WATER QUALITY AND ZOOPLANKTON COMMUNITY STRUCTURE OF TEMBAT RIVER, HULU TERENGGANU

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KUALITI AIR DAN STRUKTUR KOMUNITI ZOOPLANKTON DI SUNGAI TEMBAT, HULU TERENGGANU

ABSTRAK

Taburan dan komposisi spesies zooplankton dari segi ruang dan masa telah dikaji di Sungai Tembat, Hulu Terengganu. Persampelan ke atas empat stesen kajian terbahagi kepada zon hulu (Stesen 1 dan Stesen 2) dan hilir sungai (Stesen 3 dan Stesen 4) telah dijalankan setiap bulan bermula dari bulan Februari 2012 sehingga Mei 2013. Secara keseluruhannya, sebanyak 16 spesies rotifera, 2 spesies kladosera dan 3 spesies kopepoda telah dikenalpasti sepanjang kajian. Kelimpahan dan bilangan spesies yang direkodkan tertinggi direkodkan di zon hulu sungai dan didominasikan oleh kumpulan rotifer jika dibandingkan dengan kumpulan kladosera dan kopepoda. Tiada perbezaan yang bererti ($p>0.05$) bagi komposisi zooplankton di antara kawasan kajian tetapi terdapat perbezaan yang bererti ($p<0.05$) bagi komposisi zooplankton di antara musim kering dan basah. Bilangan spesies zooplankton tertinggi direkodkan di Stesen 1 dengan 20 spesies diikuti Stesen 2 (18 spesies), Stesen 4 (17 spesies) dan paling rendah di Stesen 3 (15 spesies). *Asplanchna priodonta* merupakan spesies zooplankton paling dominan menduduki bahagian hulu dan hilir sungai sepanjang kajian ini. Berdasarkan analisa “rarefaction”, anggaran bilangan spesies zooplankton di Stesen 1 adalah 20 spesies diikuti dengan Stesen 2 dan Stesen 4 sebanyak 18 spesies, dan akhir sekali Stesen 3 sebanyak 16 spesies. Pada amnya, kualiti air di Sungai Tembat dianggap baik merujuk kepada Indeks Kualiti Air (IKA) pada Kelas I. Terdapat beberapa parameter kualiti air seperti Jumlah Pepejal Terampai (TSS, mg/L), oksigen terlarut (DO, mg/L)

dan suhu air (^{0} C) mempengaruhi kelimpahan zooplankton sepanjang tempoh kajian. Indeks Kepelbagaian Shannon-Wiener merekodkan Stesen 4 indeks kepelbagaian tertinggi dengan 2.532 diikuti Stesen 3 (2.527), Stesen 2 (2.447) dan paling rendah di Stesen 1 (2.362).

WATER QUALITY AND ZOOPLANKTON COMMUNITY STRUCTURE OF TEMBAT RIVER, HULU TERENGGANU

ABSTRACT

Study on zooplankton and composition based on spatial and temporal of Tembat River, Hulu Terengganu been carried out. Four sampling stations been divided to upper zone (Station 1 and Station 2) and lower zone (Station 3 and Station 4) and sampling been carried out monthly started from February 2012 until May 2013. A total of 16 species of rotifers, 2 species of cladocerans and 3 species of copepods have been recorded in this study. The highest abundance and species number was recorded at upstream zone and dominance by rotifers group compared to cladocerans and copepods. There is no significant different ($p>0.05$) between zooplankton composition by sampling locations but show significant different ($p<0.05$) with dry and wet season. The highest number of zooplankton species recorded at Station 1 with 20 species followed by Station 2 (18 species), Station 4 (17 species) and the lowest at Station 3 (15 species). *Asplanchna priodonta* was the dominant zooplankton species occupying the upstream and downstream zones during this study. Based on rarefaction analysis, the estimation of zooplankton species at Station 1 was 20 species, followed by Station 2 and Station 4 with 18 species, and the lowest was at Station 3 with 16 species. In general, the water quality of the Tembat River was considered good according to Water Quality Index (WQI) classification which was in Class I. Several water quality parameters such as total suspended solids (TSS, mg/L), dissolved oxygen (DO, mg/L) and water temperature (^{0} C) influenced the abundance of zooplankton during the study period. The highest

Shannon-Weiner diversity index was recorded at Station 4 with 2.532, followed by Station 3 (2.527), Station 2 (2.447) and lowest at Station 1 (2.362).

CHAPTER 1

INTRODUCTION

1.1 Background

Plankton is defined as all those organisms suspended in free water (Goldman and Mann, 1980). The plankton comprises of aquatic organisms which drift passively and have limited ability to move contrary to the movement of the water mass. Plankton can be divided into phytoplankton and zooplankton (Chiu *et al.*, 2007). The term 'phytoplankton' encompasses all suspended microalgae in a waterbody belonging to all taxonomic algal groups and includes the cyanoprokaryotes or bluegreen algae. Phytoplankton, together with other aquatic plant life, are the primary producers in aquatic ecosystems and form the basis of the food web (Hötzel and Croome, 1999).

