DIVERSITY STUDIES OF FISH AND SHRIMP SPECIES IN DISUSED TIN-MINING PONDS OF KAMPAR, PERAK

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MAY 2011

DIVERSITY STUDIES OF FISH AND SHRIMP SPECIES IN DISUSED TIN-MINING PONDS OF KAMPAR, PERAK

By

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A project report submitted to the Department of Science

Faculty of Science

University Tunku Abdul Rahman

in partial fulfillment of the requirements for the degree of

Bachelor of Science (Hons) Biotechnology

May 2011

ABSTRACT

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Fish and shrimp species from six sampling sites situated within four major ex mining ponds surrounding UTAR Kampar campus were surveyed with the aim to investigate their diversity and distribution. Samples were collected from October to December 2010 using scoop nets. Water samples were collected for pH, copper, ammonium, nitrate, nitrite and phosphate measurements in the laboratory. A total of 3604 individuals of fish and shrimp comprising eight species and seven families of fish and two species from one family of shrimps were recorded. *Gambusia holbrooki* was the most abundant (34.05%), followed by *Macrobrachium sp*. 1 (33.44%), *Macrobrachium sp*. 2 (17.18%) and *Oreochromis sp*. (11.49%). The remaining species made up about 4% of the total catches. Overall, the fish diversity was dominated by introduced species *Gambusia holbrooki* and tilapia, which are highly reproductive with high tolerance of environmental changes. Site C, which had the contained highest number of species, displayed the highest diversity of fishes and shrimps, with mean Simpson's Diversity index 0.599 and Shannon-Weaver's index H' = 0.479.

Lowest diversity was recorded for Site D with mean Simpson's Diversity index 0.244 and Shannon-Weaver's index H' = 0.199. Nevertheless, care should be taken in choosing which diversity indices to be applied, which in turn relied on the weight one sets between the rare and the most abundant species. If the person places more weight towards rare species in a habitat, Shannon-Weaver's index (H') is more valuable; but if total abundance of dominant individuals is of interest, Simpson's Diversity index is more preferable.

ACKNOWLEDGEMENT

First and the most, I would like to thank my supervisor, Dr. Gideon Khoo for his support and guidance throughout the research and thesis writing. His expertise, encouragement and advice played a major part in assisting the completion of this project. I would also like to thank him for providing the necessary equipments in sample collections, in which greatly ease the sample collection process.

Besides, I would also wish to thank my teammates, Gerald Chew Hong Shern and Illias Yeoh Shim Shian for being helpful and supportive throughout the research.

Last but not least, special thanks to my family and friend for their moral support, companionship and help in carry out this research.

DECLARATION

I hereby declare that the project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

Ng Wei Lin

APPROVAL SHEET

This project report entitled **"DIVERSITY STUDIES OF FISH AND SHRIMP SPECIES IN DISUSED TIN-MINING PONDS OF KAMPAR, PERAK"** was prepared by NG WEI LIN and submitted as partial fulfillment of the requirements for the degree of Bachelor of Science (Hons) Biotechnology at University Tunku Abdul Rahman.

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PERMISSION SHEET

It is hereby certified that **NG WEI LIN** (ID No: **08ADB04326**) has completed this final year project entitled "**DIVERSITY STUDIES OF FISH AND SHRIMP SPECIES IN DISUSED TIN-MINING PONDS OF KAMPAR, PERAK**" supervised by Dr. Gideon Khoo from the Department of Biological Science, Faculty of Science.

I hereby give permission to my supervisor to write and prepare manuscripts of these research findings for publishing in any form, if I do not prepare it within six (6) months from this date, provided that my name is included as one of the authors for this article. The arrangement of the name depends on my supervisor.

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LIST OF ABBREVIATIONS

Cu^{2+}	Copper ion
D	Simpson’s index
et al.	And others
H’	Shannon-Weaver index
i.e.	That is
mg/L	Milligram per litre
N	Nitrogen
NH_4^+	Ammonium ion
no.	Number
NO_2^-	Nitrite ion
NO_3^-	Nitrate ion
P	Phosphorus
PO_4^{2-}	Phosphate ion
ppm	Part per million
sp.	species
TARC	Tunku Abdul Rahman College
UTAR	University Tunku Abdul Rahman

CHAPTER 1

INTRODUCTION

Ponds provide habitat for a wide range of plants and animals including bacteria, fungi, algae, plankton, insects, fishes, crustaceans, amphibians, reptiles, birds and mammals. These organisms, living within the same habitat, interact with one another, hence forming a complex interaction network within the habitat. This network further interacts with the surrounding environment which consist of non-living properties such as oxygen content, soil pH and structure, as well as light intensity to form a pond ecosystem. A pond ecosystem refers to freshwater ecosystem whereby there are communities of organism interact and dependent on each other with the prevailing physical environment for their nutrient and survival (Krohne, 2001). The non-living properties is known as abiotic components, while the living properties known as biotic components. The abiotic substances of pond ecosystem are present as a mixture of organic and inorganic materials. The basic components ranges from the water, oxygen, carbon dioxide to salt of calcium and magnesium, as well as metal content such as copper and ferum. The formation of these organic and inorganic materials in turn relies on solar input, temperature, day length and other climatic condition. On the other hand, the biotic substances in the pond consist of various organisms, which can be classified into three major groups: producer, consumers and decomposers. Both the biotic and abiotic components work together in regulating the function of the pond ecosystem (Stiling, 2002).

Since the early ages of human history, human communities tended to set up their permanent settlement near to water sources, which were the sea, river or stream, or lake or pond. Most human communities around lakes or ponds depend heavily on the biodiversity and natural processes in these areas for their water, food and way of life. These, either natural or man-made outstanding geographical structures may have certain economical values, as they can provide food, water, beautiful landscape and recreational activities. The freshwater fishes and shrimps in these habitats serve as one of the sources of animal protein and income for the surrounding community. However, the exact number of freshwater ichthyofauna in Peninsular Malaysia is still unknown, as a large area still has yet to be studied (Ruddin et al. 2009). In addition, according to Zakaria-Ismail (1987), the available literature is incomplete because most studies are short term and lacked follow-up to monitor the changes in fish distribution related to habitat changes. Based on Zakaria-Ismail's (1996) study, the total number of fish species could be more than 300, whereas Lim and Tan (2002) only listed about 278 species native to Peninsular Malaysia and 24 introduced species.

Kampar is a town situated within the state of Perak, Malaysia. Approximately 30 minutes drive from Ipoh, the capital of Perak; Kampar was once a busy mining town situated in the Kinta Valley, which was well known for its high tin ore reserves. After the collapse of the mining industry in 1984 (Foong, 2003), the surrounding areas comprised a large number of ponds. Over time, gradual succession process occurred within these man-made ponds. Nowadays, these ponds have become the habitat of various organisms; from fishes, shrimps, small clams, snails and insects to reptiles such as water monitors and birds. Besides being the habitat of various organisms, these ponds also provide opportunity for recreational activities such as fishing and bird watching, as well as aquaculture purpose. One of the ponds, situated within the UTAR compound, contained a small island which hosts several species of water fowls. Nature lovers, as well as tourists, occasionally visit the place for bird watching besides enjoying the beautiful scenery. Nevertheless, very few studies have actually been done to assess the diversity of flora and fauna in these ex-mining ponds and the diversity of these habitats is poorly known. Hence, ecological studies with regard to the biodiversity of ex-mining ponds are important for us to maintain and improve the pond ecosystem. In addition, the diversity of freshwater fishes in a particular area can provide us an idea about the general health of the ecosystem (Ambak & Mohsin, 1986). This is because any changes in the water quality will directly impact the growth of aquatic fauna.

The present study aims to determine the diversity and abundance of shrimp and fish species in six selected sites of the ex-mining ponds surrounding the UTAR Kampar campus in Perak, Peninsular Malaysia. Furthermore, this study can provide us with information about the status of the ecosystem of these freshwater ponds with regards to the effects of water quality on the diversity of fishes and shrimps in the ponds.

The biodiversity of fishes and shrimps in the ponds were determined using diversity indices. Diversity indices measure the diversity of a habitat by taking into account the species richness and species abundance. Two diversity indices were used for each of the sampling site, namely Simpson’s index and Shannon-Weaver’s index. The objective of this study was to determine the diversity and distribution patterns of the fishes and shrimps collected from the ex-mining ponds (Figure 3.2 to Figure 3.7) for a period of three months, from October to December 2010. Water parameters, such as copper (Cu^{2+}), nitrite (NO_2^-), nitrate (NO_3^-), phosphate (PO_4^{2-}) and ammonium (NH_4^+) together with pH, were measured to determine their effects on the biodiversity of each site.

CHAPTER 2

LITERATURE REVIEW

2.1 Biodiversity and Ecosystem in Freshwater Ponds

2.1.1 Emergence of “Biodiversity” and Its Definition

The word “biodiversity” is often used to define the variety of all forms of life, ranging from genes to species, to the broad scale of ecosystems (Gaston, 1996). It was coined as a contraction of “biological diversity”. Takacs (1996) described the ascent of this word in this way: “In 1988, biodiversity did not appear as a keyword in Biological Abstracts, and biological diversity appeared once. In 1993, biodiversity appeared seventy-two times, and biological diversity nineteen times". This clearly shows that the term “biodiversity” has quickly become a common word to be used in the biological field compared to the 20 years ago. Its rapid rise in importance and influence was recorded in the first biodiversity book, named *Biodiversity II* (Marjorie et al., 1997). It is usually considered at three different levels, namely “genetic diversity”, “species diversity” and “ecosystem diversity”. Genetic diversity refers to the variety within species measured in terms of gene variation (Manokaran, 1992). Species diversity refers to the variety of living organisms on Earth, in which 1.8 million have been scientifically documented (Allan & Maria, 2008). In contrast, ecosystem diversity refers to the variety of habitats, biotic communities as well as ecological processes in the biosphere (Manokaran, 1992).

2.1.2 Ecosystems

Ecosystems, on the other hand, refer to the interaction between biotic factors and abiotic factors in an area (Ellis, 2008). The term “ecosystem” was coined by a British plant ecologist A. G. Tansley (1935), which he took to include not only the biotic community of organisms in an area, but also the abiotic environment around that community. The biotic communities include plants, animal, microorganisms and the dead organic matter produced by them, while the abiotic environment is the physical environment such as soil or water pH, water salinity, soil structure, oxygen level, light intensity and temperature under which the organisms live. In addition, ecosystems also concerned with the transfer of energy and material between communities in the ecosystem (Stiling, 2002). Energy flow in trophic levels and nutrient cycle occur continuously. The abiotic-biotic linkage was shown by Lindeman (1942) in a study of a bog-lake ecosystem, through the interpretation of the food web in terms of energy flow through different trophic levels. Energy flow from the primary producers, which are able to capture energy such as sunlight, to various levels of consumers. In any ecosystem, nutrient cycling describes the uptake of some nutrients, usually from a dissolved inorganic phase, and its subsequent incorporation into biological tissue (Allan & Castillo, 2008).

In freshwater pond ecosystems, communities of organisms in biotic factors interact with each others in various forms of interactions, either as a primary producer, consumer or decomposer, or a combination of more than one of them based on their feeding mechanism (Krohne, 2001). These interactions are known as trophic interactions, and are composed of trophic levels in an energy pyramid, with most energy and mass in the primary producers at the base, and higher levels of feeding on top of the pyramid (Ellis, 2008). The organisms inhabiting a pond ecosystem include algae, fungi, microorganisms, crustaceans, mollusks, insects, plants, fishes, some reptiles and amphibians. These organisms interact with each other in various forms, such as commensalism, mutualism and parasitism. The energy in a pond ecosystem flows from the producers to the consumers, while the decomposers consume dead organisms by decomposing them. This actually generates a continuous flow of energy within the ecosystem and hence helps in maintaining the sustainability of the ecosystem (Krohne, 2001).

2.1.3 Freshwater Ecosystems

Freshwater ecosystems, occupying approximately 0.8% of the Earth' surface (Gleick, 1996), contain at least 100,000 known species (Strayer, 2006), which is about 6% of the 1.8 million described species (Allan & Castillo, 2008). Of this 100,000 known species, about 10,000 species are freshwater fishes (Berra, 2001; Lévêque et al., 2005; Nelson, 2006). Freshwater fish is defined as fish species that spend their adult lives and breed in freshwater beyond tidal influence (Lim & Tan, 2002). The main geographical distribution of freshwater ecosystems consists of lakes, river, stream and ponds, which house most of the freshwater fish species.

