DIVERSITY AND BIOLOGICAL ASPECTS OF SHRIMP/PRAWN SPECIES WITH SPECIAL REFERENCE TO *Penaeus merguiensis* IN MERBOK RIVER

NUR ILI ALIA BINTI AB DOROH

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by

NUR ILI ALIA BINTI AB DOROH

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of Variance
BW	Body Weight
CL	Carapace Length
D	Simpson's Index
df	degree of freedom
DO	Dissolved oxygen
E	Exploitation rate
ELEFAN I	Electronic Length-Frequency Analysis I
F	Fishing mortality
FiSAT II	FAO-ICLARM Stock Assessment Tools II
H'	Shannon-Weiner Index
HSD	Honest Significance Difference
K	growth constant
K_n	Relative condition factor
$L\infty$	Asymptotic length
L_{max}	Maximum length
LWR	Length-Weight Relationships
M	Natural mortality
Ø'	Growth performance index
pH	potential Hydrogen
ppt	part per thousand
S.D	Standard Deviation
S.E	Standard Error
SPSS II	Statistical Package for the Social Sciences II

St	Station
TL	Total Length
vBGF	von Bertalanffy Growth Function
Z	Total mortality
μS	microSiemens

KEPELBAGAIAN DAN ASPEK BIOLOGI SPESIES UDANG DENGAN TUMPUAN KEPADA *Penaeus merguiensis* DI SUNGAI MERBOK

ABSTRAK

Sungai Merbok terkenal dengan sumber asli yang pelbagai seperti udang yang hidup di air laut dan air tawar sungai ini. Walau bagaimana pun, sungai ini mengalami pengaruh pasang surut air yang menyebabkan fizikal air di sungai ini berubah-ubah. Oleh itu, empat objektif kajian telah dijalankan di Sungai Merbok iaitu (i) untuk mengetahui keadaan fizikal air semasa di Sungai Merbok (ii) untuk merekod kepelbagaian spesies udang di Sungai Merbok (iii) untuk mengetahui hubungan kepelbagaian taburan dan komposisi udang dengan fizikal air di Sungai Merbok (iv) untuk mengkaji beberapa aspek biologi udang dominan di Sungai Merbok. Enam parameter air (suhu, kemasinan, kekonduksian, pH, ketelusan cahaya dan oksigen terlarut) telah direkod di enam stesen berlainan selama empat bulan persampelan di Sungai Merbok. Semua parameter air yang direkod menunjukkan perbezaan ($p < 0.05$) di antara tempoh empat bulan persampelan dijalankan manakala hanya kemasinan dan kekonduksian air menunjukkan perbezaan yang ketara di antara enam stesen persampelan. Sepanjang persampelan dijalankan, sembilan spesies udang yang terdiri daripada tiga buah keluarga (Penaeidae, Palaemonidae dan Alpheidae) telah ditangkap di tiga zon (atas, tengah dan bawah) di mana *Penaeus merguiensis* menunjukkan spesies dominan di setiap zon. Taburan udang di Sungai Merbok menunjukkan perbezaan ($p < 0.05$) antara zon ($F= 17.12$, $p < 0.05$). Zon tengah mempunyai indeks kepelbagaian yang ideal (H' = 1.60, D = 0.23) kerana ia mempunyai keadaan persekitaran yang paling stabil, hasil daripada campuran sumber nutrient 'polyhaline' dan 'mesohaline' laut. Anggaran pertumbuhan udang dominan,

P. merguiensis menunjukkan udang betina mempunyai nilai '*b*' yang lebih tinggi daripada udang jantan. Namun begitu, nilai '*b*' untuk kedua-dua jantina tidak menunjukkan perbezaan ($p > 0.05$) dengan nilai kubik ($b = 3$) menunjukkan pertumbuhan isometrik untuk kedua-dua udang jantan dan betina. Udang jantan mempunyai nilai K_n yang lebih tinggi daripada udang betina berkemungkinan kerana perbezaan kitaran ekdisis yang mana dibuktikan dengan kadar pertumbuhan yang lebih tinggi oleh udang jantan (K= 0.90 year^{-1}) berbanding udang betina (K= 0.640 year^{-1}). Anggaran kadar kematian antara jantina menunjukkan udang jantan mempunyai kadar kematian yang lebih tinggi (Z = 4.39 year^{-1}, M = 1.099 year^{-1}, F = 3.29 year^{-1}, E = 0.75 year^{-1}) berbanding udang betina (Z = 2.30 year^{-1}, M = 0.879 year^{-1}, F = 1.42 year^{-1}, E = 0.62year^{-1}). Walau bagaimana pun, nilai kadar kematian di Sungai Merbok masih dianggap rendah jika dibandingkan dengan udang penaeid di kawasan kajian yang lain. Terdapat beberapa faktor (biologi dan fizikal) yang menyumbang kepada perbezaan kadar kematian di antara kawasan kajian iaitu pemangsaan, kanabalisme, persaingan, penggunaan jenis alatan penangkapan dan keluasan kawasan yang dilitupi untuk tangkapan. Oleh itu, amalan pengurusan perlu dipraktik dan ditingkatkan supaya kepelbagaian dan komposisi spesies udang boleh diurus dengan baik untuk mengekalkan sumber semula jadi ini.

