeldii* with 0.194, *Kryptopterus apogon* with 0.187, *Lobocheilos bo* with 0.179, *Osteochilus enneaporos* with 0.126 and *Puntioplites waandersii* with 0.107.

Table 4.5: Descriptive statistics and mean of hepatosomatic index for selected fish species caught from Long Apu, Baram.

Family	Species	N_D	N_I	(%)	HSI (Long Apu)		
					Min	Max	Mean±SD
Cyprinidae	*B. schwanenfeldii*	17	10	58.82	0.131	0.291	0.194±0.062
	C. apogon	16	12	75	0.112	0.582	0.266±0.141
	L. bo	40	5	12.5	0.049	0.347	0.179±0.111
	O. enneaporos	8	7	87.5	0.073	0.227	0.126±0.051
Pangasiidae	*P. waandersii*	4	4	100	0.077	0.137	0.107±0.025
Siluridae	*P. micronemus*	19	19	100	0.063	0.556	0.216±0.117
	K. apogon	18	17	94.45	0.094	0.283	0.187±0.052

(*ND; Number of samples dissected; NL; Number of good liver condition; Percentage of good liver condition.

4.3.3.3 HSI of fishes in Long San, Baram

The mean value of HSI for all samples taken in Long San is shown in Table 4.6. The mean HSI value ranged from 0.076 to 0.422. *Barbonymus schwanenfeldii* recorded the highest HSI value with a mean of 0.422, followed by *Lobocheilos hispidus* with 0.401, *Osteochilus enneaporos* with 0.132, *Puntioplites waandersii* with 0.076 and *Pseudolais micronemus* with 0.115.

Table 4.6: Descriptive statistics and mean of hepatosomatic index for selected fish species caught from Long San, Baram.

Family	Species	N_D	N_I	(%)	HSI (Long San)		
					Min	Max	Mean±SD
Cyprinidae	*B. schwanenfeldii*	12	11	91.67	0.057	1.754	0.422±0.485
	L. hispidus	7	7	100	0.116	1.493	0.401±0.491
	O. enneaporos	8	7	87.5	0.109	0.158	0.132±0.019
	P. waandersii	8	8	100	0.039	0.138	0.076±0.035
Pangasiidae	*P. micronemus*	8	8	100	0.070	0.158	0.115±0.048

(*ND; Number of samples dissected; NL; Number of good liver condition; Percentage of good liver condition.)

4.3.3.4 HSI of fishes in Long Kesseh, Baram

The mean value of HSI for all samples taken in Long Kesseh is shown in Table 4.7. The mean HSI value ranged from 0.100 to 0.366. *Hampala macrolepidota* recorded the highest HSI value with a mean of 0.366, followed by *Osteochilus vittatus* with 0.362, *Luciosoma setigerum* with 0.283, *Lobocheilos bo* with 0.239, *Barbonymus schwanenfeldii* with 0.187, *Pseudolais micronemus* with 0.179, *Puntioplites waandersii* with *0.167*, *Leptobarbus hoevenni* with 0.165 and *Kryptopterus apogon* with 0.100.

Table 4.7: Descriptive statistics and mean of hepatosomatic index for selected fish species caught from Long Kesseh, Baram.

Family	Species	N_D	N_I	(%)	HSI (Long Kesseh)		
					Min	Max	Mean±SD
Cyprinidae	*B. schwanenfeldii*	53	48	90.57	0.062	0.893	0.187±0.149
	H. macrolepidota	5	5	100	0.138	0.599	0.366±0.167
	L. hoevenni	11	7	63.67	0.092	0.279	0.165±0.076
	L. bo	4	4	100	0.207	0.272	0.239±0.027
	L. setigerum	16	16	100	0.155	0.725	0.283±0.156
	O. vittatus	15	15	100	0.120	0.457	0.362±0.090
	P. waandersii	6	6	100	0.078	0.279	0.167±0.097
Pangasiidae	*P. micronemus*	40	36	90	0.062	1.185	0.179±0.191
Siluridae	*K. apogon*	25	4	16	0.065	0.171	0.100±0.048

(*ND; Number of samples dissected; NL; Number of good liver condition; Percentage of good liver condition.)

4.3.3.5 Pooled HSI data for fishes in whole study area in Baram

The mean HSI value of 343 fish caught from the whole study area is presented in Table 4.8. A total of 58 fish species from thirteen families were caught in Baram River. However, some of the livers were already damage and only good condition livers were weight and used for the calculations of HSI index. From the family Cyprinidae, 16 species were selected namely, *Barbonymus collingwoodii* (N=11), *Barbonymus schwanenfeldii* (N=70), *Cyclocheilichthys apogon* (N=19), *Hampala bimaculata* (N=6), *Hampala macrolepidota* (N=6), *Leptobarbus hoevenni* (N=9), *Lobocheilos bo* (N=8), *Lobocheilos hispidus* (N=8), *Luciosoma setigerum* (N=25), *Luciosoma spilopleura* (N=8), *Osteochilus enneaporos* (N=15), *Osteochilus schlegelli* (N=4), *Osteochilus vittatus* (N=15), *Puntioplites waandersii* (N=18), *Rasbora caudimaculata* (N=4) and *Tor tambroides* (N=4). Only one species from the family of Bagridae, *Hemibagrus planiceps* (N=4), two species from the family of Siluridae namely *Kryptopterus apogon* (N=26), and *Kryptopterus* *macrocephalus* (N=9) and another one species from the family of Pangasiidae which is *Pseudolais micronemus* (N=74). The HSI from the whole study area varied from 0.106±0.050 to 0.648±0.273, where the lowest was recorded by *Barbonymus collingwoodii* and the highest was recorded by *Rasbora caudimaculata.*

Table 4.8: Descriptive statistics and mean of hepatosomatic index for selected fish species caught from whole study area in Baram River.

Family	Species	N_D	N_I	Percentage (%)	HSI		
					Min	Max	Mean±SD
Bagridae	*Hemibagrus planiceps*	35	4	11.43	0.066	0.656	0.324±0.248
Cyprinidae	*Barbonymus collingwoodii*	14	11	78.57	0.015	0.181	0.106±0.050
	Barbonymus schwanenfeldii	77	70	90.91	0.057	1.754	0.225±0.241
	Cyclocheilichthys apogon	22	19	86.36	0.050	1.076	0.282±0.256
	Hampala bimaculata	7	6	85.71	0.093	1.087	0.293±1.087
	Hampala macrolepidota	6	6	100	0.057	0.196	0.315±0.599
	Leptobarbus hoevenni	14	9	64.28	0.093	0.279	0.150±0.073
	Lobocheilos bo	9	8	88.89	0.049	0.347	0.206±0.086
	Lobocheilos hispidus	8	8	100	0.116	1.493	0.368±0.464
	Luciosoma setigerum	26	25	96.15	0.064	0.725	0.227±0.149
	Luciosoma spilopleura	8	8	100	0.048	0.274	0.165±0.075
	Osteochilus enneaporos	17	15	88.24	0.073	0.298	0.140±0.056
	Osteochilus schlegelii	4	4	100	0.085	0.163	0.122±0.049
	Osteochilus vittatus	15	15	100	0.120	0.457	0.362±0.090
	Puntioplites waandersii	18	18	100	0.039	0.279	0.113±0.071
	Rasbora caudimaculata	41	4	9.76	0.242	0.820	0.648±0.273
	Tor tambroides	4	4	100	0.058	1.171	0.373±0.503
Pangasiidae	*Pseudolais micronemus*	78	74	94.87	0.021	1.185	0.170±0.158
Siluridae	*Kryptopterus apogon*	30	26	86.67	0.011	0.283	0.152±0.070
	Kryptopterus macrocephalus	11	9	81.82	0.014	1.189	0.448±0.419

(*ND; Number of samples dissected; NL; Number of good liver condition; Percentage of good liver condition.

4.3.4 Gonadosomatic Index (GSI)

4.3.4.1 GSI of fishes in whole study area in Baram

Overall, the information on GSI is limited mainly due to the less number of individuals having gonads caught during this study period. The mean value of GSI for male fishes caught from whole study area at Baram River is shown in Table 4.9. The mean GSI of male fishes varied from 0.387 to 2.918. The lowest mean value was recorded by *Hemibagrus planiceps* (0.387) from the family of Bagridae while the highest GSI value was recorded by *Luciosoma spilopleura* (2.918) belonging to family Cyprinidae.

Table 4.9: Mean of gonadosomatic index of male fish caught from whole study area in Baram River.

Family	Species	N	GSI (Male)		
			Min	Max	Mean±SD
Bagridae	*Hemibagrus planiceps*	1	-	-	0.387
Cyprinidae	*Barbonymus collingwoodii*	4	0.637	3.093	1.167±1.219
	Leptobarbus hoevenni	1	-	-	0.559
	Luciosoma spilopleura	1	-	-	2.918
	Pseudolais micronemus	3	0.661	1.385	1.014±0.363
Siluridae	*Kryptopterus macrocephalus*	7	0.287	2.015	0.485±0.569

(*N; Number of gonads present; (%) represent the percentage of good condition gonad present).

The mean GSI of female varied from 0.804 to 13.041 (Table 4.10). The lowest mean value was recorded by *Puntioplites waandersii* (0.804) from the family Cyprinidae while the highest GSI value was recorded by *Luciosoma spilopleura* (13.041) belonging to family Cyprinidae.

Table 4.10: Mean of gonadosomatic index of female fish caught from whole study area in Baram River.

Family	Species	N	GSI(Female)		
			Min	Max	Mean±SD
Bagridae	*Hemibagrus planiceps*	3	1.013	4.273	2.820±1.659
	Nanobagrus armatus	1	-	-	0.838
Cyprinidae	*Barbonymus collingwoodii*	2	2.456	4.144	1.100±1.194
	Barbonymus schwanenfeldii	5	1.058	3.676	2.316±1.137
	Cyclocheilichthys apogon	3	4.010	9.263	6.268±2.703
	Lobocheilos bo	2	2.717	16.096	9.407±9.460
	Luciosoma setigerum	2	3.957	4.945	4.451±0.699
	Luciosoma spilopleura	2	8.886	17.196	13.041±5.876
	Osteochilus enneaporos	5	0.969	5.710	3.062±2.000
	Puntioplites waandersii	1	-	-	0.804
	Rasbora argyrotaenia	1	-	-	2.701
	Rasbora caudimaculata	3	3.968	5.738	4.706±0.921
Mastacembelidae	*Mastacembelus notophthalmus*	2	0.723	1.459	1.091±0.520
Pangasiidae	*Pangasius macronema*	2	8.364	12.593	10.478±2.991
	Pseudolais micronemus	1	-	-	4.410
Siluridae	*Kryptopterus cryptopterus*	2	5.527	9.105	7.316±2.530
	Kryptopterus macrocephalus	2	4.842	4.203	1.870±7.814

(*N_D; Number of samples dissected; $N_{L;}$ Number of good condition gonads present; (%) represent the percentage of good condition gonad present).

4.4 Discussion

Length-weight relationship (LWR) provides information on different types of growth patterns and growth conditions of fishes in this study. Bagenal and Tesch (1998) state that length-weight relationships are not persistent over the years and length-weight relationships parameter may differ due to biochemical factor, food availability, time and sampling factors, current health and sex of the samples.

In this study, from the 387 specimens studied, they ranged from 3.2 to 55.6 cm in total length and 2.2 to 735 g in total weight. The age sizes of fish in this study diverse considerably from young to adult stages with different growth rates. This is due to the used of different fishing gears like electro shocker, three layers net and gill nets with different mesh sizes to collect the fish samples and type of habitats. The types of mesh sizes of net could influence the various sizes of fish caught and hence different life stage condition (Mansor et al., 2010).

The b values of five fish species in this study ranged from a minimum of 2.316 for *Kryptopterus apogon* to a maximum of 3.487 for *Rasbora caudimaculata*. Tesch (1971) reported that most fishes in aquatic ecosystem have b values ranging from 2 to 4, suggesting that the result of this study was within those reported earlier. Results of the length-weight relationship in this study showed that the b value of *Rasbora caudimaculata* (3.487) was the highest. This indicates that the surrounding environment of Baram River is favorable for this species. The results also showed that the b values of *Rasbora caudimaculata* was higher than 3 and shows a positive allometric growth. Fish becomes fatter as they become longer when b value shows higher than 3 (Jobling, 2002). Two species namely, *Barbonymus schwanenfeldii* and *Pseudolais micronemus* experience isometric growth with b value of 3.039 and 3.006, respectively. Fish is considered to experience isometric growth when b=3 where the length increases in equal propotions with body weight for constant specific gravity (Hamid et al., 2015). Meanwhile, two fish species experienced negative allometric growth namely *Kryptopterus apogon* (b=2.316) and *Osteochillus enneaporos* (b=2.935). These species are getting slimmer with increase in length when b value is less than 3. In this study, *Kryptopterus apogon* recorded the lowest b value with b=2.316. This species are mainly found in Lio Mato station with 88 individuals caught.

Most stations in Lio Mato recorded the highest TSS concentration with a mean value of 98.7 mg/L and was significantly ($p<0.05$) higher than other sampling areas in Baram River. The presence of suspended solids due to runoff near the river bank can be harmful to the fish as it will affect the water quality especially the concentration of dissolved oxygen in water (Mansor et al., 2010).

In addition, there were several factors affecting the value of b throughout the fish life. The important factors that affect the value of b are gonad development and food availibility in their natural habitat at a particular time which can greatly affect this growth parameter (Ya et al., 2015). Studies by Noggle (1978) showed that fishes reduced feeding when exposed to 100 mg/L and >300 mg/L of suspended sediment. This could be due to high sedimentation that limits their vision to search for food. Apart from these factors which are directly associated to the fish, anthropogenic activities such as deforestation and aquaculture encompassing the detrimental water quality could be an additional cause leading to the destruction of this area as it would disturb all the organism that its supports (Hamid et al., 2015).