2.1.4 Freshwater Fishes Of Malaysia

In Malaysia, currently there are 282 native species of freshwater fishes have been described (Freshwater Fisheries Research Centre, 2007), with more than 100 and 200 species reported in Sabah and Sarawak, respectively (Ahmad & Khairul-Adha, 2007). Several of these species are endemic, in which their distribution are restricted to small areas, or confined to an island or to a few localities (Ahmad & Khairul-Adha, 2007). For example, a survey carried by Ng et al. (1999) on the ichthyofauna of Tioman Island showed that there are two freshwater fish species which are endemic to the island: *Sundareonectes tiomanensis* (loach) and *Clarias batu* (catfish). According to Alfred (1963), the species *Neolissocheilus hendersoni* is found to be endemic to Penang and Langkawi Islands. Nevertheless, one may occasionally find fish species in Malaysia's freshwaters which are not amongst the described species. These are the fishes which are not native to Malaysia. They are either introduced as food fish or exotic species, the ornamental fish. As of 2002, at least 24 species of freshwater fishes are recognized as non-native to Malaysia (Lim & Tan, 2002). Examples of non-native fishes in Malaysia are the bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), and tilapia (*Oreochromis mossambicus*) (Welcomme 1981; Mohsin and Ambak 1983). Many of the non-native species were introduced to Malaysia in the early 19th century either by Chinese immigrants or by fisheries officials trying to culture economically valuable species (Ang et al, 1989). These non-native species are usually cultured in mud ponds or abandoned tin mining ponds. Besides, exotic species with striking coloration and attractive appearance such as cichlids (Cichlidae) from Lake Malawi and Lake Tanganyika in Africa, Siamese fighting fish (*Betta splendens*) and mollies (*Molliniesa* sp.) were transfered to Malaysia in the aquarium trade (De Silva, 1989; Ang et al., 1989). Nevertheless, they posed a great impact to the ecosystem of that area in which they survive and thrive, particularly towards the native species. The main concerns about the fish introductions are the risks associated with any one or all of the following problems as listed by Welcomme (1986):

i. Contamination of existing natural communities with foreign species,

ii. The introduction of disease.

iii. The direct disruption of the fish community through competition or predation.

iv. The genetic degradation of the host stock.

v. The degradation of the environment by the introduced species.

vi. The disruption of human lifestyles, customs or economic systems.

2.2 Background

2.2.1 Tin Mining and Its Impact on Ecosystems

Tin mining has been one of the most important mining industries in Malaysia. Rich tin deposits are primarily located on the western side of the main mountain range in Peninsular Malaysia, beginning in the north and stretching southward through Kinta Valley in Perak to Kuala Lumpur and further down to Malacca (Ang, 1994; Fuad, 2002). In Malaysia, tin is mined from alluvial deposits through various methods, prevalently by gravel-pumping, dredging, and open cast mines (Table 2.1), leaving large holes behind which gradually fill with water and result in the formation of mining lakes, hence creating an enormous area of new lentic habitat.

Table 2.1: Percentage of tin production in Peninsular Malaysia by various methods.

Year	Gravel pumps	Dredging	Open cast	Under-ground	Other	Total (tonne)
1970	55.2	32.4	3.4	3.1	5.9	100 (73 795)
1980	56.2	29.7	4.4	1.8	8.0	100 (61 406)
1988	33.9	45.5	9.5	0.4	10.8	100 (28 866)
1989	41.4	37.3	9.1	0.3	11.8	100 (32 034)
1990	42.9	36.1	7.6	0.4	13.0	100 (28 468)

*Source: Ministry of Primary Industries, Malaysia (1991)

Mining activities since the 1930s have resulted in approximately 113,700 hectares of former mining land, whereby 14.4% of it is in the form of water pond (Nasirian, 2008). This former mining land is also known as tin tailing site. Tailings are the waste portions or by-product from mined materials that are separated from the target mineral (Alshaebi et al., 2009) in order to obtain the desired mineral, which in this case, is the tin ore. Impacts of tin mining to environment and ecosystems have been published in several studies by Alshaebi (2009), Effendi (2006), Fuad (2002) and Nasirian (2006). The effects of tin mining include widespread degradation of the environment by the formation of retention ponds, sand piles, heavy metal pollution and destruction of agricultural land (Effendi, 2006). For instance, mining activities have been cited to cause siltation of river beds and drainage systems, as well as the formation of infertile land which is not suitable for agricultural purpose (Shamsuddin et al., 1986). Large amounts of fertilisers are required to rehabilitate this land for agriculture. Currently, only small pockets of tin tailings areas are utilized for productive purposes, such as aquaculture, recreation, settlement and agriculture (Awang, 1994). One of the recent studies proposed the rehabilitation of the tin mining pond for integrated storm water management (Chang et al., 2008). The rest of the areas remain as abandoned lakes or ponds. Over time, a process of primary succession occurs within the area and results in the establishment of multiple flora and fauna, such as fishes, invertebrates and aquatic macrophytes (Yule et al., 2004).

2.2.2 Perak and Its Mining Ponds and Lakes

Perak state, which is located in Peninsular Malaysia, was well-known for its rich tin reserves. It contains several freshwater wetlands including rivers, peat swamps, freshwater swamps, lakes, and mining ponds that are either natural or man-made (Ahmad & Khairul-Adha, 2007). These water bodies support a rich diversity of flora and fauna. The diversity of flora and fauna of these habitats have been described by Mansor et al. (1999), Lim and Tan (2002), Wowor et al. (2004), Zainudin (2005), Chang et al. (2008) and Zakaria et al. (2009). These include freshwater prawns, fishes, water fowls and various species of aquatic plants. Several plant species found in these wetlands are common reed (*Phragmites karka*), bakong (*Hanguana malayana*), menderong (*Scirpus grossus*), arrow-leaf monochoria (*Monochoria hastate*), wild sugarcane (*Saccharum spontaneum*), water hyacinth (*Eichornia crassipes*) and sawah-flower rush (*Limnocharis flava*) (Chang et al., 2008).

Situated within Kinta Valley in Perak, Kampar, according to a local historian Chye Kooi Loong, was once a busy and prosperous tin mining town in Malaysia during late 19th century (Foong, 2003). Its geographical coordinates are 4 ° 18' 0" North, 101 ° 9' 0" East. As a typical ex-mining land, Kampar contains plenty of ex-mining ponds in the town after the collapsed of tin mining industry in 1984 (Foong, 2003). These ponds were surrounded by sand and a mixture of silt and clay deposits usually referred to as slime (Shamshuddin et al., 1986). There are areas where both slime and sand occur together. Some of these ponds have been utilized for aquaculture and agricultural purposes. Species such as tilapia (*Oreochromis niloticus*), marble goby (*Oxyeleotris marmorata*) and giant freshwater prawn (*Macrobrachium rosenbergii*) are widely cultured in ex-mining ponds for their high commercial value (Yap et al, 1988; Ang et al., 1989; Luong et al., 2004; Uddin, 2007). However, from time to time, culture specimens may escape from their culture sites into neighbouring abandoned ponds, and establish themselves (Ang et al., 1989). The occasional release of aquarium pet fish into the ponds by the public may also lead to the increase in fish species in these ponds (Allan & Castillo, 2008).

2.3 Diversity Indices

To evaluate the biodiversity in a particular habitat, measures of diversity are typically employed. Generally, the most critical measures of diversity are species richness, which directly reflect the number of species in an area; species evenness that accounts for the distribution of individuals and total number of existing individuals. These three features form the basis of diversity indices (Wilhm & Dorris 1968; Allan 1975). Examples of more commonly used diversity indices are Simpson's index (Simpson, 1949), Shannon-Weaver index (Shannon & Weaver, 1949), MacIntosh index (McIntosh, 1967), Berger-Parker index (Berger & Parker, 1970) and Brillouin index (Brillouin, 1956). All of these diversity indices combine the elements of species richness and evenness in calculation.

Among the most popular and frequently employed diversity indices are the Simpson's index and Shannon-Weaver index (Forman, 1995). These two diversity indices take into account both the number of species (species richness) and their heterogeneity (evenness) in a particular site when measuring the diversity. The diversity indices provide more useful information on the diversity of an area compared to merely species richness or evenness. Besides, the calculation for both indices is relatively simple.

2.3.1 Simpson's Index (D)

Simpson's index, first developed by Sir Edward H. Simpson in 1949, has been defined in three different ways in published ecological research:

1. Simpson's index (D), which shows the probability that two randomly selected individuals in the habitat would belong to the same species.
2. Simpson's index of diversity (1-D), which shows the probability that two randomly selected individuals in the habitat would belong to different species.
3. Simpson's reciprocal index (1/D).

The D value, which stands for the dominance index, is used in pollution monitoring studies. However, the main disadvantage of Simpson's index is that it is weighted more towards the abundance of the most common species in an area (Stiling, 2002). Consequently, it is less sensitive towards rare species. Any addition of rare species with a low number of individuals will not be able to affect the value of the index. Therefore, Simpson's index is less frequently applied in conservation biology if that area has many rare species with very low number of individuals (Stiling, 2002).

2.3.2 Shannon-Weaver's index (H')

In contrast to Simpson's index, the Shannon-Weaver's index or Shannon's index (Shannon & Weaver, 1949) is one of the information-statistic indices. Originally proposed by Shannon in 1948, it is an index applied to biological systems that is derived from a mathematical formula used in the communication area (Türkmen & Kazanci, 2010). It is the most popular diversity index in use by ecologists (Wang et al., 2004; Salas et al., 2006; Simboura & Reizopoulou, 2007). As an information-statistic indices, the index is based on the rationale that diversity in a natural system can be measured in a way similar to the way information contained in a message is measured (Stiling, 2002). This index is based on the notion of "uncertainty" in predicting the species of an individual chosen randomly from a habitat (Krohne, 2001). This uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes even. Heterogeneous communities have a low certainty while homogeneous communities have a high certainty. This index quantitatively measures the degree of uncertainty and hence heterogeneity, H' (Krohne, 2001). A high value indicates that the community is very heterogeneous or consists of many species and evenly spread, while a low value represents homogeneity or the community has only a few species with 1 or 2 being the dominants. Shannon's index is more sensitive towards rare species and responds strongly to changes in importance of the rarest species (Peet, 1974; Stiling, 2002). The presence of rare species, even with only 1 or 2 individuals for each species is able to contribute some value to the index. Shannon's index is the most commonly used index for comparing diversity between various habitats (Clarke & Warwick, 2001).

2.3.3 Evenness (J')

Pielou's evenness index (J') was derived by Pielou in 1966. This index expresses how evenly the individuals in a habitat are distributed among different species. It is computed through dividing the actual observed value of Shannon's index (H') with the maximum possible value of Shannon's index, H_{max} (Nagendra, 2002). H_{max} occurs when all the species (S) are represented by the same number of individuals, that is, there is perfectly even distribution with equal abundances (Meerman, 2004). In contrast, H' is 0 when there is only a single species present in the sample. The J' value is constrained between 0 to 1. When the J' value is closer to 1, it indicates that the individuals are distributed equally (Pielou, 1966). Generally, the addition of species and increasing the evenness of the individuals within each species both increase the species diversity.

2.4 Water Parameters

Water parameter tests are to determine the abiotic factors in the pond ecosystems. The parameters are water pH, copper (Cu^{2+}), nitrite (NO_2^-), nitrate (NO_3^-), ammonium (NH_4^+) and phosphate (PO_4^{2-}) contents. In fish ponds, the time of day that a sample is taken will often influence the pH because of variations in the carbon dioxide (CO_2) concentration. During day time, plants in the water remove carbon dioxide when they undergo photosynthesis, thus increasing the pH. At night, the pH will decrease as the carbon dioxide produced by the pond organisms accumulate. A pH of 4 to 10 is regarded as suitable for a freshwater ecosystem (Kutty et al., 2005). Fish will die if the pH value is lower than 4 or more than 10.