DIVERSITY AND BIOLOGICAL ASPECTS OF SHRIMP/PRAWN SPECIES WITH SPECIAL REFERENCE TO *Penaeus merguiensis* IN MERBOK RIVER

ABSTRACT

Merbok River is known with various natural resources such as the shrimps which inhabit the sea and the freshwater of the river. However, this river experienced fluctuation of physical water parameters because of the influence from the tidal cycles from the sea. Therefore, four research objectives were conducted in Merbok River (i) to know the current status of physical water parameters in Merbok River (ii) to record the shrimp's species diversity in Merbok River (iii) to relate the diversity and composition of shrimp species with physical water parameter in Merbok River and (iv) to study some biological aspect of dominant shrimp in Merbok River. Six water physical parameters (temperature, salinity, conductivity, pH, turbidity and dissolved oxygen) were recorded at six sampling stations during four months of sampling periods in Merbok River. All water parameters shows significance difference between sampling months ($p < 0.05$) but only water salinity and conductivity shows differences between six sampling stations. During sampling periods, nine shrimps species which belong to three families (Penaeidae, Palaemonidae and Alpheidae) were recorded where *P. merguiensis* was the dominant species in each zone. Shrimp's composition in Merbok River showed significance difference between zones ($F = 17.12$, $p < 0.05$). Middle zone has the best diversity indices (H' = 1.60, $D = 0.23$) because it has the most stable environmental condition, resulting from the mixture of polyhaline and mesohaline sea nutrient sources. Estimation of growth dimension of dominant shrimp species, *P. merguiensis* shows female shrimps has higher '*b*' value compared to male. However, the '*b*' value for

both sexes was not significantly difference ($p > 0.05$) with cubic value ($b = 3$) indicating isometric growth for both sexes. Male shrimps has higher K_n value compared to female shrimps probably due to different moulting cycle which was proven by estimation of growth rate where male have higher growth constant ($K= 0.90$ $year^{-1}$) compared to female ($K= 0.640$ $year^{-1}$). Mortality estimation between sexes show male shrimps has higher mortality rates ($Z = 4.39$ $year^{-1}$, $M = 1.099$ $year^{-1}$, $F = 3.29$ $year^{-1}$, $E = 0.75$ $year^{-1}$) compared to female shrimps ($Z = 2.30$ $year^{-1}$, $M = 0.879$ $year^{-1}$, $F = 1.42$ $year^{-1}$, $E = 0.62 year^{-1}$). However, the values of mortality rates estimated in Merbok River are still considered low compared to other penaeid species in other study areas. There are many factors (biologically and physically) that contribute to different mortality rates between study areas such as predation, cannibalism, competition, type of gear used and size of area covered for fishing. Therefore, management practices need to be deployed and enhanced so that the diversity and composition of shrimp species can be well-managed to maintain these natural resources.

CHAPTER 1 – INTRODUCTION

1.1 Introduction

Malaysia is situated in the mega diversity hotspot of the Southeast Asian Region (Myers et al., 2000) and ranks as one of the highest in the world in terms of species richness and endemism (Mittermeier et al., 1999). According to Bellwood and Wainwright (2002) and Mora et al., (2003), the Indo-Malay-Philippines-Archipelago (IMPA) has long been considered the area of highest marine biodiversity. Thus, the Malaysian waters can be regarded as rich breeding ground to a diverse marine and non-marine fauna assemblage.

