FISH ASSEMBLAGES IN KERIAN RIVER TRIBUTARIES, KEDAH – PERAK BORDER

MOHD. SHAFIQ BIN ZAKEYUDDIN

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FISH ASSEMBLAGES IN KERIAN RIVER TRIBUTARIES, KEDAH – PERAK BORDER

by

MOHD. SHAFIQ BIN ZAKEYUDDIN

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2. **Mohd. Shafiq, Z.**, Mansor, M. I. and Che Salmah, M. R. (2010). Length-weight relationship and mean relative condition factor (*Kn*) of six freshwater fish species at selected rivers in Kerian River Basin in northern peninsular Malaysia. Proceeding of the 7th IMT-GT ININET and the 3rd Joint International PSU-UNS Conference. Prince of Songkhla University, 7-8 October 2010, Hat Yai, Songkhla, Thailand.

LIST OF SYMBOLS AND ABBREVIATION

CCA	=	Canonical Correspondence Analysis
CPUE	=	Catch Per Unit Effort
cm	=	Centimeter
DO	=	Dissolved Oxygen
E	=	Exploitation rate
ELEFAN I	=	Electronic Length-Frequency Analysis I
F	=	Fishing mortality
FISAT II	=	FAO-ICLARM Stock Assessment Tools II
g	=	gram
IRI	=	Index of Relative Importance
K	=	Growth constant
Kn	=	Relative Condition Factor
L	=	Litre
LWR	=	Length-Weight Relationship
$L\infty$	=	Asymptotic length
M	=	Natural mortality
m	=	Metre
mg	=	Miligram
mm	=	Milimetre
NA	=	Negatively allometric
ns	=	Not Significant
PA	=	Positively allometric
ppt	=	Parts Per Thousand

R^2	=	Regression coefficient
s	=	Second
SE	=	Standard Error
SL	=	Standard Length
SPSS	=	Statistical Package for Social Science
TDS	=	Total Dissolved Solids
TL	=	Total Length
t_{max}	=	Potential longevity
W	=	Weight
Z	=	Total mortality
φ’	=	Growth performance index
µS	=	Micro Siemens
b	=	Growth coefficient
ρ	=	Spearman rho Correlation

PERKUMPULAN IKAN DI ANAK-ANAK SUNGAI SUNGAI KERIAN DI SEMPADAN KEDAH-PERAK

ABSTRAK

Pengaruh ciri-ciri habitat terhadap taburan ikan di sungai-sungai terpilih di Sungai Kerian telah dikaji dari Mei 2008 sehingga Jun 2009 dengan mengukur beberapa parameter fiziko-kimia; DO, pH, suhu, kemasinan, konduktiviti, TDS, halaju, kedalaman dan lebar sungai. Purata kandungan DO di dalam air, konduktiviti ion, suhu air, kandungan TDS, halaju air, kelebaran dan kedalaman sungai berbeza secara signifikan antara sungai (ujian Kruskal-Wallis, $P < 0.05$). Empat puluh lapan spesies ikan daripada 20 famili telah ditangkap dengan menggunakan jala, alat kejutan elektrik dan jaring serangga. Cyprinidae mempunyai kelimpahan tertinggi dengan 645 individu atau 73.3% daripada keseluruhan tangkapan. Sungai Bogak mempunyai komuniti ikan yang paling tinggi kepelbagaian (H'=2.353) manakala Sungai Kangar mempunyai kepelbagaian terendah (H'=1.344). Ordinasi CCA menerangkan hubungan yang signifikan (ujian permutasi Monte Carlo, $P < 0.05$) antara spesies ikan dan kepelbagaian persekitaran. Hubungkait panjang-berat telah dianalisis ke atas enam spesies ikan paling tinggi kelimpahan dengan menggantikan panjang dan berat ikan masing-masing kepada $W=aL^b$. Pertumbuhan ikan (*b*) menunjukkan empat spesies, *D. regina* (*b*=3.256), *P. binotatus* (*b*=3.911), *R. sumatrana* (*b*=3.642) dan *C. apogon* (*b*=3.623) membesar secara allometrik positif, manakala dua spesies, *Labiobarbus sp.* (*b*=2.898) dan *A.*

choironrhycos (*b*=2.427) mempunyai tumbesaran secara allometrik negatif. Semua spesies mempunyai kadar pertumbuhan yang cepat berdasarkan pertumbuhan malar (K) parameter pertumbuhan jangkaan, berjulat daripada 1.03 $tahun^{-1}$ sehingga 1.60 $tahun^{-1}$. Kematian daripada tangkapan ikan (F) yang bervariasi daripada 0.33 $tahun^{-1}$ sehingga 0.76 $tahun^{-1}$, lebih rendah berbanding kematian secara semulajadi (M), 1.92 $tahun^{-1}$ sehingga 2.40 $tahun^{-1}$. Kadar eksploitasi untuk semua spesies terpilih (0.26 $tahun^{-1}$ - 0.13 $tahun^{-1}$) berada di bawah daripada eksploitasi optimum stok. Analisis perut ikan menunjukkan *Devario regina* adalah pemakan aktif apabila 121 daripada 126 individu mengandungi makanan dalam perut yang penuh. Formicidae adalah makanan yang paling kerap dimakan (berdasarkan kepada IRI) dalam kelimpahan yang tinggi maka ia adalah diet utama manakala serangga daratan dan akuatik dan bahan tumbuhan dimakan dalam jumlah yang sedikit. Kedominan Formicidae di dalam ikan *D. regina* menandakan vegetasi riparian adalah penting untuk melindungi sumber-sumber makanan ikan tersebut.