2.4.1 Copper (Cu)

Copper is a naturally occurring element that is generally present in surface waters, such as lakes, river, ponds and sea (Nriagu, 1979). It serves as an essential trace element or micronutrient for both plants and animals at low concentration (Kapustka et al., 2004). Nevertheless, elevated concentrations of copper are toxic to aquatic life. Naturally occurring concentrations of copper have been reported from 0.0003 to 0.0023 mg/L in surface seawater and from 0.002 to 0.3 mg/L in freshwater systems (Bowen, 1985). Copper exists in several forms in a natural freshwater aquatic environment. They are mainly in association with various ligands to form a stronger complex, which include dissolved organic compounds, hydroxides, carbonates and other inorganic ligands (U.S. Environmental

Protection Agency, 2007). In addition, a substantial amount of copper can also be adsorbed or incorporated into suspended particles.

2.4.2 Nitrogen (N)

Nitrogen is another essential nutrient that is required by all plants and animals for the formation of the basic unit of protein, the amino acids. In its molecular form, nitrogen cannot be utilized by most aquatic plants and animals, as they lack the mechanism to fix nitrogen in the water for their own use (Allan & Castillo, 2008). Hence, nitrogen must be converted to another form in order to be utilized by aquatic organisms, such as cyanobacteria (Allan & Castillo) in a process known as biological nitrogen fixation (Wetzel, 2001). One of such forms is ammonia (NH_3). Ammonia is dissolved inorganic nitrogen present naturally in surface and wastewaters, and in some well waters. It is the major nitrogenous waste product of fish and also results from the decomposition of organic matter by fungi and bacteria (Molles, 2005). It is quite soluble in water, especially at low pH, and is usually removed by plants or bacteria as an energy source. Ammonia is present in two forms in water – unionized ammonia (NH_3) and the ionized form ammonium (NH_4^+). The relative proportion of each form depends on pH and temperature (Stone & Thomforde, n.d.). As pH increases, there is an increasing proportion of unionized ammonia, which is very toxic to fish. It has been reported that concentrations ranging from 0.2 to 2.0 mg/L is toxic to most freshwater organisms (Wilkes University of Environmental Quality Center, n.d.). The ammonium-nitrogen level in freshwater should not exceed 0.3mg/L in a clean and sustainable aquatic environment (National Water Quality Standards of Malaysia, 2005). Ammonium can be oxidized to nitrite (NO_2), and nitrite to nitrate (NO_3) by bacteria, in a process called nitrification. It can then be used directly by bacteria, fungi or plants as an important nutrient source (Molles, 2005). Normally, nitrate and nitrite concentrations should not be allowed to exceed 0.4 mg/L (National Water Quality Standards of Malaysia, 2005). Beyond this value, the system is termed as eutrophic water.

2.4.3 Phosphorus (P)

Besides ammonia, nitrites and nitrates, phosphate is another vital plant nutrient. In the natural environment, phosphorus mainly occurs as orthophosphate (PO_4^{3-}) in water and is attached to inorganic particles in suspension, as well as in dissolved organic molecules (Allan & Castillo, 2008). According to Meybeck (1982), the average natural levels of dissolved P are very low, around 0.01mg/L for PO_4^{3-}. It occurs largely in mineral deposits and marine sediments (Molles, 2005). Phosphorus is slowly released to aquatic ecosystems through weathering and erosion of phosphate deposits (Krohne, 2001), which is, in turn, absorbed by plants as a nutrient source. According to the National Water Quality Standards of Malaysia (2005), for Class IIA water (water appropriate for sensitive aquatic species), the phosphorus level should not exceed 0.2mg/L. Lakes with a phosphate concentration exceeding 0.1mg/L are termed eutrophic lakes and considered highly enriched (Fadiran et al., 2007). This leads to eutrophication, which is the enrichment of water by nutrients, leading to the accelerated growth of algae in the aquatic ecosystems, and eventually causing undesirable disturbance to the habitat (Oslo/Paris Convention (OSPAR), 2003). Eutrophic waters are characterized by excessive algal growth in extreme quantities. The bacteria responsible for the decomposition of the dead algae may use up and deplete the concentration of dissolved oxygen in the water bodies and cause fish kills (Fadiran et al., 2007).

CHAPTER 3

MATERIALS AND METHODS

3.1 Sources of Fishes and Shrimps

The fishes and shrimps were sampled from six different sampling sites around UTAR Kampar campus as shown in Figure 3.1 and 3.2, which comprised a total of four ponds around that area. Field trips were conducted on three different occasions, 21st, 25th & 26th October 2010, 23th, 24th & 25th November 2010 and 21st & 22nd December 2010, respectively. The sampling trip started at 8 a.m. each day and lasted approximately 2 hours.

Specimens were collected by random sampling, using a 36 cm width x 55.5 cm length fine mesh aquarium net. Three different locations within each site were selected for sample collection. Sampling were carried out by two persons, and the results were combined to obtain a higher number of catches. The sample collections were made once a month from 8 a.m. to 10 a.m., for three consecutive months from October to December.

3.2 Sample Preparation

Samples collected from the six different sites were stored inside six plastic fish tanks with the dimensions of 26 cm length x 16.5 cm width x 18 cm height. The genus and possibly, species name of all fishes and shrimps caught in each site were identified and their respective numbers were counted and recorded. This process was repeated for all the samples from the six different sampling sites for three months. The specimens were then released back into their ponds.

3.3 Biodiversity Analysis

BioDiversity Professional Version 2 software was used to analyse the sampling (Appendix B). This freeware is available for public use and can be downloaded from the website: http://gcmd.nasa.gov/records/NHML_Biopro.html. It is a free statistics software for ecology which was developed by Neil McAleece, and jointly devised by P.J.D. Lamshead and G.L.J. Paterson of The Natural History Museum in London (Holland, 2011). Two diversity indices; Simpson's index (Simpson, 1949) and Shannon's index, H' (Shannon & Weaver, 1949), were calculated for each site every month. The value D in Simpson's index ranged from 0 to 1, with 0 representing highest diversity and 1 representing no diversity. The value D was then subtracted from 1 to generate Simpson's Diversity index (1-D). The value also ranged from 0 to 1, but in contrast to Simpson's index, the value 0 now represents no diversity while 1 represents highest diversity. As for Shannon index (H'), the higher the value of H', the higher the diversity. The H' value was calculated using logarithm to the base of ten. The software also calculates Pielou's Evenness index (J'), which assumes a value between 0 and 1. J' measures the relative abundance of each species in an area. As the value approaches 1, the number of individuals among the species in that community is more evenly distributed. A low value indicates that the area is dominated by one or several species by having a large number of individuals, together with other species which have a relatively low number of individuals. The index is calculated by dividing H' by H_{max}. A graph of Simpson's Diversity index for Site A to F from October to December was drawn using the values obtained (Figure 4.3). Graph of Shannon's index for Site A to F from October to December was plotted (Figure 4.4). Values from both indices for each site were compared for three consecutive months (Figure 4.6). The Simpson's Diversity Index, Shannon's index (H') and Pielou's Evenness index (J') were tabulated (Table 4.3, 4.4 and 4.5).

3.4 Water Quality Tests

Water quality parameter tests were carried out for all the six sampling sites. The water's pH was measured every time after sample collection using pH meter. Water test kits (JBL Germany) were used to measure the other five water parameters, which were copper (Cu^{2+}), ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), and phosphate (PO_4^{2-}) content for two consecutive days. Copper content was measured using the JBL Copper Test Set. Ammonium content was measured using JBL Ammonium Test Set. Nitrite was measured using JBL Nitrite Test Set. Nitrate was measured using JBL Nitrate Test Set, Phosphate by JBL Phosphate Test Set.

Figure 3.1: Satellite view of map of study sites (Site A to F), Kampar, Perak

A

B

C

D

E

F

Figure 3.2: Pictures of six sampling sites. (A) Site A, (B) Site B, (C) Site C, (D) Site D, (E) Site E and (F) Site F.

CHAPTER 4

RESULTS

4.1 Species Identification

Fish samples collected from each site were identified based their family, genus and possibly species by referring mainly to literature of local researchers (Mohsin & Ambak, 1983; Freshwater Fisheries Research Centre, 2007) Shrimp samples were identified according to their family and genus using the key descriptions by Wowor et al. (2004). A total of 6 families of fishes encompassing eight species (Figure 4.1) and a single shrimp family with two species (Figure 4.2) were collected. The fish families were Poeciliidae (*G. holbrooki*), Cichlidae (*Cichlasoma urophthalmus* and *Oreochromis sp.)*, Channidae (*Channa micropeltes)*, Loricariidae (*Plecostomus sp.)*, Gobiidae (*Stigmatogobius poecilosoma* and *Oxyeleotris marmorata*) and Ambassidae (*Parambassis ranga*). The shrimp family Palaemonidae consisted of *Macrobrachium sp. 1* and *2*.

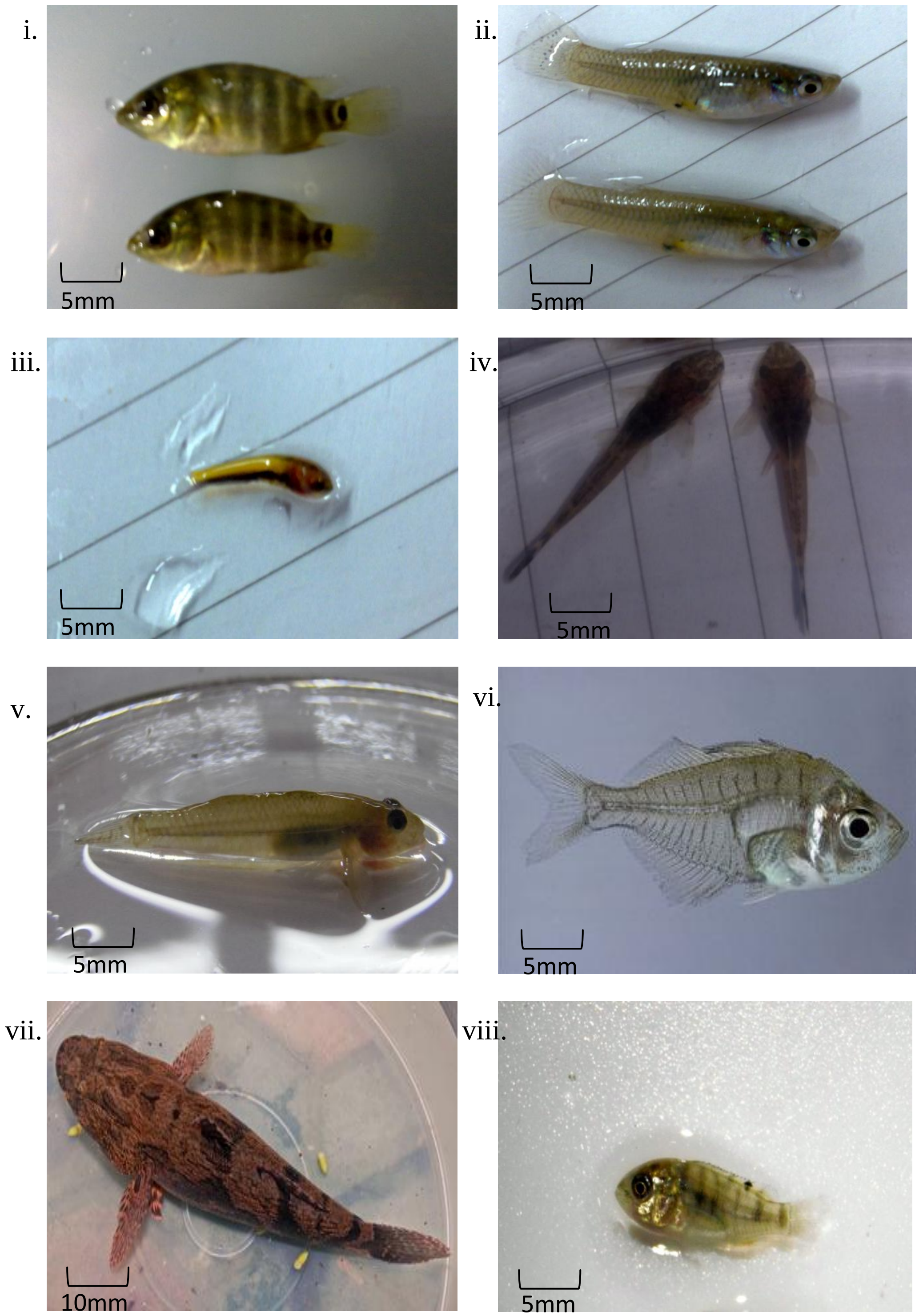

Figure 4.1: Fish species collected at six sampling sites (Site A, Site B, Site C, Site D, Site E, Site F). (i) *Cichlasoma urophthalmus*, (ii) *Gambusia holbrooki*, (iii) *Channa micropeltes* larvae, (iv) *Plecostomus spp.*, (v) *Stigmatogobius poecilosoma*, (vi) *Parambassis ranga*, (vii) *Oxyeleotris marmorata* and (viii) *Oreochromis sp.*juvenile.