Marine and non-marine ecosystems are not solely playing their part alone as many species depends on these ecosystems especially in completing their life cycle such as marine fishes, bivalves and penaeid shrimps. The existence of estuary as a junction connecting the marine and non-marine ecosystems has become a channel for these animals to migrate in and out of this area to complete their life cycles. The penaied shrimps are the most studied animals that show the migration behaviour in estuaries (Ahmad-Adnan et al., 2002; Staples and Vance, 1986). In Malaysia, there are several estuaries, such as Merbok, Matang and Kuala Selangor estuaries that play an important role as a channel of shrimp's migration.

Of the most studied estuary, the Merbok estuary is one of the unique estuaries due to its connection with Merbok River. It is surrounded with many activities such as aquaculture, agriculture and also residential area. Besides that, fishing activities that occur along this river might also have an effect on the shrimp's abundance.

Study need to been conducted to know whether these activities affected natural resources that came from this river-estuarine area.

In addition, according to the Annual Fisheries Statistics (2013), Department of Fisheries Malaysia reported over 100,000 metric ton of shrimps were harvested in Malaysia water bodies. The shrimps were consumed for several purposes such as for export, local consumption and also for processing into shrimp products such as shrimp fillet, pastes, crisp and so on. Therefore, there is a need for river-estuarine area like Merbok River to be taken care of so that the post-larvae and juveniles can grow well into adult before migrate out to the open sea (Garcia and Le Reste, 1981; Gulland and Rothschild, 1984) and thus maintaining the natural resources.

Post-larvae and juvenile stages are the most crucial stages in life cycle as they are very vulnerable to the predation and cannibalism. Furthermore, the river-estuarine area is known to have extreme environmental conditions as it experiences abrupt change of physical conditions due to several factors such as tidal patterns and mixing of sea water and freshwater (Vernberg, 1983; Dyer, 1997; McLusky and Elliot, 2004; Ramos et al., 2006). The post-larvae and juveniles need to cope with all these changes in order to survive and grow onto adult.

The pressure from biotic and abiotic factor surrounds these shrimps might disturbed the growing phase of these shrimps. Therefore, there is a need for some biological studies towards these shrimp species so that the growth condition of the shrimps can be known. Besides that, further study on population dynamics need to be conducted to get the overview of stock condition in Merbok River by estimating the growth and mortality rates of shrimp species in this area. Combining all these results, shrimp status in Merbok River can be determined and further action can be done so that the resources can still be maintained.

1.2 Objectives

This study is conducted in Merbok River, Kedah with several objectives. This study builds on to know the current status of physical conditions of Merbok River such as the physical water parameter, besides listing the species diversity in this river. Other than that, this study also focusing on the biology of the dominant species in this river. Therefore, to summarize, this study is conducted with four main objectives which are

i. To know the current status of physical water parameter in Merbok River
ii. To determine the shrimp species diversity and distribution in Merbok River
iii. To relate the diversity and composition of shrimp species with physical water parameter in Merbok River
iv. To study some biological aspect of dominant shrimp species in Merbok River

CHAPTER 2 – LITERATURE REVIEW

2.1 Overview of river-estuarine ecosystem

Estuary is the transition zone between sea and freshwater where the environment was influenced by the mix of fresh and salt waters. The water in this ecosystem continually circulates where tides creates the large flow of saltwater while river provide large flow of freshwater. The great variation in daily and seasonal of environmental conditions in the estuary, such as high variation of air temperature, humidity, water pH, dissolved oxygen and other environmental parameters fluctuates according to fluctuations of tidal currents from the sea (Vernberg, 1983; Dyer, 1997; McLusky and Elliot, 2004; Ramos et al., 2006).

The mixture of sea water and freshwater resulting of brackish water and fluctuation of tidal current will creates the rise and fall of water level and water parameters in this brackish water ecosystem. Water level and salinity can also be influenced by the changes of season as during rainy season, the rivers may flood the estuary with freshwater while during the dry season, the river-estuaries become much more saline because of high rate of evaporation (Ridd and Stieglitz, 2002). Other than these factors, the water salinity can also be different according to location, where the water salinity is weak upstream and very high at downstream of the river-estuaries area (Mansor et al., 2012).

