MACROINVERTEBRATES IN DISTURBED AND UNDISTURBED SITES IN ASAP, BELAGA

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This project is submitted in partial fulfillment of the requirement for the degree of Bachelor of Science with Honours (Aquatic Resource Science and Management)

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2010
DECLARATION

I hereby declare that no portion of this dissertation has been submitted in support of an application for another degree of qualification of this or any other university or institution of higher learning.

…………………………

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<tbody>
<tr>
<td>MPOB</td>
<td>Malaysian Palm Oil Board</td>
</tr>
<tr>
<td>MDF</td>
<td>Mix Dipterocarp Forest</td>
</tr>
<tr>
<td>DO</td>
<td>Dissolved Oxygen</td>
</tr>
<tr>
<td>Stn 1 – Stn 8</td>
<td>Station 1 – Station 8</td>
</tr>
<tr>
<td>BMWP</td>
<td>Biological Monitoring Working Party</td>
</tr>
<tr>
<td>ASPT</td>
<td>Average Score per Taxon</td>
</tr>
<tr>
<td>EPT</td>
<td>Ephemeroptera, Plecoptera, Trichoptera</td>
</tr>
<tr>
<td>IBEC</td>
<td>Institute of Biodiversity and Environmental Conservation</td>
</tr>
<tr>
<td>UNIMAS</td>
<td>Universiti Malaysia Sarawak</td>
</tr>
<tr>
<td>FBA</td>
<td>Freshwater Biological Association</td>
</tr>
<tr>
<td>FBI</td>
<td>Family Biotic Index</td>
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<tr>
<td>MCI</td>
<td>New Zealand Macroinvertebrates Community Index</td>
</tr>
<tr>
<td>BMWQ</td>
<td>Spanish Biological Monitoring Water Quality</td>
</tr>
<tr>
<td>U.K.</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>CANOCO</td>
<td>Canonical Community Ordination</td>
</tr>
<tr>
<td>CCA</td>
<td>Canonical Correspondence Analysis</td>
</tr>
<tr>
<td>DCA</td>
<td>Detrended Correspondence Analysis</td>
</tr>
<tr>
<td>MRPP</td>
<td>Multi-response Permutation Procedures</td>
</tr>
<tr>
<td>BDA</td>
<td>MPOB area being developed</td>
</tr>
<tr>
<td>LOF</td>
<td>20-year logged over forest</td>
</tr>
<tr>
<td>7OP</td>
<td>7-year oil palm plantation</td>
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ABSTRACT

Species diversity of macroinvertebrate among three different types of land uses, namely Malaysian Palm Oil Board area to be developed (BDA), a 20-year logged over forest streams (LOF) and 7-year oil palm plantation (7OP) was compared. The categories of water quality of the streams were evaluated using macroinvertebrates as the biological indicators with Average Score per Taxon (ASPT) and taxa richness of Ephemeroptera, Plecoptera and Trichoptera (EPT) as the biological indices. Environmental variables such as pH, temperature, dissolved oxygen, water current, depth, and wetted width were significantly associated with the abundance of macroinvertebrates. A total of 4,776 individuals comprising 18 orders, 65 families, 76 genera and 95 species of macroinvertebrates were recorded from the three land uses. LOF has the highest taxa richness during wet season with 52 species, followed by BDA with 45 species also in wet season and 7OP with 29 species during dry season. Stream in BDA has the lowest number of individuals with 292 individuals. Environmental and species variables were correlated with seasons and type of land uses where seasons give much more influence than land uses due to unclear categorization of disturbed and undisturbed streams. The biological indicator generally showed BDA, LOF and 7OP streams were moderately polluted. Consecutively, Canonical Correspondence Analysis, Multi-response permutation procedure and indicator species analysis were conducted and showed that the community structure of macroinvertebrate was significantly different between BDA and LOF sites. Functional feeding groups revealed land uses have influenced the food resources for the macroinvertebrate subsequently affect the functional groups.