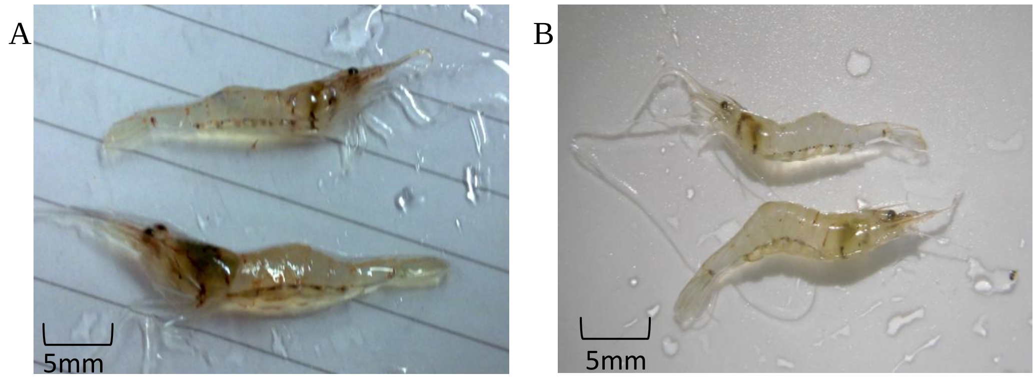

Figure 4.2: Shrimp species collected at the six sampling sites. (A) *Macrobrachium sp. 1* and (B) *Macrobrachium sp. 2*.

4.2 Diversity Indices of Sampling Sites from October to December 2010

4.2.1 Simpson's Diversity index (1-D)

Simpson's Diversity indices (1-D) for Site A to F from October to December 2010 were shown in Table 4.1 and Figure 4.3. The values were between 0.134 to 0.609 for October, 0.04 to 0.659 in November and 0.1 to 0.672 in December. In October, Simpson's Diversity index was highest at Site A (0.609), followed by Site C (0.574), F (0.432), B (0.304), E (0.173) and D (0.134). In November, Site B showed the highest diversity (0.659), followed by Site D (0.588), Site C (0.552), Site E (0.501), Site A (0.136) and Site F (0.04). As for December, Simpson's Diversity index was highest at Site C (0.672), followed by Site F (0.540), Site E (0.504), Site B (0.332), Site A (0.246) and Site D (0.01). Based on Table 4.1, Site C showed the highest diversity of fishes and shrimps within the 3 month period, with a mean value of 0.599, followed by Site B (0.432), Site E (0.393), Site F (0.337) and Site A (0.330). The least was Site D (0.244).

Table 4.1: Simpson's Diversity (1-D) for sampling sites A to F from October to December 2010.

Month	Sampling site					
	A	B	C	D	E	F
October	0.609	0.304	0.574	0.134	0.173	0.432
November	0.136	0.659	0.552	0.588	0.501	0.040
December	0.246	0.332	0.672	0.010	0.504	0.540
Mean	0.330 (±0.202)	0.432 (±0.200)	0.599 (±0.064)	0.244 (±0.304)	0.393 (±0.190)	0.337 (±0.263)

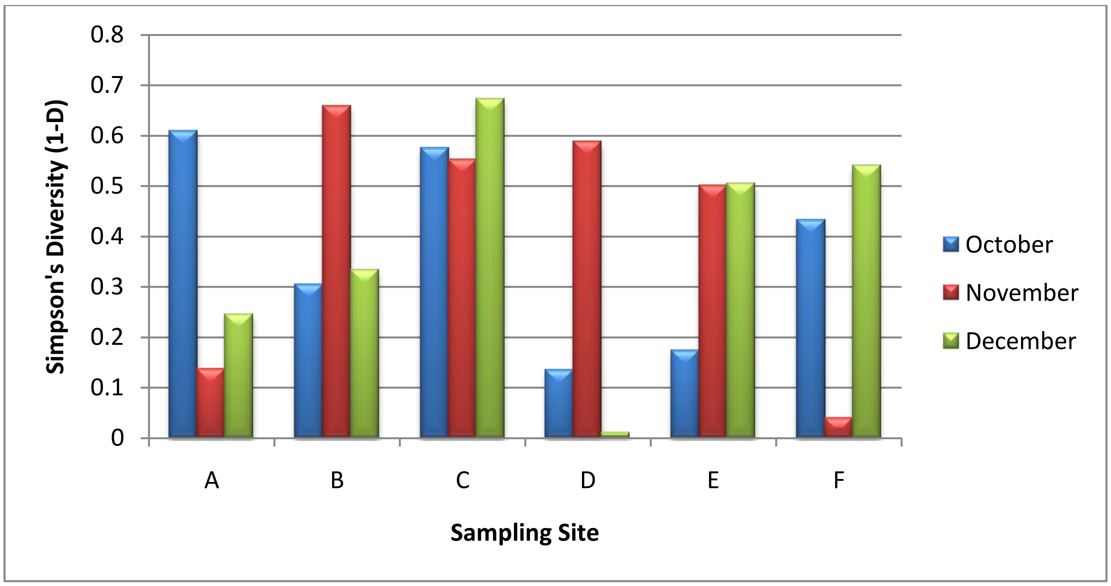

Figure 4.3: Simpson's Diversity (1-D) for sampling sites A to F from October to December 2010.

4.2.2 Shannon index (H')

Shannon indices (H') for Site A to Site F from October to December 2010 were shown in Table 4.2 and Figure 4.4. The values were between 0.151 to 0.437 for October, 0.049 to 0.47 in November and 0.013 to 0.535 in December. In October, Site A displayed the highest H' value (0.437), followed by Site C (0.436), Site B (0.267), Site F (0.266), Site E (0.175) and Site D (0.151). As for November, Site B showed the highest H' value (0.47), followed by Site C (0.466), Site D (0.432), Site E (0.312), Site A (0.149) and Site F (0.049). In December, Site C expressed the highest H' value (0.535), followed by Site F (0.38), Site E (0.32), Site B (0.301), Site A (0.232) and, lastly, Site D (0.013). Similar to Simpson's Diversity index (1-D), Site C contained the highest diversity of fishes and shrimps, with a mean value of 0.479, followed by Site B (0.346). Sites A, D, E and F showed a relatively low diversity, of 0.273, 0.199, 0.269 and 0.232, respectively.

Table 4.2: Shannon index, H' for sampling sites A to F from October to December 2010.

Month	Sampling site					
	A	B	C	D	E	F
October	0.437	0.267	0.436	0.151	0.175	0.266
November	0.149	0.470	0.466	0.432	0.312	0.049
December	0.232	0.301	0.535	0.013	0.320	0.380
Mean	0.273	0.346	0.479	0.199	0.269	0.232
	(±0.148)	(±0.109)	(±0.044)	(±0.214)	(±0.313)	(±0.168)

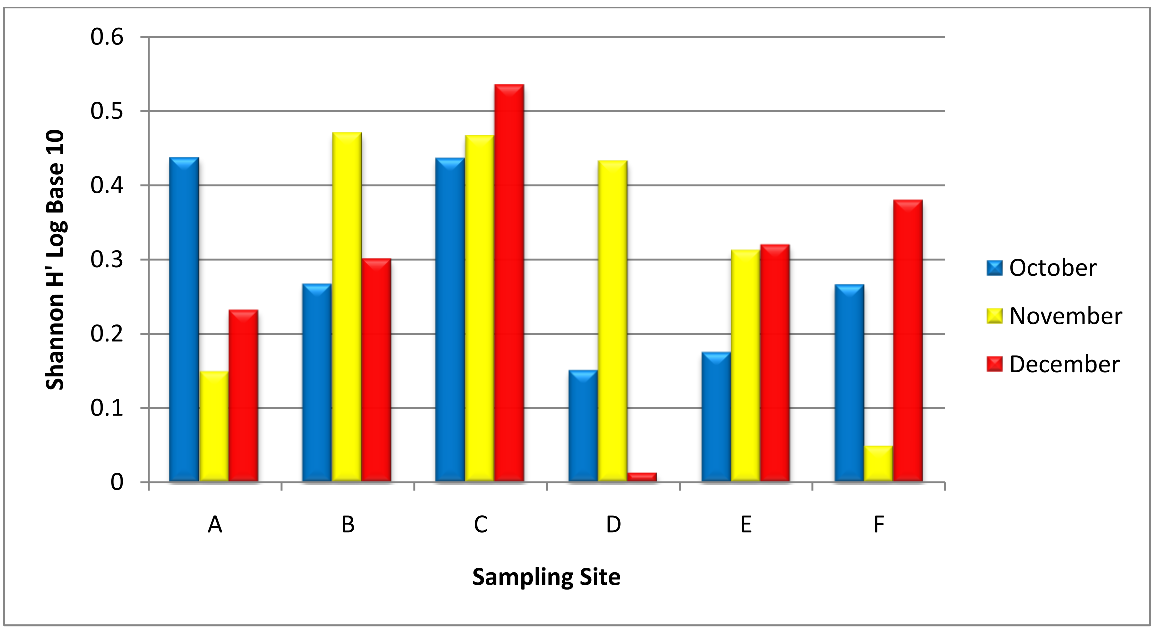

Figure 4.4: Shannon index (H') for sampling sites A, B, C, D, E and F from October to December 2010.

4.2.3 Evenness, J’

Pielou’ evenness index (J’) for the month of October to December 2010 were tabulated in Table 4.3 and in Figure 4.5. The index value the six sampling sites were between 0.216 to 0.916 in October, 0.103 to 0.985 in November and 0.044 to 0.687 in December. The lowest value in October came from Site D and the highest value was for Site A. In November, the lowest value occurred in Site F and the highest value was from Site B. For December, Site D had the lowest evenness and Site C had the highest evenness value.

Table 4.3: Pielou's evenness index (J') for sampling sites A, B, C, D, E and F from October to December 2010.

Months	Sampling sites					
	A	B	C	D	E	F
October	0.916	0.443	0.623	0.216	0.251	0.884
November	0.191	0.985	0.667	0.718	0.653	0.103
December	0.333	0.431	0.687	0.044	0.670	0.631
Mean	0.480 (±0.384)	0.620 (±0.316)	0.659 (±0.033)	0.326 (±0.350)	0.525 (±0.237)	0.539 (±0.398)

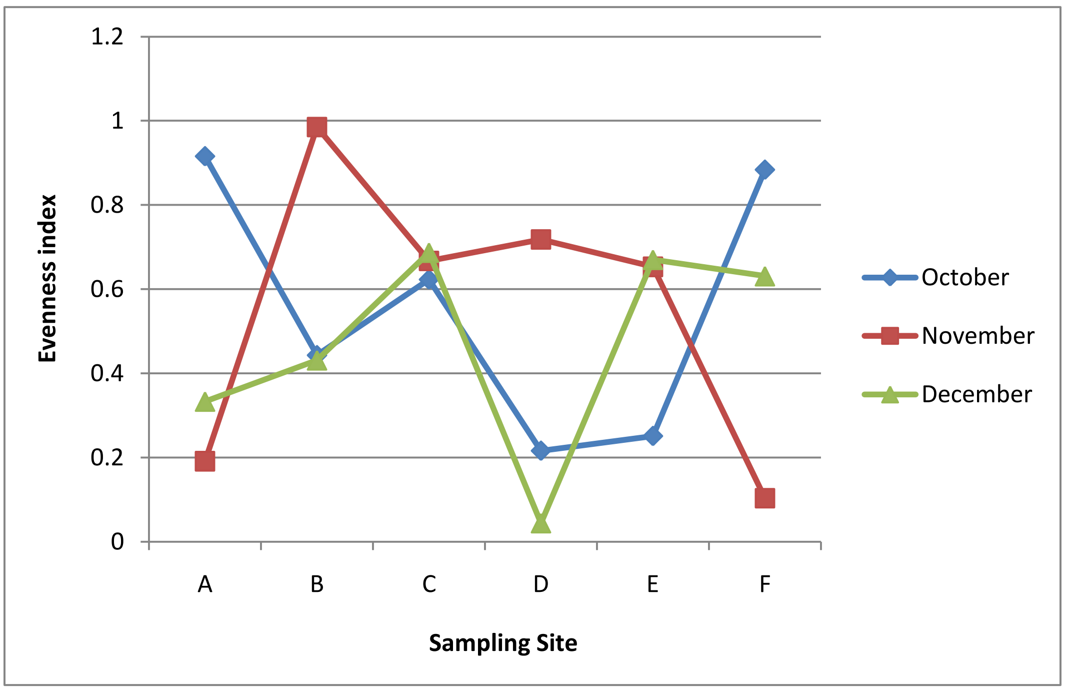

Figure 4.5: Graphs of Pielou's evenness index (J') for Site A to Site F from October to December 2010.

