CHAPTER 4

THE COMMUNITY OF BENTHIC MACROINVERTEBRATES IN SELAI RIVER AND THE USE OF ITS STRUCTURE METRIC AS A CRITERION FOR WATER QUALITY CLASSIFICATION

4.1 INTRODUCTION

Benthic macroinvertebrates are common inhabitants in freshwater environment. They have been long recognised as an intermediate source for the transferring of contaminant in aquatic ecosystems from one trophic level to another higher level. Among these, the aquatic insects that are commonly found and successfully inhabit the pristine environment are the Ephemeroptera, Plecoptera and Trichoptera (EPT). The composition and distributional pattern of the EPT are determined by their tolerance to an array of environment factors (Morse *et al.*, 1994). EPT have been proposed to be good indicators of water quality in pristine areas (Lenat, 1993). This group has been studied in Krian River Basin in Malaysia (Che Salmah *et al.*, 2001). The taxa richness of this sub-category has been described as a reliable metric and this idea will be further illustrated in this present study results.

4.2 METHODOLOGY

4.2.1 Field Study

Intensive and comprehensive sampling works were carried out during the second and third trips. The second trip was carried out in October 2002, just before the monsoon season and the third trip was in May 2003, after the monsoon but had intermittent wet spell during the trip.

4.2.1.1 Sampling of Fauna

Bottom-dwelling macroinvertebrate samples were collected using kick sampling and visual collection methods depending on the site conditions and accessibility. Basically, the choice of using which method for sampling purposes was determined primarily by the site accessibility, substrate types (stony against sandy or silty) on the river beds and vegetation types on the littoral areas. A kick net was used for sampling at stations where the water was deep enough, about knee-deep, and also clear from obstructions such as rocks and branches in order to sample the planktonic and bottom-living life forms. It was employed at all the stations except S2, S3 and S4. The rocky and rugged riverbeds of S2 and S3 make the sampling of benthic macroinvertebrates using kicking method quite impossible. At S4, the small and shallow stream with stony bottom is too shallow to allow the use of kick net.

The kick net used for semi-quantitative sampling is a rectangular bag with a dimension of 40 cm long x 40 cm wide x 60 cm deep and nylon netting of 30 μm mesh size. During the sampling exercise, the kick net was held vertically with the mouth facing the on-coming current by a field personnel. At the same time, another field personnel, by using feet or a stick, continuously disturbed a defined area of 1 m^2 just immediately upstream of the net for approximately 3 minutes. Through these actions, the benthic macroinvertebrates would be dislodged from its hiding places and trapped into the kick net with the assistance of the water current. After the 3 minutes duration, the contents were gently washed into one corner with the flowing water before discharging all the contents into a sieve by turning the net inside out. The size of the sieve was 15 cm x 18 cm with a mesh size of 1 mm. Dead leave, twigs and other debris were removed before emptying the bottom-living macro-organisms into plastic containers. These plastic containers contained 70 - 95 % alcohol for preservation purposes. The 70 - 95 % alcohol preservative would kill most of the living macro-organisms instantly in order to prevent smaller animals from being eaten up by the larger, carnivorous animals when putting them together inside the same container. Any macro-organisms left in the sieve would be hand picked using a pair of forceps or by bare hand.

Besides the kick net, hand rubbing on stones or gravel and picking within the designated 1 m^2 area was also employed during the sampling works. This visual and hand-picking method was best used in shallow and stony or rocky area where kick net could not be used. The bottom living macro-organisms were hand picked using a pair of forceps or by bare hand into plastic containers containing 70 - 95 % alcohol preservative.

The combined methods of kick net collection and visual-hand picking at each station were consistently carried out for a period of two hours and at least three replicates were taken. There were four field personnel sampling at each station and each personnel worked within their designated 1 m^2 area. Plastic containers with specimens for each station were labeled clearly before storing them into a bigger plastic container to prevent spillage of preservative during transportation. Traveling from base camp to forested hilly sampling stations S1 – S8 was by foot while S9 – S13 using 4 x 4 wheel-drive vehicles.

4.2.1.2 Measurement of Water Quality Parameters

Several water quality parameters were measured to investigate the characteristics of microhabitats that possibly influenced the distribution of benthic macroinvertebrates in the river basin. They were also used to justify the reliabilities of scores of biological indices derived from the data collected. The physical-chemical parameters taken during the field trips were water temperature (°C), conductivity (mSiemen/m), pH, dissolved oxygen (mg/l), PO_4 (mg/l), NO_3 (mg/l), Si_4 (mg/l) and turbidity (NTU). These parameters were measured using the HACH DR/2000 Direct Spectrophotometer.