The coefficient of determination (R^2) of the length-weight relationship ranged from 0.928 for *Kryptopterus apogon* to 0.997 for *Osteochilus enneaporos*. All R^2 values obtained were higher than 0.9. High coefficient of determination (R^2) demonstrated a strong relationship between the body length and body weight in this fish species (Ahemad & Irman, 2005).

The condition factors of the studied fish species were found to be between 0.35±0.03 for *Kryptopterus apogon* to 1.21±0.23 for *Barbonymus schwanenfeldii*. A good and well-proportioned fish would have a K value that is approximately 1.40 (Hamid et al., 2015). Based on this information, the fishes in Baram are in poor condition except for *Barbonymus schwanenfeldii* and *Osteochilus enneaporos* that exibit moderate condition with K value equal to 1.21 and 1.02, respectively. High K values of *Barbonymus schwanenfeldii* and *Osteochilus enneaporos* show the good habitat condition in this area for these species. According to Le Cren (1951), the condition factor (K) of a fish reveals physical and biochemical conditions and variations in interaction among feeding conditions, parasitic infections and physiological factors. This also indicates the changes in food reserves and therefore is an indicator of the general fish well-being.

The average HSI of fish species in whole study area of Baram River ranged from 0.106±0.050 for *Barbonymus collingwoodii* to 0.648±0.273 for *Rasbora caudimaculata*. Sadekarpawar and Parikh (2013) and Cek et al. (2001), reported the HSI value ranging from 0.87 to 1.97 and 0.84 to 2.76, which is much higher than the result obtained in this study. The low HSI value may be due to the usage of store energy accumulated in the liver for supplying energetic requirements during time of scarce food items, sexual product elaboration and spawning activitiy. Poor environment lead to lack of food availability and deterioration of water quality resulting in smaller liver of fish thus less energy reserved in the liver (Pait & Nelson, 2003). On the other hand, Arockiaraj et al. (2004) reported that HSI was lowest during post spawning season, suggesting that liver was depleted during yolk formation. In this study, *Rasbora caudimaculata* (0.648±0.273), *Kryptopterus macrocephalus* (0.448±0.419) and *Tor tambroides* (0.373±0.503) are the top three species that recorded the highest HSI value compare to other species while *Pangasius macronema* recorded the lowest HSI value with 0.648±0.273.

The mean GSI of male fishes varied from 0.340 to 2.918, while the mean GSI of females varied from 0.804 to 13.041. The GSI values obtained in this study showed that females had higher GSI values than males in all study areas. This was associated with the heavier weight of ovaries which contained eggs (Shinkafi & Ipinjolu, 2012). Gonadosomatic index has been considered as valid estimate for gonad maturity and spawning of any species. According to Nandikeswari et al. (2014), gonadosomatic index increased with the maturation of fish and reaches its maximum at peak period of maturity.

4.5 Conclusion

The length-weight relationships of fish population have not been reported from upper stretch of Baram River. This result provides basic data on length-weight parameters for twelve major species collected from Baram River. The b values for LWR in this study range from 2.316 to 3.487. This shows that their growth is still in the normal range for freshwater fish. The variation of growth in these species was mainly influenced by the physicochemical parameters in this area. Two species namely, *Pseudolais micronemus* and *Rasbora caudimaculata* exhibited a trend of positive growth, whereas *Barbonymus schwanenfeldii* experienced isometric growth. Thus, it can be concluded that the growth pattern for these fish species in Baram can be considered good. These growth trends indicate that this river could provide a suitable environment and favorable habitat for the growth of those fish species. Two species, *Kryptopterus apogon* and *Osteochilus enneaporos* showed negative allometric growth.Gonadal maturity and spawning season of each species in this area could not be determined in detailed as sampling were not done continuously. However, this study could also serve as baseline data for carrying out further study in the documentation, management and protection of fisheries resources in Baram.

CHAPTER 5

FEEDING HABITS OF SEVEN SELECTED FISH SPECIES IN UPPER BARAM RIVER

5.1 Introduction

The study on feeding habits of freshwater fish species is important in fisheries as it generates the basis for the development of an effective fisheries management programme on fish capture and culture (Oronsaye & Nakpodia, 2005). Studies on stomach content and feeding habits are important in community ecology because the use of resources by organisms has a major impact on population interactions within a community (Mequilla & Campos, 2007) as well as to identify factors affecting the assemblages and abundance of organisms (Ross, 1986). Besides, knowledge about the specification of food items both qualitatively and quantitatively can be applied in aquaculture development (Ara et al., 2010). In terms of management, such studies are vital for evaluation of the ecological role of fish larvae as well as the understanding of its position in the food web structure in the ecosystem (Ara et al., 2010).

Studies on the feeding habit and gut contents have been well documented for some species including mullet fish, *Liza subviridis* and *Valamugil buchanani* (Fatema et al., 2013), snakehead *Channa striatus* (Amin et al., 2014), as well as demersal and pelagic fish from Terengganu waters (Bachok et al., 2004). However, very little is known about the feeding habits of fishes in Baram area. Therefore, the current study aimed to identify the food items in the stomach content of selected fish species in Baram.

5.2 Materials and Methods

5.2.1 Stomach Content Analysis

A total of 298 fish from seven species namely, *Barbonymus schwanenfeldii* (N=63), *Cyclochelichthys apogon* (N=29), *Hemibagrus planiceps* (N=28), *Kryptopterus apogon* (N=48), *Luciosoma setigerum* (N=29), *Pseudolais micronemus* (N=63), and *Rasbora caudimaculata* (N=38) were analysed and the sample size of each species ranged from 29 to 63 individuals. These species were selected because they were dominant in the whole study area.

The stomach of selected fish species was carefully dissected longitudinally by opening the abdominal portion of the fish using GOLD CROSS dissecting set. The tip of oesophagus (stomach) to the end of the rectum was carefully removed by using forceps. The stomach content was weighed using analytical balance SHIMADZU, BL-220H (220 g) with 3 decimal places. The stomach were preserved immediately in ziplock bag containing 5 % formalin and transported to the Aquatic Vertebrate laboratory for further analysis. The preservation of the gut in 5 % formalin stopped further digestion so that food items were not degraded. In addition, it is to enhance the coagulation of the diet components for ease of identification (Job, 2006).

The content of the stomach was examined under stereomicroscope (Motic SMZ-140 Series) for further analysis. Stomach contents found were identified up to the lowest possible taxa level (Bouchard, 2004) (Appendix 4). The fish diet was measured quantitatively; 1) insects - including Coleoptera, Ephemenoptera, Hemiptera, Hymenoptera, Orthoptera and Trichoptera; 2) fish - whole individual or body parts of fish including fish bones and fish scales; 3) plant materials - consisting of flower bud, seeds, leaves, fruit; 4) mollusc; 5) pinworm; 6) oligochaete; 7) nematode; 8) sediments - sand grains; 9) digested material; 10) rocks, and 11) unidentified materials (Bouchard, 2004). Data from stomach contents were analyzed in the following ways; (1) frequency occurrence of food items (Hynes, 1950; Lima-Junior & Gotein, 2001) and (2) mass method (Ahlbeck et al., 2012).

5.2.2 Frequency of Occurence

The Frequency of Occurence method was used to record the number of stomachs containing one type of food item and the total was expressed as a percentage of the total number of stomachs examined using the formula below (Hynes, 1950; Lima-Junior & Gotein, 2001):

$$Fi = 100\, n_i / n$$

where,

F_i: Frequency of occurrence of the ί food item in the sample

n_i: Number of stomach in which the ί item is found

n: Total number of stomachs with food in the sample

5.2.3 Gravimetric Method

Gravimetric method was used to calculate the weight of different food items, as a proportion of total weight of all food items. The formula of mass method is as shown below (Hyslop, 1980).

$$W_{ij} = 100\, w_{ij} / w_j$$

where,

W_{ij} = Gravimetric method

wij= weight of *i* food item in the stomach of fish *j*

wj = Total weight of all food items in stomach of fish *j*

5.3 Results

5.3.1 Stomach contents of *Barbonymus schwanenfeldii*

A total of 82 stomach contents were obtained for *Barbonymus schwanenfeldii* from the whole study area of Baram River. However, only 63 stomachs were present with food items while the remaining 19 were empty. The types of food item consumed, gravimetric method and frequency of occurrence of stomach contents of *B. schwanenfeldii* in Baram River is listed in Table 5.1.

A total of ten types of food items were found from the stomach contents of *B. schwanenfeldii*. The food items were made up of six categories namely, insects, plants, molluscs, oligochaete, pinworm and digested matter.

The gravimetric method resulted in the following percentage of food items; insects (Coleoptera, Hymenoptera, Hemiptera) constitutes the most important food item with a total of 42.67%, followed by plant materials (fruits, flower bud and seeds) with 36.44%, digested food (13.87%), molluscs (3.10%), pinworm (2.78%) and oligochaete (1.13%).
Based on the frequency of occurrence, the most frequently consumed food items were insect (Coleoptera, Hemiptera, Hymenoptera) making up about 36%, closely followed by plant materials (fruits, flower bud and seeds) which represent 34%, digested matter represent 15.33%, oligochaete (6.67%), pinworm (5.33%) and molluscs (2.67%).

Table 5.1: Food item, gravimetric method and frequency of occurrence observed in stomach of *Barbonymus schwanenfeldii* (n = 63).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
Barbonymus schwanenfeldii	82	63	19	65.77			
Insect							
Coleoptera				16.21	23.88	26	17.33
Hemiptera				4.83	7.11	10	6.67
Hymenoptera				7.93	11.68	18	12.00
Plant							
Fruits				5.59	8.23	13	8.67
Flower bud				8.53	12.57	20	13.33
Seed				10.62	15.64	18	12.00
Molluscs				2.11	3.10	4	2.67
Oligochaete				0.76	1.13	10	6.67
Pinworm				1.89	2.78	8	5.33
Digested matter				9.41	13.87	23	15.33

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.3.2 Stomach contents of *Cyclocheilichthys apogon*

A total of 29 stomach contents were obtained for *Cyclocheilichthys apogon* from the whole study area of Baram River. The types of food item consumed, method and frequency of occurrence of stomach contents of *C. apogon* in Baram River is listed in Table 5.2.

A total of seven types of food items were found in the stomach contents of *C. apogon* and were made up of six food categories namely, insects, plants, fish, nematode, oligochaete, digested matter and sediment.

The gravimetric method resulted in the following percentage of food items; insects (Coleoptera and Hymenoptera) constitutes the most important food item with a total of 33.82%, followed by plant materials (leaves) with 23.77%, digested food (20.73%), fish scales (12.90%), sediment (5.65%) and oligochaete (3.12%).

Based on the frequency of occurrence, the most frequently consumed food items by *C. apogon* were insect (Coleoptera and Hymenoptera) making up about 39.48%, followed by plant materials (leaves) and digested food, each with 15.79%, oligochaete (13.16%) and sediment (5.26%) (Table 5.2).

Table 5.2: Food item, gravimetric method and frequency of occurrence observed in stomach of *Cyclocheilichthys apogon* (n = 29).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
Cyclocheilichthys apogon	29	29	0	32.90			
Insect							
Coleoptera				8.78	26.68	17	22.37
Hymenoptera				2.35	7.14	13	17.11
Fish							
Fish scales				4.24	12.90	8	10.53
Plant							
leaves				7.82	23.77	12	15.79
Oligochaete				1.03	3.12	10	13.16
Digested food				6.82	20.73	12	15.79
Sediment							
Sand				1.86	5.65	4	5.26

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.3.3 Stomach contents of *Hemibagrus planiceps*

A total of 35 stomach contents were obtained for *Hemibagrus planiceps* from the whole study area of Baram River. However, only 28 stomachs were present with food items while the remaining 7 were empty. The types of food item consumed, gravimetric method and frequency of occurrence of stomach contents of *H. planiceps* in Baram River is listed in Table 5.3. A total of eleven types of food items were found from the stomach contents of *H. planiceps* and were made up of seven food categories namely, insects, fish, plants, molluscs, digested food, unidentified matter and stones.

The gravimetric method resulted in the following percentage of food items; insects (Coleoptera, Ephemeroptera and Hymenoptera) constitutes the most important food item with a total of 32.71%, followed digested food (19.97%), plant materials (flower bud and seeds) with 16.06%, fish (eggs and scales) with 15.24%, molluscs (12.61%), small rocks (3.23%) and unidentified matter (0.18%).

Based on the frequency of occurrence, the most frequently consumed food items were insect (Coleoptera, Ephemeroptera and Hymenoptera) making up about 35.71%, followed by digested food with 27.14%, fish (eggs and scales) with 14.29%, plant materials (flower bud and seeds) representing 14.29%, stones represent 5.71%, molluscs (1.43%) and unidentified matter (1.43%).

Table 5.3: Food item, gravimetric method and frequency of occurrence observed in stomach of *Hemibagrus planiceps* (n = 28).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
H.planiceps	35	28	7	6.66			
Insect							
Coleoptera				1.08	16.24	9	12.86
Ephemeroptera				0.85	12.69	4	5.71
Hymenoptera				0.25	3.78	12	17.14
Fish							
Fish Egg				0.18	2.75	1	1.43
Fish Scales				0.83	12.49	9	12.86
Plant							
Flower bud				0.71	10.69	3	4.29
Seed				0.36	5.37	7	10.00
Molluscs							
Gastropod				0.84	12.61	1	1.43
Digested food				1.33	19.97	19	27.14
Unidentified matter				0.01	0.18	1	1.43
Stones				0.22	3.23	4	5.71

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.3.4 Stomach contents of *Kryptopterus apogon*

A total of 51 stomach contents were obtained for *Kryptopterus apogon* from the whole study area of Baram River. However, only 48 stomachs were present with food items while the remaining 3 were empty. The types of food item consumed, gravimetric method and frequency of occurrence of stomach contents of *K. apogon* in Baram River is listed in Table 5.4.

A total of nine types of food items were recorded from the stomach contents of *K. apogon*. They were made up of three food categories namely, insects, fish, and digested food.

