CHAPTER 1
INTRODUCTION

Natural setting of an undisturbed and pristine river demonstrates the biological phenomena underlying the river continuum concept (Margalef, 1960; Vannote et al., 1980). The river continuum concept considers a natural river as a functional continuum and the gradual stabilisation from its source determines and controls the population dynamics of biotic communities. At stability, the longitudinal gradient exhibited by the biotic community can be broadly zoned into upper headwaters and lower lower-river part. Although general patterns of riverine fauna along the lengths of rivers may exist, deviations from the continuum concept model that are found in nature have been explained by variations in climate, riparian vegetation, drainage basin, tributaries and several environmental factors (Minshall et al., 1985). Environmental stress and changes in water quality due to pollution disturbance change this natural gradient demonstrable by biological community function and structure like their composition, richness, abundance, spatial distribution patterns and diversity.

Changes in water quality associated with allochthonous and exogenous matter may cause longitudinal change in functional organisation of macroinvertebrate community that has attracted much research interest (Dudgeon, 1984) and can be usefully assessed and monitored. Environmental perturbations caused by human interact in complex ways, and therefore, their impacts on aquatic ecosystems and biological integrity can rarely be adequately assessed by using only the conventional physical and chemical variables. Simple physical or chemical determinations though can be used to measure the rates of pollutant inputs, their distribution and dispersal in
the environment, as well as their assimilation into living tissues are conservatively estimated. Moreover, the total concentration measured in an individual basis can easily overestimate its biological significance, such as high levels of surface contamination, or the binding of the pollutant at inert sites may mean that the effective dose is much lower. Thus, biological integrity should be assessed directly by measurements of biota. However, it should be emphasised that biological analysis cannot replace chemical, physical or biochemical analysis, but can indeed significantly complement them. Only a complete spectrum of information can fully characterise the quality condition of a water body and serve as the necessary basis for its use in management and protection (Beeby, 1993).

1.1 WATER QUALITY MANAGEMENT

Maintenance of aesthetic aspects of water quality is the principal motivation for national park management. The decline in quality of water sources becomes a concern when natural water loses its coolness, cleanliness and pleasantness to users. The growth in socio-economic activities, large scale agricultural operations and logging have reached a point where, they also have wide impact on water resources, besides interfering the natural processes within the same watershed. As a result, there is a need to assess the trends of water quality comprehensively and accurately in order to raise awareness of the consequent threats of water quality interference and quality deterioration (Bartram & Helmer, 1996). Reliable monitoring data gathered from a well-planned water quality monitoring programme is necessary for such assessments.
The importance of water quality management should be stressed as fresh water is a finite resource and it is essential for the existence of all living things on earth. Emphasis on the control of water quality at its source has proven to be an effective management technique, since there are growing concerns of the public with the health, aesthetic and recreational aspects of water resources. The principles of water quality management in large river basins, regional aquifer systems and other watersheds should be well documented (Reinert & Hroncich, 1990).

1.1.1 Water Quality Monitoring Programme

Water quality monitoring is the foundation on which water quality management is based. The fundamental objective of regular water quality monitoring is to maintain or enhance water quality by controlling or identifying and eliminating sources of pollution. Monitoring of the quality of aquatic environment and the effect of pollution on the environment is known as impact monitoring (Makela & Meybeck, 1996).

Water quality monitoring and assessment is based on physical, chemical and biological properties of the observed water. It can be carried out from a number of different perspectives such as the intended usage of water in terms of quality as well as quantity (Makela & Meybeck, 1996). Influence by natural processes or human-induced processes and its impact on water quality is another perspective where the monitoring can be based on. Water quality monitoring and assessment is not a fixed process of analysis and interpretation where it needs to change in order to fulfill the present requirements. However, the main goal is to provide useful information to the authorities for a more efficient water quality management. In order to come out with
a practical and useful water quality monitoring programme, it is necessary to define clearly the main objectives of the monitoring programme and its operational details. A well-designed monitoring programme should begin with a clear statement of the objectives and aims of the programme. Descriptions of the study area and the sampling sites selected are important for deciding the geographical limits of the study area and representing the microhabitats. Identification on the present and planned water usage, and the present and also expected pollution sources helps in the information expectations and intended uses of the programme. A list of water quality parameters that are to be measured, proposed frequency and timing of sampling should be documented. All these background information will be of great help in preparing a precise description of the programme objectives and in deciding on some major elements of the programme. The programme should also specify whether the analyses to be carried out in the field and/or in the laboratory. This depends very much on the availability of the resources and laboratory equipment in the field, data processing, analysis, interpretation, and reporting. The possible limitations of the programme should also be identified (Reinert & Hroncich, 1990; Makela & Meybeck, 1996).