Zooplankton is the animal portion of the plankton (Ismail, 2012). Zooplankton is defined as pelagic animals which are unable to maintain their position by swimming against the physical movement of water (Goldman and Mann, 1980). They occupied both freshwater and saline water and also can be found in almost all water bodies, including river, stream, lakes, reservoir, ponds, irrigation canals, rice-field and temporary water body. Zooplankton are the key role in the pelagic food web by controlling phytoplankton production and shaping pelagic ecosystem. They are heterotrophic animals that are incapable of synthesizing organic matter itself (Ismail, 2012). Planktonic algae is grazed by a variety of larval and adults zooplankton (Barnes, 1980). Then, they are being fed upon by fishes, aquatic insects and some other aquatic organisms.

Zooplankton is essentially a group of non-motile or have little mobility organisms relative to the water mass. They drift with the current, susceptible to pollutants, land use and other changes occurred within the aquatic system. According to Dawson and Knatz (1980), the groups of freshwater zooplankton can be divided into three main groups namely Cladocera, Copepoda, and Rotifera. The zooplankton occupies a key position in shaping the pelagic food web by acting as primary consumer in aquatic food chains or food web in the aquatic environment. Therefore, in order to understand the function of zooplankton in food webs and chain, it is necessary to gain knowledge about the temporal and spatial structure of the zooplankton community in the aquatic environment.

A majority of zooplankton study in Malaysia were focused on marines and lakes ecosystem compared with rivers (Yoshida *et al.*, 2012). There were limited study of zooplankton species and community in undisturbed and pristine rivers or lotic environment as it is not conducive for zooplankton's development. Idris (1983) has identified 46 species of cladocerans in streams and drains.

In order to fulfill the national energy demands, Tembat River has been selected for hydroelectric development. This development will change the river characteristic from lotic to lentic environment. Based on Detailed Environmental Impact Assessment (DEIA) for Hulu Terengganu Hydroelectric Project report in 2007, Tembat River are classified as 5th river order using Strahler method (TNB, 2007). In this report, Tembat

River is classified as Class I of National Water Quality Standard (NWQS). This river consists of several important and highly commercial value of fish species such as *Tor tambroides* (mahseer), *Channa lucius* (snake head), and *Hemibagrus nemurus* (catfish). This development had a direct impact on water quality and aquatic organisms such as phytoplankton, zooplankton, aquatic insects and fishes. Therefore, this study focusing the existing zooplankton diversity and composition to the existing water quality of the lotic environment during the construction phase. As a result, the finding from this study will become a baseline data for zooplankton species and its composition before the creation of newly reservoir (lentic environment).

The following are the objectives of this study;

i. To determine the existing surface water quality of Tembat River.
ii. To obtain the zooplankton checklist, composition and abundance.
iii. To correlate the temporal and spatial distribution of zooplankton community with physico-chemical parameters.

The hypothesis of this study were as follows;

H_0 = Zooplankton community in Tembat River is not affected by physico-chemical parameters of the sampling stations spatially and seasonally.

H_α = Zooplankton community in Tembat River is affected by physico-chemical parameters of the sampling stations spatially and seasonally.

CHAPTER 2

LITERATURE REVIEW

2.1 River zonation

Characteristic zones may be recognized in rivers and streams according to aspects of the habitats or biotic communities present, and the biological processes which occur along the length of the water course (Hawkes, 1975). The aquatic zone on a river system is normally permanently submerged, and the associated communities are unable to withstand desiccation. The lotic zone and flood plain of a stream are the areas between the mean low water zone, e.g. the zone where reeds grow, and the mean high water limit. As a result, this area is subject to frequent, recurring fluctuations in water level. In large rivers the lotic zone may be very large and many meters wide, but in smaller rivers and streams, it can be rather fragmented as the banks tend to be steep. As a result of increased erosion caused by human activity, particularly in deforested tropical areas, rivers and streams may become so deep that they cannot develop an active lentic zone.

Impoundment of a river transformed the river ecosystem to the lake ecosystem. The zonation were changed into riverine, transition, lacustrine, and tailwater which alter the physical, chemical and biological of the existing flowing river.

2.2 Water quality

Water temperature influences the rate of physiological processes of organisms, such as the microbial respiration which is responsible for much of the self-purification that occurs in water bodies. Higher temperatures support faster growth rates and enable some biota to attain significant populations. In running water, the temperature normally increases gradually from the source of the river to its mouth. Increased in temperatures cause problems for sensitive organisms due to the increased oxygen demand (lowering oxygen saturation) and increased levels of toxicity of harmful substances. Temperature can affect the dissolved oxygen (DO) content of the water (Boyd, 1990), where high temperature of water holds a much lower level of DO.