The gravimetric method resulted in the following percentage of food items; insect (Coleoptera, Ephemeroptera, Hemiptera, Hymenoptera and Trichoptera) constitutes the most important food item with a total of 49.57%, followed by fish (bones, scales, and flesh) with 25.55% and digested food (24.88%).

Based on the frequency of occurrence, the most frequently consumed food items were insect (Coleoptera, Ephemeroptera, Hemiptera, Hymenoptera and Trichoptera) making up about 49.54%, followed by digested food with 25.66%, and fish (bones, scales, and flesh) with 24.78%.

Table 5.4: Food item, gravimetric method and frequency of occurrence observed in stomach of *Kryptopterus apogon* (n = 48).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
Kryptopterus apogon	51	48	3	41.17			
Insect							
Coleoptera				13.49	32.77	25	22.12
Ephemeroptera				1.97	4.79	6	5.31
Hemiptera				2.26	5.49	8	6.19
Hymenoptera				2.66	6.47	15	13.27
Trichoptera				0.02	0.05	3	2.65
Fish							
Fish Bones				1.79	4.34	10	8.85
Fish scales				5.75	13.97	14	12.39
Fish flesh				2.98	7.24	4	3.54
Digested food				10.24	24.88	28	25.66

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.3.5 Stomach contents of *Luciosoma setigerum*

A total of 29 stomach contents were obtained for *Luciosoma setigerum* from the whole study area of Baram River. The types of food item consumed, gravimetric method and frequency of occurrence of stomach contents of *L. setigerum* in Baram River is listed in Table 5.5.

A total of eight types of food items were recorded from the stomach contents of *L. setigerum* and were made up of five food categories namely, insects, plant materials, nematode, oligochaete and digested food.

The gravimetric method resulted in the following percentage of food item; plant materials (leaves and seeds) constitutes the most important food item with a total of 34.82%, followed by insect (Coleoptera, Hymenoptera and Trichoptera) with 34.23%, digested food (28.05%), nematode (1.50%) and oligochaete (1.41%).

Based on the frequency of occurrence, the most frequently consumed food items were insect (Coleoptera, Hymenoptera and Trichoptera) making up about 34.61%, followed by plant materials (leaves and seeds) with 26.92%, digested food (19.23%), oligochaete (10.26%) and nematode (8.97%).

Table 5.5: Food item, gravimetric method and frequency of occurrence observed in stomach of *Luciosoma setigerum* (n = 29).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
Luciosoma setigerum	29	29	0	36.45			
Insect							
Coleoptera				5.53	15.18	12	15.38
Hymenoptera				3.50	9.60	8	10.26
Trichoptera				3.44	9.45	7	8.97
Plant							
leaves				5.04	13.84	11	14.10
Seed				7.65	20.98	10	12.82
Nematode				0.55	1.50	7	8.97
Oligochaete				0.52	1.41	8	10.26
Digested food				10.23	28.05	15	19.23

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.3.6 Stomach contents of *Psedolais micronemus*

A total of 82 stomach contents were obtained for *Pseudolais micronemus* from the whole study area of Baram River. However, only 63 stomachs were present with food items, while the remaining 19 were empty. The types of food item consumed, gravimetric method and frequency of occurrence of stomach contents of *P. micronemus* in Baram River is listed in Table 5.6. A total of eleven types of food items were observed from the stomach contents of *P. micronemus* and were made up of four categories namely, insects, plant materials, oligochaete and digested food.

The gravimetric method resulted in the following percentage of food items; plant materials (flower bud, leaves, fruits and seeds) constitutes the most important food item with a total of 49.86%, followed by digested food with 31.1%, insect (Coleoptera, Ephemeroptera, Hymenoptera, Orthoptera and Trichoptera) with 18.94%, and oligochaete (0.11%).

Based on the frequency of occurrence, the most frequently consumed food items were plant materials (flower bud, leaves, fruits and seeds) making up about 42.86%, followed by insect (Coleoptera, Ephemeroptera, Hymenoptera, Orthoptera and Trichoptera) with 38.71%, digested food (15.41%) and oligochaete (3.01%).

Table 5.6: Food item, gravimetric method and frequency of occurrence observed in stomach of *Pseudolais micronemus* (n = 74).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
Pseudolais micronemus	78	74	4	223.54			
Insect							
Coleoptera				18.14	8.12	44	16.54
Ephemeroptera				1.57	0.70	9	3.38
Hymenoptera				7.12	3.19	32	12.03
Orthoptera				12.32	5.51	9	3.38
Trichoptera				3.17	1.42	9	3.38
Plant materials							
Flower bud				16.33	7.30	22	8.27
Fruits				10.28	4.60	3	1.13
Leaves				33.21	14.86	48	18.05
Seed				51.63	23.10	41	15.41
Oligochaete				0.24	0.11	8	3.01
Digested food				69.53	31.11	41	15.41

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.3.7 Stomach contents of *Rasbora caudimaculata*

A total of 41 stomach contents were obtained for *Rasbora caudimaculata* from the whole study area of Baram River. However, only 38 stomachs were present with food items, while the remaining 3 were empty. The types of food item consumed, gravimetric method and frequency of occurrence of stomach contents of *R. caudimaculata* in Baram River is listed in Table 5.7.

A total of eight types of food items were recorded from the stomach contents of *R. caudimaculata* and were made up of four food categories namely, insects, fish plant materials and digested food.

The gravimetric method resulted in the following percentage of food items; insect (Coleoptera, Ephemeroptera and Hymenoptera) constitutes the most important food item with a total of 56.91%, followed by plant materials (flower bud, leaves and seeds) with 37.78%, digested food (5%) and fish scales (0.31%).

Based on the frequency of occurrence, the most frequently consumed food items were insect (Coleoptera, Ephemeroptera and Hymenoptera) making up about 56.56%, followed by plant materials (flower bud, leaves and seeds) with 30.03%, digested food (11.11%) and fish scales (2.02%).

Table 5.7: Food item, gravimetric method and frequency of occurrence observed in stomach of *Rasbora caudimaculata* (n = 38).

Food item	(D)	(N)	(E)	(g)	Gravimetric method	(n)	Frequency of occurrence
Rasbora caudimaculata	41	38	3	8.37			
Insect							
Coleoptera				2.03	24.22	24	24.24
Ephemeroptera				0.08	0.99	7	7.07
Hymenoptera				2.65	31.70	25	25.25
Fish							
Fish scales				0.03	0.31	2	2.02
Plant materials							
Flower bud				0.22	2.68	4	4.04
Leaves				0.97	11.53	17	17.17
Seed				1.97	23.57	9	9.09
Digested food				0.42	5.00	11	11.11

(*D, number of samples dissected; N, number of stomach with food item present; E, number of empty stomach; g, total weight of each food item; and n, number of stomach where each food item is found).

5.4 Discussion

A total of 349 stomach contents from 7 species caught from the whole study area of Baram River were analyzed for their content. However, only 298 stomachs were present with food items while the remaining 51 were empty. Royle (2001) reported that all materials of food sources for fish can be found in its environment, while the fish with empty stomach could be due to longer periods of time the fish got stuck in hooks or nets before being removed for examination (Badamasi, 2014). Other studies reported that an empty gut, however, does not always indicate that the fish avoids the food available in its surroundings but probably due to the insufficient temperature to support metabolic rates in the gut of the fish (Brett and Higgs, 2011).

The stomach content of *Barbonymus schwanenfeldii* in Baram River indicates that this species feds on various types of food items ranging from insects to plant materials as well as nematode. Thus, this species is considered as omnivorous. This is similar to the findings by Mustafa-Kamal et al. (2012) which stated that *Barbonymus schwanenfeldii* is considered to be omnivorous, displaying both plant and animal in the food items they consumed.

Cyclocheilichthys apogon in Baram River also feed on a wide range of food including plant materials and insect, reflecting their omnivorous diets. In this study, the occurence of sand particles were also recorded in stomach content this species. The sand could be taken in coincidentally while the fish was burrowing in the sand to prey upon benthic animals and this revealed the evidence of the bottom feeding habit of this species (Hamid et al., 2015). Similar results were reported in Temengor and Bersia Reservoirs which documented the occurrence of sand in the stomach of *C. apogon* was due to accidental intake (Hamid et al., 2015).

Different type of food items such as insects, plant materials, fish, stones and molluscs were found in the stomach content of *Hemibagrus planiceps* in Baram. The same finding was also observed for *Hemibagrus* sp. in Yuanking River (Du et al., 2010) which documented wide range of food items including molluscs, insects, copepod and algae in the stomach. A study by Mustafa-Kamal et al. (2012) suggested that *Hemibagrus* sp. can be catogerized as omnivorous feeder as they consumed wide ranged of food items including fish, molluscs, insects, copepod, rotifier and algae. In addition, the presence of various food items in the stomach of *Hemibagrus planiceps* suggests that they are euryphagous as they feed on a wide range of organisms (Du et al., 2010). The small stones found in the stomach of *Hemibagrus planiceps* in Baram area were believed to be ingested accidentally due to its opportunistic feeding habits. Comparison with the finding of Melo et al. (2004) on *Hemibagrus* sp. at Ariguaia Basin in Brazil reveals a minor shift in food items. In their study *Hemibagrus* sp. predominantly feed on arthropod but none were found in the stomach content of *Hemibagrus planiceps* in Baram River. This could be due to differences in habitats and abundance of prey organisms (Alfred-Ockiya, 2000).

This study shows that fishes feed on a wide variety of items ranging from fishes, plant materials, insects and nematode. On the basis of different food items found in the stomach contents, all the species were regarded as an omnivorous except for *Kryptopterus apogon*. In this study, high percentage of occurrence for insect was found in *Kryptopterus apogon*. *Krytopterus* sp. was classified as carnivorous. They posses the characteristic of carnivorous fish like strongly projected lower jaw beyond upper when mouth is closed, have strong hook teeth and the intestine may reach 60% of the body length (Adiyanda et al., 2014). In Baram River, the main food items contained in *K. apogon* stomach are insects, fish scales and digested materials. This is in contrast to a study by Adiyanda et al. (2014) where

Krytopterus sp. in Sungai Tapung Hilir preferred arthropod, detritus and fish (*Puntius* sp.). This indicates that this species is able to adapt its feeding strategy in accordance with the availability of food resources in the area it habitats.

IUCN's Red List database listed *Luciosoma setigerum* as Data Deficient (Vidthayanon, 2012). The major proportion of *Luciosoma setigerum* natural diet in Baram is composed of insects which are captured at the water surface, nematode and plant materials. This was similar with a study by Juliana (2014) on stomach content of *Luciosoma setigerum* with the occurence of insect and seed in their stomach content.

IUCN's Red List database listed *Pseudolais micronemus* as Data Deficient (Vidthayanon, 2012). This study revealed that the gut of this species was abundant with Coleoptera, leaves, seed and digested matter, while other food items consumed by the fish were not abundant. It was also observed that *Pseudolais micronemus* can be classified as an omnivorous feeder as the diet covers a wide range of food items ranging from various types of insects to plant materials and nematode.

In Baram, *Rasbora caudimaculata* feeds on both plant material and insects. This was similar with the results obtained by Djumanto and Setyawan (2009) on *Rasbora* sp. which showed that *Rasbora* sp. is categorized as omnivorous feeder. This is also supported by Sulistiyarto (2013) who reported *Rasbora argyrotaenia* in Kalimantan Tengah as omnivores as they feed on varieties of food including detritus, invertebrates and planktons.
According to Casatti and Castro (2006), the rocky substrates and strong current usually creates habitat that is rich in food such as periphytic algae and insect larvae that are indirectly and directly feed by the fishes. In Baram, insect can be found dominant in the stomach content of several species such as *B. schwanenfeldii, H. planiceps, K. apogon, P.*

micronemus and *R. caudimaculata*. On the other hand, insects which were found in fish stomachs may have been due to the location of the tributaries which is situated within the primary rain forest (Mustafa-Kamal et al., 2012). All species except *Kryptopterus apogon* analyzed in Baram River ingest fruits, seeds, leaves and flower bud, demonstrating a strong influence of the vegetation on the fish fauna (Melo et al., 2004).

5.5 Conclusion

The finding of this study clearly indicates the importance of riparian vegetation along rivers that served as insects' habitats, especially for ants. In Baram River, fish mainly feed on terrestrial ants that accidentally fall from riparian trees onto the water surface. Besides, one of the most frequent food items consumed by all species in Baram was insects, constituting more than half of the diet of the fishes. The fishes could also behave as an opportunistic feeder which consumes any available food items. The food items varied from sand particles and insect to bigger sized prey such as fish and molluscs. Other food materials were less commonly encountered from the fish stomach, implying their low importance or low availability to the fish. This study reveals the importance of plant materials, insects, nematode and digested food as common food items found in the stomach contents. It can be concluded that *Barbonymus schwanenfeldii*, *Luciosoma setigerum*, *Pseudolais micronemus* and *Rasbora caudimaculata* in Baram feed on both plant and insect and thus suggest that these species are omnivorous. On the other hand, *Krytopterus apogon* is carnivorous whereas *C. apogon* could be classified as benthic omnivore as it feeds on wide range of benthic organisms. *Hemibagrus planiceps* is suggested as euryphagous as they feed on wide range of food items.