Key Words: biological indicator, macroinvertebrate, land uses, seasons, water quality

ABSTRAK

Kepelbagaian spesies makroinvertebrata di tiga kawasan guna tanah yang berlainan, iaitu ladang kelapa sawit MPOB yang baru diusahakan (BDA), kawasan pembalakan yang telah berumur 20 tahun (LOF) dan ladang kelapa sawit yang berumur tujuh tahun (7OP) telah dibandingkan. Kategori kualiti air telah dinilai dengan menggunakan makroinvertebrata sebagai petunjuk di mana Purata Skor per Taksa dan Kekayaan Taksa Ephemeroptera, Plecoptera dan Trichoptera digunakan sebagai indek biologikal. Parameter persekitaran seperti pH, suhu air, jumlah oksigen terlarut, kelajuan arus air, dalam dan lebar sungai adalah berkait rapat dengan kelimpahan makroinvertebrata. Sebanyak 4,776 individu dari 18 order, 65 famili, 76 genera dan 95 spesies makroinvertebrata telah direkod dari tiga jenis guna tanah yang berlainan. LOF mencatatkan kekayaan taksa yang tinggi pada musim hujan iaitu 52 spesies, diikuti dengan BDA yang mencatatkan 45 spesies juga pada musim hujan dan 7OP dengan 29 spesies pada musim panas. Sungai di kawasan BDA mencatatkan kelimpahan yang terendah, iaitu 292 individu. Parameter persekitaran dan kepelbagaian spesies adalah berkait rapat dengan musim dan guna tanah yang berlainan di mana musim memberi lebih kesan berbanding guna tanah yang berlainan disebabkan oleh pengkalan kawasan terganggu dan tak terganggu adalah tidak jelas. Petunjuk biologikal umumnya menunjukkan sungai di kawasan BDA, LOF dan 7OP adalah sederhana tercemar. Seterusnya, Canonical Correspondence Analysis, Multi-response permutation procedure dan indicator species analysis telah dibuat dan menunjukkan bahawa struktur komuniti makroinvertebrata adalah sederhana antara kawasan BDA dan LOF. Kumpulan Fungsi Pemakanan menunjukkan guna tanah memberi kesan kepada sumber makanan makroinvertebrata yang seterusnya mempengaruhi komposisi kumpulan tersebut.

Kata kunci: petunjuk biologikal, makroinvertebrata, guna tanah, musim, kualiti air
1.0 INTRODUCTION

Macroinvertebrates as its name implies are animals that can be seen with the naked eye (Maryland State Environthon, 2007) with body length of at least 0.5 mm (Dudgeon, 1999), and retained on 0.25 mm mesh net (Water and Rivers Commission, 2001). The stream macroinvertebrates comprise mainly those of aquatic insect larvae and nymphs such as Ephemeroptera, Plecoptera, Trichoptera and Odonata, as well as crustaceans, molluscs and worms (Derleth, 2003).

The macroinvertebrates are of ecological important in stream ecosystem which provide source of food for fish, can have significant influence in nutrient cycle, primary productivity, decomposition and translocation of materials and also act as indicators of stream degradation (Wallace & Webster, 1996). This is particularly due to the characteristics of macroinvertebrates as a community of high diversity and abundant which are initially sensitive to environmental changes (Derleth, 2003). Besides, macroinvertebrates that inhabit the sediments (infauna) and on the substrate (epifauna) are more subjected to water changes.