4.3 Comparison of Diversity Indices Among Sampling Sites

The mean value of Simpson's Diversity (1-D) and Shannon index (H') for each site were compared from October to December 2010 (Figure 4.6). The trend in both indices generally resembled to each other. For instance, the three sites which had the highest values (Site A, C and F) in October and Site C, E and F in December were the same for both indices. Nevertheless, the results from November showed a slight deviation from this trend. Both indices had the same site (Site B) ranked as highest value, but not for the subsequent ranking. Site C, which had higher H' than Site D, ranked second when using Shannon's index. In contrast, Site D, which displayed higher Simpson's diversity index than Site C, ranked second when applying Simpson's Diversity index (Table 4.4).

Table 4.4: Abundance of individual species together with Shannon's and Simpson's diversity indices for Site C and Site D during November 2010.

Species	Abundance (No. of individuals)	
	Site C	Site D
Macrobrachium sp. 1	10	33
Macrobrachium sp. 2	13	12
Gambusia holbrooki	98	55
Oreochromis sp.	3	1
Channa micropeltes	31	-
Simpson's Diversity (1-D)	0.552	0.588
Shannon's index (H')	0.466	0.432

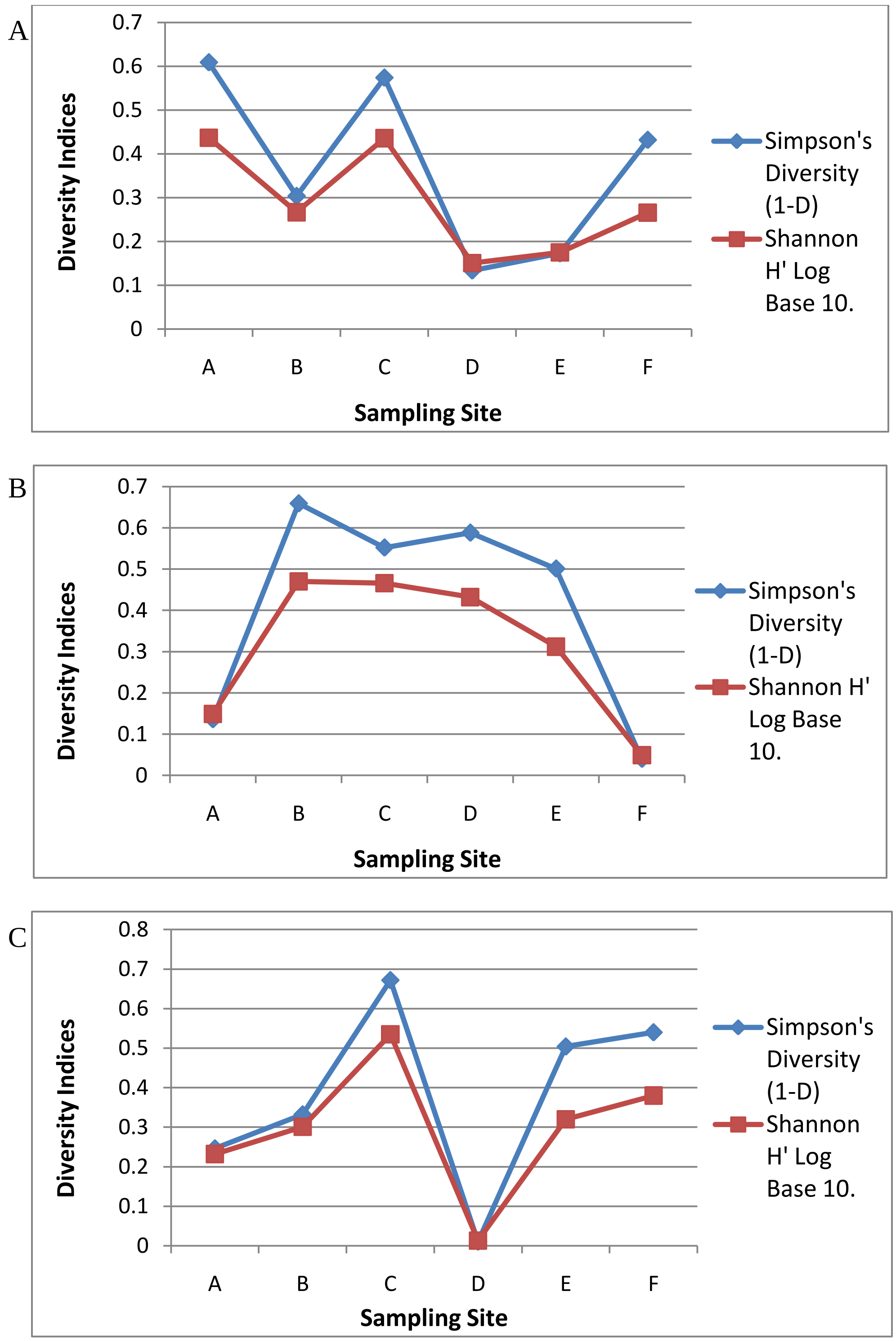

Figure 4.6: Comparison between Simpson's Diversity (1-D) and Shannon's index (H') for Site A to Site F from October to December 2010. (A) October, (B) November and (C) December.

4.4 Comparison of the Number of Species and Abundance among Sites

Throughout the three months of sampling period, a total of eight species of fishes and two species of shrimps were collected from the six sampling sites. Table 4.5 was a summary of the number of species and relative abundance of fish and shrimp individuals collected from Site A to F for the months of October 2010 to December 2010. Results from Site C showed that it had the most species, which was eight, followed by Site F, which had seven species, then Site A and D, which contained six species each and Site B and E which contained five species each. *Gambusia holbrooki* from the Family Poeciliidae was the dominant species, contributing 34.05% of the total samples collected from the six sites. The next dominant group was the freshwater shrimps of the Family Palaemonidae (*Macrobrachium sp. 1* and *Macrobrachium sp.2*), which comprised 33.44% and 17.18%, respectively of the total samples. This was followed by two species of the Family Cichlidae, namely *Oreochromis sp.* (11.49%) and *Cichlasoma urophthalmus* (2.47%). The remaining fishes, comprising five species made up less than 1.5% of the total samples.

Table 4.5: Relative abundance (%) of fish and shrimp species in Kampar ex-mining ponds (Site A to F) from October 2010 to December 2010 (in increasing order of abundance).

No.	Genus/Species	Number of individuals						Total	Relative abundance (%)
		Site A	Site B	Site C	Site D	Site E	Site F		
1	*Parambassis ranga*	-	-	1	-	-	-	1	0.03
2	*Plecostomus sp.*	2	-	1	-	-	-	3	0.08
3	*Oxyeleotris marmorata*	3	1	-	-	-	1	5	0.14
4	*Stigmatogobius poecilosoma*	-	-	-	3	6	1	10	0.28
5	*Channa micropeltes*	-	-	31	-	-	-	31	0.86
6	*Cichlasoma urophthalmus*	-	41	28	2	3	15	89	2.47
7	*Oreochromis sp.*	2	-	7	5	399	1	414	11.49
8	*Macrobrachium sp. 2*	417	73	92	12	3	22	619	17.18
9	*Macrobrachium sp. 1*	105	704	327	36	-	33	1205	33.44
10	*Gambusia holbrooki*	41	117	354	397	191	127	1227	34.05
							Total:	3604	100.00
Total no. of species for each site		A = 6	B = 5	C = 8	D = 6	E = 5	F = 7		

4.5 Water Quality Parameter Tests

Table 4.6 showed the water quality parameters for the six samplings sites on 13 and 14 January 2011. Results from the JBL Copper Test Set showed that the copper content in all six sites were less than 0.1 mg/L. Readings for nitrite levels were 0.05 mg/L for all the sites, with the exception of Site F which fluctuated between 0.05 to 0.1 mg/L. All the six sites showed a nitrate level of less than 0.5 mg/L. Readings of ammonium revealed that the levels were highest for Site C and E, which were 0.6 mg/L, and lowest for site A and F, which were less than 0.05 mg/L. Phosphate levels for all the six sites were less than 0.02 mg/L, which was below the phosphate threshold concentration (0.2 mg/L) for lakes.

Table 4.6: Water quality parameters for the six sampling sites in January 2011.

	mg/L (ppm)				
Sampling sites	Cu^{2+}	NO_2^-	NO_3^-	NH_4^+	PO_4^{2-}
A	< 0.1	0.05	< 0.5	< 0.05	< 0.02
B	< 0.1	0.05	< 0.5	0.1	< 0.02
C	< 0.1	0.05	< 0.5	0.6	< 0.02
D	< 0.1	0.05	< 0.5	0.1~0.2	< 0.02
E	< 0.1	0.05	< 0.5	0.4~0.6	< 0.02
F	< 0.1	0.05~0.1	< 0.5	<0.05	< 0.02

Table 4.7 showed the water pH for the six sampling sites from October 2010 to December 2010. The overall pH of all six sites was slightly alkaline, pH 7 to pH 8. All the sites displayed the highest pH value in the month of November, which were pH 7.28, 7.30, 7.86, 7.86, 7.71 and 8.08 for Site A, B, C, D, E and F, respectively. The pH values for Site A fluctuated between pH 7.28 in November

and pH 6.89 in December. There was a slight fluctuation of pH from October 2010 to December 2010 for Site B, with the highest value at pH 7.30 in November and lowest value at 7.17 in October. From October 2010 to December 2010, the pH value for Site C fluctuated between pH 7.24 to pH 7.86, Site D between pH 7.41 to pH 7.86, Site E between pH 7.00 to pH 7.71 and Site F pH 7.14 to pH 8.08.

Table 4.7: Water pH for the six sampling sites from October to December 2010.

	Water pH			
Sampling sites	October	November	December	Mean
A	7.05	7.28	6.89	7.07 ±0.20
B	7.17	7.30	7.21	7.23 ±0.06
C	7.38	7.86	7.24	7.49 ±0.33
D	7.51	7.86	7.41	7.54 ±0.25
E	7.00	7.71	7.35	7.35 ±0.36
F	7.14	8.08	7.16	7.46 ±0.54

CHAPTER 5

DISCUSSION

5.1 Fish and Shrimp Fauna

The community of the mining ponds in all the six sampling sites consist mainly of non-native fish species. Out of the eight species of fishes recorded, five of them were non-indigenous to Peninsular Malaysia. They were *G. holbrooki, C. urophthalmus, Oreochromis sp., Plecostomus sp.*and *P. ranga.* The rest of the fishes and shrimps comprising three fish species and two shrimp species were native to the freshwater habitats of Malaysia (Freshwater Fisheries Research Centre, 2007). Two of the fish species belonged to the family Gobiidae, which were *S. poecilosoma* and *O. marmorata*, and *C. micropeltes* of the Family Channidae. Both the shrimp species were *Macrobrachium* from the Family Palaemonidae.