Estuarine ecosystem harbour critical ecosystems (mangroves, sea grasses, intertidal reefs, salt marshes and mudflats) that provide habitat for a unique assortment of plants and animals. This area was reported rich in faunal and floral diversity as they have the combination of marine and freshwater species (Claridge et al., 1986; Akin et al., 2005). The presence of these ecosystems may attract many fauna to live and inhabit this ecosystem. For example, the estuarine that associated with mangrove forest is the habitat and nursery ground for shrimps, crabs and fishes (Chong et al., 1990; Sasekumar et al., 1992; Sasekumar and Chong, 1998; Nagelkerken et al., 2008; Sheaves et al., 2012). The shrimp species that was reported to inhabit mangrove areas are *Penaeus merguiensis* (Staples and Vance, 1986; Robertson and Duke, 1987; Mohan et al., 1995; Ahmad-Adnan et al., 2002) and *Penaeus monodon* (Chong et al., 1990; Mohan et al., 1995; Hajisame and Yeesin, 2014).

This ecosystem has been known as the spawning and nursery grounds of many species (Raynie and Shaw, 1994; Sanvicente-Anorve et al., 2000; Harris et al., 2001; Cowley and Whitfield, 2002; Franco-Gordo et al., 2003). Thus, it makes this environment are highly productive (Nixon et al., 1986; Day et al., 1989) with high diversity and abundance especially for the juveniles (Whitfield, 1999).

Juveniles of the resident and migrating species prefer this ecosystem as it offers protection and helping them to complete their life cycle (Weinstein, 1985; Weisberg et al., 1996; Blaber, 2000; Cowley and Whitfield, 2002; McLusky and Elliot, 2004). In order to complete the life cycle, the greatest differences between phases of larval, juvenile and adult stages are attributed to their habitat choice either demersal, pelagic, estuaries, inshore or offshore (Dall et al., 1990).

In the case of Merbok estuarine ecosystem, this ecosystem is associated with mangrove forest where mangrove has been known as the habitat for shrimps as they provide abundance of food and good refuge to the shrimps to grow and develop. It is believed that the main reasons post-larvae and juveniles select a particular nursery area is because of the food availability (plankton productivity, benthic algae and detritus) in that area (Macia, 2004).

The mangrove serves as the consumer in food cycle where detritus from mangroves become the primary source of food for small organisms including larvae and post-larvae shrimps. In addition, the tidal influence also helps to transport these detritus to many parts of the river and thus the supply from the producer can be transport along the river.

Besides availability of food, mangrove forest also serves as a shelter for the shrimps. The mangrove provides shelter to these shrimps as the prop roots, fallen trees, channels and other obstructions gave structures for the shrimps to hide behind and within them. These structures are very beneficial as these juveniles can hide from larger predators besides getting their food source because the smaller juveniles (the preys) also hide in the structure as well (Young, 2010).

The presence of these protective physical and structurally heterogenous habitats (soft bottoms and mangrove roots) has improved the shelter for these juveniles (Williams, 1955; Zimmerman et al., 1984; Staples et al., 1985; de Freitas, 1986; Coles et al., 1987; Stoner, 1988; Robertson and Blaber, 1993; Vance et al., 1996; Primavera, 1996; 1997, 1998; Ronnback, 1999; Laegdsgaard and Johnson, 2001; Ronnback et al., 2002). Furthermore, mangrove refuge also contribute in several factors such as reduction of efficiency of visual predator because of its high turbidity and the availability of large area of shallow water contains only few predators (Johnson and Sheaves, 2007; Hajisame and Yeesin, 2014).

2.2 Shrimp's distribution in river-estuarine ecosystem

Shrimps constitute a large group of crustaceans with 3047 species of shrimps has been recorded in its distributional range (Chan, 1998). Shrimps are well-distributed in both marine and freshwater ecosystems and mostly in from temperate and tropical regions (Raupach et al., 2010; Basher et al., 2014) and Arctic (Hudon, 1990; De Grave et al., 2008). Shrimps in the tropical regions are mostly concentrated in Indo-Pacific region (Bellwood and Wainwright, 2002; Mora et al., 2003).

However, there are few species that need both ecosystems to complete their life cycle especially the penaeid species. Penaeid shrimps usually inhabit marine ecosystem and spawn there but the larvae migrate to the inshore ecosystem which is the river-estuarine ecosystem to grow and develop into juvenile or sub-adult stage (Motoh, 1981; Staples and Vance, 1986; Loneragan, 1999; Ahmad-Adnan et al., 2002).