FISH ASSEMBLAGES IN KERIAN RIVER TRIBUTARIES, KEDAH – PERAK BORDER

ABSTRACT

Influence of habitat characteristics on fish distribution in selected Kerian River tributaries was investigated from May 2008 to June 2009 by measuring several physico-chemical parameters; DO, pH, temperature, salinity, conductivity, TDS, velocity, river depth and width. Mean DO content in the water, ion conductivity, water temperature, TDS content, water velocity, river width and depth were significantly different among rivers (Kruskal-Wallis Test, $P < 0.05$). Forty eight fish species from 20 families were collected using a cast net, an electrofishing and an insect net. Cyprinidae had the highest abundance with 645 individuals or 73.3% from all the catch. Bogak River had the most diverse fish community (H'=2.353) while Kangar River was the least diverse (H'=1.344). The CCA ordination explained significant relationship (Monte Carlo permutation tests, $p < 0.05$) between fish species and environmental variables. The length-weight relationship was analyzed for six most abundant fish species by substituting respective fish length and weight values into $W=aL^b$. The fish growth (*b*) showed that four species, *D. regina* (*b*=3.256), *P. binotatus* (*b*=3.911), *R. sumatrana* (*b*=3.642) and *C. apogon* (*b*=3.623) had positive allometric growth, while two species, *Labiobarbus sp.* (*b*=2.898) and *A. choironrhycos* (*b*=2.427) had negative allometric growth. All species had fast growth rates as indicated by a growth constant (K) of the estimated growth parameters, ranging from 1.03 $year^{-1}$ to 1.60 $year^{-1}$. Fishing mortality (F) that varied from 0.33 $year^{-1}$ to 0.76 $year^{-1}$, were lower than calculated natural mortality (M) of 1.92 $year^{-1}$

to 2.40 $year^{-1}$. Exploitation rates for all selected species (0.26 $year^{-1}$ - 0.13 $year^{-1}$) fell below the optimal stock exploitation rate. The analysis of stomach content indicated *Devario regina* was an active feeder when 121 of 126 individuals had full stomachs. Formicidae was the most frequently eaten (based on IRI) in high abundance hence was its main diet while other terrestrial and aquatic insects and plant materials were taken in lesser amount. The dominance of Formicidae in the stomach of *D. regina* indicated the importance of riparian vegetations as shelters for its food sources.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background

Freshwater fish in the tropics are extremely diverse and they are estimated that more than 1000 species present in Southeast Asia (Zakaria-Ismail, 1994). They have diverse morphology and behavior, which their lifespans range from 1 to 120 years (Ambak *et al.,* 2010). Fish assemblages that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores), integrate effects of lower trophic levels (Garcia *et al.,* 2006) and serve as good indicators of long-term effects because they are long-lived and mobile (Barbour *et al.,* 1999). Stream fishes are segregated depending on species and life stages (Gorman & Karr, 1978; Welcomme, 1985).

The fish fauna in Asia is dominated by Cypriniformes (barbs and loaches), Siluriformes, anabantoids (gouramis, climbing perches, snakeheads) and mastacembeliods (spiny eels) (Winemiller *et al.,* 2008). Fish diversity increases from headwaters to downstream (Schlosser, 1982) and the trophic structure of the fish community also changes with greater dependence on invertebrates and herbivory in upland streams while omnivory and piscivory are more important in lowland rivers (Martin-Smith, 2004).

The fish community is an assemblage of species that combines the species richness, diversity, morphological and physiological attributes and tropic structure (Zarul Hazrin, 2006). Rahel and Hubert (1991) observed that the fish community changes from headwater to downstream due to the progressing addition of new species. Streams in headwater were dominated by the insectivore feeding guild, while other trophic guilds were dominated at downstream (Rahel & Hubert, 1991).

Studies on the fish assemblage in streams in the same river basin are essential to understand the functioning of the river basin. The interaction between fish and habitat determines the relationship between aquatic and terrestrial habitats because fish usually consume terrestrial food sources such as insects and fruits that are useful information for conservation management (Lagler *et al.,* 1977; Ponton & Copp, 1997; Fialho *et al.,* 2007).