Disturbance caused by logging is known to have profound effects on both physical and biological structure of streams (reviews by Blackie et al., 1980, Campbell & Doeg, 1989). Several studies had been done on the effects of logging in Southeast Asian rainforests, such as in Danum Valley Field Centre (Martin-Smith, 1998), Malinau (Derleth, 2003) and Kinabatangan River (Akutsu et al., 2007). As a result, stream flow would generally increases after logging due to increased runoff but with subsequent decreases as reforestation occurs (Bosch & Hewlett, 1982). Bera’an River in Asap, Belaga had been logged more than 20 years ago (Anon, 2008) but baseline information on biological and the effects of past logging activities has not yet been investigated.
The impressive performance of oil palm industry in Malaysia has influence Sarawak government to expand its oil palm plantation area to 0.59 million ha in 2007 and is targeting of 1 million ha by 2010 (MPOB, 2008). One of the biggest oil palm companies operating in the state is Malaysian Palm Oil Board (MPOB), a corporate body established under the Malaysian Palm Oil Board Act 1998. Oil palm industries have been criticized by the NGOs because the industry is presumed to cause declining in biological diversity as well as contributing to the climate change. In this regard, oil palm industries have been urged to apply a good plantation practices especially with respect to biodiversity conservation. As the response to the criticisms from the international communities, MPOB has selected a logged over forest area in Belaga (Bintulu Division) as their plantation model where all the operating stages (including forest clearing and soil bulldozing) would be granted cause very minima impacts to the biological diversity within and around the surrounding area.

The river systems in Sarawak are important for used in transportation and for economic resources especially in the rural areas. However, as logging become a major source of income and activity in Sarawak (Ministry of Agriculture Malaysia, 1992), effects can be seen on hydrology and sediment yield. According to Chappell et al. (1999), logging and ground clearance increases the river sediments by two to fifty times in some rivers in Sabah. Soil erosion can have impact on water quality, of which can affect humans as users of drinking water (Sève, 1999). Bera’an River, which is located several kilometers from Belaga, the nearest small town, is important to people around the area. Although there was water treatment system provided for the people, it was not necessarily be effective in many ways. It can be hypothesized that the water quality of those streams in logged over forest and oil palm plantation might be much better to consume and for aquatic organisms to live
in than that of recent logged forest and other developments. The null hypothesis is that no significant difference of macroinvertebrates diversity between land use categories. The alternative hypothesis is that significant difference of macroinvertebrates between land use categories.

Studies done by Valaitham (2009) and Ahmad Salleh (2005) focusing on macroinvertebrates as an indicator and their distribution in streams of different land uses. Although studies on macroinvertebrates in oil palm plantation and logged over forest streams have been done in several rivers in Borneo, the similar study in Bera’an River had not been carried out. Thus, the objectives of this study were:

1. To determine the species diversity and composition of macroinvertebrate in streams of different degrees of disturbance (i.e. MPOB area being developed, 20-year logged over forest, 7-year oil palm plantation).

2. To assess the relationships between assemblage structure of macroinvertebrates and the degree of disturbances.

3. To assess water quality of the streams using macroinvertebrates as the indicator.
2.1 Ecology of Macroinvertebrates

Macroinvertebrates are generally referred to aquatic organisms without backbones that inhabit the bottom substrates such as sediments, debris, logs, macrophytes and filamentous algae for at least part of their life cycle (Wiederholm, 1984). They are divided into two large groups which are the lower and higher invertebrates (Dudgeon, 1999). Different from higher invertebrates, the lower invertebrates are lacking in detailed taxonomy classification and this includes all the invertebrates except molluscs and arthropods (Dudgeon, 1999). Since these animals live in the water for all or part of their lives, they are highly dependent on water quality for survival (Water and Rivers Commission, 2001).

All the macroinvertebrates start their lives in the water and have varied life cycles. The most common type of macroinvertebrates are insects (Water and Rivers Commission, 2001) which almost all are included in the following studies; Houghton (2007), Zhao et al. (2009), Subramanian et al. (2005), Budin et al. (2008) and Benstead & Pringle (2004). The insects will show both complete and incomplete metamorphosis (change of body shapes) as they grow (Water and Rivers Commission, 2001). Incomplete metamorphosis involves the egg hatching into a nymph, while in complete metamorphosis, the egg hatching into larva, which is different from the adult and later develop into an adult (Water and Rivers Commission, 2001).