CHAPTER 6

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 General Discussion

The cyprinids are the dominant fish family in the Baram River. Many studies have shown that the cyprinids are the most common species found in Malaysian freshwater bodies (Zakaria-Ismail, 1991). The fish survey of Baram River is not yet complete as most work to date has involved short-term collection over a period of only a few days, and the surveys were performed at times that could miss rare or seasonally abundant species. In this study, a total of 1376 individuals of fish were caught from 29 stations at upper stretch of Baram River comprising 58 species belonging to 13 families. The number of fish species present in this study was higher than those reported for some other areas in Sarawak. In Lutong River, Nyanti et al. (2012) reported the presence of 33 species of fish from 23 families and 36 species of fish from 13 families in Batang Kerang (Adha et al., 2009). However, it was lower than that reported in Rajang Basin where at least 164 species were present (Parenti & Lim, 2005). In terms of number of fish individuals caught by study area, there were 34 species of fish found in Lio Mato (upper zone) compared to only 27 species each in Long Apu and Long San which is located at the middle zone and 23 species found in Long Kesseh (lower zone). The differences in the number of species along sampling area were probably due to stream slope. According to Schlosser (1982), the changes in fish community structure and function along the physical gradient support the qualitative contention of the stream continuum concept, where shift in community organization are associated with spatial or temporal changes in resources availability, channel morphology and flow regime. This is supported by Grenouillet et al. (2004) who suggested that shape and stream topography affect longitudinal distribution of fish species, as it could be a barrier for fish migration. Besides, steep end and stream slope as well as the geographical condition in Lio Mato area also produces strong current. These conditions present significant barriers for fish attempting to migrate to the lower zone (Hashim et al., 2012). According to Horwitz (1978), deeper water, wider rivers and more discharges downstream are factors to increase diversity parameters. However in Baram River, species richness and *H'* index increased from the lower to the upper zone. Higher species diversity and richness at upper zone (Lio Mato, Long Apu) may be associated with rivers morphology and the presence of large rocks, rapid riffles and shallow pools, which increase its habitat heterogeneity resulting in greater habitat niches.

BOD_5, DO, TSS, water temperature, conductivity, pH, turbidity and chlrophyll-α are the major factors affecting fish distribution in the upper stretch of Baram River, Sarawak. The physico-chemical parameters were significantly different among areas. This could ascertain the fact that the variation in fish abundance and diversity is also dependant on the water quality. As the sampling areas were located further upstream in Baram River, they are ranked as a lower river order. According to Paugy (2002), low order streams have high concentrations of dissolved oxygen and low levels of suspended solids. These characteristics are favorable for fish and other aquatic organisms. Paugy (2002) also noted that low order streams are important nursery grounds for fish, as many juvenile fish were observed in her study. Similar result was also obtained by Zarul et al. (2004) at two headwater streams of Temengor Reservoir. However, these results suggest that Baram River may have had some setbacks with respect to water quality. The high temperatures recorded at the Long San area are probably due to lack of coverage by riparian vegetation. Besides, siltation of the stream became more obvious during the rainy season. This effect was also observed in Lio Mato which is located at the upper zone of the study area, resulting in high turbidity and TSS value in this area compared to other stations. However, while some of the fish species need clear water to survive, *M. notophthalmus, P. oxygastroides, K. apogon, L. spilopleura, O. scptemfasciatus, B. collingwoodii, O. triporos, P. hypophthalmus, K. macrocephalus, C. chinensis, O. waandersii* and *N. armatus* were well-adapted to live in higher tubidity and higher TSS concentration of environment such as stations located at Lio Mato. In addition, relatively lower DO readings at Lio Mato (7.08 mg/L) compared to other stations does not seem to affect fishes as the highest number of fish individuals was caught here. This is because it still meets the optimum requirement for aquatic organism, which is above 5 mg/L (Poxton and Allouse, 1982). Generally, the water quality of tributaries of Baram River is still classified as good since most of the water quality index is classified as Class I and II based on the National Water Quality Standard.

For length-weight relationship, six species of fish were analysed and the b value ranged from 2.316 to 3.487. Among the five fish species, only *B. schwanenfeldii* showed isometric growth, two species, *P. micronemus* and *R. caudimaculata*, experienced positive allometric growth which means they grow robust with an increasing body length, causing them to have heavier body weight. The other two species, *O. enneaporos* and *K. apogon*, showed negative allometric growth. Although these species exhibited negative allometric growth, both species can be found abundant throughout the study period with 70 and 113 individuals, respectively. This, suggest that they are able to adapt to the environment in Baram River. For *K. apogon*, more than 90 % of the specimens had food in the stomach, which consist of a wide variety of food organisms. This indicates availability of food organisms within the study area. The difference in growth pattern of fish can be influenced by many factors such as the environmental conditions, fish activities, feeding habits, seasonal growth rates, temperature, trophic level as well as food availability (Mansor et al., 2010). Small tributaries in Baram are characteristically shaded and have warmer temperature due to overhanging riparian vegetation, which also contributes to dead organic matter (detritus) to the stream. Riparian vegetation supplies organic matter in the form of dead leaves, bud, fruits, branches and droppings of terrestrial insect (ants) (Knight & Bottoroff, 1981). This may explain the abundance of these food items in the stomach contents of fish species in Baram River.

6.2 General Conclusions

This study suggests that fish species diversity is closely related to morphology, food availability and water quality of the rivers. Baram River supported high number of fish families and have comparable number of fish individuals with other areas despite its lower water quality at certain area (high turbidity and TSS at Lio Mato area). However, TSS and turbidity values were within the standard permissible limits of NWQS for Malaysian rivers. Generally, water quality of the tributaries of Baram River is still classified as good since most of the water quality indices fall under Class I and II based on the National Water Quality Standard.

The majority of fish species from Baram conformed to the typical b values of 2.5 to 3.5 although it varied significantly within this range. Two species namely, *P. micronemus* and *R. caudimaculata* exhibited a trend of positive growth, whereas *B. schwanenfeldii* showed isometric growth. These growth trends indicate that Baram River could still provide a favorable environment and suitable habitat for the growth of those fishes. Although *K. apogon* and *O. enneaporos* exihibited negative growth, these species can be found abundance in Baram River, suggesting that they are tolerable to the ecosystem. More overhanging vegetation found on narrow tributaries of the sampling areas contributes organic matter to the stream. Thus, supplies organic matters to the stream to be utilized by the fish. In addition, high availability of food resources is one of the main factors that affect the suitability of Baram River as habitat for the fish. The diversity of natural food items found in the stomach of fishes is an indication that the feeding habits of the species was euryphagous, feeding on a broad range and variety of food available in the environment. It also confirmed that the analyzed fish species are benthic, omnivorous, carnivorous and euryphagous although the species can fit into different trophic levels in the food chain.

This study serves as baseline data for future study in the area and could be used for the documentation, management and conservation of fisheries resources in Baram area, especially for the sustainability of the low diversity species/families to prevent their extinction.

6.3 Recommendations

Baram River still provides an important habitat for diverse aquatic organisms as shown by the fish assemblages in all stations along the river. Therefore, proper management of the area is recommended for the protection or conservation of the habitat, fish population and fisheries in order to ensure sustainable fishing activities along the river.

It is therefore recommended that:

- continuance of water quality monitoring is necessary to record environmental fluctuations over time and to make biotic predictions possible,
- addditional sampling sites, including more habitats be carried out to determine habitat relationships, and
- use of technology such as GIS models in mapping fish locations and measuring rates of fish movement to provide information on populations and fish habitats.

REFERENCES

Abdel-Tawwab, M., Hagras, A. E., Elbaghdady, H. A. M., & Monier, M. N. (2015). Effects of Dissolved Dxygen and Fish Size on Nile Tilapia, *Oreochromis niloticus* (L.): Growth Performance, Whole Body Composition, and Innate Immunity. *Aquaculture International, 23*, 1261-1274.

Addy, K., & Green, L. (1997). Dissolved oxygen and temperature. *Natural Resources Fact Sheet*, 96-3.

Adiyanda, R., Elvyra, R., & Yusfiati. (2014). Analisis isi lambung ikan lais janggut (*Kryptopterus limpok*, Bleeker 1852) di Sungai Tapung Hilir, Propinsi Riau. *Jom Fakultas Matematika dan Ilmu Pengetahuan Alam, 1*(2), 511-524.

Ahemad, S., & Irman, I. (2005). Information collection for sustainable fisheries in the South China Sea. Country progress report III for Sabah, East Malaysia. 4th Technical Consultation Meeting on Information Collection for Sustainable Pelagic Fisheries in the South China Sea. Jakarta, Indonesia, November. Kuala Terengganu: Southeast Asian Fisheries Development Centre (SEAFDEC) and Marine Fishery Resources Development and Management Department (MFRDMD).

Ahlbeck, I., Hansson, S., & Hjerne, O. (2012). Evaluating fish diet analysis methods by individual-based modeling. *Canadian Journal of Fisheries and Aquatic Sci*ence, *69*, 1184-1201.

Ahmad, A., & Khairul-Adha, A. R. (2005). State of Knowledge on Freshwater Fishes of Malaysia. Proceedings of the Seminar and Workshop. Forest Research Institute Malaysia, Kepong, Malaysia, 28-30 June 2005.

Ahmad, A. K., Mushrifah, I., & Othman, M. S. (2009). Water quality and heavy metal concentrations in sediment of Kelantan, Kelantan, Malaysia: A baseline study. *Sains Malaysiana, 38*(4), 435-442.

Al-Badaii, F., Shuhaimi-Othman, M., & Gasim, M. B. (2013). Water quality assessment of the Semenyih River, Selangor, Malaysia. *Journal of Chemistry*, *2013*, 1-10.

Alfred-Ockiya, J. F. (2000). Study of food habits of goby, *Porogobius schlegelli* (Gunther, 1861) from Elechi Creek, off Bonny River, Niger Delta, Nigeria. *Journal of Aquatic Science*, *16*, 79-82.

Ali, A., Mohammad, S. K., Mashor, M., & Mohammad, H. M. B. (1988). Fish population distribution in the Perak River: A Comparative study. *Proc. 11th Annual Seminar of the Malaysian Society of Marine Science*. 67-81.

Alam, M., Sharma, S., & Pathak, J. K. (2011). Food preferences of *Labeo rohita* (Hamilton) in River Ramganga, Uttar Pradesh, India. *International Journal of Fisheries and Aquaculture Sciences*, *1*(2), 99-105.

Amin, S. M. N., Ara, R., Mohammad, H., & Arshad, A. (2014). Food habits of snakehead, *Channa striatus* (Bloch), in the lotic streams of Universiti Putra Malaysia, Malaysia. *Journal of Food, Agriculture and Environment, 12*(2), 979-981.

Amneera, W. A., Wahidatul, A. Z. N., Rawdhoh, M. Y., & Ragunathan, S. (2013). Water quality index of Perlis River, Malaysia. *International Journal of Civil & Environmental Engineering*, *13*(2), 1-6.

Anene, A., (2005). Condition factors of four cichlid species of a man-made lake in Imo state, Southeast, Nigeria. *Turkish Journal of Fisheries and Aquatic Sicences*, *5*, 43-47.

Angeler, D. G., Allen, C. R., Birge, H. E., Drakare, S., McKie, B. G., & Johnson, R. K. (2014). Assessing and managing freshwater ecosystems vulnerable to environmental change. *Ambio, 43,* 113-125.

APHA. (2005). *Standard methods for the examination of water and wastewater* (21th ed.). Washington, DC: American Public Health Association.

Ara, R., Arshad, A., Amin, S. M. N., Daud, S. K., Bujang, J. S., & Ghaffar, M. A. (2010). Feeding habits of larval fishes of the family Gobiidae (Actinopterygii: Perciformes) in seagrass beds of Sungai Pulai estuary, Johor Strait, Malaysia. *Coastal Marine Science, 34*(1), 123-128.

Arockiaraj, A. J., Haniffa, M. A., Seetharaman, S., & Singh, S. P. (2004). Indices and fecundity of threatened freshwater catfish *Mystus Montanus*. *Journal of the Indian Fisheries Association*, *31*, 87-96.

Arruda, L. M., Azevedo, I. N. & Neto, A. I., (1993). Abundance, Age Structure and Growth, and Reproduction of Gobies in the Riade Avciro Lagoon (Portugal). *Estuarine, Coast and Shelf Science*, *37*, 509-523.

Arthington, A. H., Dulvy, N. K., Gladstone, W., & Windfield, I. J. (2016). Fish Conservation in Freshwater and Marine Realms: Status, Threats and Management. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(5), 838-857.

Aryani, N., Suharman, I., & Hasibuan, S. (2016). Length-weight relationship and condition factor of the critically endangered fish of Geso, *Hemibagrus wyckii* (Bleeker, 1858) bagridae from Kampar Kanan River, Indonesia. *Journal of Entomology and Zoology Studies*, *4*(2), 119-122.

Azmir, I. A., & Samat, A. (2010). Diversity and distribution of stream fishes of Pulau Langkawi, Malaysia. *Sains Malaysiana*, *39*(6), 869-875.

Bachok, Z., Mansor, M. I., & Noordin, R. M. (2004). Diet composition and food habits of demersal and pelagic marine fishes from Terengganu waters, east coast of Peninsular Malaysia. *NAGA, World Fish Center Quarterly, 27*(3), 41-47.

Badamasi, I. (2014). Distribution of stomach food content of fish species collected from industrial waste water effluents a case study of Jakara Dam, Kano, Nigeria. *International Journal of Innovation, Management and Technology, 5*(2), 124-129.

Bagenal, T. B., & Tesch, F. W. (1998). *Age and growth*. Oxford: Blackwell Scientific Publications.

Balik, I., Karasahin, B., Ozkok, R., Cubuk, H., & Uysal, R., (2003). Diet of silver crucian carp, *Carassius gibelio* in Lake Egirdir. *Turkish Journal of Fisheries and Aquatic Sciences, 3*, 87-91.

Behar, S. (1997). Testing the waters: Chemical and Physical Vital Signs of a River. Montpelier: River Watch Network.

Begum, M., Alam, M. J. Islam, M. A & Pal, H. K. (2008). On the Food and Feeding Habit of an Estuarine Catfish (*Mystus gulio*, Hamilton) in the South West Coast of Bangladesh. *University Journal of Zoology Rajshahi University*, *27*, 91-94.

Berry, W., Rubinstein, N., Melzian, B., & Hill, B. (2003). The biological effects of suspended and bedded sediment (SABS) in aquatic systems: a review. US Environment Protection Agency, National Health and Environmental Health Effects Laboratory, Rhode Island, USA.