Besides the primary data of in-situ measurement, secondary data were also taken into consideration. These secondary data were obtained during the Endau-Rompin Heritage Expedition (Phase II) carried out by UM-Endau National Park Research Team in 2002 and Yap (2004). The additional parameter recorded and published was water turbidity.

Qualitative observations on the water conditions and its surrounding were made and recorded. Water and environmental conditions (Table 1) such as depth and width of water bodies, its flow rate, substrate conditions (e.g: boulders, rocky bed) and the microhabitats were recorded on a typical field record sheet reproduced from Chapman *et al.*, (1996)(Appendix L).

4.2.2 Sorting and Laboratory Analysis

In the laboratory, the benthic macroinvertebrates were sorted out in petri dishes and identified to the order level using standard identification keys as soon as possible within two days. The animals were then placed into different plastic containers or glass vials according to their orders for permanent storage. After the sorting exercise was completed, these containers or vials were then labeled accordingly and placed into a bigger plastic container before storing them in the refrigerator or freezer.

The second round of identification exercise was carried out to identify the organisms as far as possible to family and genus levels using identification keys detailed in Brinkhurst and Jamieson (1971), Wells (1991), and Morse *et al.* (1994) as references in order to maintain taxonomic-level consistency. Dissecting and compound microscopes, Olympus SZ40 and BH-2, were used for identification and counting, using appropriate magnification on minute and important features. This exercise was repeated for all the samples collected and the results were systematically tabulated for the analyses on its community structure and distribution.

4.2.3 Data Processing

After the identification exercise was completed, populations of benthic macroinvertebrates at stations along Selai River were tabulated from the inventory data of second and third trips. From these data, the mean population ($\bar{x}$) of benthic macroinvertebrates at each station and their standard deviations (s), composition (by orders), taxa richness and relative abundance of dominant taxa were computed. The standard deviation's values (Appendix C) would indicate precision of sampling and answer the possible errors like whether the sampling frequency is adequate or how many samplings are required.

The community structure of the benthic macroinvertebrates collected was expressed by composition (%), total taxa richness (total number of genera of all organisms collected) and Ephemeroptera–Plecoptera–Trichoptera (EPT) taxa richness (total number of genera of EPT collected). It was then expressed in proportion of EPT (expressed in % of total taxa of all organisms collected) and EPT abundance (total number of EPT individuals collected). The composition of benthic macroinvertebrates at stations along Selai River was computed by the summation of total number of individuals of a particular order from S1 to S13 and then divided with the grand total of the total number of individuals of all orders. From the species composition, pie chart was drawn to indicate the main groups in the community and also the most dominant species throughout the routine sampling exercise.

Since the Ephemeroptera - Plecoptera - Trichoptera (EPT) were recognised as good and reliable water quality indicators (Lenat, 1988 & 1993), their taxa richness (percentage) and abundance along the 13 stations were calculated. The abundance data of all benthos was log (x + 1) transformed to ensure homogenity of the means and variances. The transformed abundance data of all organisms was subjected to One-Way ANOVA to detect any significant difference between stations. The STATISTICA® Version 5.0 software was used. The Newman-Keuls test was done on any significant dependent variables. In addition, cluster analysis was run to detect any similarity or any possible out-groups between stations. The basic model used was the single linkage clustering (Legendre & Legendre, 1998), applying on the number of families and genera as a comparison.

4.2.4 Biotic Indices

The EPT taxa richness, (in percentage) and abundance were required to provide information for the classification and ratings of water quality along Selai River.

4.2.4.1 Tolerance Values of Family- and Genus Biotic Indices (FBI & GBI)

A tolerance score system for both the Family- and Genus Biotic Indices (FBI and GBI) based on aquatic insects was adopted with modifications from the list of

Hilsenhoff (1988) and Lenat (1993) to reflect the tropical conditions of Malaysia. The formula for the FBI and GBI is:

$$\text{FBI and GBI} = \sum x_i \,.\, t_i / n \quad \text{..........................(1)}$$

where; x_i = the number of individuals (x) in a particular family or genus (i)

t_i = the tolerance value of the family or genus (i)

n = the total number of organisms in the sample

From the inventory data on benthic macroinvertebrates, the numbers of known indicator species of each family were multiplied with their respective assigned tolerance values ranging from 0 to 10. These products were then summed to be further divided by the total number of individuals found in the population to obtain the values of FBI. The FBI values for each station were then tabulated. As for the GBI values for each station, the same steps were taken for computation, but in this level, the tolerance scores published by Lenat (1993) were used with slight modifications to consider the eco-region differences. The modified biotic index ranking system used in North Carolina Standard sampling program (Lenat, 1993) for water quality classification was adopted and reproduced in Table 2 for the Endau-Rompin River hilly landscape.