Macroinvertebrates are important in the aquatic food chain and they can be categorized on the roles as functional feeding groups which generally determine their abundance in the river (Water and Rivers Commission, 2001; Derleth, 2003; Wallace & Webster, 1996). The shredders feed on organic material, such as leaves and woody
materials and convert this matter into finer particles. They comprised of amphipods, isopods, freshwater crayfish and some Trichoptera (caddisfly) larvae (Water and Rivers Commission, 2001). Collectors or filter feeders feed on fine organic particles produced by shredders, microorganisms and by physical processes. These include Ephemeroptera (mayflies) nymph, mussels, water fleas and worms (Water and Rivers Commission, 2001). The scrapers graze on algae and other organic matter attached to rocks and plants. Examples of scrapers include snails, limpets and Ephemeroptera larvae. Lastly, the highest level of Predators feed on live prey and this includes dragonfly and damselfly larvae, adult beetles and beetles larvae, some midge larvae and some stonefly larvae (Water and Rivers Commission, 2001).

The abundance of macroinvertebrate seem to be much lower in the oil palm plantation area than in disturbed forest (logged or secondary) (Fitzherbert et al., 2008) and other land uses (Koh & Wilcove, 2008). Oil palm plantation involving the clearing of secondary or logged over forest would increase the river sediments up to fifty times which can have an impact on water quality, primarily through total suspended solids. A small increase in sediment may reduce macroinvertebrates population densities due to reduction in habitat space from the increase of substrate embeddedness (Culp et al., 1983). In contrast, study done by Valaitham (2009) in Bau, Sarawak has found high diversity of macroinvertebrates in oil palm plantation area than of other land uses. This is due to the domination of intolerant macroinvertebrates, such as Heptageniidae, Leptoceridae and Leptophlebiidae which have high tolerance value.

On the other hand, even though the logged over forest contributed in species distribution changes due to exposure to high temperature, and lead to increase in water temperature (Derleth, 2003), the streams seem to recover from the logging impacts
between 4 to 5 years (for small streams) after logging in the absence of other disturbances (Derleth, 2003). Furthermore, study by Iwata et al. (2003) at streams in Kubah National Park, Sarawak revealed that a few benthic taxa, such as caenid mayflies and shrimps have survived through the habitat alteration.

### 2.1.1 Macroinvertebrate Diversity

Aquatic insects have the basic segmentation plan characteristic similar to the phylum of Annelida-Arthropoda evolutionary line (Cummins et al., 1993). They are numerous and divergent in taxonomic composition which includes the orders Ephemeroptera (mayflies), Odonata (damselflies, dragonflies), Plecoptera (stoneflies), Trichoptera (caddisflies), some Blattodea (cockroaches), some Hemiptera (water bugs), some Coleoptera (aquatic beetles), some Lepidoptera (moths), and some Diptera (midges) (Hayashi, 2004). The segmented body of aquatic insect can be considered as separate boxes, each comprising of three functional divisions or tagmata: the head (six or seven fused segments), the thorax (three segments) and the abdomen (eight to 11 segments). Trunk is the term used when the thorax and abdomen cannot be distinguished for some of the Diptera larvae (Dudgeon, 1999). The eggs, larvae, pupae, and/or adults of aquatic insects spend time in water (Hayashi, 2004).