The distribution of fish in its ecosystem is a result of interaction among fishes and their chemical, physical and biological surroundings (Lagler *et al.,* 1977; Gordon *et al.,* 1996; Bistoni & Hued, 2002). There are variety of factors affecting the abundance, distribution and productivity of stream fish such as competition for space, predation, water quality, nutrient supplies and flow variability (Gorman & Karr, 1978; Zakaria-Ismail & Sabariah, 1994; Gordon *et al.,* 1996; Casatti *et al.,* 2006; Andrus, 2008). The presence of riffles, pools, in-stream woody debris forms heterogeneous habitats that influence fish assemblages (Platts *et al.,* 1983; Angermeier & Karr, 1983; Benke *et al.,* 1985; Bisson *et al.,* 1987). However, disturbances such as flash floods or droughts can cause short-term changes in fish abundance (Zarul Hazrin, 2006).

Freshwater fishes need suitable water quality, migration routes, spawning grounds, feeding sites, resting sites and shelter from predators and disturbance because they spend their entire life in the same habitat (Angermeier & Karr, 1983; Cowx & Welcomme, 1998). The importance of stream characteristics on fish diversity had been documented in several studies both in temperate (e.g., Gorman & Karr, 1978; Meffe & Sheldon, 1988; Moran-Lopez *et al.,* 2006) and tropical regions (e.g., Inger & Chin, 1962; Gorman & Karr, 1978; Angermeier & Karr, 1983; Mohsin & Ambak, 1983; Martin-Smith, 1998).

Dudgeon (1992) pointed out that Asian river ecosystem degradations are related to human activites. However, overfishing is less contributing to the extinction of freshwater fish although more freshwater fish are threatened than marine species (Kottelat & Whitten, 1996; Coates *et al.,* 2003). The human activites on land will have a direct or an indirect influence on fish diversity (Nguyen & De Silva, 2006). The impacts of land use are often measured by looking at fish assemblage structure, their presence or absence and abundance (Bojsen & Barriga, 2002; Diana *et al.,* 2006; Di Prinzio *et al.,* 2009). However, the study of functional properties of fish such as feeding habit, growth or production may give more details on the possible effects of deforestation (Vila-Gispert *et al.,* 2000; Bojsen, 2005) especially in tropical systems, in which terrestrial invertebrates are very important food sources for stream fishes (Angermeier & Karr, 1983).

Previous studies on fish in Peninsular Malaysia focused primarily on biology, taxonomy and distributional patterns of freshwater fish (Ali *et al*., 1988). One of the earlier studies in Kerian River Basin, Ali *et al*. (1988) included distributional patterns of freshwater fishes, preliminary stock assessment of the Perak River and food habit studies of various species of cyprinids. They recorded more than half of their total catches (55%) were cyprinids. The study of fish composition in Pusu River and Keling River, Selangor reported high abundance of Cyprinidae (Zakaria-Ismail, 1994) while Zakaria *et al*. (1999) compared the diversity of fish in both swamp-riverine areas namely Beriah and Ulu Sedili rivers. Between the two rivers, Beriah River had higher fish diversity and *Rasbora einthovenii* was found to be the most dominant species. Apart from Zakaria *et al.* (1999), the fish study in Kerian River is scarce especially in the upper area of the river basin. Yap (1990) studied fish diversity at the lower part of Kerian River basin while Ali (1998) surveyed the middle spent of the river especially in Beriah Swamp. In his study, Ali (1998) worked on increasing public awareness on the importance of wetlands and their resource primarily fish. However, there was no fish study has been focused on the upper catchment of Kerian River Basin. Thus this study was carried out in both upper and lower catchment of the river basin at selected river tributaries to determine fish assemblages.

1.2 Objectives

In view of the present status of freshwater fish studies in Peninsular Malaysia, this research is undertaken with the following objectives:

1. To determine the fish distribution in selected Kerian River tributaries, Perak.
2. To assess the suitability and wellness of Kerian River tributaries using population parameters of six freshwater fish species.
3. To determine the trophic level of the most abundance species in Kerian River tributaries.

CHAPTER 2

LITERATURE REVIEW

2.1 River ecosystem

In general, river is associated with ’larger’ and stream with ‘smaller’ running water bodies (Gordon *et al.,* 1996). Streams are defined as fluvial systems with channel widths up to approximately 30m (Winemiller *et al*., 2008) and shaped by trees growing near the channel (Andrus, 2008). Streams and rivers are characterized by unidirectional movement of water (Martin-Smith, 2004). River that stretches from headwater to estuary is influenced by longitudinal, lateral and vertical fluxes and temporal changes (Cowx & Welcomme, 1998).

Upper river habitats provide more than 80% of stream networks and watershed land areas (Wipfli *et al.,* 2007). Upper river ecosystems are the most important freshwater resources that high in species endemism and biological productivity (Zarul Hazrin, 2006; Wipfli *et al.,* 2007). These lotic ecosystems transport water, sediments, chemicals, detritus and biota from headwaters to floodplain, estuaries and to the sea (Downes *et al.,* 2002).

Generally, upper streams have fast currents and are characterized by riffles, rapids dominated by boulders and cobbles (Winemiller *et al.,* 2008). In upper streams, allochthonous resources such as drifting terrestrial invertebrates and detritus are very important (Cloe & Garman 1996, Kawaguchi & Nakono 2001; Winemiller *et al.,* 2008). Fish assemblage structures in upstream rivers are controlled primarily by abiotic conditions such as floods and drought (Echelle *et al.,* 1972).