DO can be defined as a measurement of the amount of oxygen that is measured in milligrams or millimeters dissolved in one liter of water (Jack*et al.*, 2009). Smith (2004) mentioned that DO in warmer water have a lower saturation point compared with in cooler water. Besides, water with higher velocity can hold more DO than slower moving water. The DO content in natural waters can be affected by salinity, pressure, photosynthetic activity, temperature and turbulence. In the tropics, the rate of decomposition is high at the bottom of a water body; hence the production of oxygen through photosynthesis at the surface, is less than oxygen consumption (Makhlough, 2008).

Biological Oxygen Demand (BOD) is the amount of oxygen that would be consumed if all the organic materials in one liter of water were oxidized by bacteria and protozoa

(Boyd, 1990). Organic materials are the rich food supplies for bacteria which occur naturally in water. Those organic matters, then will be decomposed by the bacteria. When this happens, much of the oxygen present in the water will be used by the aerobic bacteria, robbing other aquatic organisms of the oxygen that they need for living. When BOD levels are high, the DO may decrease as the oxygen has been used during the respiration of the organic materials. The great reduction of oxygen may threaten the lives of other aquatic organism, and causes high level of BOD.

Nutrients are essential for phytoplankton to reproduce, survive and grow, but the excessive input of nutrients into water increase the algal growth, which contribute to eutrophication (Schindler, 2006). According to Cech (2003), ammonia (NH_3) can be described as inorganic substance in the water column and soil, which is released by decaying plant tissue and animal waste. With low DO in water, the soil bacteria *Nitrosomonas* will oxidize the $NH_3$to nitrite (NO_2). Nitrification occurred where nitrite is oxidized to nitrate (NO_3) by *Nitrobacter* bacteria (Cech, 2003). When NH_3 level reaches 0.1 mg/L, the surface water is considered polluted, while if the NH_3 level increases to 0.2 mg/L, the water body is in high toxicity, thus considered to be unsafe for aquatic life.

2.3 Definition and classification of zooplankton

Zooplankton are microscopic animals which float freely in the aquatic ecosystems and whose distribution is primarily determined by water currents. The majority of them are unicellular or multicellular with a size ranging from a few micrometers (Protozoa) to more than a millimeter (macro-zooplankton) (Goswami, 2004). In aquatic ecosystems, zooplankton form an important link in the food chain from primary to tertiary levels leading to the production of fishery, also as intermediaries for nutrients/energy transfer between primary and tertiary trophic level (Gajbhiye, 2002). Furthermore, a specific group of zooplanktons which was Cladocera, Copepoda, and Rotifera are important in freshwater ecosystem in food webs (Imoobe and Akoma, 2009).

Zooplankton are characterized by their faunal diversity and arrays of animal organism, varying in size from microns (μ) to several millimeters (mm). No single system of classification has been adopted universally as mentioned by Gajbhiye (2002). They are classified into several groups by size (Cushing, 1989).

i.	Ultraplankton	:	<5 μm
ii.	Nanoplankton	:	5-60 μm
iii.	Microplankton	:	1-500μm
iv.	Mesoplankton	:	0.5-1.0 mm
v.	Macroplankton	:	1-10 mm
vi.	Megaplankton	:	10-20 mm

Rotifers play a pivotal role in many freshwater ecosystems. They are ubiquitous, occurring in almost all types of freshwater habitat. Most well-known and diverse are the predominantly freshwater *Bdelloidea* and *Monogononta* as reported by Segers (2008). Rotifers vary widely in their morphology, but most species have distinguishable head, trunk, and foot regions as well as an elongated body (Wetzel, 1983). Feeding occurs by moving organic matter to the mouth cavity by using cilia (Wetzel, 1983). This ciliated region around the mouth, called a corona, is also used for locomotion. All rotifers have a muscular pharynx, the mastax, which contains a set of jaws called trophi (Wallace and Snell, 2010). Rotifers mostly have asexual reproduction via cyclical parthenogenesis, but sexual reproduction can occur when there is a switch from an amictic phase, where malesare absent, to a mictic phase, where males are produced (Wallace and Snell, 2010).

Although most rotifers are non-predatory, the largest rotifers *Asplanchna*, feed generally on algae and other rotifers. Species of the genus *Asplanchna* draw in prey by creating suction with the mastax and then squeeze the prey into the stomach by using the trophi(Wallace and Snell, 2010). Furthermore, *Asplanchna*, which lack both an intestine and anus, use the trophi to remove undigested matter from the stomach (Wallace and Snell, 2010). Though most rotifers are oviparous (that is, having embryos that develop outside the body), *Asplanchna* are ovoviviparous, and embryos develop within the body until hatched. In the mictic phase, *Asplanchna* produce males that are structurally reduced and possess certain degenerate organs, a condition known as male dwarfism (Wallace and Snell, 2010).

Rotifers can be free-swimming, sessile, or a combination of both throughout their life period. Locomotion is important for *Asplanchna* because this rotifer actively acquires its food (Wallace and Snell, 2010). Previous study has found rotifers can be used a good indicators for water quality classification (Wallace and Snell, 2010). The distribution and diversity of rotifers are influenced by the water quality in freshwater ecosystems

(Segers, 2008). Fernando and Zankai (1981) study noted there are 165 species of rotifers and they mainly belong to the *Monogononta*, while *Bdelloida* was rarely identified.