Bhat, A. (2004). Patterns in the Distribution of Freshwater Fishes in Rivers of Central Western Ghats, India and Their Association with Environmental Gradients. *Hydrobiologia, 529*, 83-97.

Bhatnagar, A. & Garg, S. K., (2000). Causative Factors of Fish Mortality in Still Water Fish Ponds Under Subtropical Conditions. *Aquaculture*, *1*(2), 91-96.

Bhatti, M. T., & Latif, M. (2011). Assessment of water quality of a river using an indexing approach during the low-flow season. *Irrigation Drainage*, *60*, 103-114.

Bilotta, G. S., & Brazier, R. E. (2008). Understanding the influence of suspended solids on water quality and aquatic biota. *Water Research*, *42*, 2849-2861.

Blaber, S. J. M. (2000). *Tropical Estuarine Fishes: Ecology, Exploitation and Conservation*. Oxford: Blackwell Science.

Bouchard, R. W., Jr. (2004). *Guide to aquatic macroinvertebrates of the Upper Midwest*. University of Minnesota, St. Paul, MN: Water Resources Center.

Boyd, C. E., & Tucker, C. S. (1998). *Pond aquaculture and water quality management*. London: Kluwer Academic Publication.

Brett, J. R., & Higgs, D. A. (2011). Effect of Temperature on the rate of gastric digestion in fingerling sockeye salmon, *Oncorhynchus nerka*. *Journal of the Fisheries Research Board of Canada*, *27*(10), 1767-1779.

Casatti, L., & Castro, R. M. C. (2006). Testing the ecomorphological hypothesis in a headwater riffles fish assemblage of the São Francisco River, southeastern Brazil. *Neotropical Ichthyology*, *4*, 203-214.

Cerda, J. B, Calman, G, Lafleur, Jr, & Limesand, G. J. (1996). Pattern of Vitellogenesis and Follicle Maturational Competence during the Ovarian Follicular Cycle of Fundulus heteroclitus. *General and Comparative Endocrinology*, *103*(1), 24-35.

Coen, L. D. (1995). A review of the potential impacts of mechanical harvesting on subtidal and intertidal shellfish resources. South Carolina Division of Natural Resources, Marine Resources Research Institute, James Island, South Carolina, 46.

Chong, V. C., Lee, P. K., & Lau, C. M. (2010). Diversity, extinction risk and conservation of Malaysians fishes. *Journal of Fish Biology*, *76(*9), 2009-2066.

Chow, V. K. K., Said, M. I. M., Mohamed, M., & Sabri, S. (2016). Species Composition and Abundance of Freshwater Fishes in Selected Rivers of Johor, Malaysia. *International Journal of Research in Chemical, Metallurgical and Civil Engineering, 3*, 214-218.

Cleophas, F. N., Isidore, F., Lee, K. H., & Bidin, K. (2013). Water quality status of Liwagu River, Tambunan, Sabah, Malaysia. *Journal of Tropical Biology and Conservation*, *10*, 67-73.

Das, J., & Acharya, B. C. (2003). Hydrology and assessment of lotic water quality in Cuttack city, India. *Water, Air, and Soil Pollution*, *150*, 163-175.

Djumanto, D., & Setyawan, F. (2009). Food habits of the hellow hasbora, *Rasbora Lateristriata*, (family: cyprinidae) broodfish during moving to spawning ground. *Jurnal Perikanan Universitas Gadjah Mada*, *11*(1), 107-116.

Dodson, S. (2005). *Introduction to limnology.* New York: McGraw-Hill.

Du, X. T., Zhu, B. K., Zhang, J. B., & Tian, Z. F. (2010). Feeding habits of *Hemibagrus pluriradiatus* (Vaillant) in Yuanjiang River. *Journal of Hydroecology*, *3*(1), 38-43.

Dubey, V. K., Sarkar, U. K., Pandey, A., Sani, R., & Lakra, W. S. (2012). The influence of habitat on the spatial variation in fish assemblage composition in an unimpacted tropical River of Ganga basin, India. *Aquatic Ecology*, *46*, 165-174.

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., K., Nowler, D. J., Leveque, C., Naiman, R. J., Prieur-Richard, A., Soto, D., Stiassny, M. L. J., & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol Rev Camb Philos* Soc, *81*(2), 163-8.

Ekpo, I. E., Essien-Ibok, M. A & Nkwoji, J. N. (2014). Food and feeding habits and condition factor of fish species in Qua Iboe River estuary, Akwa Ibom State, southeastern Nigeria. *International Journal of Fisheries and Aquatic Studies*, *2*(2), 38-46.

Ellender, B. R., & Weyl, O. L. F. (2015). Resilience of imperilled headwater stream fish to an unpredictable high-magnitude flood. Resilience of Koedoe *57*(1), Art. #1258, 8 pages. http://dx.doi.org/10.4102/koedoe.v57i1.1258.

Fagade, S. O., & Olaniyan, C. I. O. (1972). The biology of the West African shad, *Ethmalosa fimbriata* (Bowdich) in the Lagos lagoon, Nigeria. *Journal of Fish Biol*ogy, *4*, 519-533.

Fedor, P. J., & Spellerberg, I. F. (2013). Reference Module in Earth Systems and Environmental Sciences. Elsevier.

Finger, T. R. (1982). Fish community habitat relations in central New York stream. *Journal of Freshwater Ecology*, *1*, 343-52.

Froese. R. (2006). Cube law, condition factor and weight–length relationships: History, meta-analysis and recommendations. *Journal of Applied Ichthyology*, *22*, 241-253.

Galactos, K., Barriga-Salazar, R., & Stewart, D. J. (2004). Seasonal and habitat influences on fish communities within the lower Yasuni River basin of the Ecuadorian Amazon. *Environmental Biology of Fishes*, *71*, 33-51.

Gophen, M. (1998). From Natural to Man-Made Hula Wetland (Israel) (1950-1998): Utilization and nutrient removal. In S. M. T. Tornisielo (Ed.). Proceedings of the 6th International Conference on Wetland Systems for Water Pollution Control, Sao Paulo, 27th September-2nd October, 195-205.

Gosomji, A. D., & Okooboh, M. A. (2013). Determination of the concentration of dissolved oxygen in water samples from Pankshin Town to monitor water pollution. *Chemistry and Materials Research*, *3*(3), 13-16.

Grenouillet, G., Pontand, D., & Herisse, C. (2004). Within-basin fish assemblage structure: the relative influence of habitat versus stream spatial position on local species richness. *Canadian Journal of Fish Aquatic Science*, *61*, 93-102.

Hamid, M. A., Bagheri, S., Nor, S. A. M., & Mansor, M. (2015). A comparative study of seasonal food and feeding habits of beardless barb, *Cyclocheilichthys apogon* (Valenciennes, 1842), in Temengor and Bersia Reservoirs, Malaysia. *Iranian Journal of Fisheries Sciences*, *14* (4) 1018-1028.

Harris, J. H. (1995). The use of fish in ecological assessments. *Australian Journal of Ecology*, *20*, 65-80.

Hashim, Z. H., Zainuddin, R. Y., Shah, A. S. R. M., Sah, S. A. M., Mohammad, M. S., & Mansor, M. (2012). Fish checklist of Perak River, Malaysia. *Journal of Species Lists and Distribution*, *8*(3), 408-413.

Hassan, R., Esa, F. A., & Harith, M. N. (2010). Fish assemblages in Nanga Merit area, Kapit, Sarawak. *The Sarawak Museum Journal*, *88*, 275-284.

Hasyimah, N. R., Syakira, M. H., Syahril, M. Z., Samat, A., & Iwana, I. (2013). Water quality, diversity and distribution of freshwater fishes in Negeri Sembilan. *Journal of Academia*, *3*, 10-19.

Hismayasari, I. B., Marhendra, A. P. W., Rahayu, S, S., & Supriyadi, D. S. (2015). Gonadosomatic index (GSI), Hepatosomatic index (HSI) and proportion of oocytes stadia as an indicator of rainbowfish *Melanotaenia boesemani* spawning season. *International Journal of Fisheries and Aquatic Studies*, *2*(5), 359-362.

Horwitz, R. J. (1978). Temporal variability patterns and the distributional patterns of stream fishes. *Ecology Monographs*, *48*, 307-312.

Hossain, M. Y., Ahmed, Z. F., Leunda, P. M., Jasmine, S., Oscoz, J., Miranda, R., & Ohtomi, J. (2006). Condition, length–weight and length–length relationships of the Asian striped catfish *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae) in the Mathabhanga River, southwestern Bangladesh. *Journal Applied Ichthyology*, *22*, 304-307.

Hynes, H. B. N. (1950). The food of freshwater sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of food fishes. *Journal of Animal Ecology*, *19*, 36-58.

Iglesias-Rios, R & Mazzoni, R. (2014). Measuring Diversity: Looking for Processes That Generate Diversity. *Brazillian Journal of Nature Conservation, 12*(2), 156-161.

Ikhwanuddin, M. E. M., Amal, M. N. A., Hasan, S. S. H. H., & Jamil, N. R. (2016). Environmental Influences on Fish Assemblages of the Upper Sungai Pelus, Kuala Kangsar, Perak, Malaysia. *Sains Malaysiana*, *45*(10), 1487-1495.

Inger, R. F., & Chin, P. K. (2002). *The freshwater fishes of North Borneo.* (Revised edition with supplementary chapter by P.K. Chin). Kota Kinabalu, Malaysia: Natural History Publication (Borneo).

Iqbal, F., Ali, M., Salam, A., Khan, B. A., Ahmad, A., Qamar, M., & Umer, K. (2004). Seasonal variations of physico-chemical characteristics of River Soan Water at Dhoak Pathan Bridge (Chakwal), Pakistan. *International Journal of Agriculture & Biology, 6*(1), 89-92.

Isa, M. M., Rawi, C. S. M., Rosla, R., Shah, S. A. M., & Shah, A. S. R. M. (2010). Length-weight relationships of freshwater fish species in Kerian River Basin and Pedu Lake. *Research Journal of Fisheries and Hydrobiology*, *5*(1), 1-8.

Iyabo, U. B. (2016). Food and feeding habit and condition factor of tilapia species in Ebonyi River, Southeastern Nigeria. *American Association for Science and Technology*, *3*(6), 248-253.

Izzati, A. A., & Samat, A. (2010). Diversity and distribution of stream fishes of Pulau Langkawi, Malaysia. *Sains Malaysian*, *39*(6), 869-875.

Jeffrine, R. R. J., Dennis, K. P., Khairul-Adha, A. R., & Yuzine, E. (2009). Freshwater fishes of Layar and Spak Rivers, Betong, Sarawak. *Malaysia Fisheries Journal*, *8*(1), 35-42.

Job, B. E. (2006). Food, feeding and condition factor of the brackish river prawn *Macrobrachium macrobradion* (Herklots, 1851) (Crustacea, Palaemonedae) in the Cross River Estuary, Southeast Nigeria. Proceedings of the 21st Annual Conference of the Fisheries Society of Nigeria (FISON) Cala-bar, 13th- 17th November, pp. 137-143.

Jobling, M. (2002). *Environmental factors and rates of development and growth. In*: *P J B Hart and J D Reynolds (Eds.). Handbook of fish biology and fisheries, vol. 1.* Oxford, UK: Blackwell Publishing.

Jost, L. (2010). The Relation between Evenness and Diversity. *Diversity 2,* 207-232.

Juahir, H., Zain, S. M., Yusoff, M. K., Hanidza, T. I. T., Armi, A. S. M., Toriman, M. E., & Mokhtar, M. (2011). Spatial water quality assessment of Langat River basin (Malaysia) using environmetric techniques. *Environmental Monitoring Assessment*, *173*, 625-641.

Juliana, S. (2014). Fish Composition and Fisheries at Downstream and Upstream of Baram River. Final year project report, Aquatic Resource Science and Management Program, Universiti Malaysia Sarawak, Kota Samarahan.

Kalny, G., Laaha, G., Melcher, A., Trimmel, H., Weihs, P., & Rauch, H. P. (2017). The influence of riparian vegetation shading on water temperature during low flow conditions in a medium sized river. *Knowledge & Management of Aquatic Ecosystems, 418*(5), 1-14.

Kamaruddin, I. S., Kamal, A. S. M., Christianus, A., Daud, S. K., & Yu Abit, L. (2011). Fish community in Pengkalan Gawi- Pulau Dula section of Kenyir Lake, Terengganu, Malaysia. *Journal of Sustainability Science and Management*, *1*(6), 89-97.

Keat-Chuan, N. C., Aun-Chuan, O. P., Wong, W. L., & Khoo, G. (2017). An overview of the status, trends and challenges of freshwater fish research and conservation in Malaysia. *Journal of Survey in Fisheries Sciences*, *3*(2), 7-21.

Kemenes, A., & Forsberg, B. R. (2014). Factors influencing the structure and spatial distribution of fishes in the headwater streams of the Jaú River in the Brazilian Amazon. *Brazilian Journal of Biology, 74*(3), 23-32.

Khairul-Adha, A. R., Siti, A. K., Siti, S. S., Aziz, A., Yuzine, E., & Eza, R. I. (2009). Freshwater fish diversity and composition in Batang Kerang floodplain, Balai Ringin, Sarawak. *Pertanika Journal of Tropical Agricultural Science, 32*(1), 7-16.

Khajuria, B., Langer, S., & Sharma, R. (2014). Length weight relationship and condition factor of *Tor putitora* from Jhajjar stream. *International Journal of Scientific & Engineering Research, 5*(2), 567-572.

Khallaf, E., Galal, M., & Athuman, M. (2003). The biology of *Oreochromis niloticus* in a polluted canal. *Ecotoxicology, 12*, 405-416.

Khan, M. A., Khan, S., & Miyan, K. (2012). Studies on length-weight and length-length relationships of four freshwater fishes collected from River Ganga. *Journal of Fisheries and Aquatic Science, 7,* 481-484.

King, M., (2007). Fisheries biology, assessment and management. USA: Wiley-Blackwell.