According to Winemiller *et al.* (2008), streams have high substrate diversity (bedrock, cobble, gravel, sand and terrestrial litter), periodic spates and flash floods during the wet season. They found that fish tend to segregate according to pool-glide-riffle mesohabitats. Lower river ecosystems have slow currents, pools, high in organic sediments with abundant aquatic macrophytes, allochthonous and autochthonous resources (Winemiller *et al.,* 2008).

During wet season, fishes migrate from larger, deeper channel to spawn in floodplain areas that serve as productive nursery habitats (Welcomme, 1969; McAdam *et al.,* 1999). In some circumstances, biotic interactions such as competition and predation may be important in structuring fish assemblages in the downstream (Ostrand & Wilde, 2002). Floods have significant impacts on fish species because the inundation of floodplains regulates plant growth and nutrient input to the stream (Gordon *et al.,* 1996). During floods, fish migrates to floodplain areas to spawn (Gordon *et al.,* 1996) while the juveniles depend on floodplain areas as a nursery area.

2.2 River system in Malaysia

Malaysia is drained by 150 river systems, in which 100 river systems are in Peninsular Malaysia and 50 in Sabah and Sarawak (Abdullah, 2002). Rajang River is the largest river in Malaysia with a catchment area of 51,000 km^2, while Pahang River was the largest river in peninsular with a catchment area of 29,000 km^2 (Abdullah, 2002). Most river systems in Malaysia generally arise from small headwater streams and increase longitudinally in size, discharge and fish species (Allan & Castillo, 2007). It begins in mountainous or hilly areas and release water falling to the earth's surface as rain to the sea (Winemiller *et al*., 2008).

2.3 Possible impacts of land use on the aquatic ecosystem

Generally, rivers are the most disturbed ecosystems by direct and indirect human influence (Maddock, 1999; Oscoz *et al.,* 2005). Channelized rivers are characterized by straight, trapezoidal channel sections, clear of river bank trees and uniform bed morphology (Brookes, 1988).

Channelization by straightening of streams is one of the major losses of fish habitat. The uniform of the bed structure causes a decrease in fish abundance and biomass and the loss of valuable species (Cowx & Welcomme, 1998). Hortle & Lake (1983) reported that channelized reach suffered of lower abundance and lower species richness compared to an unchannelised reach of a Victorian River. Less heterogeneity in width, velocity and substrate type due to the channelization recorded lower biomass and fewer species and families of fish in a northwestern Iowa prairie (Scarnecchia, 1988).

The impacts of agriculture and urbanization particularly in lowland areas influence the changes in water quality (Sweeting, 1994; Maddock, 1999). As a consequence, these human activities led to changes in the composition of biotic community, reducing the biological diversity of the aquatic ecosystem (Boon, 1992; Maddock, 1999). Excessive siltation leads to suffocation of fish eggs, thus adversely affecting fish populations (Gordon *et al.,* 1996).

2.4 Factors influencing the distribution of fish

It is important to understand the relationship between biotic community structure and the physical habitat (Martin-Smith, 1998) because every fish species has different preference of different habitats (Fialho *et al.,* 2007). Habitat diversity, biomass, richness, mean fish size and density of fish are correlated with water depth and velocity (Mendelson, 1975; Schlosser, 1985; Ali *et al.,* 1988; Meffe & Sheldon, 1988; Sheldon & Meffe, 1995), substrate type, aquatic vegetation and bank cover (Gorman & Karr, 1978; Schlosser, 1982; Rakocinski, 1988; Bishop & Forbes, 1991). Sheldon (1968), Moyle and Vondracek (1985), Bain *et al.* (1988) and Koehn (1992) found that water depth and current velocity were the most important variables influencing fish distribution. Fish preference on the physical habitat depends on geological, morphological and hydrological processes (Cowx and Welcomme, 1998).

2.4.1 Dissolved oxygen (DO)

Oxygen gas that dissolved in water is measured as dissolved oxygen (DO) (Boyd, 1990). DO is very important for respiration of aquatic animals (Gordon *et al.,* 1996). Sources of oxygen in the water come from direct diffusion of oxygen from the atmosphere, wind and wave action and photosynthesis by aquatic plants and phytoplankton (Gordon *et al.,* 1996; Francis-Floyd, 2003). A recommended DO for optimum fish health is 5 mg/L (Jain *et al.,* 1977; Alabaster & Lloyd, 1982; Othman *et al.,* 2002).

The mortality of fish is determined by the duration of low DO concentration in the water (Francis-Floyd, 2003). Fishes are stressed when DO falls to 2-4 mg/L and the mortality occurs when DO concentration is less than 2 mg/L (Francis-Floyd, 2003). Still water may have more oxygen at the surface due to diffusion from the air. Some fishes take advantage of this by coming toward the surface to breathe when oxygen is limited (Helfman *et al.,* 2009). Hynes (1970) found that the variation of swimming speed of young salmon depends on DO content in the water.