Cladocerans are important contributors to the fauna and energy dynamics of most lentic freshwater ecosystems (Giller and Malmqvist, 1998). However, lotic waters have been viewed as largely inhospitable environments for cladocerans development (Viroux, 2002). Despite this, many studies have found them to occur in rivers and streams, sometimes in significant abundance (Kim and Joo, 2000) but usually low in species richness (Burger *et al.,* 2002) and indicate them to occur in predictable groupings (Jackson *et al.,* 1992). These cladocerans are commonly known as 'water flea' as they are recognized by the unclear segmented body which consists of two main parts, the head and trunk. The head bears two pairs of antennae which act as their locomotion organs while the trunk is covered by a bivalve carapace (SilvaBriano and Mirabdullayev, 2004). Cladocerans reproduce mostly asexually via parthenogenesis, but can reproduce sexually based on the environmental conditions (Zadereev, 2003). Resting eggs from fertilization or, in some species, asexual reproduction can be produced if the presence of crowding or toxic food is signaled (Dodson *et al.*, 2010). This causes the carapace, an extension of its back, to thicken, called the ephippium. These eggs are resistant to desiccation and can survive on dry land or in water sediments for lengthy periods of time (Mort, 1991). Leaving diapause, which is a halt in its growth cycle, requires favorable stimuli from the environment (Dodson *et al.*, 2010).

Cladocerans are one of the important elements in the aquatic micro-faunal food webs (Shiel, 1995). Cladocerans feed on algae, small rotifers, and copepods (Dodson *et al.*, 2010). Their metabolic rate is variable with temperature, and death can occur above the required optimal temperature (Dodson *et al.*, 2010). Underfood limiting conditions, a smaller body size is favored (Dodson *et al.*, 2010). For example, *Bosmina* may be able to out-compete a larger species because it could grow faster when food is limited (Sommer *et al.*, 1986). Additionally, cladocerans that have a larger body size seem to be scarce when fish are present as fish are visual predators (Sommer e*t al.*, 1986). They are the main food of choice of almost all young freshwater fishes as well as other macro-invertebrates (Silva Briano and Mirabdullayev, 2004). According to Idris (1983), there are about 63 cladocerans species been identified in Malaysia and Singapore.

The free-living copepods are divided into three suborders *i.e.* Calanoida, Cyclopoida, and Harpacticoida (Wetzel, 1983). Copepods have a segmented body with an exoskeleton and five pairs of jointed appendages (Reid and Williamson, 2010). The first antennae, one of the notable appendages, have roles in reproduction, locomotion, and feeding. Calanoids and cyclopoids can be distinguished by their first antennae, with calanoids possessing the long antennae (Wetzel, 1983). Copepods dominated the zooplanktonic community in both freshwater and marine ecosystems (Boxshall and Halsey, 2004). Generally, copepods form a major component with about 50% of zooplanktonic community and are the essential food source to many primary carnivores, including fish (Pechenik, 2005). Unlike cladocerans and rotifers, copepods only reproduce sexually and have a larval stage called the nauplius. Temperature, food availability, and predation heavily influence their mating behavior and variations in their dynamics (Reid and Williamson, 2010). Egg development and clutch size have been known to be dependent on temperature for copepods (Devreker *et al.*, 2009). They are also known to have a broad adaptation to unfavorable environmental conditions. They respond by reducing their metabolic rate and entering diapause (Reid and Williamson, 2010). Lim and Fernando (1985) reported a total of 15 species of freshwater copepods was recorded in Malaysia that cover lakes, paddy fields etc.

Zooplankton of freshwater systems has been recognized as an important energy resource for fish of small body size that, in turn, provide energy to piscivorous fish consumers higher up the food web (Kingsford *et al.*, 1999). Within this context, zooplankton have been recognized as an important trophic link between primary production and consumers (Jones *et al.*, 1999).

According to Piasecki*et al.* (2004), some copepods roles are obvious that serve as food for small fish. However, there are roles which are not often considered, such as copepods as micropredators of fish, their role as intermediate hosts of fish parasites, and their role ashosts and vectors of human diseases. While progress has been made to better understand the biology of copepods, some areas still require further research, especially including studies of the taxonomy of different copepod species.

According to Tasevska *et al.* (2010), there are numerous studies from all over the world been conducted in assessing the changes of aquatic environmental and water quality. Indices such as diversity, evenness, dominance and species richness are among ecological index structure that has been used by the researchers to monitor and discuss the level of water quality, pollution and disturbances of the stream and estuary and even to identify the indicator species (Tasevska *et al.*, 2010). For instance, Neumann-Leitão*et* *al.* (1992) found in Ipojuca River, Brazil had a significant higher population of rotifers due to high levels of toxic substances loaded from the factories, textile mile and domestic sewage.