The community of fishes in these ex-mining sites were dominated by the mosquito fish (*G. holbrooki*), which comprised 34.05% of the total samples collected. This is followed by the tilapia *Oreochromis sp.* (17.18%) and Mayan cichlid *C. urophthalmus* (2.47%) both of which make up 20% of the total catch. The results obtained did not conform to the regular trend of natural freshwater ichthyofauna in Peninsular Malaysia (Ambak & Mohsin, 1986; Lowe-McConnell, 1987; Samat et al., 2005; Azmir & Samat, 2010), which were predominantly cyprinids (Cyprinidae) that occupy about 30% to 50% of the total species present, followed by the catfish (Siluriformes). This maybe because the ex-mining ponds were not natural lentic habitats, but were rather, a geographical structure created by the activities of tin mining and gradual fill-in of rain water into these sites (Yule et al, 2004).

Fish diversity in these areas is largely affected by the activities of the earlier settlers and inhabitants. For instance, the introduction of non-indigenous species by the early Chinese immigrants in 19^{th} century or by fisheries officials in an effort to culture economically valuable species (Ang et al., 1989) such as tilapia (*Oreochromis sp.*) and some carp species. In addition, occasional escapees from fish farms may also contribute to the fish diversity of these mining ponds. According to Allan and Castillo (2008), release of aquarium pet fish into freshwater habitats might also increase the fish diversity. This is particularly possible as two of the sampling sites (Site E and F) are located in the vicinity of housing areas, occupied mostly by university students or locals. Hence, dumping of unwanted fish might occur from time to time, offering an almost unlimited range of freshwater fish species in these mining ponds.

In the present study, mosquito fish (*G. holbrooki*) was found to be the most abundant in all the six sampling sites, followed by tilapia (*Oreochromis sp.*). The result agreed with the findings of Nemeth and Platenberg (2007) which proposed that habitats in a highly developed area contained more non-native fish species such as guppies and tilapia compared to those with low to moderate levels of development. This is particularly true as the human population in the rapidly growing Kampar town is increasing every year due to the two higher education institutes (UTAR and TARC) in the town. Increased number of students may lead to a higher chance of non-native fish introduction into the surrounding ponds, either accidentally or intentionally. The tropical livebearer mosquito fish (*G. holbrooki*) was first introduced into Malaysia as a larvicidal fish for mosquito control (Ang et al., 1989). Its ability to withstand a broad range of water chemistry together with a high reproductive rate allows them to readily colonize these man-made mining ponds. The characteristics of the tilapia which include the ability to adapt to a wide range of environments, high tolerance of critical environments, fast growth, high reproduction rate and versatile feeding behavior (Zainudin, 2005; Uddin, 2007) have enabled them to successfully establish themselves in these freshwater mining ponds. In addition, the dense vegetation along the banks of the ponds provides protection for fish and shrimp fry from possible predators, as well as serves as a suitable breeding habitat with rich supplies of natural food, particularly algae and plankton.

5.2 Comparison between Diversity Indices

All the six sampling sites displayed relatively low diversity when compared to other studies of freshwater ichthyofauna done in Chenderoh Reservoir (Kong &

Ali, 2000), Pulau Langkawi (Azmir & Samat, 2010) and Batu Kerang (Khairul-Adha et al., 2009). Out of the six sites, Site C was found to be the most diverse site which contained the highest number of species (Table 4.5) throughout the three months sampling period. This was in parallel with the Shannon's index and Simpson's diversity index of Site C obtained from October to December 2010 (Figure 4.3 and 4.4). Unlike other sites which displayed major fluctuations in the Pielou's evenness index (J'), the evenness index from Site C were fairly consistent, ranging from 0.623 to 0.687 throughout the three months sampling period (Table 4.3).

The overall trend of results from Simpson's diversity index and Shannon's index highly resembled each other, whereby the sites with the highest and lowest values were the same when calculated using both indices (Figure 4.6). However, there was an exception during the month of November, in which Simpson's diversity index ranked Site D as having greater diversity than Site C, whereas Shannon's index (H') gave the converse ranking (Figure 4.6B). The possible explanation lies within the differential sensitivity of these indices for rare and dominant species (Stiling, 2002). The contrasting responses possibly due to the difference in distribution pattern of dominant species and less abundance species in both sites. Site D displayed higher evenness in the dominant species distribution while Site C displayed higher evenness distribution of less abundant species (Table 4.4). Consequently, Simpson's Diversity index which put more weight towards dominant species gave a higher value in Site D, while Shannon's index which is sensitive to the presence of rare species gave a higher value in Site C. These contrasting responses between Simpson's and Shannon's index were also noted by Nagendra (2002) in his study on the landscape diversity. In his study, landscapes with identical richness were ranked oppositely by Shannon's and Simpson's diversity indices due to the differences in evenness.

5.3 Distribution Pattern

The fish and shrimp populations in all the six sampling sites exhibited complex patterns of distribution. The mosquito fish (*G. holbrooki*) was found in all the sampling sites. This suggests their ability to adapt and thrive in various environments. Overall, the unequal fish and shrimp species composition and distribution at these sites could be attributed to many factors.

Site C displayed the highest diversity among all the six sites, with a total of eight species. This might be related to its physical geography, as Site C is the stream which joins the lake in Site E to the lake in Site D. It is the only site with constantly running water instead of stagnant water. According to Paugy (2002), fast-flowing streams have relatively high concentrations of dissolved oxygen and low levels of suspended solids, which made them good habitats for various fish and other aquatic organisms. Therefore, most of the species observed in other sampling sites were also present in Site C. The growth of weeds and other vegetation along the banks of the stream also contribute to its high diversity. Overgrowth of water spinach (*Ipomoea sp.*) is commonly observed floating on the stream. The roots of these floating plants serve as an important nursery ground for young fish (Putz, 1997; Paugy, 2002). This characteristic could probably create a suitable niche for a variety of fish species, and subsequently higher fish abundance and species richness in a particular habitat. This agrees with our findings that most of the specimens caught at this site were juvenile fish. For instance, a large shoal of giant snakehead (*C. micropeltes*) fry were spotted hiding under the roots of these plants during the sampling in November.

Site E contained the highest number of tilapia (*Oreochromis sp.*) followed by mosquito fish (*G. holbrooki*). The low diversity could be due to the relatively high ammonium content (0.6 mg/L) and the presence of algae near the shore. This is because the enriched pond water accelerates the growth of algae, causing a drop in oxygen level during the decomposition of dead algae by bacteria (Fadiran et al., 2007).

Seasonal fluctuation in water level might also influence the fish and shrimp distribution at the sampling sites. A greater number of individuals were caught during the drier season, which was in October when water levels were lower. In contrast, in the month of November which had heavy rain fall, significantly fewer individuals were caught. Different fish communities found during high and low water seasons may be associated with variations in the migratory movements of the fish species (Renato et al., 2000). In addition, high water level increases the size of the aquatic environment, which in turn affected the sample collection process by decreasing the fish densities per unit area. During the low water season (October), the availability of aquatic habitats was reduced, thus leading to increase in fish densities and biotic interactions (Rodr'iguez and Lewis, 1994; 1997). This may explain the quantity of specimens captured was lower during the rainy season than during the drier seasons.

5.4 Environmental Parameters

All environmental parameters play a significant role in determining the diversity of flora and fauna in a habitat. Physicochemistry of the water quality, topographical and hydrological characteristics, and habitat destruction, play major roles in species richness, diversity and survival in aquatic habitats (Khairul-Adha et al., 2009).A set of water quality parameters (pH, copper, phosphate, ammonia, nitrate and nitrite levels) were measured for all six sampling sites (Table 4.1 and 4.2). The data was not statistically compared because the water sample collection period and fish and shrimp sampling period were different, in which fish sampling period occurred in October to December 2010, while water sampling carried out on January 2011. The water parameters might vary substantially over time. Overall, the copper content, soluble nitrogen (ammonia, nitrate and nitrite) and phosphate concentrations for Site A to Site F were relatively consistent (0.05mg/L to 0.2 mg/L), except for the comparatively higher ammonium-nitrogen concentration (0.6 mg/L) of Site C and Site E. Nevertheless, all the water parameters measured were below the critical values for freshwater ecosystem approved by the National Water Quality Standards of Malaysia (2005).

Site E which is situated at the Kampar Eastlake is located within the vicinity of housing areas. The higher concentrations of ammonium-nitrogen may be associated with leachate from the septic tank located adjacent to the sampling site. In addition, the abundance of cow dung which is commonly observed in the area might contribute to the higher level of ammonium concentration observed. The decomposition of organic animal wastes by fungus and bacteria generate a rich source of ammonia (Molles, 2005) which eventually washes into the pond, particularly through surface runoff during the rainy days. Furthermore, the relatively higher ammonium-nitrogen content in Site E is parallel with the observation of algae growth on the water surface near the shore during the sampling period. As the chief excretory product of aquatic invertebrates, ammonia is a nutrient which is preferred over nitrate by the phytoplankton community (Satpathy et al., 2008). According to Olson (1980), the excretory release and utilization of ammonia by phytoplankton significantly affects its concentration in aquatic environment.

Generally, according to National Water Quality Standards of Malaysia (2005), the water quality of Site A to Site E is categorized under Class IIA, which is appropriate for sensitive aquatic species. However, the ammonia content in Site E should be monitored and regulated continuously to prevent it from rising above 0.9 mg/L, which is the level beyond Class III (National Water Quality Standards of Malaysia, 2005) and is not suitable for aquatic species. This is because excess phosphorous and nitrogen can negatively impact freshwater habitats through their promotion of harmful algae growth and subsequent hypoxia as the algae decomposes, leading to fish death (Lomoljo et al., 2009).

5.5 Future studies

Future experiment can be carried out by sampling in larger amount of samples for a better accuracy. More efficient sampling methods such as cast nets, gill nets and electrofisher can be employed to obtain a higher number and perhaps, variety of samples. Besides, further investigations can be carried out in other months of the year to find out are there any temporal differences in the diversity of fish and shrimps. Statistical tests could then be applied in aiding the data analysis of the variables.

In addition, assessment of impacts of development in surrounding areas towards the aquatic fauna in these disused mining ponds is important. The rapidly developing and extension of UTAR Kampar campus may pose some effects on the diversity of aquatic flora and fauna in these habitats. Apart from preventing habitat destruction, evaluation of the impact of development may assist in maintaining a sustainable aquatic habitat in this area, thus maintaining the magnificent scenery around the university's campus.

Furthermore, the diversity studies of ex-mining ponds in Malaysia are scarce despite the abundance of these areas in the country. It is truly a waste to leave these mining ponds abandoned, as these lands possess unlimited potential of economic values. Some of the fishes in these ponds have the potential value for aquarium industry due to their coloration and body structure. The numerous *Macrobrachium sp.* found in these lakes are known to be popular food for large ornamental fish. Hence it is a worthwhile effort for researchers to invest more time into the ecological study of these habitats.

CHAPTER 6

CONCLUSIONS

The study of diversity of fish and shrimp species in disused mining ponds of Kampar showed a total of eight species of fish and two species of shrimps. Mosquito fish (*G. holbrooki*) appeared as the most abundant fish species (34.05%), followed by two types of cichlid, which were tilapia (*Oreochromis sp*.) (11.49%) and Mayan cichlid (*C. urophthalmus*) (2.47%). The shrimps' populations consist of *Macrobrachium* sp. 1 and *Macrobrachium* sp. 2, with abundance of 33.44% and 17.18% respectively.

The diversity indices showed that Site C contained greatest diversity, with a Shannon's index of 0.479 (±0.044) and Simpson's Diversity index of 0.599 (± 0.064). In contrast, Site D appeared to be the least diverse site, with a Shannon's index of 0.199(± 0.214) and Simpson's Diversity index of 0.244 (±0.304). Site C also displayed greatest evenness among the sites, with J' value of 0.659 (± 0.033), whereas Site D exhibit least even distribution, with a J' value of 0.326 (± 0.350).

The study on the distribution patterns of aquatic fauna in ex-mining ponds showed that Site C with the constant flow of water had the most species (eight species), followed by Site F (seven species). Site A and D each had six species, while Site B and E each had five species. Greatest number of specimens was caught during the drier season, which was October (1497 specimens), while least number of specimens was obtained during the raining season, which was November (727 specimens). Yield from December fall in between these two values, which was 1380 specimens.