2.4.2 Water temperature

Low water temperature is influenced by the presence of riparian vegetations. The riparian vegetations shaded most of stream water surfaces prevented excessive warming (Allan & Castillo, 2007) and provide inputs of allochthonous organic materials that is important for biological production in small stream ecosystems (Rohasliney & Jackson, 2009).

The increasing of water temperature will influence the body temperature, growth rate, food consumption and feed conversion of fishes because they are cold-blooded animals (Gadowaski & Caddel, 1991; Kausar & Salim, 2006). Fish growth and livability are optimum at certain temperature range (Gadowaski & Caddel, 1991). For example, the optimum growing temperature for warmwater fish ranged from 25 – 30 °C (Afzal Khan *et al.,* 2004). An increase in temperature may accelerate the digestion of nutrients due to increasing in enzyme activities (Shcherbina & Kazlauskene, 1971; Gordon *et al.,* 1996). High temperatures can lead to disease outbreaks that cause inhibition of fish growth (Platts *et al.,* 1983).

2.4.3. Salinity

Salinity is a concentration of ions dissolved in water consisting of sodium, magnesium, calcium, chloride, sulphate, carbonate and bicarbonate (Gordon *et al.,* 1996). Salts enter a stream through saline groundwater, sea salts dissolved in the rainwater and agricultural runoff (Gordon *et al.,* 1996). The gas solubility in water was reduced as salinity increased and for each 9000 mg/L increase in salinity reduces the solubility of oxygen in water to about 5°C (Hazzeman, 2009). Most freshwater fishes are unable to maintain their internal ionic balance, leading to dehydration (Gordon *et al.,* 1996).

The loss of water molecules during evaporation increased the ion conductivity, Total Dissolved Solids (TDS) and salinity by leaving dissolved minerals in the water system (Jacobsen, 2008). TDS includes solutes such as sodium, calcium, magnesium, chloride remained in the water as dissolved ions (Gordon *et al.,* 1996). These ions had the ability to conduct an electrical current, resulted increased in conductivity. Since the salinity and the conductivity were positively correlated Jacobsen, 2008), the increase in salinity will cause an increase in conductivity.

2.4.4 Water velocity

Velocity is a rate of water movement (Gordon *et al.,* 1996). The increasing of water velocity that creates turbulence increases the tendency of oxygen molecules in the air to dissolve into the water (Hazzeman, 2009). Currents were classified into five classes; very slow (< 0.05 m/s), slow (0.05-2 m/s), moderate (0.2-0.4 m/s), fast

(0.4-1.0 m/s) and torrent (> 1.0 m/s) (Gorman & Karr, 1978). Stream flow influences fish communities and other physical habitat variables such as substrates, depth, habitat heterogeneity and presence of debris (Martin-Smith, 1998).

Fish species that inhabit strong water currents are streamlined while those who spend near the streambed are more flattened from top to bottom (Gorman & Karr, 1978; Townsend, 1980). Some fish species burrowing into the streambed, hiding under rocks or building shelters to tolerate against strong currents (Gordon *et al.,* 1996). In running water, the metabolic rates of plants and animals are higher than in still water (Hynes, 1970).

2.4.5 Water depth

Variations in channel form such as pools and riffles will create variation in water depth (Gordon *et al.,* 1996). Water depth is categorized as very shallow (0-5 cm), shallow (5-20 cm), moderate (20-50 cm) and deep (> 50 cm) (Gorman & Karr, 1978). Fish species diversity has been reported to increase with depth of river (Mendelson, 1975; Meffe & Sheldon, 1988). Pool and run habitats that is deeper than riffle generally are more complex with the presence of debris, roots or group of boulders with extensive space in between (Martin-Smith, 1998). In addition, there is a positive correlation between pool depth and the fish size (Power, 1987; Harvey & Stewart, 1991). Larger fish tend to live in pools and small fish in shallower water (Gordon *et al.,* 1996).

Fish species occupied distinct depth-determined microhabitats as an evolutionary adaptation and predator avoidance (Grossman *et al.,* 1987). The vertical segregation of fish had also been found by other studies (Sheldon, 1968; Mendelson, 1975; Moyle & Senanayake, 1984). Schlosser (1982) and Bain *et al.* (1988) observed that small, young fish inhabited shallow, slow flowing rivers while deep rivers were inhabited by larger, older fish.

2.4.6 Substrate

Substrate usually refers to the particles on the streambed (Gordon *et al.,* 1996). Large particles such as cobble and gravel are associated with fast currents while small particles such as silt and clay with slow currents (Gordon *et al.,* 1996). Cobble, large rocks, fallen trees, logs and branches provide shelter, feeding, spawning ground and nursery sites for freshwater fish (Barbour *et al.,* 1999; Casatti *et al.,* 2006).

2.4.7 Streamside cover

Riparian vegetation acts as buffers against siltation, regulating water temperature and nutrient input (Gordon *et al.,* 1996; Barbour *et al.,* 1999; Casatti *et al.,* 2006; Wipfli *et al.,* 2007). Tree boles and rootwards of fallen trees shape the river by forming deep pools, multiple channel and sorted gravels (Andrus, 2008). In some situations, fish utilize woody debris as a protection from high water velocity, sunlight and places to spawn (Parson, 1991). The vegetation helps fish that has specific temperature tolerance by maintaining water temperature of streams (Koehn & O'Connor, 1990).