4.2.4.2 Biological Monitoring Working Party (BMWP) Scores

The tolerance scores of organisms used in the Biological Monitoring Working Party (BMWP) method that had been published (Chapman *et al.*, 1996) were adopted and reproduced in for this study (Appendix K). The scoring scheme has been standardised by the International Organisation for Standardisation (ISO) and can be used to reflect the impact of pollution on water bodies. This method is based on the absence and presence of species and not the total number of specimens in a particular family or genus as for the FBI or GBI.

The families present in each station were ticked off once even if more than one species occurred for a particular family. For example, there were 15 individuals of Baetidae collected at Station 1 (Appendix J) but the score for that particular family was counted only once. The scores for all the families then were summed up to give the BMWP values. Table 3 shows an empirical BMWP category for the water quality of Malaysian rivers, which could be adopted for Endau-Rompin rivers.

The formula used in this BMWP scheme is:

$$\text{BMWP Values} = \sum t_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where; t_i = the tolerance score of the family (i)

The Average Score Per Taxon (ASPT) was considered in order to minimise the effect of sampling size and effort on the results computed using this BMWP method. The ASPT score was obtained by dividing the BMWP score by the total number of taxa or family found in each station.

Therefore, the formula employed is:

$$\text{ASTP} = \sum t_i / n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where; t_i = the tolerance score of the family (i)

n = the total number of families present disregarding the number of individuals

In the interpretation of results, the BMWP value greater than 100 while the ASPT value greater than 4 are categorised as good water quality indication. The water quality classification based on BMWP method for assigning water quality ratings of Selai River was adopted from the ratings used by the Department of Environment on Langat River (DOE, 1999).

4.2.5 Criteria for Assigning Water Quality Classification

A classification scheme and water quality rating that considered the possible bias of eco-region difference and that suits the scenario of the hilly area of Endau River (Yap, 2003) was adopted for the present study (reproduced as Tables 2 and 3). The biotic index criteria for assigning water quality in hilly country published by Lenat (1993) was analysed and followed. The data obtained on EPT taxa richness (%), abundance (total number of EPT individuals), and FBI / GBI and BMWP scores for each station of Selai River were matched with the five categories of the published classification scheme to establish the likely water quality classes of Selai River and its tributaries.

Water quality data were used as benchmarks to conclude the overall ratings, principally based on median class. This was aimed to improve the subjectivity in the semi-qualitative classifying approach for water quality management decision.

Table 2. Community Structure and Biotic Index Criteria for Assigning Water Quality Ratings Appropriate for Endau River Hilly Areas (Lenat, 1993; Yap, 2003).

Biotic Count / Index Criteria				**Water Quality Ratings**	
EPT Taxa			***Biotix Index Ratings***		
Richness		Abundance	*FBI and GBI*		
No.	%				
>31	>70	>100	*<5.24*	**I.**	Excellent
24-31	50-69	75-99	5.25-5.95	**II.**	Good
16-23	30-49	50-74	5.96-6.67	**III.**	Good-fair
8-15	10-29	25-49	6.68-7.70	**IV.**	Fair
0-7	<9	0-24	>7.71	**V.**	Poor

Table 3. BMWP Categories for Assigning Water Quality Classification Ratings of Malaysian Rivers (DOE, 1999).

BMWP Categories	Water Quality Ratings
> 150	**I.** Excellent water quality, no treatment necessary for water supply
101 – 150	**II.** Good quality, requires conventional treatment
51 – 100	**III.** Slightly polluted, requires conventional treatment
17 – 50	**IV.** Moderately polluted to polluted, requires extensive treatment
0 – 16	**V.** Heavily polluted, requires extensive treatment

4.3 RESULTS AND DISCUSSIONS

Mean populations of benthic macroinvertebrates (Table 4) at Stations 1 to 13, along Selai River, Endau-Rompin Forest Reserve, Johor, were derived from the data of benthic macroinvertebrates' populations of Trip 2 and Trip 3 (Appendix A & Appendix B). The preliminary data of the first trip was excluded from the calculation, though the information served as a basis for the subsequent selection of a comprehensive set of the 13 sampling stations.