Studies pertaining zooplankton community as indicators of water quality in Malaysia are still inadequate and limited. So far, studies that involve zooplankton only restricted in terms of ecological distribution, taxonomical identification and morphological study and many of them were from marine community (Fernando and Zankai, 1981). There were also some studies carried out in freshwater such as reservoirs, lakes and paddy fields (Shah *et al.,* 2011).

Zooplankton may form an important component of the biological communities for their ability to cycle nutrients in the aquatic environment (Kobayashi *et al.,* 1998). The water quality was also improved by zooplankton grazing on phytoplankton and bacteria (Pinto-Coeluo *et al.,* 2005). According to Paterson (2001), zooplankton communities are highly sensitive to environmental variations, such as water temperature, light, pH, DO, phosphate, food availability (algae and bacteria) and predation by invertebrates and fishes. Therefore, thechanges in zooplankton abundance, species diversity, or community composition can provide potential indications of environmental changes or disturbances.

Most of zooplankton species have short generation times usually took a day or weeks (Jaiswal *et al.,* 2014) which makes them suitable indicators to assess the ecosystem healthdue to their ability to respond quickly to environmental stress (Gannon and

Stemberger, 1978).Understanding their structure communities and the affecting factors to diversity and abundance, as well as their linkages with the other ecosystem components is essential tooptimize the resources use and to improve the sustainable management of the river ecosystems.

Recent studies show zooplankton have been identified as good bio-indicator species. According to Zannatul and Muktadir (2009), *Brachionus dolabrorus, Keratella tropica* and *Hexarthra mira* were indicators for high turbidity with high suspended solids. Study by Naumann*et al.* (2011) revealed that genus *Brachionus, Keratella, Trichocerca, Filinia,* as well as species *K. cochlearis, Polyartha macrouruss, P. euryptera, Pompholyx* sp., *Asplanchna* sp., *Trichocerca* sp., *Moina* sp., *Ceriodaphnia* sp., and *Diaptomus* sp. known to be the indicators for eutrophic waters. Case *et al.* (2008) also noted the shortest life cycle among the plankton are some of the specialties that make rotifers to be a great biological indicator, fairly distinct patterns displayed in the species composition and abundance as the water quality changed spatially and rapid reproduction and growth rate. In addition, rapid turnover rates and small in size of rotifers allow them to contribute significantly to nutrient recycling in aquatic habitats and to have sensitivity in the changes of the aquatic ecosystem (Zannatul and Muktadir, 2009).

2.4 Factors affecting zooplankton distribution and abundance

Water quality assessment is often viewed as an integrated environmental indicator of ecosystem function and stress. According to Hasan *et al.* (2015), poor water quality may cause disturbance to the natural ecosystem, affecting the food chain, and degrade population of aquatic life and wildlife. Changes in growth and the corresponding increases in impervious surfaces and decreases in natural vegetation have resulted in severe impacts on ecosystem health and integrity, riparian zones and water quality over time.

According to Ma *et al.* (2009), human activities were found to be the cause of higher levels of several parameters like pH, total suspended solids (TSS) and chemical oxygen demands (COD) in the developed area. The causes of water pollution are diverse and vary both spatially and temporally. This included the release of wastewater from scattered industrial operations (Wang *et al.*, 2008) and urbanized areas (Drechsel and Varma, 2007) as well as sediment discharge from cultivated land affected by soil erosion (Vigiak *et al.*, 2007).

Clear cutting eventually will increase the water temperature as the solar radiation reaching the stream after the removal canopy cover that been provided by the forest (Brown and Krygier, 1970). According to Krenkel (1979), the deforestion at upstream has drastic changes to the downstream river by increasing in water temperature with decreasing DO. As a results,water temperature increased and decreased in DO will affect the distribution aquatic life such as plankton and fish.

Physical factors such as discharge and water retention time have been reported as the most powerful environmental factors limiting zooplankton production and distribution in rivers (Basu and Pick, 1996). However, those zooplankton studies have focused on large lowland rivers, and relatively little is known about temporal and spatial distribution of zooplankton in small rivers.

2.5 Zooplankton studies in Malaysia

In previous studies, zooplankton have considered as unimportant in small stream reaches because densities appear to be considerably less than those described for lake or large river ecosystems (Statzner and Higler, 1985). Hence, this study was undertaken to understand the zooplankton population in a clean river located in the headwaters ecosystem, subsequently to compare with previous studies conducted.

Zooplankton studies in Malaysia started as early as 1900's as calanoida copepods from Penang area and Kurau Estuary in Perak state that been by Yoshida *et al.*,(2012). Many zooplankton studies such as by Karunakaran and Johnson (1978), Fernando and Zankai (1981), Dussart *et al.* (1984), Lim *et al.* (1984), Lai and Fernando (1978, 1979, 1980, 1981), Kamaruddin *et al.* (2010) been conducted to verifying the taxonomy and the composition of the zooplankton community in freshwater such as These studies contribute knowledge on zooplankton biodiversity in this region.