The study of water quality parameters showed a slight alkaline pH that range from 7.00 to 8.08 for all the sites. The overall water quality can be considered as good and appropriate for the growth of sensitive aquatic species, with copper concentration less than 0.1 mg/L, nitrite concentrations range from 0.05 to 0.1 mg/L, nitrate concentration less than 0.5 mg/L, ammonium concentrations range from 0.05 to 0.6 mg/L and phosphate less than 0.02 mg/L.

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APPENDIX A

Table 1: Simpson's Diversity (1-D) and Shannon index (H') for Site A to F in October 2010.

Diversity Indices	Sampling sites					
	A	B	C	D	E	F
Simpson's Diversity (1-D)	0.609	0.304	0.574	0.134	0.173	0.432
Shannon index (H')	0.437	0.267	0.436	0.151	0.175	0.266

Table 2: Simpson's Diversity (1-D) and Shannon index (H') for Site A to F in November 2010.

Diversity Indices	Sampling sites					
	A	B	C	D	E	F
Simpson's Diversity (1-D)	0.136	0.659	0.552	0.588	0.501	0.040
Shannon index (H')	0.149	0.470	0.466	0.432	0.312	0.049

Table 3: Simpson's Diversity (1-D) and Shannon index (H') for Site A to F in December 2010.

Diversity Indices	Sampling sites					
	A	B	C	D	E	F
Simpson's Diversity (1-D)	0.246	0.332	0.672	0.010	0.504	0.540
Shannon index (H')	0.232	0.301	0.535	0.013	0.320	0.380

APPENDIX B

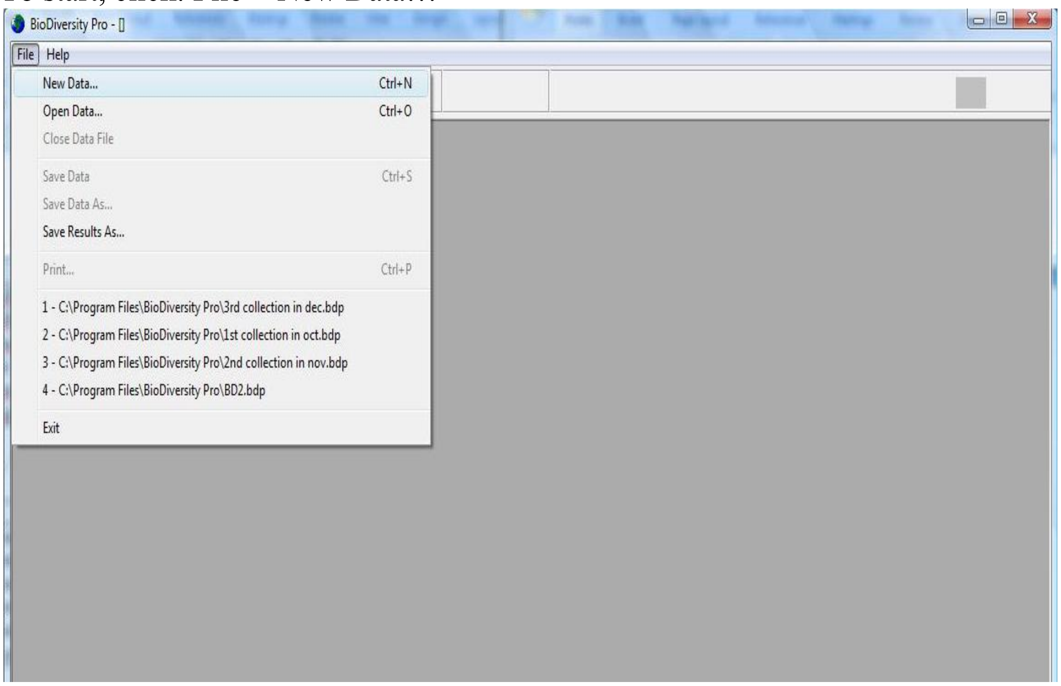
Species composition and abundance of catches of shrimp and fishes samples collected from Site A to Site F from October 2010 to December 2010.

No.	Genus/Species	October No. of individual in each sites						November No. of individual in each sites						December No. of individual in each sites					
		A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F
1	*Macrobrachium sp. 1*	83	479	174	3	-	-	9	67	10	33	-	-	13	158	143	-	-	33
2	*Macrobrachium sp. 2*	48	7	24	-	3	-	196	51	13	12	-	-	173	15	55	-	-	22
3	*Gambusia holbrooki*	28	58	116	134	14	30	2	43	98	55	74	97	11	16	140	208	103	-
4	*Oreochromis sp.*	-	-	4	3	226	-	1	-	3	1	95	1	1	-	-	1	78	-
5	*Cichlasoma urophthalmus*	-	36	4	2	1	13	-	-	-	-	-	-	-	5	24	-	2	2
6	*Stigmatogobius poecilosoma*	-	-	-	2	5	-	-	-	-	-	1	1	-	-	-	-	-	-
7	*Parambassis ranga*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
8	*Plecostomus sp.*	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-
9	*Oxyeleotris marmorata*	-	-	-	-	-	-	1	-	-	-	-	-	2	1	-	-	-	1
10	*Channa micropeltes*	-	-	-	-	-	-	-	-	31	-	-	-	-	-	-	-	-	-
No. of species		3	4	5	5	5	2	6	3	5	4	3	3	5	5	6	2	3	4
No. of individuals		1497						727						1380					
*Total no. of species for each sites			A = 6			B = 5			C = 8			D = 6			E = 5			F = 7	

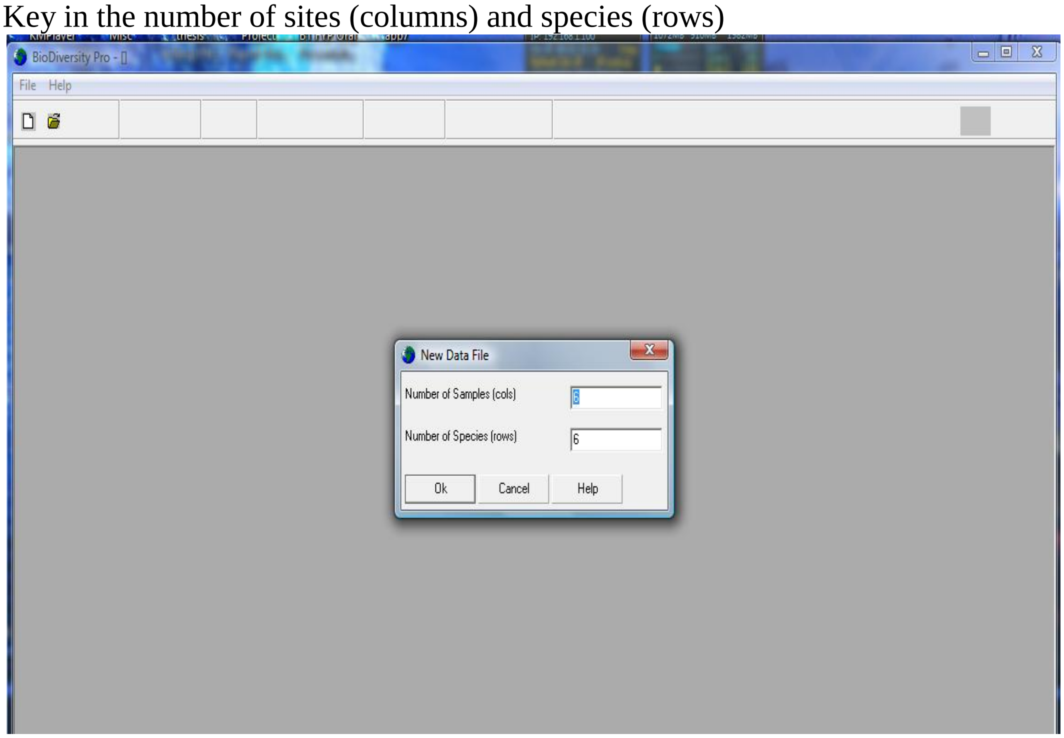
APPENDIX C

Methods of Using BioDiversity Professional Version 2 Software

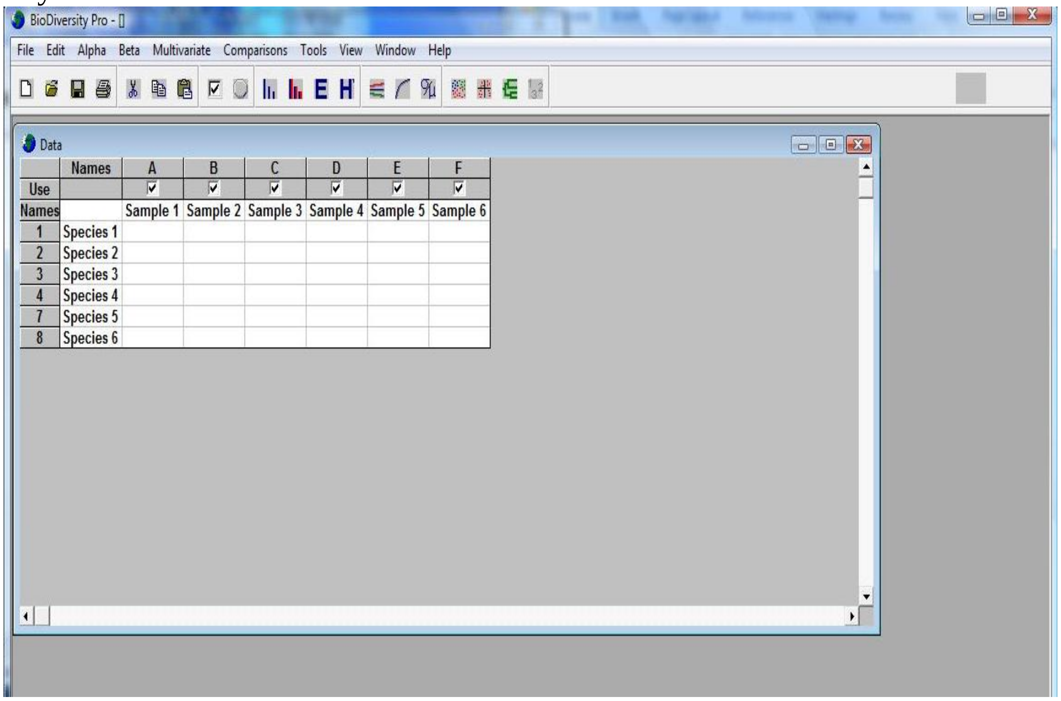
To start, click: File > New Data…

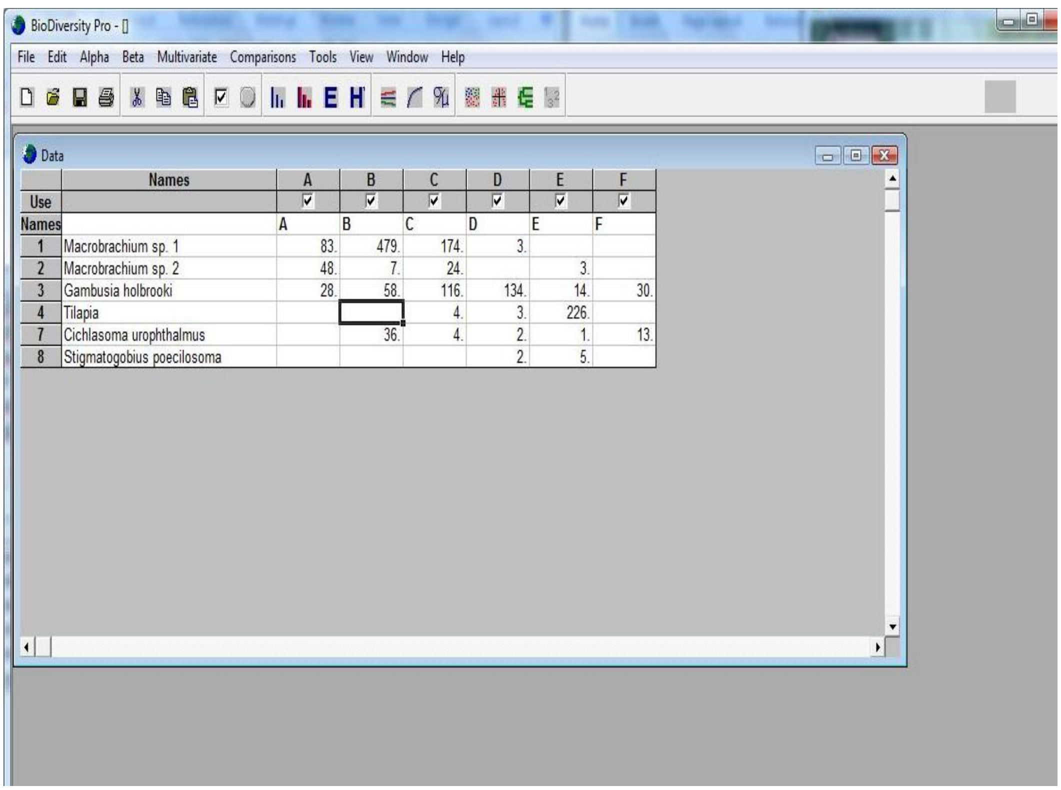


Key in the number of sites (columns) and species (rows)