4.3.1 Benthic Macroinvertebrate Population

4.3.1.1 Species Composition

The number of species recorded was high. There were 67 families and 129 genera of benthic macroinvertebrates being identified. Generally, the overall inventory data on benthic macroinvertebrates of Table 4 indicates that the Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) and Odonata (damselflies & dragonflies) were found abundantly as compared with the remaining groups, such as Coleoptera (aquatic beetles), Diptera (2-winged true-flies), Decapoda (prawns & crabs) and Gastropoda (freshwater snails). These four main orders contributed approximately 78.5 % of the total number of species throughout the routine sampling. The remaining 21.5 % was contributed by the other 9 orders.

Table 4 and Figure 3, derived from Appendix D, present the species composition of the fauna where Ephemeroptera constituted 207 individuals (22.33 %), Plecoptera 109 individuals (11.76 %), Trichoptera 302 individuals (32.58 %) and Odonata 109 individuals (11.76 %). These four abundant taxa significantly contributed towards the bulk of the population. Among this indicating assemblage, Trichoptera was the dominant species in terms of numbers, suggesting the possibility of a rich diversity. The relative importance of Trichoptera in running waters had been recognised and well studied. Caddisflies has been a subject of interest and massive data on their occurrence and habitats were presented in the proceedings of the International Symposia on Trichoptera since 1974 when the first symposium was held in Lyon, France (Bournaud & Tachet, 1986). The Coleoptera and Diptera made up 5.50 and 5.29 % respectively. The remaining groups had an overall percentage fluctuating between 0.11 % and 3.88 %.

In the order of Ephemeroptera, the Baetidae and Heptageniidae families were the more dominant taxa where genera *Baetis* and *Heptagenia* spp predominated and can be found in most of the thirteen stations. The Plecoptera was not well represented as compared with the Ephemeroptera and Trichoptera. The restriction of Plecoptera larvae to clean and cool running water could be one of the main reasons while small samples taken during field works could also contributed to this low collection. Among the Plecoptera, Perlidae was the most dominant family, with the highest count totaling 43 individuals. The *Neoperla* sp. was found to have the highest numbers with 13 individuals and occurred in most upstream stations. Past studies had showed that some genera among the Perlidae are quite tolerant of warm, silty and eutrophicated habitats (Harper, 1994). In the order of Trichoptera, the Hydropsychidae was recorded with seven genera while the genus *Chimarra* sp. of the Philopotamidae, was the most dominant species with a count of 129 individuals. It also had the highest occurrence frequency and was recorded in all the stations except Station 12, suggesting an omnipresent caddisfly.

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin.

Macroinvertebrates	**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
EPHEMEROPTERA (Mayflies)														
Baetidae	*Baetis*	3	2	1	1	2	2	8	2	7	1	0	1	1
	Centroptilum	11	0	0	0	0	0	0	0	0	0	0	0	0
	Cloeon	0	0	0	0	0	0	0	0	1	3	1	0	1
	Pseudocloeon	1	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	*Caenis*	0	0	1	0	0	1	2	0	0	2	2	1	0
Ephemerellidae	*Serratella*	0	0	0	0	0	0	3	0	2	0	0	0	0
Heptageniidae	*Cinygma*	1	0	1	0	2	3	0	1	0	0	0	0	0
	Cinygmula	0	0	0	0	0	1	0	0	0	0	2	0	0
	Heptagenia	7	5	4	6	4	7	4	10	17	1	7	0	0
	Nixe	1	1	0	1	0	0	0	3	2	0	0	0	0
	Rhithrogena	2	0	0	0	0	0	0	0	0	0	0	0	0
Isonychiidae	*Isonychia*	1	0	0	0	4	1	0	2	0	0	0	0	0
Leptophlebiidae	*Choroterpes*	0	0	0	0	1	0	0	0	0	0	0	0	0
	Habrophlebiodes	1	1	1	1	1	2	1	3	1	0	0	0	0
	Leptophlebia	0	0	1	0	0	0	0	1	2	1	1	0	0
Potamanthidae	*Potamanthus*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Rhoenanthus	0	0	0	0	4	1	0	1	0	0	0	0	0
Siphlonuridae	*Siphlonurus*	1	5	3	3	1	1	0	0	3	0	0	0	0
	Sub-total	**30**	**14**	**12**	**12**	**19**	**19**	**18**	**23**	**35**	**8**	**13**	**2**	**2**
PLECOPTERA (Stoneflies)														
Chloroperlidae	*Sweitsa*	0	0	0	0	0	0	0	1	1	0	0	0	0
Nemouridae	*Mesonemura and*	0	0	0	0	0	0	0	0	1	0	0	0	0
	Indonemura	0	0	0	0	0	0	0	0	0	0	0	0	0
Peltoperlidae	*Cryptoperla*	0	0	0	0	0	0	0	0	2	0	0	0	0
	Peltoperlopsis	1	1	3	0	0	0	0	0	0	0	0	0	0
Perlidae	*Etrocorema*	3	2	2	0	0	0	0	2	3	0	0	0	0
	Neoperla	0	2	2	0	1	1	1	2	3	1	0	0	0
	Phanoperla	1	1	1	0	3	1	0	5	0	0	0	0	0
	Tetropina	2	1	0	2	0	0	1	0	0	0	0	0	0
Perlodidae	*Arcynopteryx*	0	2	2	0	0	0	1	1	1	0	0	0	0
	Isoperla	0	0	1	0	1	0	1	1	0	0	0	0	0
	Pictetiella	1	0	0	0	0	0	0	0	0	0	0	0	0
	Skwala	0	2	0	0	0	0	0	4	0	0	0	0	0
	Stavsolus	0	1	1	0	1	1	0	6	0	0	0	0	0
Pteronarcyidae	*Pteronarcys*	0	0	0	0	0	1	0	0	0	0	0	0	0
Styloperlidae	*Cerconychia*	0	0	0	1	0	0	0	0	0	0	0	0	0
Taeniopterygidae	*Strophopteryx*	1	1	2	0	1	1	1	1	2	0	0	0	0
	Taeniopteryx	4	0	1	0	1	1	0	0	0	0	0	0	0
	Taenionema & Mesyatsia	2	0	1	0	1	4	0	0	1	0	0	0	0
	Sub-total	**15**	**13**	**16**	**3**	**9**	**10**	**5**	**23**	**14**	**1**	**0**	**0**	**0**
TRICHOPTERA (Caddisflies)														
Ecnomidae	*Ecnomus*	1	0	0	0	0	0	0	0	3	1	0	1	2
Glossosomatidae	*Agapetus*	3	0	0	0	0	0	0	0	0	0	0	0	0
Helicopsychidae	*Helicopsyche (case)*	0	0	0	1	0	0	0	0	0	0	0	0	0
Hydropsychidae	*Aethalopsyche*	0	0	0	0	0	0	2	0	0	0	0	1	0
	Ceratopsyche	1	1	0	0	0	0	0	4	0	0	0	0	0