According to Green (1971), the typical tropical rotifers species composition are *Brachionus* and *Lecane* species. The typical cladocerans species composition in tropical is very low (maximum 3 species in any area). The important limnetic species such as*Ceriodaphnia cornuta*, *Moinamicrura* and *Diaphanosoma excisum*plus *Daphnia* sp.

are often found in a static water (Dumont and Tundisi, 2013). The copepods are not very diverse (Fernando and Ponyi, 1981), but are quite numerous in individual samples. This species included *Mesocyclops leuckarti, M. ruttneri, M. thermocyclopoides*, *M. aspericornis*and *Thermocyclops crassus* which are the common limnetic species.

There were some significant zooplankton studies, which was extensively conducted all around inland Malaysian waters. One of them was the systematic chain of rotifers in Malaysia and Singapore which were documented by Karunakaran and Johnson (1978). In their study from 18 localities in Malaysia and 23 major localities in Singapore, a total of 118 species rotifers were recorded. The majority of these rotifers were predominated pond ecosystems. Among all 23 families, Brachionidae were found to be the most dominant family. On the other hand Fernando and Zankai (1981) recorded approximately 165 rotifers species from various types of ecosystems such as ponds, stream and rivers, marshes, lakes and reservoirs that covered Singopre, east and west Malaysia.

Idris and Fernando (1981) reported that there were 63 species of cladocerans found in Malaysia and Singapore. The study covered different kinds of sampling locations such as marshes, lakes, streams and rivers, reservoirs and ponds of Singapore, east and west Malaysia.. Majority of the cladocerans species were found in rivers which occupied by 33 species (Idris and Fernando, 1981). According to Idris (1983), Malaysian cladocerans been represented by six families, namely Sididae, Daphniidae, Moinidae, Bosminidae, Macrothricidae and Chydoridae. Although Idris (1983) stated that cladocerans is the commonest microcrustacean in Malaysia, they were poorly known taxonomically and ecologically compared to other neighboring region such as Philippine, Indonesia, India and Sri Lanka.

2.6 Importance Relative Index (IRI)

Studies by Keenan (1996), Bowen (1996) and Cortes (1997) used an Importance Relative Index (IRI) to evaluate the monthly variation of zooplankton biodiversity and composistion. Greater species diversity means larger food chain and more cases of interspecific interactions and greater possibilities for negative feedback control, which reduces oscillations and hence increases (Gholap, 2009).

Relative species abundance describes the patterns or the range of the ecological communities, and can be visualized and represented in the form of distribution plot. Relative species abundance play an important role in determining the distribution of individuals among species within the trophic level. The abundances of higher trophic level may have a variety of effects as a result of increasing productivity (Bozelli, 1998). Number of species usually fit a hollow curve, in which most species are rare (represented by a single individual in a community sample), and relatively few species are abundant (represented by a large number of individuals in a community sample) (McGill *et al.*, 2007).

Ecologists have assumed that biological mechanisms were differentially influence species such that their relative abundances shift in habitats that vary in energy inputs, altering their likelihood of coexistence beyond sampling (Storch *et al.,* 2005; Hurlbert and Jetz, 2010). According to Ward and Stanford (1979), the relative abundance of some group of the aquatic life may not change appreciably, although composition within the group will be greatly modified in the receiving stream. The type of life cycle may largely determine whether a species can withstand the modified conditions (Henricson and Muller, 1979).

The zooplankton fauna of the Murray River consisted mostly of lacustrine species, which were predominantly clacedorans and copepods derived from the headwaters. However, the Darling River has predominantly rotifers (Shiel, 1978). Schuler *et al.* (2014) states that the several zooplankton species participate in intrigued predation. For example, many copepods and some cladocerans can strongly influence rotifers abundance and diversity through predation and several species of rotifers were among those species that responded most to the treatments (Diéguez and Gilbert, 2003).

The highest abundance of zooplankton in Mida Creek occurred during dry season and reduced during the rainy day due to the dilution factor (Osore *et al.,* 2004). Increases in zooplankton in the early rainy season due to high amounts of nutrients washed into the creek, which in turn ameliorated plankton production (Kazungu *et al.,* 1989). According to Ogbuagu and Ayoade (2012), an area that has less human activities will have high species abundance by encouraging stability and growth of more plankton species.

Gholap (2009) study showed that the rotifers have the highest abundance among the population of zooplankton followed by cladocerans and copepods. Gholap (2009) also noted that this was due to rotifers ability to withstand and survive in varying limnological conditions prevailing at different seasons. Some of the rotifers were reported as primary consumers that fed on various phytoplanktons, while others were reported as raptorial predators that fed on bacteria and detritus matters (Winner, 1975). Analysis of the numerical superiority of zooplankton reveals that rotifers is a dominant species.