Kjelland, M. E., Woodley, C. M., Swannack, T. M., & Smith, D. L. (2015). A review ofthe potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. *Environment System and Decision, 35,* 334-350.

Knight, A. W., & Bottoroff, R. L. (1981). The Importance of Riparian Vegetation to Stream Ecosystem. California Riparian System Conference. pp. 160-167.

Kottelat, M., Whitten, T., Kartikasari, S. N., & Wirjoatmodjo, S. (1993*). Freshwater fishes of western Indonesia and Sulawesi*. Singapore: Periplus Publisher.

Kottelat, M., & Lim, K. K. P. (1995). Freshwater fishes of Sarawak and Brunei Darussalam: A preliminary annotated checklist. *The Sarawak Museum Journal*, *69*, 228-256.

Kottelat, M., & Whitten, A. J. (1996). Freshwater biodiversity in Asia with special reference to fish. *World Bank Technical Paper, 343,* 1-59.

Kwak, J., Khang, B., Kim, E., & Kim, H. (2013). Estimation of Biochemical Oxygen Demand Based on Dissolved Organic Carbon, UV Absorption, and Fluorescence Measurements. *Journal of Chemistry, 2013,* 1-9.

Lagler, K. F. (1949). *Studies in freshwater biology*. Michigan: An Arbor.

Lee, K. D. Y., Yeo, M. E., & Khan, M. S. (1993). Database of Freshwater Fish of Peninsular Malaysia. AWB Publication No. 93, Kuala Lumpur, Malaysia.

Le Cren, E. D. (1951). The length-weight relationships and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal Animal Ecology, 20,* 201-219.

Lim, K. K. P., Ng, P. K. L., Kottelat, M., & Zakaria-Ismail, M. (1993). A preliminary working list of native freshwater fishes of Peninsular Malaysia. AWB Publication No. 94, Kuala Lumpur, Malaysia.

Lima-Junior, S. E., & Gotein, R. (2001). A new method for the analysis of fish stomach content. *Acta Scientiarum, 2*(23), 421-424.

Lynch, J. A., Rishel, G. B., & Corbett, E. S. (1984). Thermal alterations of streams draining clearcut watersheds: Quantification and biological implications. *Hydrobiologia, 11,* 161-169.

Mac Gregoer, J. S. (1959). Relation between fish condition and population size in the sardine (*Sardinops cacrulea*). U.S. Fishery Wild Service, Fish Bulletin. *60*, 215-230.

Magurran, A. E. (1988). *Ecological diversity and its measurement*. Princeton: Princeton University Press.

Mansor, M., Said, I. Mohamad, I. (2010). Experiential contact with green infrastructure's diversity and well-being of urban community. *Asian Journal of Environment-Behaviour Studies, 1*(3), 33-48.

Margalef, R. (1958). Information Theory in Ecology. *General System, 3,* 36-71.

Martin-Smith, K. M. (1996). Length-weight relationships of fishes in a diverse tropical freshwater community, Sabah, Malaysia. *Journal of Fish Biology, 49,* 731-734.

May, J. T., & Brown, L. R. (2002). Fish communities of the Sacramento River basin: Implications for conservation of native fishes in the Central Valley, California. *Environmental Biology of Fishes, 63*, 373-388.

Melo, C. E., Machado, F. A., & Pinto-Silva, V. (2004). Feeding habits of fish from a stream in the Savanna of Central Brazil, Araguaia Basin. *Neotropical Ichthyology*, *2*(1), 37-44.

Meyer, J. L., Strayer, D. L., Wallace, J. B., Eggert, S. L., Helfman, G. S. & Leonard, N. E. (2007). The contribution of headwater streams to biodiversity in river networks. *Journal of the American Water Resources Association, 4*3, 86–103.

Mwagi, B. M., Ombogo, M. A., Amadi, J., Baker, N., & Mugalu, D. (2012). Fish species composition and diversity of small riverine ecosystems in the Lake Victoria Basin, Kenya. *International Journal of Science and Technology, 2*(9), 675-680.

Mohsin, A. K. M., & Ambak, M. A. (1983). *Freshwater fishes of Peninsular Malaysia.* Selangor: Penerbit Universiti Pertanian.

Muchlisin, Z. A., Batubara, A. S., Siti-Azizah, M. N., Adlim, M., Hendri, A., Fadli, N., Muhammadar, A. A., & Sugianto, S. (2014). Feeding habit and length weight relationship of keureling fish, *Tor tambra* Valenciennes, 1842 (Cyprinidae) from the western region of Aceh Province, Indonesia. *Biodiversitas*, *16*(1), 89-94.

Mustafa-Kamal, A. S., Kamaruddin, I. S., Christianus, A., Daud, S. K., & Yu-Abit, L. (2012). Feeding habits of fishes in the Pengkalan Gawi–Pulau Dula section of Kenyir Lake Terengganu, Malaysia. *Asian Fisheries Science*, *25*, 144-157.

Naigaga, I., Kaiser, H., Muller, W. J., Ojok, L., Mbabazi, D., Magezi, G., & Muhumuza, E. (2011). Fish as bioindicator in aquatic environmental pollution assessment: A case study in Lake Victoria Wetlands, Uganda. *Physic and Chemistry of the Earth*, *36*, 918-928.

Negi, R. K., & Mamgain, S. (2013). Species Diversity, Abundance and Distribution of Fish Community and Conservation Status of Tons River of Uttarakhand State, India. *Journal of Fisheries and Aquatic Science, 8*(5), 617-626.

Nehemia, A., Maginira, J. D., & Rumisha, C. (2012). Length-weight relationship and condition factor of tilapia species grown in marine and freshwater pond. *Agriculture and Biology Journal of North America*, *3*(3), 117-124.

Nelson, J. S., Grande, T. C., & Wilson, M. V. H. (2016). Fishes of the World, 5th edn. Hoboken, New Jersey: John Wiley & Sons.

Ngueku, B. B. (2014). Water monitoring in fish ponds. *International Journal of Fisheries and Aquatic Studies*, *2*(3), 31-32.

Nguyen, T. T. T. (2008). Population structure in the highly fragmented range of *Tor douronensis* (Cyprinidae) in Sarawak, Malaysia revealed by microsatellite DNA markers. *Freshwater Biology, 53*(5), 924-934.

Nikol'skii, G. V. (1963). *The ecology of fishes*. New York: Academic Press.

Northcote T. G., & Hartman, G. F. (2004). *Fishes and Forestry*. Worlwide Watershed Interactions and Management. Oxford: Blackwell Science.

Nyanti, L., Ling, T. Y., & Khairul-Adha, A. R. (1999). Freshwater fishes from Bario, Kelabit Highlands Sarawak. *ASEAN Review of Biodiversity and Environmental Conservation*, *4,* 1-6.

Nyanti, L., Ling, T. Y., & Jongkar, G. (2012). Fish and crustacean communities and fish length-weight relationship of Lutong River, Miri, Sarawak, Malaysia. *World Journal of Fish and Marine Sciences*, *4*(1), 102-110.

Nyunja J. A., Mavuti K. M., & Wakwabi, E. O., (2002). Tropic ecology of *Sardinella gibbosa* (Pisces: Clupeidae) and *Atherinomorous lacunosus* (Pisces: Atherinidae) in Mtwapa Creek and Wasini Channel, Kenya. *Western Indian Ocean Journal of Marine Science, 1*, 181-189.

Noggle, C. C. (1978). Behavior, physiological and lethal effects of suspended sediment on juvenile salmonids. MSc. thesis, University of Washington, Seattle, WA.

Olojo, E. A., Olurin, K. B., & Osiikoya, O. J. (2003). Food and feeding habit of *Synodontis nigrita* from the Osun River, SW Nigeria. NAGA. *World Fish Centre Quarterly, 26*, 421-424.

Oronsaye, C. G., & Nakpodia, F. A. (2005). A comparative study of the food and feeding habits of *Chrysichthys nigrodigitatus* and *Brycinus nurse* in a tropical river. *Pakistan Journal of Scientific and Industrial Research*, *48*(2), 118-121.

Packman, J. J., Comings, K. J., & Booth, D. B. (1999). Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands: in confronting uncertainty: Managing Change in Water Resources and the Environment, Canadian Water Resources Association annual meeting, Vancouver, BC, 27-29 October 1999, 158-165.

Pang, X., Zheng-Dong, C., & Shi-Jian, F. (2011). The effects of temperature on metabolic interaction between digestion and locomotion in juveniles of three cyprinid fish (*Carassius* *auratus, Cyprinus carpio*, and *Spinibarbus sinensis*). *Comparative Biochemistry and Physiology*, *159*, 253-260.

Parenti, L. R., & Lim, K. K. P. (2005). Fishes of Rajang Basin, Sarawak, Malaysia. *The Raffles Buletin of Zoology*, *13*, 175-208.

Pait, A. S., & Nelson, J. O. (2003). Vitellogenesis in Male *Fundulus heteroclitus* (Killifish) Induced by Selected Estrogenic Compounds. *Aquatic Toxicology*, *64*, 331-342.

Pathak, B. C., & Serajuddin, M. (2015). A Comparative Study of length-weight relationship and condition factor of lesser spiny eel, *Macrognathus aculeatus* (Bloach) from the different river basins of India. *World Journal of Fish and Marine Sciences*, *7*, 82-86.

Paugy, D. (2002). Reproductive strategies of fishes in a tropical temporary stream of the Upper Senegal basin: Baoule River in Mali. *Aquatic Living Resources*. *15*(1), 25-35.

Pauly, D. (1993). Linear regressions in fisheries research. *Journal of the Fisheries Research Board of Canada*, *30*, 409-434.

Penn, M. R., Pauer, J. J., & Mihelcic, J. R. (2006). In *Encyclopedia of Life Support Systems online*. Retrieved from http://www.eolss.net/sample-chapters/c06/e6-13-04-03.pdf.

Pielou, E. C. (1966). Species Diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology*, *10*, 370-383.

Pimple, N. S., & Kharat, S. S (2014). The Study of Gonadosomatic Index (GSI) and Fecundity of Rohtee ogilbii (sykes 1839) from Nira River Bhor, District Pune, (Maharashtra) India. *World Journal of Pharmaceutical Research*, *3*(10), 1277-1283.

Pough, F. H., Christine M. J., & Heiser. J. B. (2009). Vertebrate Life 8th edition. San Francisco, CA: Pearson Education, Inc.

Poxton, M. G., & Allouse, S. B. (1982). Water quality criteria for marine fisheries. *Aquaculture Engineering*, *1*(3), 153-191.

Prasad, G., & Ali, P. H. A. (2007). Length-weight relationship of a cyprinid fish *Puntius filamentosus* from Chalakudy River, Kerala. *Zoos' Print Journal*, *22*(3), 2637-2638.

Rajan, D. S. (2015). An assessment of the biological oxygen demand of Thekkumbhagam creek of Ashtamudi estuary. *International Journal of Fisheries and Aquatic Studies*, *2*(6), 395-397.

Resh, V. H., Brown, A. V, Covich, A. P., Gurtz, M. E., Li H. W., & Minshall, G. W. (1988). The Role of Disturbance in Stream Ecology. *Journal of the North American Benthological Society*, *7*, 433–455.

Riedel, R., Caskey, L. M., & Hurlbert, S. H. (2007). Length-weight relations and growth rates of dominant fishes of the Salton Sea: Implications for predation by fish-eating birds. *Lake and Reservoir Management*, *23*, 528-535.

Roberts, T. R. (1989). *The freshwater fishes of western Borneo*. San Francisco, USA: California Academy of Science.

Rosli, N., Gandaseca, S., Ismail, J., & Jailan, M. I. (2010). Comparative study of water quality at different peat swamp forest of Batang Igan, Sibu Sarawak. *American Journal of Environmental Sciences*, *6*(5), 416-421.

Rosnani, I. (2001). River water quality status in Malaysia. In Proceedings national conference on sustainable river basin management in Malaysia, 13-14 November 2000, Kuala Lumpur, Malaysia.

Rowe, D. K., & Dean, T. L. (1998). Effects of turbidity on the feeding ability of the juvenile migrant stage of six New Zealand freshwater fish species. *New Zealand Journal of Marine and Freshwater Research, 32*, 21-29.

Royle, W. (2001). Observation on feeding habits of Clarias barrage experimental pond found in food scheme. *Technology*, *5*(2), 76-79.

Sadekarpawar, S., & Parikh, P. (2013). Gonadosomatic and hepatosomatic indices of freshwater fish *Oreochromis mossambicus* in response to a plant nutrient. *World Journal of Zoology 8*(1), 110-118.

Salam, M. N. A., & Gopinath, N. (2006). Riverine and fisheries in Malaysia: An ignored resource. *Aquatic Ecosystem Health & Management*, *9*(2), 159-164.

Samat, A., Shukor, M. N., Siti-Farahayu, A. B., & Mazlan, A. G. (2005). A snapshot study on community structure of fishes inhabiting a small forest stream of Sungai Rengit in Krau Wildlife Reserve, Pahang Malaysia. *Journal of Wildlife and Parks, 22*, 97-109.

Schlosser, I. J. (1982). Fish community structure and function along two habitat gradients in a headwater stream. *Ecological Monograph*, *52*, 395-414.

Schneider, J. C., Laarman, P. W., & Gowing, H. (2000). Length-weight relationships. In: Schneider, J.C. (Eds.). *Manual of fisheries survey methods II: with periodic updates.* Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Shannon, C. E., & Weaver, W. (1963). *The mathematical theory of communication.* Urbana, USA: University of Illinois Press.

Sharma, P., & Gupta, S. (2014). Study of amount of oxygen (BOD, OD, COD) in water and their effect on fishes. *American International Journal of Research in Formal, Applied & Natural Sciences, 7*(1), 53-58.

Shinkafi, B. A., & Ipinjolu, J. K. (2012). Gonadosomatic index, fecundity and egg size of *Auchenoglanis occidentalis* (Cuvier and Valenciennes) in River Rima, North-Western Nigeria. *Nigerian Journal of Basic and Applied Science, 20*(3): 217-224.