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates	Stations:	1	2	3	4	5	6	7	8	9	10	11	12	13
	Diplectrona	1	6	1	0	0	0	0	4	1	0	0	0	0
	Hydropsyche	4	2	1	0	16	1	3	2	1	0	0	0	0
	Amphipsyche	0	0	0	0	0	0	0	1	0	0	0	0	0
	Potamyia	0	0	1	2	0	0	0	8	1	0	0	0	0
Hydroptilidae	*Orthotrichia(+cases)*	22	0	0	0	0	0	0	0	0	0	0	0	0
	Oxyethira (+ cases)	7	0	0	1	0	0	0	0	0	0	0	0	0
	Stactobia	1	0	0	0	0	0	0	0	0	0	0	0	0
	Ugandatrichia	2	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	*Leptocerus*	1	0	0	0	0	0	0	0	0	0	0	0	0
Limnephilidae	*Arctopora*	0	1	0	0	0	0	0	0	0	0	0	0	0
	Dicosmoecus	3	0	1	1	0	1	0	0	0	0	0	0	0
Philopotamidae	*Chimarra*	17	19	30	10	13	2	5	4	22	4	2	0	1
	Dolophilodes	0	0	1	0	0	0	0	1	0	0	0	0	0
	Wormaldia	0	0	0	0	0	0	0	1	0	0	0	0	0
Polycentropodidae	*Nyctiophylax*	1	0	0	0	0	0	0	0	0	0	0	0	0
Psychomyiidae	*Psychomyia*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Tinodes	0	1	0	0	0	0	0	0	0	0	0	0	0
Stenopsychidae	*Stenopsyche*	0	0	0	0	2	2	1	13	0	0	0	0	0
	Sub-total	**68**	**30**	**35**	**17**	**31**	**10**	**11**	**39**	**47**	**6**	**2**	**2**	**4**
ODONATA, ZYGOPTERA (Damselflies)														
Amphipterygidae	*Philoganga*	0	1	0	2	0	0	0	1	0	1	0	0	0
Calopterygidae	*Neurobasis*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Vestalis	0	0	1	0	1	0	0	0	0	0	0	0	0
Chlorocyphidae	*Libellago*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Rhinocypha	0	0	0	0	0	0	0	0	0	0	0	1	0
Chlorolestidae	*Megalestes*	0	0	0	0	1	0	0	0	1	0	0	1	1
	Sinolestes	0	0	0	0	0	0	0	0	0	0	0	1	0
Euphaeidae	*Anisopleura*	1	0	1	0	1	0	0	0	0	0	0	0	0
	Dysphae	13	15	2	5	0	2	0	6	9	8	0	0	1
	Euphaea	0	0	0	1	0	0	0	0	0	0	0	0	0
Lestidae	*Indolestes*	0	0	0	0	0	0	0	0	0	1	1	0	0
Megapodagrionidae		1	0	0	1	0	0	0	0	0	0	0	0	0
ODONATA, ANISOPTERA (Dragonflies)														
Aeshnidae	*Boyerla*	0	1	0	0	0	0	0	0	0	0	0	0	0
Cordulegastridae	*Cordulegaster*	0	0	0	1	0	0	0	0	0	0	0	0	0
Corduliidae	*Epitheca*	0	1	0	0	0	0	0	0	0	0	0	0	0
	Idionyx	1	1	0	0	0	0	1	0	0	0	0	0	0
Gomphidae	*Labrogomphus*	0	0	0	0	0	0	0	2	0	1	0	0	0
	Leptogomphus	0	0	1	0	0	0	0	0	0	0	0	0	0
	Merogomphus	0	0	1	0	0	0	0	0	0	1	0	1	1
	Macrogomphus	0	0	0	0	1	1	0	2	0	0	0	0	1
Libellulidae	*Orthetrum*	0	0	0	0	0	0	1	0	0	0	0	0	0
Macromiidae	*Macromia*	0	0	0	0	3	1	0	0	0	0	0	0	0
	Sub-total	**18**	**19**	**6**	**10**	**7**	**4**	**2**	**11**	**10**	**12**	**1**	**4**	**4**
LEPIDOPTERA (Aquatic moths)														