The dominant species are reported to be the most important ecological indicators as they received the full impact of the habitat for a longer period and manifest different level of sensitivity (Vasisht and Sharma, 1975). Ecological indicators are effective tools in environmental monitoring which is required to assess the changes caused by anthropogenic activities (Gannon and Stemberger, 1978).

CHAPTER 3

MATERIALS AND METHODS

3.1 Sampling location

The study area is located at Tembat River, at the north of existing Kenyir Dam in Kuala Berang, Hulu Terengganu District, TerengganuDarul Iman. It is about 50 km from GuaMusang to Hulu Terengganu roadway, and about 65 km west of Kuala Terengganu. Progressively at the downstream of this river, a hydroelectric dam known as “Tembat Dam” are being constructed. Tembat Dam was expected to complete by the end of 2015, with a total of 1.3 km^2 surface area will be created for electricity generation and certainly will change the natural flowing river characteristic.

Four sampling stations were selected and the location of this sampling stations can be summarized in Figure 3.1. The stations were selected based on the potential changes of the river characteristic after impoundment. Originally, all stations were having lotic river characteristic. After impoundment, Station 1 (ST1) the most upstream sampling location will remained the existing lotic characteristic or located in the riverine zone, whereas Station 2 (ST2) located in the transition zone, which experience lotic and lenticcondition based on water level. On the other hand, Station 3 (ST3) located at lacustrine zone (lentic) area and Station 4 (ST4) located at the downstream of proposed dam site or known as tailwater zone. Generally the zooplankton sampling stations location and characteristic along Tembat River are shown in Table 3.1.