![Figure 1: General anatomy of insects. Caddisfly larvae (left) and Stonefly nymph (right) (adopted from Maryland State Environthon, 2007).](image-url)
Phylum mollusca are free-living organisms with body completely enclosed by an unsegmented calcareous shell which may be coiled, spherical or bi-valved. Its body is soft and unsegmented with a ventral muscular foot, including the snails, clams and mussels (Dudgeon, 1999). The subphylum Crustacea, under phylum Arthropoda has more than three pairs of jointed legs and two pairs of antennae. In general, it has a segmented body which is usually divided into two or more discrete regions, as in head, thorax and abdomen (Dudgeon, 1999). The annelids comprise those of oligochaetes, leeches and polychaetes. Oligochaetes are commonly known as terrestrial earthworms and it is typically small and thin, usually less than 1 mm to a few centimeters long. It has obvious external features of distinct segmentation, presence of chitinous chaetae and clitellum in mature specimens (Pinder & Ohtaka, 2004). Leeches, on the other hand lack chaetae and typically have anterior and posterior suckers, used for locomotion and for attachment to substrates, prey or hosts (Govedich et al., 2004). Polychaetes have a body with three fundamental regions of head, serially repeated body segments, and pygidium (the posterior end of body) (Rouse, 2004).

2.1.2 Macroinvertebrates as Bioindicators

Biomonitoring as in biological monitoring can be defined as the systematic use of biological responses to evaluate changes due to anthropogenic sources in the environment with the intention to use the information in a quality control program (Matthews et al., 1982). In other words, it can be used for environmental surveillance (McBride, 1985) before and after a toxicant is spilled (Sebastien et al., 1989). Benthic invertebrates had been used as a specialized form of surveillance biomonitoring prior to a development (Rosenberg & Snow, 1977). Hellawell (1986) has made known that macroinvertebrates
was one of the most often recommended groups of organisms in assessing water quality. In fact, macroinvertebrates has been widely used in literatures such as Kasangaki et al. (2007), Azrina et al. (2006), Akutsu et al. (2007) and Klemm et al. (2002).

Many studies had also been done using macroinvertebrate as biological indicator in the impact of land use on habitat quality (Hawkins et al., 1982; Robinson & Rushforth, 1987), in examining the effect of agriculture (Neumann & Dudgeon, 2002), in monitoring long-term recovery from logging (Haynes, 1999; Derleth, 2003) or from wildfire (Minshall et al., 2001).

There are several reasons which explain the popularity of macroinvertebrates as an indicator of water quality. Firstly, they are present everywhere (Lenat et al., 1980) which makes them vulnerable to different types of changes in the aquatic systems. There are many species and this provides various responses to environmental stresses (Hellawell, 1986; Abel, 1989) and their sensitivity to organic pollution (Rosenberg & Resh, 1993). Secondly, the sedentary nature of benthic macroinvertebrate allows effective analyses of disturbance effects (Abel, 1989) and lastly, having a long life cycles compared to other groups allows illumination of temporal changes in environment (Abel, 1989; Hellawell, 1986).

Macroinvertebrates as biological indicator has certain range of physical and chemical conditions in which they can survive (Maryland State Environthon, 2007), where some organisms are more tolerable to a wide range of conditions, while others are very sensitive and cannot tolerate changes. They indicate excellent, good, fair or poor water quality. The EPT (Ephemeroptera, Plecoptera and Trichoptera) orders are observed as pollution sensitive (Lenat, 1988) and thus makes them important indicators with excellent
water quality. Pollution tolerant organisms that can adapt to poor water quality include leeches, aquatic worms and some Diptera larvae (Maryland State Environthon, 2007).

2.2 Biological Water Quality Indices

In many parts of the world, various measurements on biological indices had been invented and improved using stream macroinvertebrate to detect and monitor water pollution, species abundance and other form of human impacts. These include the Biological Monitoring Working Party (BMWP) Score used in Great Britain, Family Biotic Index (FBI), New Zealand Macroinvertebrates Community Index (MCI), Spanish Biological Monitoring Water Quality (BMWQ) Score system, and the Australian SIGNAL index (Resh & Jackson, 1993). Biotic indices are used to assess water quality which applied macroinvertebrates as indicators. It is calculated based on the tolerance values with relative abundances of taxa (Resh & Jackson, 1993). The rivers in Thailand once used BMWP score in classifying water quality in Thailand (Mustow, 2002). The research intends to determine the successfulness of BMWP which was originally developed in U.K., to be used in subtropical and tropical developing countries. However, due to the incapability of distinguishing between sites of highly impacted by pollution and relatively unpolluted sites, the BMWP score was later being modified (Mustow, 2002). The working party has developed a standardized score system derived from the degree of intolerance to pollution. A standard list is used based on National Water Council 1981 with scores from 1 to 10, categorizing from the most to the least pollution tolerant, respectively (Mustow, 2002). The Average Score per Taxon (ASPT) is the sum of the score of all the families collected, and divided by the number of taxa used in the calculation (Mustow, 2002).
2.3 Multivariate Analysis of Ecological Data