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates	**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Pyralidae, Nymphulinae	*Elophila*	1	0	0	0	0	1	1	1	0	0	0	0	0
	Eoophyla	4	0	0	0	0	0	0	2	1	0	0	0	0
	Eristena	1	0	0	0	0	0	0	0	0	0	0	0	0
	Nymphula	0	0	0	0	0	0	0	0	0	1	0	0	0
	Sub-total	**6**	**0**	**0**	**0**	**0**	**1**	**1**	**3**	**1**	**1**	**0**	**0**	**0**
MEGALOPTERA (Alderflies/ Dobsonflies)														
Corydalidae	*Protohermes*	3	3	2	0	0	0	1	1	0	0	0	0	0
HETEROPTERA (Aquatic bugs)														
Gelastocoridae	*Nerthra*	0	0	0	0	0	0	0	0	0	0	0	1	0
Gerridae Subfamily-Halobatine		1	1	0	0	2	1	0	0	1	0	0	0	0
Helotrephidae	*Distotrephes*	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	*Hydrometra*	0	0	0	0	0	0	0	0	0	0	1	0	0
Nepidae	*Cercometus*	0	0	0	0	0	0	0	0	0	0	0	1	0
	Ranatra	0	0	0	0	1	0	1	0	0	0	0	0	0
Veliidae	*Rhagovelia*	0	0	0	0	0	1	0	0	1	0	0	0	0
	Sub-total	**2**	**1**	**0**	**0**	**3**	**2**	**1**	**0**	**2**	**0**	**1**	**2**	**0**
COLEOPTERA (Aquatic beetles)														
Elmididae/Elmidae	*Dryopomorphus*	0	0	0	0	1	0	0	0	0	0	0	0	0
	Ordobrevia	0	0	0	1	0	0	0	0	0	0	0	0	0
	Pseudamophilus	0	0	0	2	0	0	0	0	0	0	0	0	0
Gyrinidae	*Dineutus*	0	0	1	1	0	0	0	0	0	3	0	0	0
	Porrorhynchus	0	1	0	0	0	0	0	0	2	0	0	0	0
Haliplidae	*Haliplus*	0	0	0	0	0	0	0	0	0	0	0	3	0
Hydrophilidae	*Anacaena*	0	0	0	0	0	0	0	0	0	0	0	0	1
	Paracymus	0	0	0	0	0	0	0	0	0	1	0	0	0
Psephenidae	*Eubrianax*	3	0	1	2	0	0	2	0	5	3	1	0	0
	Mataeopsephus	5	2	0	1	0	1	1	1	1	0	0	0	0
Scirtidae	*Cyphon*	0	0	0	0	0	0	0	0	0	1	0	0	0
	Prionocyphon	0	0	0	0	0	0	0	0	1	1	0	0	0
	Scirtes	0	0	0	0	0	0	0	0	0	1	0	0	0
Staphylinidae	*Staphylinid larva*	0	0	0	0	0	0	0	0	0	1	0	0	0
	Sub-total	**8**	**3**	**2**	**7**	**1**	**1**	**3**	**1**	**9**	**11**	**1**	**3**	**1**
DIPTERA (2-wing true flies)														
Chaoboridae	*Chaoborus*	0	0	0	1	0	0	0	0	0	0	0	0	0
Chironomidae	*Ablabesmyia*	0	0	0	0	0	0	0	0	0	0	0	0	1
	Chironomus	1	1	2	0	0	0	3	1	0	0	0	0	1
	Cryptochironomus	0	0	0	0	0	0	0	0	0	1	0	0	0
	Conchapelopia	0	0	0	0	0	0	0	0	0	1	0	0	0
Other sub-family	Tanypodinae	0	0	0	0	1	0	2	0	0	1	0	0	1
Deuterophlebiidae	*Deuterophlebia*	0	0	1	0	0	0	0	0	0	0	0	0	0
Simuliidae	*Prosimulium*	0	0	0	1	0	0	0	0	0	0	0	0	0
	Simulium	0	0	2	1	0	0	6	0	1	5	0	0	0
Stratiomyidae	Stratiomys	1	0	1	0	0	0	0	1	0	0	0	0	0
Tipulidae	*Holorusia*	0	0	0	0	0	0	0	0	0	1	0	0	0
	Prionocera & Tipula	1	1	0	0	1	0	1	0	0	0	0	0	0