Deforestation of riparian forest increases water temperature, light levels, suspended solids and water chemistry (Sweeney, 1993), altering fish and macroinvertebrate communities and their food sources (Sweeney 1993; Bojsen & Barriga 2002; Bojsen, 2005). Inputs of dissolved, particulate and large organic matter are greater in forested catchments than in nonforested catchments (Martin-Smith, 2004). Deforestation is also reducing the input of allochthonous sources such as plant litter and terrestrial invertebrates (Delong & Brusven 1994) that are important as fish food. The impacts of deforestation and conversion of land to agriculture increases mortality of eggs and larvae due to high temperature (Winemiller *et al.,* 2008).

2.5 The role of fish as bioindicator

Markert *et al.* (2003) define bioindicator as an organism that provides information on the quality of the environment. They suggested that sensitive species that lead to a change in biodiversity are taken as surrogates for larger communities and act as indicators for the condition of habitat or ecosystem. Many groups of organisms have been used as a bioindicator such as diatoms and benthic invertebrates (Karr, 1981). However, some disadvantages of using these organisms are recognized. They lack in life-history information, need specialized taxonomists, difficult and time consuming to sample, sort and identify (Karr, 1981). Thus, fish are one of the best bioindicators proposed and they remain an important part of an aquatic study to evaluate water quality (Simon, 1999).

The advantages of using fish as bioindicator have been listed by many researchers working in this field such as Karr (1981), Leonard and Orth (1986), Hughes and Noss (1992), Barbour *et al.* (1999) and Simon (1999). Among the advantages are:

a) Fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and mobile.
b) Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and they tend to integrate effects of lower trophic levels.
c) Fish are at the top of the aquatic food web and are consumed by humans, making them important for assessing contamination.
d) Fish are relatively easy to collect and identify to the species level. Indeed, most specimens can be sorted and identified in the field and subsequently released unharmed.
e) Environmental requirements of most fish are comparatively well known. Life history information is extensively for most fish species.
f) Fish are suitable indicators of habitat connectivity because they are migratory organisms.

g) While assessing the environmental quality by fish assemblage, the stock assessment also can be determined that is important for the sustainable harvest resource.

h) They have both economic and aesthetic values and help to raise awareness of the value of conserving aquatic systems.

2.6 Food and feeding habits of fish

The feeding habits of fish influence its growth, behaviour and other ecological characteristics (Ogbe *et al.,* 2008). There are many types of food present in aquatic ecosystems. The studies of natural feeding of fish are important to determine the trophic relationships in aquatic ecosystems and provide knowledge for the development of artificial foods used in the fish culture (Lima-Junior & Goitein, 2004).

Table 2.1. Food resources in freshwater habitat as described by Okafor (2011).

Food resources	Description
Detritus	Particulate organic material originating from dead plants or excretions of living organisms and usually combined with silt or sand, bacteria, algae and other unicellular organisms.
Plankton	Smaller aquatic life, free-floating organisms in the sea or freshwater consisting of diatoms, protozoan, and copepods.
Periphyton	Freshwater organisms attached or clinging to plants, surface of animals, rock, fallen woods or sand grains.

Benthos	Organisms inhabiting or resting on the bottom or living in the bottom sediments. For example insect larvae, worms, small crustaceans.
Neuston	Organisms resting or swimming on the surface of water such as beetles and spider.
Nekton	Aquatic animals including large swimming animals such as prawns, shrimps, crabs, fish and other vertebrates that swim and move independently of water currents.
Plants	Filamentous algae and higher aquatic vegetation of floating, submerged and emergent species.

2.6.1 Feeding types of fish

Usually in unpolluted tropical streams, fish of various feeding types such as algivores, insectivores, planktivores, piscivores, herbivors and omnivores can be found in a fish population (Rohasliney, 2011). However, feeding habits are most likely to change over an individual’s life cycle (Rohasliney, 2011). For example, *Brycon petrosus* shifted its diet from being insectivorous during larval stages to specialize on terrestrial plant materials during adult stages (Angermeier & Karr, 1983). According to Angermeier & Karr (1983), species richness of fish feeding types increased with stream size and canopy openness. They also found that densities of algivores and terrestrial herbivores increased with the increase of stream size. However the density of aquatic insectivores declined in bigger streams.

Adult fishes can be divided into following groups (Ali, 1992) according to feeding types:

Table 2.2. Feeding types of fish and their descriptions.

Feeding types	Description
Mud feeder	Fish that feeds silt at bottom.
Detritivores	Feeding on detritus.
Scavenger	Feed on dead organisms.
Herbivores	a. Grazers – Fish that scrape algae from the substrate by using their specialized mouthparts. b. Browser – Feed regularly on leaves and stems of higher plants. c. Phytoplanktivore – Feed primarily on phytoplankton.
Carnivores	a. Zooplanktivore – Feed mainly on zooplankton. b. Benthivore – Feed mostly on insect larvae, small crustaceans. c. Aerial feeders – Feed on insect flying or resting on a surface the water. d. Piscivores – Feed on fish.
Omnivores	Feed on both plants and animals.