Strum, L. M. G. (1978). Aspects of the biology of *Scombemorus maculates* (Mitchill) in Trinidad. *Journal of Fish Biology, 13*, 155-172.

Sulistiyarto, B. (2013). The relationship between the distribution of *Rasbora Argyrotaenia* and the population of in floodplain of Rungan River Kalimantan Tengah. *Journal of Tropical Animal Science, 2*(1), 27-30.

Tan, H. H. (2006). *The Borneo suckers. Kota Kinabalu*. Borneo, Malaysia: Natural History Publications.

Tyler, A. V., & Dunns, R. S. (1976). Ration, growth and measures of somatic and organ condition in relation to meal frequency in winter flounder, Pseudopleuronectes americanus, with hypothesis regarding population homeostasis. *Journal Fisheries Resource Biology Canada, 33*, 63-75.

Taylor, R. S. (1989). A survey of fish fauna of the Tabin Wildlife Reserve, Sabah. *Sabah Museum Monograph, 3*, 87-99.

Taylor, C. M., Winston, M. R., & Matthews, W. J. (1993). Fish species-environment and abundance relationships in a Great Plains river system. *Ecography, 16*, 16-23.

Tesch, F. W. (1971). Age and growth in fish production in freshwaters. Oxford: Blackwell Publisher.

Victor, R. M., Sivakumar, R., & Mathialagan, R. (2014). Food and feeding habit and length-weight relationship of the Asian striped catfish *Mystus vittatus* (Blotch, 1794) (Siluformes: Bagridae) in the Vadavar River, Lower Anicut, Tamil Nadu. *Indian Journal of Science*, *8*, 55-63.

Vidthayanon, C. 2012. *Luciosoma setigerum*. The IUCN Red List of Threatened Species 2012: e. T181231A1711604. Downloaded on 04 February 2018.

Vidthayanon, C. 2012. *Pseudolais micronemus*. The IUCN Red List of Threatened Species 2012: e.T181073A1695516. Downloaded on 04 February 2018.

Walberg, E. (2011). Effect of increased water temperature on warm water fish feeding behavior and habitat use. *Journal of Undergraduate Research at Minnesota State University*, *11,* 1-12.

Ward-Campbell, B. M. S., Beamish, F. W. H., & Kongchaiya, C. (2005). Morphological characteristics in relation to diet in five co-existing Thai fish species. *Journal of Fish Biology*, *67*, 1266-1279.

Watson, D. J., & Balon, E. K. (1984). Ecomorphological analysis of fish taxocenes in rainforest streams in Northern Borneo. *Fish Biology, 25*, 371-384.

Wootton, R. J. Fish ecology. Springer Science & Business Media, 1991.

Ya, N. A., Singh, H. R., Samat, A., Mohammad, H. N., Ramli, N. H., Makhtar, N., & Dzakaria, N. (2015). Length-weight relationship of six fish species from Sepang Besar river estuary, Malaysia. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *1*(1), 27-35.

Yogendra, K., & Puttaiah, E. T. (2008). Determination of Water Quality Index and Suitability of an Urban. Proceedings of Taal 2007: The 12th World Lake Conference, Jaipur, 29th October - 2nd November, pp. 342-346.

Yusoff, F. M., Shariff, M., & Gopinath, N. (2006). Diversity of Malaysian aquatic ecosystems and resources. *Aquatic Ecosystem Health & Management*, *9*(2), 119-135.

Zakaria-Ismail. (1991). Freshwater fishes in Peninsular Malaysia, In: R. Kiew (Ed.), The State of Nature Conservation in Malaysia. Kuala Lumpur: Malayan Nature Society, 115-119.

Zakaria, R., Mansor, M., & Ali, A.B. (1999). Swamp-riverine tropical fish population: A comparative study of two spatially isolated freshwater ecosystems in Peninsular Malaysia. *Wetlands and Ecology Management*, *6*, 261-268.

Zakeyyudin, M. S., Isa, M. M., Rawi, C. S. M., Sah, A. S. R. M., & Ahmad, A. S. (2017). Terrestrial Insects as the Main Food for Freshwater Fish in Sungai Kerian Tributaries: An Implication on Habitat Conservation. *Sains Malaysiana, 46*(6), 833-843.

Zarul, H. H., Shah A. S. R. M., & Khoo, K. H. (2004). Physico-chemical overview of two selected rivers in Temenggor Reservoir. In: Shah ASRM, Chan KY, Zarul Hazrin H, Emi Sherizan AR, Wan Fatma Zuharah WM, Nik Fadzly NR, editors. Proceedings of the 2nd Life Sciences Postgraduate Conference, Life Sciences: The power to explore, discover and stimulate; Universiti Sains Malaysia, Pulau Pinang.

Zulkafli, A. RM. N. A. Amal, M. N. A., Shohaimi, S., Mustafa, A., Ghani, A. H., Hashim, H., Anuar, M. I., & Hasfairi, M. P. Length–weight relationships of 20 fish species from Pahang River, Maran district, Pahang, Malaysia. Journal of Applied Ichthyology, *31*, 409–410.

APPENDICES

Appendix 1: Photo of some fish species caught in Baram River

Fish species: *Puntioplites waandersii*

Fish species: *Hemibagrus planiceps*

Fish species: *Kryptopterus apogon*

Fish species: *Hampala bimaculata*

Fish species: *Barbonymus schwanenfeldii*

Fish species: *Osteochilus enneaporos*

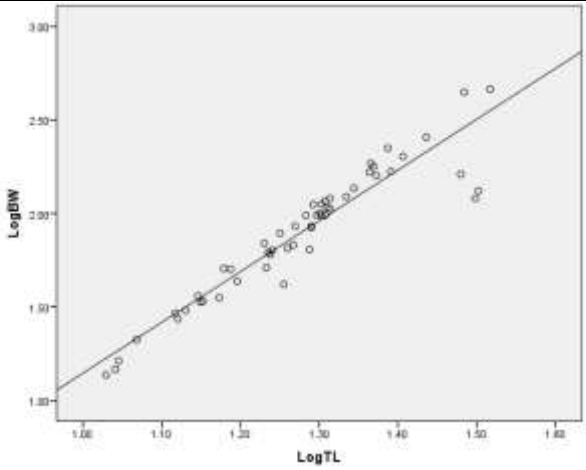
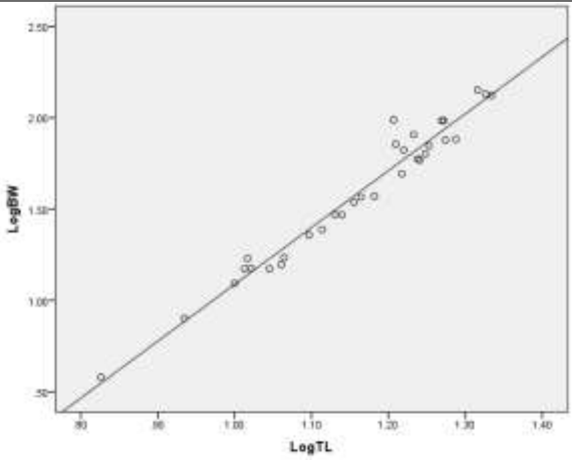
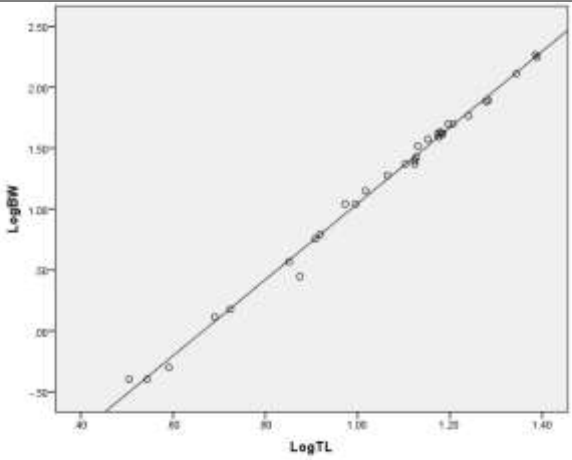
Appendix 2: National Water Quality Standards for Malaysia.

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
Biochemical Oxygen Demand	mg/L	1	3	3	6	12	>12
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	-
Elctrical Conductivity	µS/cm	1000	1000	-	-	6000	-
Total Suspended Solids	Mg/L	25	50	50	150	300	300
Temperature	°C	-	Normal + 2°C	-	Normal + 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-

Water Classes and Uses

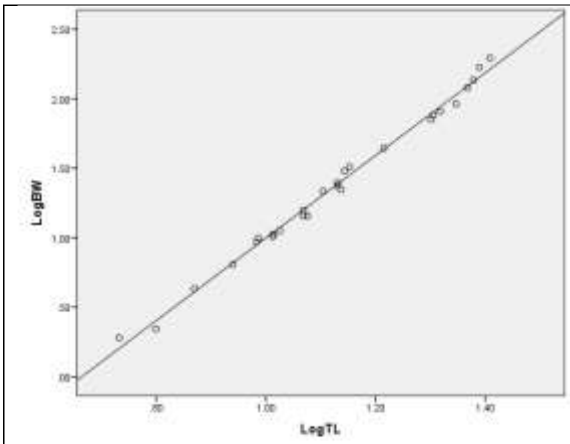
Class	Uses
Class I	Conservation of natural environment. Water Supply I - Practically no treatment necessary. Fishery I - Very sentive aquatic species.
Class IIA Class IIB	Water Supply II- Conventional treatment. Fishery II- Sensitive aquatic species. Recreational use body contact.
Class III	Water Supply 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 3: Length-weight Relationship

	*Barbonymus schwanenfeldii* (Long Kesseh) N = 53 R^2= 0.891 a = 0.027 b = 2.716
	*Barbonymus schwanenfeldii* (Long Apu) N = 32 R^2= 0.963 a = 0.009 b = 3.039
	*Barbonymus schwanenfeldii* (Long San) N = 32 R^2= 0.995 a = 0.008 b = 3.124

Length weight relationship of *Barbonymus schwanenfeldii.*

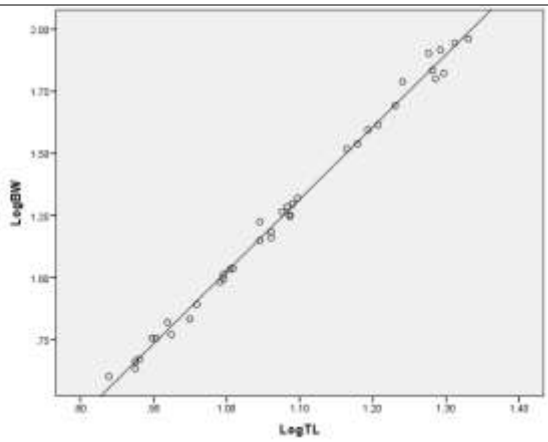
Appendix 3 continued



Osteochilus enneaporos (Long Apu)

N=27 a=0.011

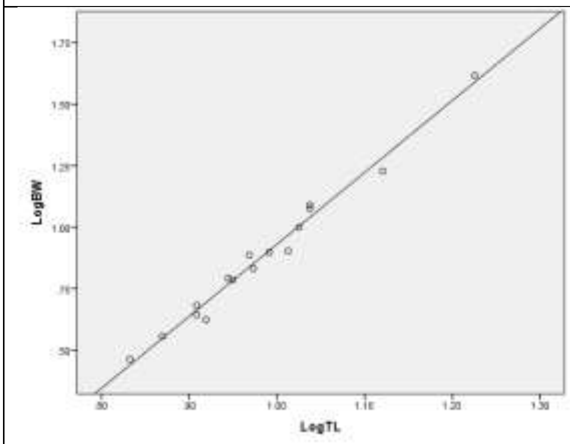
b=2.973 R^2=0.994



Osteochilus enneaporos (Long San)

N=38 a=0.013

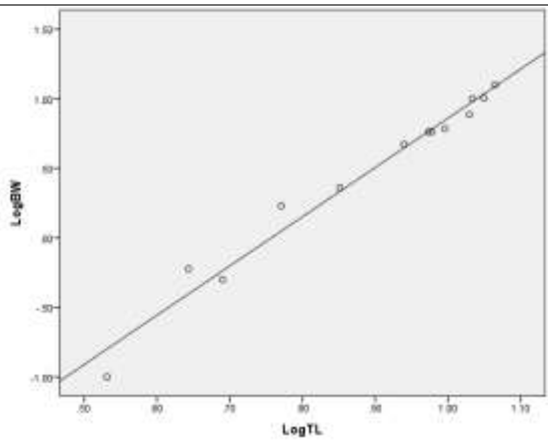
b=2.912 R^2=0.994



Rasbora caudimaculata (Long Apu)

N=16 a=0.010

b=2.927 R^2=0.982



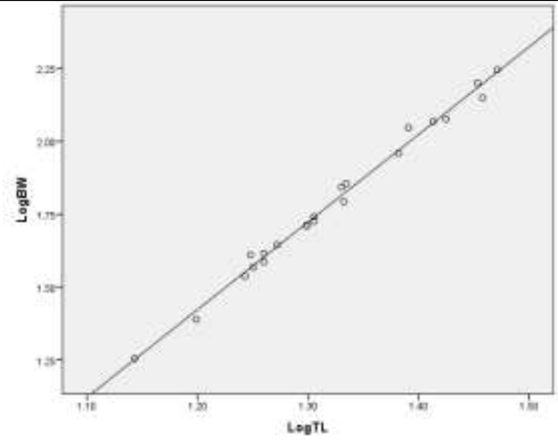
Rasbora caudimaculata (Long San)

N=13 a=0.002

b=3.542 R^2=0.974

Length weight relationship of *Osteochillus enneaporos* and *Rasbora caudimaculata*.