Ordination, according to McCune & Grace (2002), is simply arranging the items along a scale (axis) or multiple axes. In a way, the items are arranged graphically summarizing complex relationships and extracting a few dominant patterns to an infinite number of possible patterns (Dolédec & Chessel, 1994). In community ecology, ordination is the most often used methods to seek and describe pattern due to continuity of change in community composition (Lepš & Šmilauer, 2003). Ordination analysis with CANOCO can help researchers by providing insights into the structure of biological communities and determine the impact of natural and human-induced environmental disturbances on biological assemblages (ter Braak & Šmilauer, 2002; Gibbins et al., 2001). The Canonical Correspondence Analysis (CCA) is currently one of the most commonly used constrained ordination methods which is basically used in getting a relatively normal distribution that are reflective of the real communities and when the species responses to environment are unimodal (McCune & Grace, 2002).

Multi-response Permutation Procedures (MRPP) has the advantage of not requiring distributional assumptions (i.e. multivariate normality and homogeneity of variances) which are seldom met in ecological community data (McCune & Grace, 2002). It is one of the very useful nonparametric procedures for testing group differences, such as the bird communities differed from two controlled burns and pre-burns (Bouwman & Hoffman, 2007) and variability of macroinvertebrate assemblage structure among stream size classes (Heino et al., 2005). Indicator species analysis is usually associated to MRPP where it is used to detect and describe the value of different species for indicating environmental conditions (McCune & Grace, 2002). This method combines information on the concentration of species abundance and the faithfulness of species occurrence in a
particular group (McCune & Grace, 2002). A perfect indicator of a particular group should be ‘faithful’ (always present) and ‘exclusive’ (never occurring to other groups) to that group. Thus, the indicator values are given range from zero (no indication) to 100 (perfect indication) where 100 simply means the presence of a species points to a particular group without error (McCune & Grace, 2002).

2.4 Habitat Assessment

Past study had demonstrated that habitat and biological diversity in rivers are closely linked (Raven et al., 1998). Barbour et al. (1999) defines habitat as incorporating all aspects of the physical and chemical constituents along with the biotic interactions. In streams ecosystem, the definition of habitat is narrowed to the quality of the in-stream and riparian habitat that influences the structure and function of the aquatic community in a stream (Barbour et al., 1999). Thus, any presence of habitat alteration is considered one of the major stressors of aquatic systems (Karr et al., 1986). The habitat assessment undertaken is an easy approach for identifying and assessing the elements of a stream’s habitat (Water Action Volunteers, 2006). It is useful as: i) a screening tool to identify habitat stressors and, ii) a method for learning about stream ecosystems and environmental stewardship (Water Action Volunteers, 2006).

In the stream assessment data sheet, a habitat is rated and the ratings make it possible to compare sites from different parts of the catchment (Waterwatch Australia National Technical Manual, 2004). The habitat ratings recorded in-situ were particularly include those of the vegetation cover, substrate type, canopy cover, forest type, watershed, water condition and land use. A healthy riparian vegetation cover is characterized by trees, bushes, shrubs and tall grasses that help to buffer the stream from polluted runoff and
create habitat for aquatic organisms (Water Action Volunteers, 2006). These plants also provide stream shading (or overhead canopy) and help to keep water temperatures cool by shading it from the sun. A good canopy cover will provide protection and refuge for animals.