According to Tripathy (1999), fish can be classified according to the extent of variation in the food consumed such as euryphagic, stenophagic and monophagic. Euryphagic is classified for fish that feed on a variety of food, stenophagic is fish that feed on a few types of food while for single type of food is classified as monophagic.

CHAPTER 3

THE FISH DISTRIBUTION IN SELECTED KERIAN RIVER TRIBUTARIES, PERAK

3.1 Introduction

Studies on stream fish assemblages have investigated the relationship between species and their environment and often associated with physical factors such as stream gradient, flow velocity and depth. Fish communities are influenced by a variety of factors both physical and biological including climatic stability, spatial heterogeneity, competition, predation and primary productivity (Martin-Smith & Laird, 1998; Galacatos *et al.,* 2004; Andrus, 2008; Kadye *et al.,* 2008). Habitats used for spawning, foraging and shelter are essential fish habitat that normally have high species diversity (Love & May, 2007).

Spatio-temporal variations in the environmental characteristics as well as resource availability are among the main determinants of the species distribution, species interaction and habitat adaptations, thus determining the diversity of fish communities (Súarez *et al.,* 2007; Khairul Adha *et al.,* 2009). Spatially, streams in tropical areas show large variation in local microhabitats, longitudinal patterns of zonation along elevation gradients and inter-regional faunal differences while temporal variation in many important environmental and ecological parameters occurs daily or seasonaly (Winemiller *et al.,* 2008).

Like other animals, fish are continually gathering information about their environment using their brains, which then transmits a response (Ward, 2007). For example, if a nocturnal predator approaches under cover of darkness, any surrounding prey fish may detect a large pressure wave using their lateral line. This information will be transmitted to the brain via the spinal column and the brain will then stimulate contraction of muscles that cause the fish to swim away from the direction of the pressure wave (Ward, 2007).

The relationship between fish assemblage and environmental factors had been documented by several studies. Most of the studies found that fish assemblages were related to changes in water temperature, dissolved oxygen (DO), salinity, velocity and depth (Martin-Smith, 1998; Beamish *et al.*, 2003; Love and May, 2007; Kadye *et al.* 2008)

Yap (1990) successfully recorded 61 fish species mainly at the modified area of Kerian River basin such as the tidal barrage. Later, Ali (1998) managed to list 54 fish species in Beriah wetland. Previously, there was no report of fish diversity at the upper areas of the river basin has been published. Thus, the objective of this study is to determine the fish distribution in selected Kerian River tributaries.

3.2 Materials and methods

3.2.1 Study area

Kerian River Basin (5°9' - 5°21'N and 100°36.5' - 100°46.8'E) covers the northern part of Malaysia and has a population of about 190,000 in a catchments area of 1418 km^2 (Yap & Ong, 1990). Kerian River Basin is a formation of Kerian River together with a number of tributaries that supply water to thousands of people downstream (Che Salmah *et al.*, 2004). Kerian River originates from the hilly headwaters in Mahang River, Kedah while the Selama River begines from hilly areas in Selama, Perak (Che Salmah *et al.*, 2001). They meet at the middle of the basin and eventually flow westward to the Strait of Malacca. Seven sampling sites were selected for this study namely Mahang, Kangar, Selama, upper Kerian, middle Kerian-Selama, Serdang and Bogak rivers (Fig. 3.1). General characteristics of the sampling sites are listed in Table 3.1.