1.1.2 Quality Assurance

The monitoring programme should include a plan for quality control and quality assurance (QC/QA) on all activities, from sampling techniques in the field to data analyses in the laboratory. Precise details of each operating procedure of the monitoring programme such as area, man-hour and duration of sampling at each site and laboratory procedures are recorded and made available to all trained personnel
involved. With these, all personnel that are involved in the monitoring programme will use only the standard operating procedures assigned for that particular programme (Briggs, 1996). Relevant observations at each step of the standard procedures as well as deviations from them during field and laboratory works shall be recorded for references or discrepancies. Cross-referencing the findings with established methodology and others' previous studies will also help to eliminate any discrepancies.

1.2 APPROACH OF BIOLOGICAL ASSESSMENT AND MONITORING

Water quality can be interpreted integrally in terms of physical, chemical and biological aspects of it. Changes in water quality will have diverse biological effect to those organisms living in the habitat and the effects can range from subtle to severe magnitude where the biota are under stress which leads to an unbalanced ecosystem.

1.2.1 Concept of Biological Assessment and Monitoring

Adverse environmental effects, such as depletion of forested area, and loss of biodiversity are threatening the natural ecosystems. Before some of these lives are being threatened to extinction, corrective action is urgently required. Monitoring and managing the environment, especially the aquatic ecosystems are some of the many actions that are most needed.

Biological monitoring is to monitor the responses of the biological community towards certain environmental stress. It is a mean of assessing water quality, or levels of pollutants present, by employing living organisms as sensors since
organisms are known to have particular requirements for growth and reproduction. It gives indications of the chronic effects on a particular ecosystem and provides promising ways to identify the danger of certain pollutants to human ecosystem and health. Monitoring the environment using biological test systems, which are referred as biomonitors and bioindicators, gives reliable ways to identify pollution to the environment and natural systems. Since the ancient time, animals are used as biomonitors to warn or alert the community of the environmental dangers. As both human and animals share the same environment, and consuming food and water from the same sources, it is rational to use certain types of animals as a biomonitor for a particular pollutant. Humans and animals usually react to toxic pollutants in analogous way. Furthermore, the adverse effect of toxic pollutants on animals is often shown or developed sooner when compared with humans thus providing earlier warning of the pollutant’s toxicity (Butterworth, 1995).

It has become increasingly obvious that the interest in biomonitoring has grown as such monitoring methods are being employed in the monitoring of terrestrial and aquatic ecosystems. This is because in nature, the organisms are exposed to a complex mixture of pollutants rather than a single pollutant at any one time. Careful and well-selected bioindicators for a designated purpose could be economically and effectively help in monitoring the combined effect of pollutants on the ecosystems. They have been used to alert people of the danger of a particular environment. As an example, canaries were used in ancient Rome mine by miners to detect the carbon monoxide. The canaries, besides small and inexpensive, could detect the toxicity of carbon monoxide more rapidly than the miners. Furthermore, the birds could be revived for surveillance again after that (Butterworth, 1995).
1.2.2 Use of Biological Assessment and Monitoring Programme

Biomonitoring has many purposes, where the main reason of biological monitoring is to protect and maintain the integrity of natural ecosystems. Biological monitoring of water quality is a useful complementary approach where it is usually accompanied with other appropriate physical and chemical methods. Comparison shall be made with other physical and chemical measurements in order to have more accurate and reliable interpretation of results.

As discussed above, there are a few advantages of biological monitoring of water quality compared with chemical and physical analyses. Biological monitoring will reflect the effects of a combination of pollutants and environmental stress on the organisms. It gives the overall adverse effect of the environment as the pollutants interact in various ways with the organisms, and these interactions cannot be analysed using chemical or physical methods. It is well established that the water quality is not constant all the time but fluctuates hourly or daily according to the weather and seasonal change. The chemical and physical analysis measurements are valid only at the discrete sampling time but biological monitoring provides an integrated or accumulative effect of environmental stress over a period of time on the organisms. The cost of biological monitoring is cheap and affordable even by a small set-up as it requires only some simple equipment and preservatives as compared with the complicated set-up with expensive analytical instruments and chemicals of physical-chemical analyses.

Many toxin chemicals and other potential pollutants may present at a concentration that produce biological effects on the aquatic ecosystems but undetectable by the present analytical capabilities. It is also known that the parameters of water quality
such as hardness, pH, dissolved oxygen and temperature have influence on the toxicity of certain pollutants. Therefore, a combination of toxic pollutants, water quality and organisms present produces a certain degree of harmful effect to a particular species at certain pollutants' concentrations and water quality conditions (Cairns & van der Schalie, 1980).

Although biological monitoring has a number of advantages, it also has some disadvantages. It is not capable to single out the effect of a particular pollutant on the organisms and the environment from other pollutants. It is also not able to differentiate whether the environmental stress is initiated through natural process and cycles or human-induced processes. Furthermore, it depends on records of damages caused by certain pollutants on a system rather than preventing the damages from occurring and the records of effects on a particular ecosystem might not be the same in other ecosystems (Cairns, 1981).