Information of the present weather conditions on the day of the survey and those from the earlier day of the survey is important to interpret the effects of storm events on the sampling effort (Barbour et al., 1999). A photograph may be helpful in identifying station location and documenting habitat conditions of the sampling site. Any observations or data that are not requested but are seem important by the field observer should be recorded (Barbour et al., 1999).

In-stream features are measured where the length of the sampling reach are measured or estimated. This is important if a surveyor wanted to assess the streams of variable length. The stream width from bank to bank at a transect are estimated and mean are taken for variable width. From here, the sampling area can be obtained by multiplying the sampling reach length with the stream width. Stream depth is estimated from the water surface to stream bottom and average depth is obtained. The surface velocity is measured and average data is taken. If measurement is not done, the velocity are estimated as slow, moderate or fast (Barbour et al., 1999). The stream velocity can influence the health, variety and abundance of aquatic animals, where if water flows too quickly, some organisms might be unable to hold on rocks and vegetation and be flushed downstream. But if water flows too slowly, oxygen diffusion will be restricted especially for species which needs high level of dissolved oxygen. Stream gradient are determined through visual observation of the bank.
The stream bottom substrates are classified according to the comprising material (Water Action Volunteers, 2006). Rocky bottom streams are consists of those gravel, pebble, cobbles and boulders in any combination. They are usually located in the riffle areas. Soft bottom streams have muddy, silty or sandy bottoms. When this substrate predominates, the streams are usually slow flowing and low-gradient. Embeddedness is the extent to which rocks (gravel, cobbles and boulders) are buried by sand or mud on the stream bottom. Generally, the more embedded rocks, the less rock surface or space between rocks are available for macroinvertebrate habitat (Water Action Volunteers, 2006).

A mixture of flows and depths creates a variety of habitats for macroinvertebrate. Pools, riffles and runs are three different habitats in a stream (Figure 2), where pools are deep with slow water, while riffles are shallow with fast, turbulent water running over rocks, and runs are deep with fast moving water with little or no turbulence (Water Action Volunteers, 2006).

Figure 2: Diagram of a stream physical characteristic with a mixture of pools, riffles and runs. Varying flows and depths create a variety of habitats for macroinvertebrate (adopted from Water Action Volunteers, 2006).
3.0 MATERIALS AND METHODS

3.1 Study Site

The site for the MPOB plantation area is mainly logged over forest while few areas had been converted into oil palm plantation of about seven years old. Other than that, small scale of hill paddy cultivation is also found in few areas. The area is drained by a major river, Bera’an River and its tributaries that eventually discharge into Batang Belaga. Generally, the streams in the area are small and shallow (categorized between 1st – 3rd order streams). The climate of Sarawak is equatorial with a relatively uniform temperature in the range of 23 to 32°C and high humidity (85-95%) on the lowlands. The average rainfall is between 3,300 mm and 4,600 mm, influenced by the West Coast East Monsoon (November-February) which usually brings heavy rainfall and South West Monsoon (March-September) which the weather is generally dry and warm (Sarawak Tourism Board, 2010).

In order to assess the effects of oil palm plantation activities on stream macroinvertebrates, eight stations were selected that represent the MPOB area being developed (Stn 1 and 2; refer as BDA), 20-year logged over forest (Stn 3, 4, 5 and 8; refer as LOF) and existing 7-year oil palm plantation (Stn 6 and 7; refer as 7OP). Since no pristine stream in the study site, thus LOF streams were classified as undisturbed area (control site), whereas 7OP and BDA streams were classified as disturbed sites. The sampling stations were surveyed once for wet (end of December 2008) and dry seasons (early October 2009).

The area for MPOB site was cleared and bulldozed (Table 1). Forest clearing for the MPOB site however has not reached the Station 2. A rice field has been established on