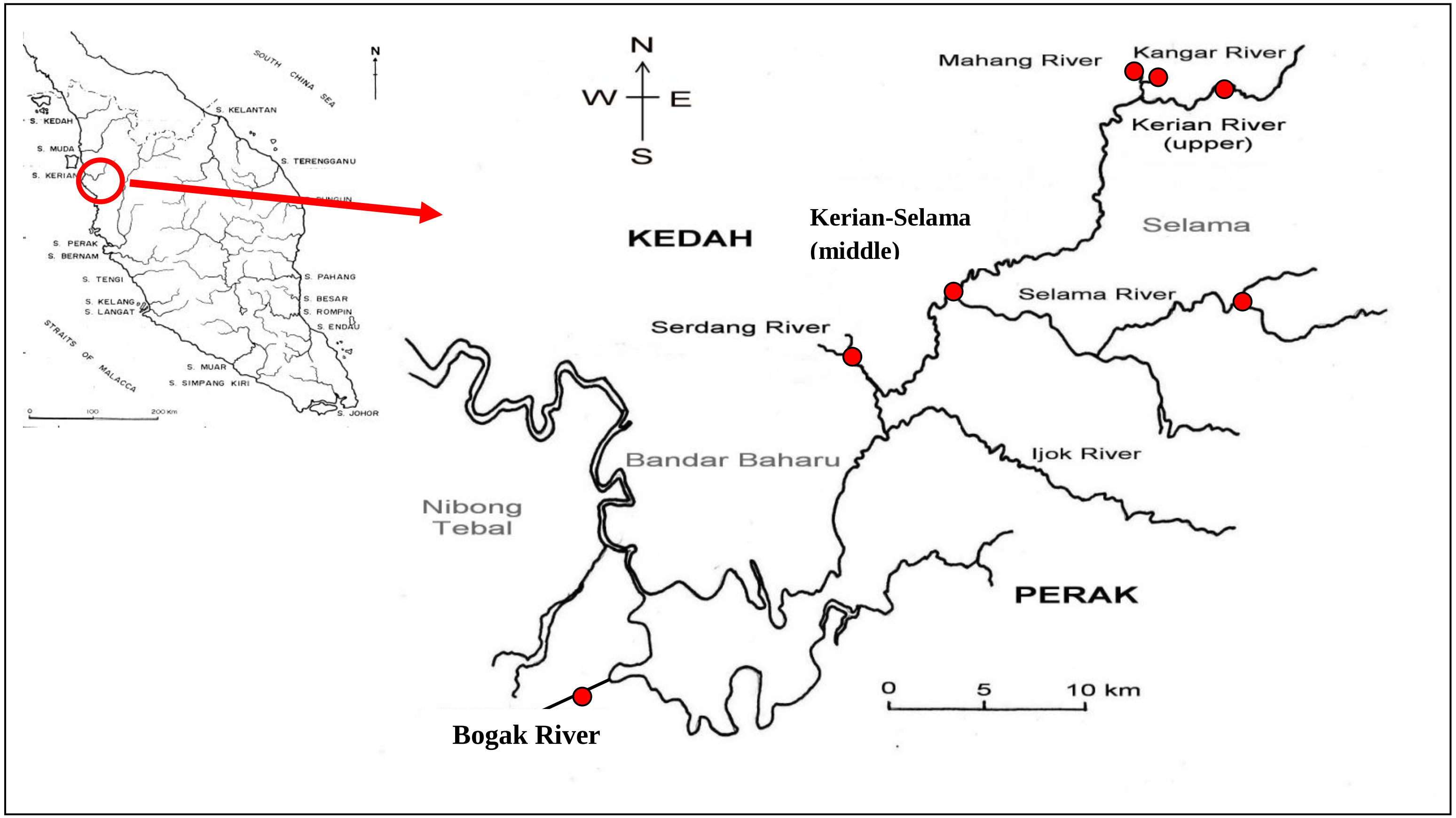

Figure 3.1. Location of sampling sites (●) along Kerian River Basin in the northern of Peninsular Malaysia.

Table 3.1. General characteristics of selected rivers with coordinates in Kerian River Basin.

Name of site	Approximate sampling location	Description of site
Mahang River	5°20'43.70"N 100°46'17.70"E	A small hillstream river with steep river banks. It has relatively fast flowing water, partially shaded by fruit trees and bamboo, sand mining areas and fruit orchards on both river banks. The main substrates for this river are sand and gravel (Plate 3.1)
Kangar River	5°20'17.17" N 100°46'28.30"E	A small hillstream river with low gradient river banks. Its shallow, fast flowing water is partially shaded by the riparian vegetation. The main substrate for this river is sand (Plate 3.2).
Selama River	5°15'34.60"N 100°50'42.10"E	A moderate size hillstream river with low gradient river banks. It is located in hilly areas with fruit orchards nearby. This river is relatively fast flowing with the main substrates are boulder and cobble. This river is partially shaded by riparian vegetations such as *Koompassia malaccensis*, *Aglaonema nitidum*, *Chassalia chartacea* and *Bambusa* sp. (Plate 3.3).
Upper Kerian River	5°18'48.60"N 100°46'57.30"E	A large hillstream river with moderate gradient river banks. It has very fast flowing water with substrate dominated by cobble. The river bank is dominated by *Melastoma malabathricum* (Plate3.4).
Middle Kerian-Selama River	5°13'41.50"N 100°41'13.50"E	This is a large river with steep and unstable banks near surrounded by oil palm plantation and residential areas (Plate 3.5).
Serdang River	5°11'32.40"N 100°36'57.20"E	This river is a moderate river with steep river banks surrounded by oil palm plantation and residential areas. This water surface is exposed directly to sunlight. The main substrate is sand and only grass is found to be the main vegetation. There is aquaculture farm on one side of the river (Plate 3.6).
Bogak River	5°2'38.30"N 100°31'13.70"E	This river has been modified to become an irrigation canal to supply water for paddy fields and oil palm plantations. The Bogak Pumping Plant, about 500m from the sampling area supplements the irrigation water. *Cabomba* sp. and *Salvinia molesta* are dominant aquatic plants in the river (Plate 3.7).

Plate 3.1. Mahang River

Plate 3.2. Kangar River

Plate 3.3. Selama River

Plate 3.4. Upper Kerian River

Plate 3.5. Middle Kerian-Selama River

Plate 3.6. Serdang River