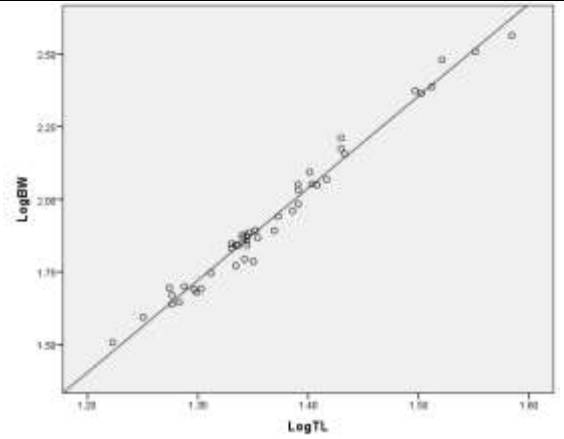
Appendix 3 continued



Pseudolais micronemus (Long Apu)

N=22 a=0.007

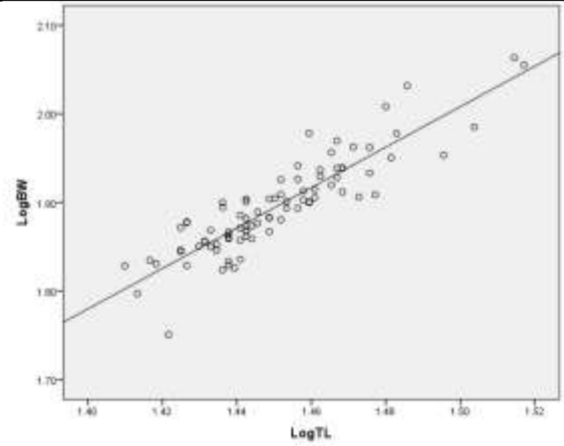
b=3.006 R^2=0.992



Pseudolais micronemus (Long Kesseh)

N=48 a=0.004

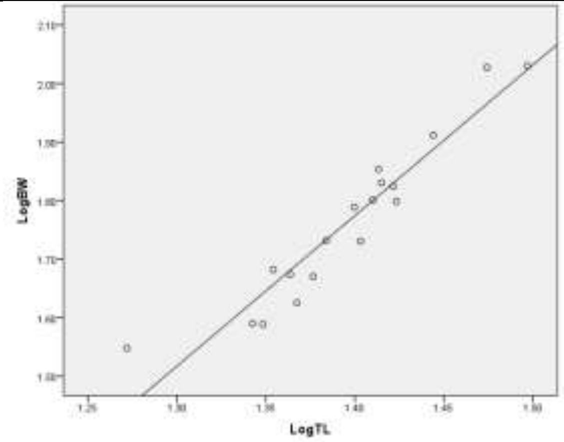
b=3.171 R^2=0.981



Kryptopterus apogon (Lio Mato)

N=88 a=0.005

b=2.866 R^2=0.892



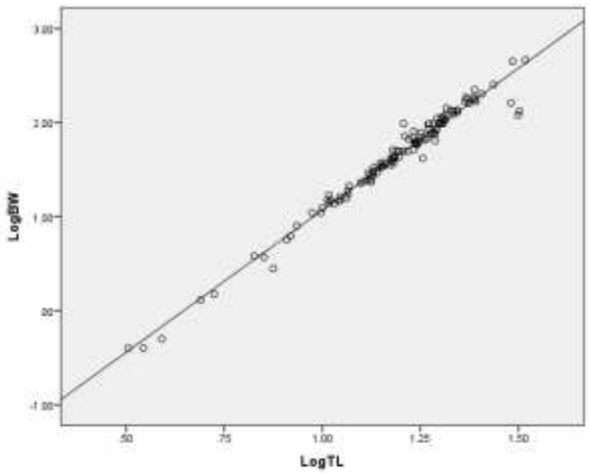
Kryptopterus apogon (Long Apu)

N=18 a=0.015

b=2.570 R^2=0.902

Length weight relationship of *Pseudolais micronemus* and *Kryptopterus apogon.*

Appendix 3 continued

<table>
<tr><td>
</td><td>

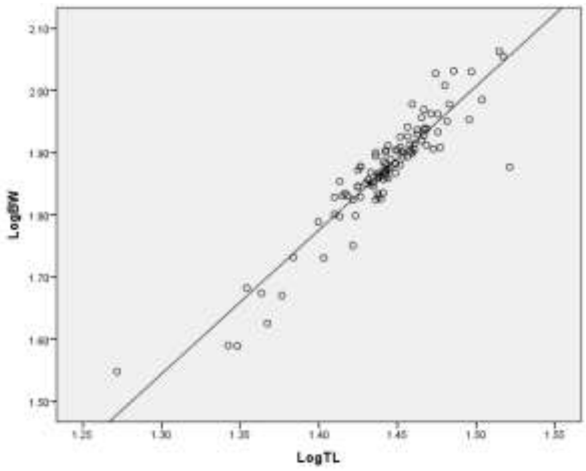
Barbonymus schwanenfeldii

N = 117

R^2= 0.986

a = 0.011

b = 3.024

</td></tr>
<tr><td>
</td><td>

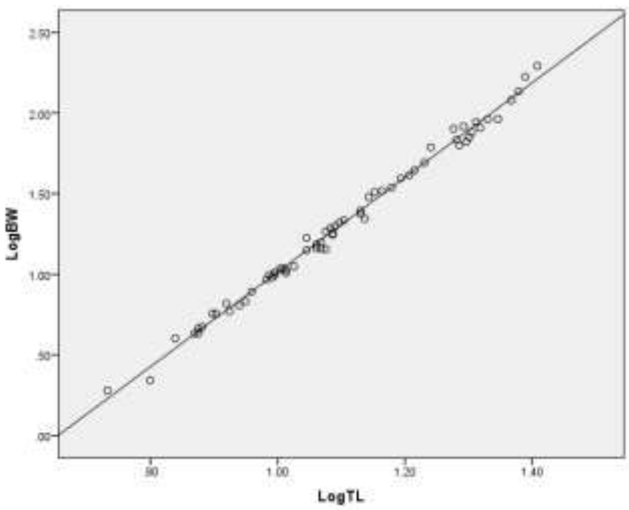
Kryptopterus apogon

N = 106

R^2= 0.928

a = 0.034

b = 2.316

</td></tr>
<tr><td>
</td><td>

Osteochilus enneaporos

N = 65

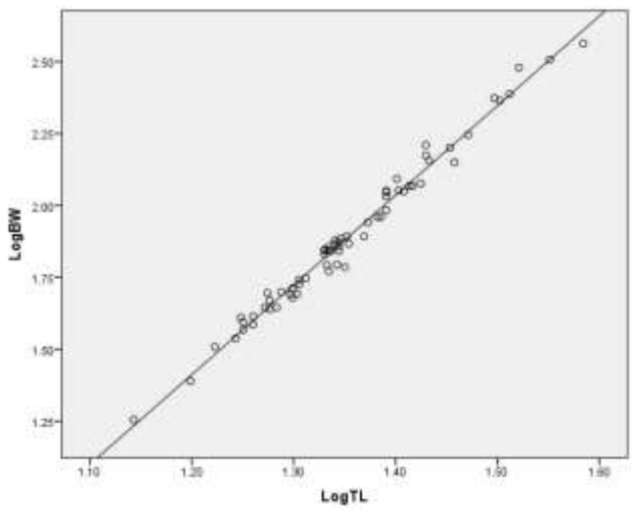
R^2= 0.997

a = 0.012

b = 2.935

</td></tr>
</table>

Appendix 3 continued



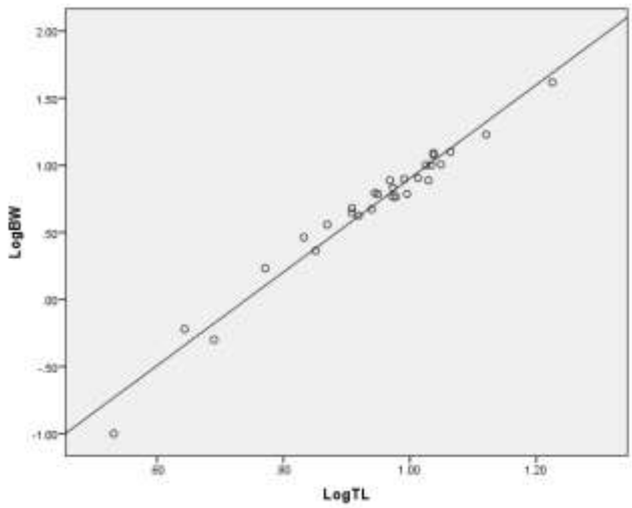
Pseudolais micronemus

N = 70

R^2= 0.992

a = 0.005

b = 3.117



Rasbora caudimaculata

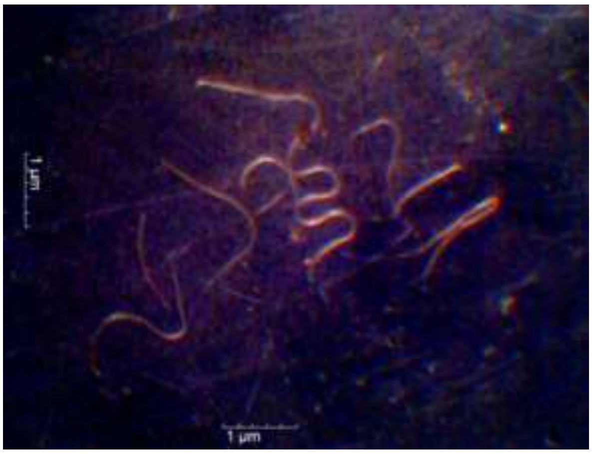
N = 29

R^2= 0.983

a = 0.003

b = 3.487

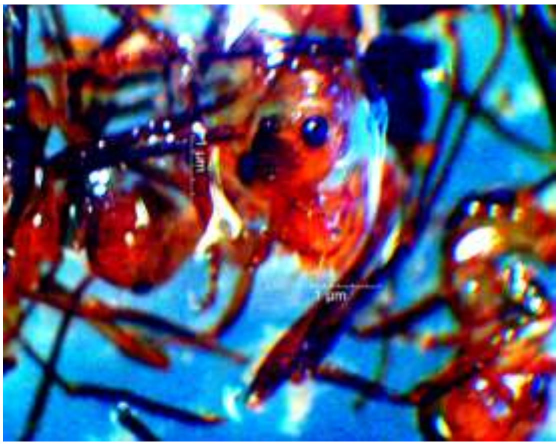
Appendix 4: Photo of food items observed from analyzed samples.



Food items: Nematodes

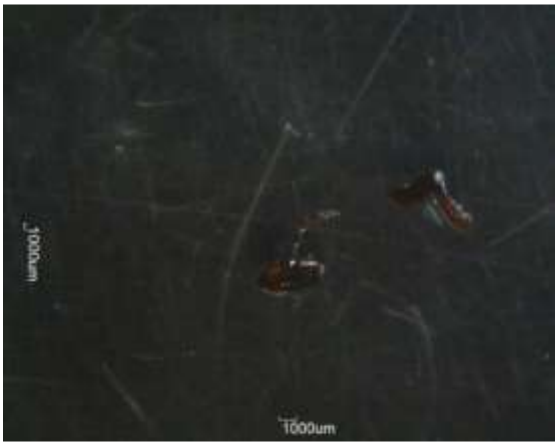
Food items: Orthoptera

Food items : Coleoptera



Food items: Hymenoptera

Food items: Trichoptera



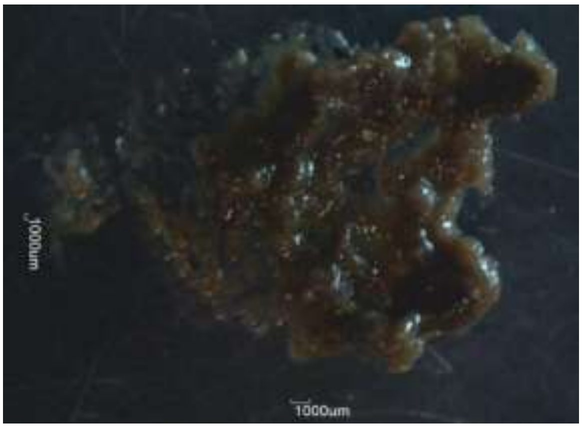
Food items: Part of insects

Appendix 4 continued

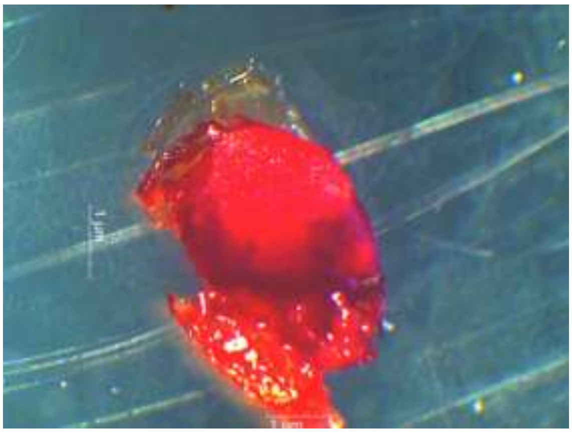
Food items: Fish scales

Food items: Flower buds

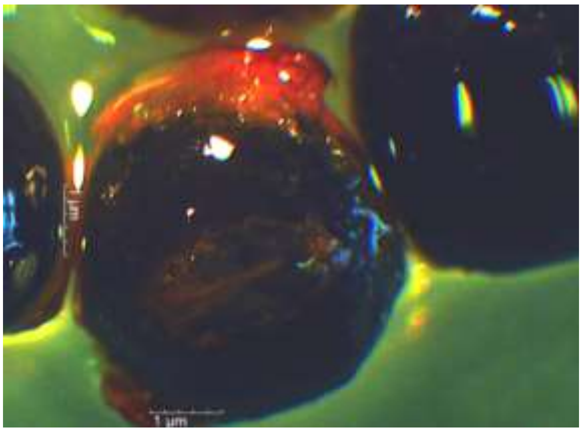
Food items : Plant materials



Food items: Sands



Food items: Fruits



Food items: Seeds