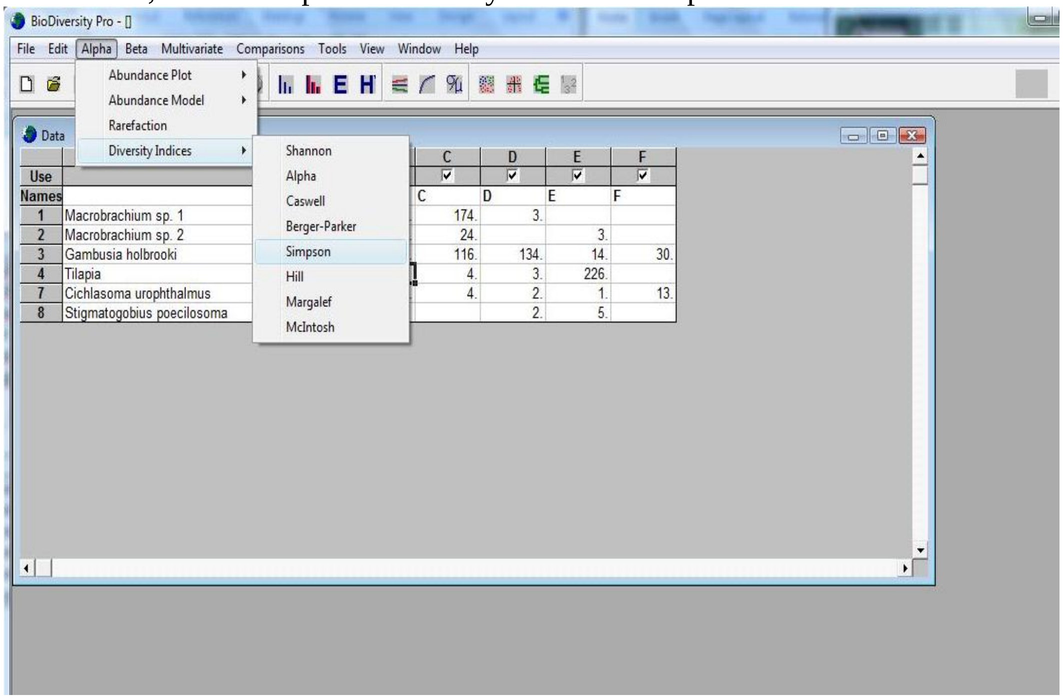
Key in the raw data

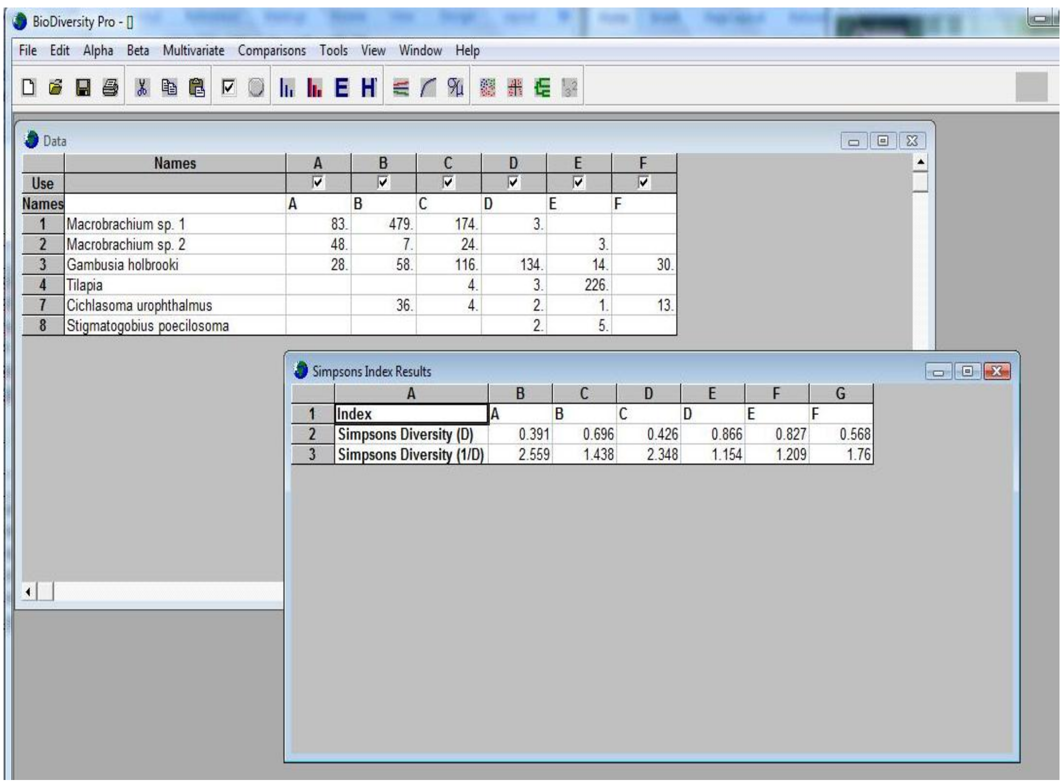




Simpson's Index

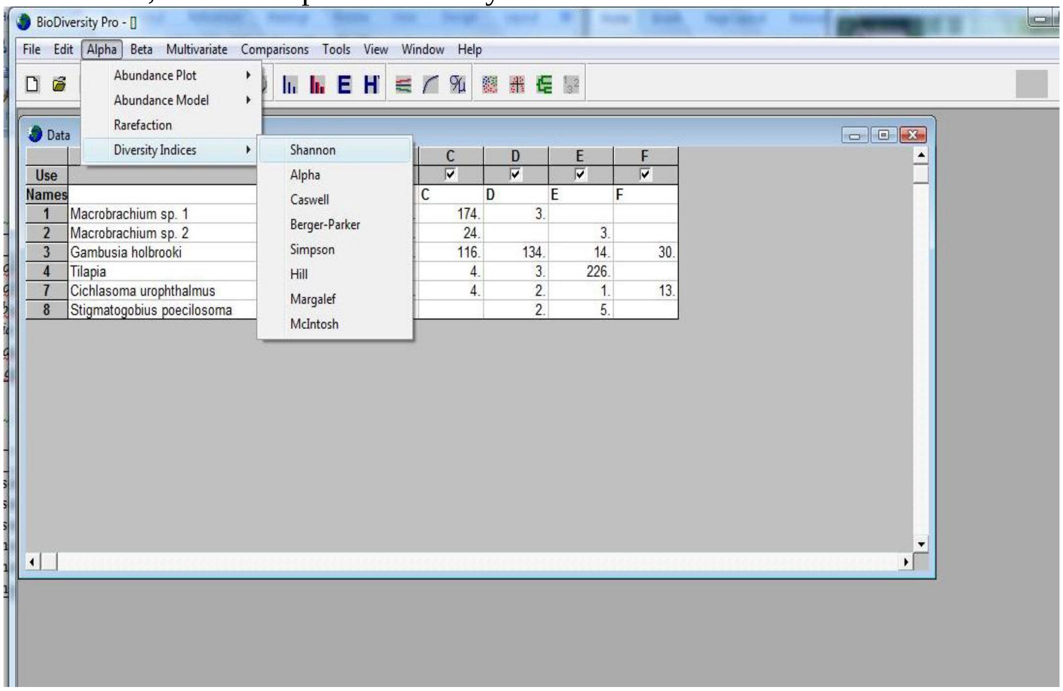
From menu, choose: Alpha > Diversity Indices > Simpson

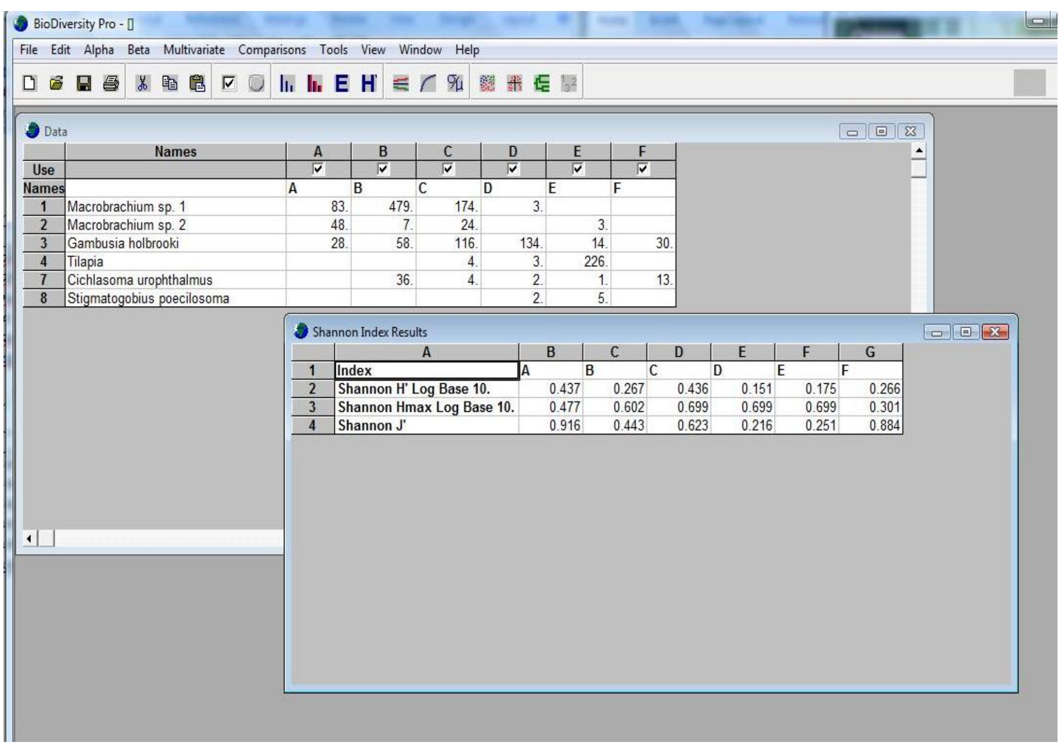




Shannon's Index (H') and Evenness (J')

From menu, choose: Alpha > Diversity Indices > Shannon





	Names	A	B	C	D	E	F
Use		☑	☑	☑	☑	☑	☑
Names		A	B	C	D	E	F
1	Macrobrachium sp. 1	83.	479.	174.	3.		
2	Macrobrachium sp. 2	48.	7.	24.		3.	
3	Gambusia holbrooki	28.	58.	116.	134.	14.	30.
4	Tilapia			4.	3.	226.	
7	Cichlasoma urophthalmus		36.	4.	2.	1.	13.
8	Stigmatogobius poecilosoma				2.	5.	

	A	B	C	D	E	F	G
1	Index	A	B	C	D	E	F
2	Shannon H' Log Base 10.	0.437	0.267	0.436	0.151	0.175	0.266
3	Shannon Hmax Log Base 10.	0.477	0.602	0.699	0.699	0.699	0.301
4	Shannon J'	0.916	0.443	0.623	0.216	0.251	0.884