In addition, they almost can be seen at every region of the river-estuarine ecosystem and based on Staples and Vance (1986), penaied shrimp such as *Penaeus merguiensis* can enter mangroves for about 45 km long. Once these larvae and post-larvae become juvenile or in sub-adult stage, they migrate to open sea and spawn there. Therefore, penaeid shrimps usually can tolerate wide range of salinities for them to adapt in both ecosystem in order to complete their life cycle.

Contrasts with penaeid shrimps, palaemonid shrimps (*Macrobrachium sp*) usually inhabit freshwater area (Sebastian, 1990; Rao, 1991) but they migrate to downstream of the river where the salinity is a bit higher to spawn (Sarvaiya, 1990). The larvae used that ecosystem to grow and develop before migrating back to the upper stream. The distribution of *Macrobrachium* s*p* in river-estuarine area is limited to only freshwater zone, river mouths and back waters with salinity range from 0 to 20 ppt (Khair et al., 2000).

2.3 Factors determining shrimp's distribution

The assemblages of shrimps within estuarine ecosystems were influenced biotic and abiotic factors (Shenker and Dean, 1979; Rakocinski et al., 1996; Blaber, 2000; Elliot and Hemmingway, 2002; Akin et al., 2003). Study on biotic and abiotic factors has to determine the factor that determining shrimp distribution.

2.3.1 Abiotic factor

Examination of ecological factors has been the main focus of many previous studies (Able, 1999; Martino and Able, 2003) since it has been known that river-estuarine experienced relatively extreme and varying environmental condition but high in biological productivity (Day et al., 1989; Kennish, 1990; Whitfield, 1999). These factors include water salinity (Hagan and Able, 2003; Jaurequizar et al., 2003; Martino and Able, 2003), water temperature (Szedlmayer and Able, 1996; Marshall and Elliot, 1998; Aroujo et al., 1999), water transparency (Peterson and Ross, 1991; Cyrus and Blaber, 1992; Hagan and Able, 2003), water pH (Kingdom et al., 2013) and dissolved oxygen (DO) (Blaber and Blaber, 1980; Rakocinski et al., 1992; Fraser, 1997; Maes et al., 1998; Whitfield, 1999).

2.3.1(a) Water salinity

Water salinity have been shown to play an important role in the occurrence, density and growth of the larval stages (Haedrich, 1983; Day et al., 1989; Houde, 1987; Rakocinski et al., 1996; Strydom et al., 2003; Ramos et al., 2006). In tropical countries such as in Indo-Pacific region, salinity assumes greater importance among the various abiotic factors. It influences post-larvae as they ascend the brackish water areas after completion of their larval phase in the sea. Salinity plays a vital role during larval and juvenile phases by affecting functional and structural responses and thereby the survival, growth and distribution of the shrimps (Zacharia and Kakati, 2002). Undoubtedly salinity is one of the important factors that affect the distribution of marine life since it involves the organism capability to osmoregulate (Cervetto et al., 1999).

2.3.1(b) Water temperature

Besides water salinity, water temperature also plays an important role in the occurrence, density and growth of shrimp's larval stages (Haedrich, 1983; Day et al., 1989; Houde, 1989; Rakocinski et al., 1996; Strydom et al., 2003; Ramos et al., 2006). Temperature is a key factor because it influences the biochemistry, physiology and behaviour of the shrimps (Magnuson et al., 1979). Temperature influences metabolism and growth rate of shrimps as the right temperature will induce their moulting process and thus increase their growth (Vijayan and Diwan, 1995; Hesni et al., 2008). Besides that, it also influences photosynthesis, solubility in water, organism sensitivity to disease caused by parasites and accumulation of toxic materials (Whitefiled and Bruton, 1989; Longley, 1994). In addition, differences in temperature gradients seem to affect the species composition, abundance, and distribution of aquatic species (Magnuson et al., 1979).

2.3.1(c) Water turbidity

Transparency is related to another water quality characteristic that professionals normally monitored, known as turbidity. Turbidity describes how suspended particles affect water transparency. It does not actually measure the concentration of minerals in water, but their scattering and shadowing effect on light shining through the water (Preisendorfer, 1986; Kerker, 2013). It is the condition resulting from suspended solids in water including silt, clay, industrial waste, sewage and plankton. Differences in transparency or turbidity level did not possible to divide species into turbid water species, species indifferent to turbidity or clear water species (Blaber and Blaber, 1980). The differences in turbidity level in an ecosystem just help the species to avoid predators and these conditions may be associated with shallow, food-rich areas (Boehlert and Morgan, 1985).