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates		Stations: 1	2	3	4	5	6	7	8	9	10	11	12	13
	Triogma	2	0	0	0	0	0	0	3	0	1	0	0	0
	Sub-total	**5**	**2**	**6**	**3**	**2**	**0**	**12**	**5**	**1**	**10**	**0**	**0**	**3**
DECAPODA (Prawns & crab)														
Palaemonidae	*Macrobrachium*	2	0	0	0	1	1	1	1	4	0	1	3	0
	Palaemonetes	1	0	0	0	1	0	0	1	0	0	0	0	0
Potamoidea (Freshwater crab)		0	1	1	0	1	0	1	0	1	0	1	1	0
	Sub-total	**3**	**1**	**1**	**0**	**3**	**1**	**2**	**2**	**5**	**0**	**2**	**4**	**0**
GASTROPODA (Freshwater snails)														
Lymnaeidae 1	*Lymnaea*	0	0	0	2	2	1	4	1	0	2	2	3	1
Lymnaeidae 2		2	4	1	2	1	0	0	1	1	0	3	2	1
	Sub-total	**2**	**4**	**1**	**4**	**3**	**1**	**4**	**2**	**1**	**2**	**5**	**5**	**2**
GNATHOBDELLIDA (Leech)														
Hirudinidae		0	0	0	0	1	0	1	0	0	0	0	0	0
LUMBRICULIDA (Aquatic earthworm)														
Lumbriculidae		0	0	0	0	0	0	0	0	0	0	0	1	0

Note: Station 1, Takah Pandan is the reference point of the rhithronic headwaters.
Station 11, Upstream of a tributary Kelembai River is the reference point for the potamonic lower part of Selai River.

For the corresponding standard deviation of mean populations, refer Appendix C.

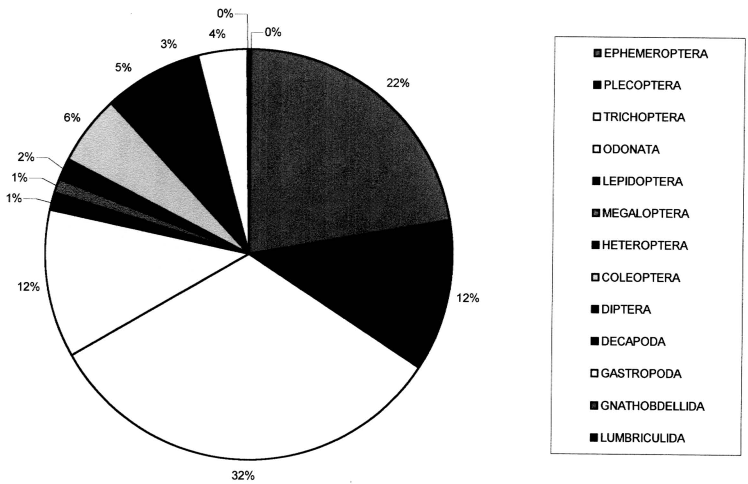


Figure 3. Taxa Composition of Benthic Macroinvertebrates along Selai River, Endau-Rompin