A properly designed biomonitoring programme requires a clear statement of goals, appropriate standard operating procedures, a good quality control/ quality assurance plan, as detailed in sub-sections 1.1.1 – 1.1.2. In addition to the conventional method, similar sampling conditions and analyses among sampling sites and consistency in using identification keys during the biological specimen identification process, sampling instruments, are defined and implemented. In biological analyses, skillful personnel should undergo proper training and supervision.
1.2.3 Biological Monitoring Techniques

There are a few different types of biological assessments that may be used to provide useful information in monitoring programmes. The principal biological assessments can be divided into five groups (Chapman et al., 1996). They are:

(1) the ecological survey methods, which is based on the community structure and the absence and presence of the indicating species or taxa; (2) physiological and biochemical methods, which is based on community metabolisms or biochemical effects in individuals or communities; (3) controlled biotests, which is based on measuring toxic effects on organisms under defined laboratory conditions or effects on behaviour in controlled environments; (4) bioconcentration, bioaccumulation and biomagnification, which are based on measurements of the accumulation of specific contaminants in the tissues of living things in the environment or deliberately exposed in the environment; and (5) histological and morphological methods, which is based on the observation of cellular or morphological changes.

Each method has its advantages and disadvantages, which should be critically evaluated when being used. The ecological survey methods are widely used in bioassessment. The most commonly used methods for biological assessments of pollution in aquatic ecosystems are based upon species absence or presence, abundance and community structure of its biota. It is depended on the assumption that if a critical species with low tolerance score appeared to be healthy and present in great abundance, the ecosystem will be deduced as healthy condition. This type of method is based on the specific requirement of each particular aquatic organism in relation to the physical, chemical and biological condition of its habitat. Any disturbance to the ecosystem may affect the population of some sensitive species, its
dominance, which may eventually lead to total loss of these species by death or migration (Chapman et al., 1996). However, the absence of a key species does not mean that the ecosystem is in critical condition. It might be the sampling error or another species has assumed the functional niche of that ecosystem. Another possibility may be that the key species does not have the opportunity to exploit the ecosystem and would survive if were introduced into it (Cairns, 1979).

1.2.4 Macrinovertebrate-Based Monitors and Assessment

As it has established that using certain organisms as biomonitors to reflect the conditions of an ecosystem, the selection of a suitable organism to indicate a particular environment from, which it is sampled, is very important (Butterworth, 1995). Carnivorous fishes are good biomonitors as they accumulate pollutants found in the water body while consuming smaller animals but they are highly mobile. Therefore, the result may not really reflect the actual local condition of that designated study area. In order to detect the actual condition of the study area, the organisms collected from the area should be relatively immobile and must not migrate from one area to another. Benthic macroinvertebrates seem to be the most commonly selected aquatic animals for the study of biological monitoring. These organisms fulfill the requirement of indicating the actual local condition of the study area since they are relatively immobile and not habitat-related. Moreover, invertebrates are ubiquitous and found in abundant in most aquatic ecosystems. Many of these benthic macroinvertebrates have a life span of about a year or more, which is sufficient for a complete cycle on different seasonal change conditions. They are also easy to collect with simple and inexpensive equipment, preserve and to
be taxonomically identified up to the genus level by following standard identification keys. The condition of an aquatic ecosystem can be reflected by the absence and presence of certain organisms with different tolerant levels and its community structure.

1.3 OBJECTIVES OF THE STUDY

The idea of using biota to indicate changing environmental conditions is well recognised. Some species of fishes, benthic invertebrates and algae are becoming increasingly recognised and used as indicators of water quality.

In this present study, the ecological survey method has been opted to examine the faunal characteristics and biodiversity of benthic macroinvertebrates populations and the ambient water quality as an indication of the ecosystem health of the Endau-Rompin Forest Reserve, Johore. The abundance and distributinal pattern of benthic macro-invertebrates are generally considered to be indicative of the water quality and baseline condition of the aquatic environment and also of the natural longitudinal gradient of river continuum.

The main objectives of this research are:

i. to survey and establish an inventory of the benthic fauna in Selai River, which is based on presence or absence of macroinvertebrate species and some aspects of community structure. Some relevant physical-chemical data were attempted by obtaining directly or from secondary sources. An ecological/biological database of the macroinvertebrates and their habitat-affiliation is to be established as the end product.
ii. to establish structure metric and biotic index criteria for assigning water quality classification ratings in Selai River as guided by some chemical parameters.

iii. to study the diversity of, some morphology and taxonomical features of caddisflies (Trichoptera) with a view to understand how caddisflies populate in the pristine running water like Selai River and its tributaries, Endau-Rompin Forest Reserve, Johore. Their habitat preference, distribution and seasonal abundance are to be reviewed from published documents.