2.3.1(d) Water conductivity

Conductivity is a measure of water's capability to pass electrical flow which is directly related to the concentration of ions in the water. Ion concentrations which influence the conductivity value can be affected by many factors such as rainfall, water temperature and also the geology of the area as soils and rocks release dissolve solids into the water that flow through or over them (Ramos et al., 2008). In addition, in a coastal streams or estuaries, salt water often mixed with fresh water. Therefore, the addition of saltwater will generally increase the water conductivity and it makes the estuaries has higher electrical conductivity compared to the freshwater. Conductivity measurement can be non-selective for water quality assessment in the sense that it does not distinguish individual concentrations of different ionic chemicals mixed in water (Ramos et al., 2008). However, this measurement is important in water quality assessment systems because the high and low levels of measurements, based on its nominal value can be used to detect any environmental changes and pollution events.

2.3.1(e) Water pH

The pH of water is a measure of hydrogen ion concentration and how acidic or basic the water is on scale of 0 – 14. The pH of water affects the normal physiological functions of aquatic organisms including the exchange of ions with the water and respiration. Important physiological process usually operates at pH range between 6 – 9 units in aquatic biota (Thurston, 1979; Alabaster and Llyod, 2013). Therefore, extreme pH can make the water body inhospitable to life.

2.3.1(f) Dissolved oxygen

Adequate oxygen level is very crucial to maintain the grow-out of shrimps as it involves in natural biological process and it determines the capacity of the aquaculture environment (Boyd, 1990; Vinatea, 1997; Bett and Vinatea, 2009). Dissolved oxygen in a water ecosystem usually affected mainly by physical circulation as a result of atmospheric exchange and turbulence, water temperature as well as organic activity such as primary production, decomposition of organic matter and other biological process (Nelson et al., 1994). Concentration of dissolved oxygen is a function of temperature, salinity and pressure (Wetzel, 1983; Tyson and Pearson, 1991). Furthermore, the main abiotic factors which are influenced by oxygen consumption in aquatic animals are the water temperature and water salinity (Vernberg, 1983; Bett and Vinatea, 2009). In addition to these physical factors, biological activities and pollutant can alter dissolved oxygen levels.

2.3.2 Biotic factor

Competition and predation has been pointed out by several estuarine ecologists as the important factors that driving the occurrence of spatial and temporal patterns of crustacean assemblage in estuaries (Holbrook and Schmitt, 1989; Ogburn-Matthews and Allen, 1993; Lankford and Targett, 1994; Barry et al., 1996). Predation is said to be the ultimate cause of death for most aquatic species, especially during early life-story stages. Thus, the complex cover in a habitat, such as fallen trees and leaves, undercut banks and boulders could increase the survivorship of aquatic communities as they provide a complex channels for hiding.

In the other hand, competition in a habitat can be happen between the same species (intraspecies competition) and also between different species (interspecies competition) where it can occur for any resources that needed for survival such as light, nutrients, space and even mates. Nevertheless, competitions in a habitat are very important in shaping communities since it controls the carrying capacity in that certain habitat.

Besides these two main factors above, other biological factors that influenced the shrimp's distribution are said to be freshwater inflow (Rogers et al., 1984; Fraser, 1997; Whitfield, 1999), structural attributes of habitat (Weinsten et al., 1980; Thorman, 1986; Sogard and Able, 1991; Everett and Ruiz, 1993; Szedlmayer and Able, 1996; Wagner and Austin, 1999), geographic distance from the estuary mouth (Martino and Able, 2003) and hydrography pattern (Cowen et al., 1993).

2.4 Diversity indices

A variety of diversity indices have been employed in aquatic ecology research to assess quality of the environment. They are commonly applied to evaluate and describe the ecological status of the habitat that served to the aquatic communities. There are many ecological indices used for environmental studies and each of them has its own potential and limitations (Magurran, 2004).

2.4.1 Shannon-Wiener Index

Shannon-Wiener Index (H') was introduced by Shannon and Weaver (1949)**,** is commonly used index in aquatic ecology studies despite of its limitation and sensitivity (Magurran, 2004). The typical values usually range from 1.5 to 3.5 and rarely greater than 4.0 in ecological studies. This index increase when richness and evenness increase. Thus, the popularity and reliability are proven due to the fact that this index incorporates both the richness and evenness. The advantage of this index is that it can provide a simple and synthetic summary but the weakness is that it is difficult to compare the communities that differ greatly in richness (Magurran, 2004).