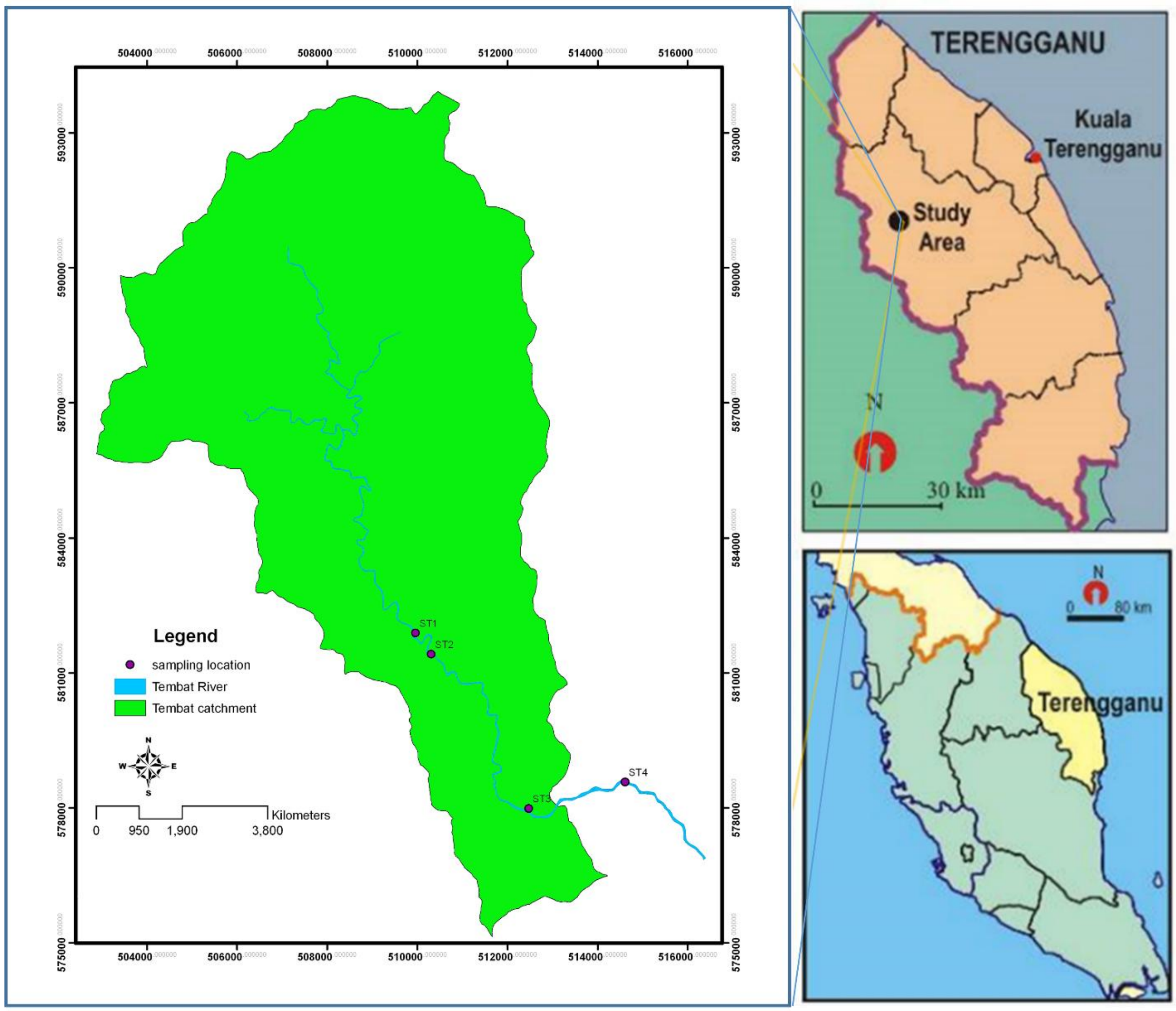

Figure 3.1: Location of sampling stations at Tembat River

Table 3.1: Zooplankton sampling stations along Tembat River, Hulu Terengganu

Station (ST)	**GPS Reading (N)**	**GPS Reading (E)**	**Elevation (m)**	**Bedrock condition**	**Canopy Coverage (%)**
1	05^{0} 13.916	102^{0} 37.477	463	Pebble, cobble	100%
2	05^{0} 13.944	103^{0} 07.333	446	Pebble, cobble	100%
3	05^{0} 13.987	104^{0} 36.561	432	Pebble, sand	80%
4	05^{0} 13.916	105^{0} 37.477	319	Pebble, sand	70%

3.2 Sampling strategy

The sampling was carried out monthly starting from February 2012 until May 2013 which cover the wet and dry season. However, no sampling was carried out during December 2012 and January 2013 due to heavy downpours and sampling stations was not accessible.

3.3 Water quality analysis

The surface water quality parameters were measured *in-situ* and *ex-situ*. Each parameter was measured in triplicates. Water temperature (^oC), pH, dissolved oxygen DO (mg/L) were measured *in-situ* using multi-parameter probe YSI model 556 MPS. The parameters measured *ex-situ* were biological oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solid (TSS), total phosphorus (TP), total nitrogen (TN), nitrate (NO_3), and ammoniacal-nitrogen, NH_3-N (Maiti, 2004). Three bottles were used for water sample collection, one bottle for BOD with volume of 100mL, other bottles for TSS with 100mL and one bottle with 100mL for the remaining tests.

3.3.1 Biochemical oxygen demand in five days (BOD_5)

Water samples at stations were collected by using BOD_5 glass bottles in triplicates and the initial DO was recorded by using BOD probe. The bottles were filled completely and stopper was inserted into the BOD bottles. While filling the bottles, special care has to be taken to avoid trapping of air bubbles. Then, the bottles were wrapped with aluminium foil to avoid direct sunlight and prevent any photosynthetic process. The bottles were placed in a cooler box for 5 days. The DO readings were recorded again on the 5th day. Finally, BOD_5 was calculated by using the following formula (APHA, 1998):

Where;

D_1 = Initial *in-situ* DO reading

D_5 = Day 5 DO reading

3.3.2 Chemical oxygen demand (COD)

The collected water sample was poured 20mL into a 500 mL capacity flat-bottom conical flask and added with 0.4g of $HgSO_4$. Subsequently, tt sample was diluted and mixed well with 20 mL distilled water. Then, a few glass beads were added, followed by 10 mL of 0.25 N potassium dichromate. Next, 30 mL of$H_2SO_4 + Ag_2SO_4$ reagent added slowly and mix thoroughly. The slow addition along with swirling prevents fatty acids to escape out due to high temperature. The flask was connected to condenser. The contents were mixed before heating. The reflux was done for a minimum of 2 hours. The condenser was cooled with running distilled water. Diluted for a minimum of 150 mL (about 300 mL), cool to room temperature and titrated excess $K_2Cr_2O_7$ remaining after retluxing with corresponding standard ferrous ammonium sulfate using ferroin as an indicator (8-10 drops). Sharp colour changes from blue green to wine red indicates end point or completion of the titration was observed. Blank in the same manner using distilled water instead or sample was performed.

Where

A	=	mL of ferrous ammonium sulfate used for blank
B	=	mL of ferrous ammonium sulfate used for sample
N	=	Normality of ferrous ammonium sulfate
8	=	Milliequivalent weight of oxygen

3.3.3 Total suspended solids (TSS)

Filter paper (G/F. 1.5 µm, 47 mm) was dried at 103 to 105°C for 1 hours and cooled at room temperature. Subsequently, weighted immediately. Note the initial weight (Wi) in mg. Then, the water sample (1000 mL) was filtered using filter paper and the paper was dried at 103 to 105°C for 3 hours. Next, the filter paper, cooled at room temperature and take the final weight (Wt) in mg. The cycle of drying, cooling, and weighing was repeated until a constant weight is obtained. When weighing dried samples, be alert to change in weight.

3.3.4 Total phosphorus (TP)

The collected water sample was poured 50 mL into a Kjeldahl flask. Then, 1 mL H_2SO_4 and 5 mL HNO_3 was added. The sample was digested on a hot plate till the volume becomes nearly 5 mL and the heating continued further until the solution becomes colourless after complete removal of HNO_3. The sample was cooled and transferred to a 100-mL volumetric flask. Subsequently 1 drop of phenolphthalein indicator was added.