2.4.2 Simpson's Index

Simpson's Index (*D*) was introduced by Simpson (1949) is used to measure the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). This index is used to explain heterogeneity and evenness of the species. The values ranges from 0 to 1 where 0 represent the infinite diversity while 1 represent no diversity. It also concluded that the bigger the value, the lower the diversity.

2.4.3 Species Richness

Species Richness is the number of species present in a sample, community or taxonomic group. The more species present in a sample, the richer the sample. It is one component of species diversity where total number of species present in a habitat can be estimated. Species Richness alone incomplete to measure diversity, therefore estimation of species evenness is needed to incorporate with species richness so that the estimation can be more accurate (Bock et al., 2007).

2.5 Population dynamic parameters

The population dynamic parameters can be divided into several parts where it usually involves the assessment of length and weight. From these data, several estimations can be done such as the size composition, weight composition, growth rates and mortality rates. All these data then can be used for stock assessment of the individuals.

2.5.1 Length-weight relationships

Traditionally most estimates of growth curves have been made as in terms of length rather than in weight. However, the importance of fish or shrimps, either in the ecosystem or to the fishermen, is better measured by its weight (Gulland, 1983). In order to know their biology, study and knowledge on both length and weight are very important. The relation and calculation between length and weight can be used to predict weight from length measurements made in the yield assessment (Pauly, 1993) and the calculation will give the value of '*b*' that is close to, but not quite equal to 3.

This '*b*' value will indicate the somatic growth of fish whether it is isometric or allometric (Le Cren, 1951; Ricker, 1973). Isometric growth is when length increases in equal proportions with body weight. Allometric growth can be divided into positive and negative allometric growth where positive allometric growth is when the fish or shrimps become relatively stouter or deeper-bodied as it increased in length while negative allometric growth is when fish or shrimps becomes more slender as it increase in weight (Riedel et al., 2007; Nahemia et al., 2012).

According to Pitcher and Hart (1982), length-weight relationships are beneficial in fishery management to estimate weight from the obtained length observations in order to provide information on stock organism condition at the corporal level as well as to calculate production and biomass of stock populations. This is because by using length and weight data, one can predict the growth parameters as well as the mortality rates which useful in stock assessment study (Samat and Arshad, 2008). These relationships also give information on the conditions and growth patterns of individuals (Bagenal and Tesch, 1978).

2.5.2 Relative condition factor

The continuous of length-weight relationships give information on the conditions and growth pattern of individuals (Bagenal and Tesch, 1978). It showed the well-being of the fish in their habitat. It measure various ecological and biological factor such as degree of fitness, gonad development and the suitability of the environment with regard to feeding condition (Mac Greagor, 1959). The higher the means value, it showed the individuals has attained a better condition. The values can be difference because of several factors depending on stress, sex, seasons, availability of feeds and other water quality parameters (Khallaf et al., 2003; Nahemia et al., 2012).

2.5.3 Bhattacharya's plot

Bhattacharya's method was developed by Buchanan-Wollaston and Hodgson (1929) and was subsequently developed by Bhattacharya (1967). It is proposed as a graphical method for separation of normally distributed groups from a mixture of normal distributions. It is used to split the age groups from the length-frequency data using FiSAT II software where a straight line with a negative slope will be obtained. It is obtained by plotting the natural logarithm of ratios of successive frequencies against the midpoints of the corresponding classes.

2.5.4 Growth rates

Growth can be defined as the change in size (length or weight) over time or as the change in calories that are stored as somatic and reproductive tissue. The growth and age become an important tool to predict the potential yield of the fishery and to describe the status of fisheries population as well as accelerates the assessment of stock size, production, mortalities and recruitment to adult stock (Lowe-McConnel, 1987).

However, it is very difficult to estimate growth in crustaceans since the exoskeletons are lost during moulting and thus cannot serve as an index of the age of an individual. Furthermore, the growth is discontinuous and limited due to the presence of rigid, chitinous, calcified exoskeleton (King, 1995; Oh et al., 1999). Therefore analysis of length-frequency data has been widely used for growth estimation and basically, study on growth is the determination of body size as a function of age.

Growth, like other process, is individual in nature and it depends on many covariates such as seasonality, food availability, sex and many other factors (Lloyd-Jones et al., 2014). In order to describe the mean growth, growth model such as von Bertalanffy is often used where body length is used as a function of age. This growth model is then reviewed by Beverton and Holt (1957), Ursin (1967), Ricker (1975), Gulland (1983), Pauly (1984a, b) and Pauly and Morgan (1987) to compose new sub-models to describe the dynamics of fishes and invertebrates in more complexes.

Growth model is very important in fisheries because it can used to estimate and determine the population dynamics of a population. From these models, several growth functions such as $L\infty$ and K are estimated. These growth parameters are important as it is used to describe the species (Sparre and Venema, 1998; Hilborn and Walters, 1992). $L\infty$ is the largest theoretical mean length that a species could attain in its habitat given the ecological peculiarities in that environment and K is the speed it grows towards their final size and related to the metabolic rate of the species. Nevertheless, these growth parameters are differ from species to another species, from habitat to another habitat and may vary from stock to stock within the same species (Sparre and Venema, 1998).

2.5.5 Mortality rates

Estimation of vital rate such as mortality and growth rates are very beneficial in identifying essential habitat for an organism and assessing nursery habitat for marine organisms such as penaeid shrimps (Beck et al., 2001; Yoklarich et al., 2010; Mace and Rozas, 2015). In term of mortality, it is mainly caused by several factors including environmental stress (Chapman and Van Well, 1978), parasites and diseases (Overstreet, 1973; Johnson, 1989; Lightner and Redman, 1998; Primavera, 2006), predation (Otobo, 1993) and fishing activity and age (King, 1995). Therefore in fisheries, mortality can be caused by fishing mortality or natural mortality where fishing mortality is due to the direct removal of individuals from population by humans while natural mortality is death cause by all other cases (Ricker, 1975; Mace and Rozas, 2015).

Similar with estimation of growth rates, estimation of mortality rates also based on length-frequency data (Minello et al., 1989; Haywood and Staples, 1993; Wang and Haywood, 1999; Pérez-Castañeda and Defeo 2005; Baker and Minello, 2010). In order to estimate mortality using length-frequency, there are two approaches can be used and it usually include some-type of catch-curve analysis (Mace and Rozas, 2015). The first method involves sampling a population of shrimp over time and using length-frequency distribution to identify individual groups or cohorts of shrimps. Meanwhile the second method is to convert the length-frequency data to age-frequency data and then conduct a horizontal catch-curve analysis (Vetter, 1988).

Even though mortality likely to be affected by many factors such as natural mortality and fishing mortality, most fishery population models assume a constant mortality rates (Vetter, 1988) and because of natural mortality cannot be controlled, managing fishing mortality could be the best thing to do. Furthermore, knowledge about mortality is especially important because in an exploited population, managing such population need to be based on regulating mortality caused by humans (Mace and Rozas, 2015).

CHAPTER 3 – MATERIALS AND METHODS

3.1 Sampling area

This study was conducted at Merbok River which is located at the northern part of Peninsular Malaysia in the district of Kuala Muda, Kedah (lies between 100°20’57.33” E; 5°40’53”N at the lower part and 100°30’24.56” E; 5°42’13.46”N at the upper part). The upper part of the river started at Bedong and the water drain to the Straits of Malacca. The length of Merbok River was about 35 km, and the depth varies from 0.3 to 15 m depth (Mansor et al., 2012). Merbok River has catchment area of 440km^2 which was made up of alluvium deposits overlying an extensive span of ferruginous shale and mudstone with a few scattered outcrops of granites and ferruginous sandstone or quartzite (Ong et al., 1991; Khoo, 1996).

In this study, the sampling area was divided into three zones which were upper, middle and lower zones (Figure 3.1). The zonation was divided by looking at the topography of the river (Mansor et al., 2012). The upper zone that stretches from Lalang River to Semeling River is associated with residential, pond culture, artisanal fishing and agricultural activities. The middle zone that extends from Keluang River to Teluk Wang River is influenced by human activities, including agricultural, artisanal fishing, residential and cage culture activities while the lower zone extends from Gelam River to Lubuk Pusing is significantly affected by the effluent from cage culture, agricultural activities, pond culture and artisanal fishing.

Shrimp sampling was conducted at every zones of Merbok River (Figure 3.1) in September 2012, November 2012, January 2013 and March 2013 which then will represent as dry and wet months. Two sampling stations were chosen at each