With the exception of Euphaeidae, the odonates were not very well represented when compared with the Ephemeroptera and Trichoptera. The damselfly, Euphaeidae, was well represented especially the *Dysphae* sp. which was recorded in considerable numbers in most of the stations while the dragonfly, such as Gomphidae, was collected in a lesser number. The poor collection of the odonates in the present short-term study is attributable to the small samples taken. The population size of the odonates can be expected to increase considerably if more samplings are to be carried out in this pristine riverine environment. An earlier study on adult and larval biology of Odonata reported 12 families consisting of 32 species being collected from about 11 tributaries of the Endau River (Norma-Rashid in UM-Endau National Park Research Expedition 2002 Newsletter). In this early study, Libellulidae was reported to be the dominant family, constituting 32 % while Euphaeidae and Gomphidae each constituted 9 % of the total odonate populations. Another study conducted in the standing water body of Tasik Bera, Pahang recorded 59 species where Libellulidae was also reported to be the dominant family, constituting 66.5 % of the total collection of Odonata. Gomphidae was found to be moderately represented with 7.1 % while Euphaeidae were poorly represented with less than 1 % (Norma-Rashid *et al.*, 2001) in the lentic system. This study which took about 32 months confirmed that more samplings were required in order to have a more accurate representation of the odonates or other insects inhabiting in the semi-riverine environment and riparian vegetation. The difference in population size of the odonates, besides sampling errors, could be due to the lotic condition prevailing in Selai River and Endau River while Tasik Bera is a mix of lotic and lentic environment in which aquatic insects abound.

Other orders that contributed to the remaining percentage of the species composition were Lepidoptera (aquatic moths), Megaloptera (alderflies/ dobsonflies), Heteroptera (aquatic bugs), Coleoptera (aquatic beetles), Diptera (2-winged true-flies), Decapoda (prawns & crabs), Gastropoda (freshwater snails), Gnathobdellida (leeches) and Lumbriculida (aquatic earthworms). Individuals of these orders were recorded in much lower numbers.

4.3.1.2 Community Structure: Taxa Richness and Abundance

The taxa richness of benthic macroinvertebrates at the 13 stations along Selai River, Endau-Rompin Forest Reserve was tabulated in Table 5. The values indicate the number of the genera of 13 orders. In addition, Table 5 gives an easy assessment on the dominant groups, their frequency of occurrence and also abundance. The square matrix consisting of 13 groups (orders) and 13 sampling stations indicates an interesting pattern of fluctuation in the number of genera of each group. It allows a comparison on the richness of taxa along the river to be made. The total taxa richness fluctuated between 13 and 55 genera. The relative importance of the Ephemeroptera - Plecoptera - Trichoptera (EPT) taxa richness was certainly portrayed, ranging from 4 to 34 genera and representing 25 % to 70 % of total taxa richness. As indicated in Figure 4, EPT/Total Taxa Richness (%) values were higher than 60 % in Stations 1, 2, 3, 6, 8 and 9. The EPT/Total Taxa Richness (%) values of Stations 4, 5, 7 and 11 were recorded at intermediate proportion (approximately 50 %) while the rest were in low proportion. Station 12 harboured the lowest EPT taxa richness with 25 %. This pattern was well expected at the downstream site due to the predominance of Odonata and non-insect fauna. The richness of EPT were

Table 5. Taxa Richness of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates	Stations: 1	2	3	4	5	6	7	8	9	10	11	12	13
Group													
EPHEMEROPTERA (Mayflies)	11	5	7	5	8	9	5	8	8	5	5	2	2
PLECOPTERA (Stoneflies)	8	9	10	2	7	7	5	9	8	1	0	0	0
TRICHOPTERA (Caddisflies)	15	6	6	6	3	5	4	10	6	3	1	2	3
ODONATA(Damselflies & Dragonflies)	6	5	5	5	5	3	2	4	2	5	1	4	4
LEPIDOPTERA (Aquatic moths)	3	0	0	0	0	1	1	2	1	1	0	0	0
MEGALOPTERA (Alder/Dobsonflies)	1	1	1	0	0	0	1	1	0	0	0	0	0
HETEROPTERA (Aquatic bugs)	2	1	0	0	2	2	1	0	2	0	1	2	0
COLEOPTERA (Aquatic beetles)	2	2	2	5	1	1	2	1	4	7	1	1	1
DIPTERA (2-wing true flies)	4	2	4	3	2	0	4	3	1	6	0	0	3
DECAPODA (Prawns & Crab)	2	1	1	0	3	1	2	2	2	0	2	2	0
GASTROPODA (Freshwater snails)	1	1	1	2	2	1	1	2	1	1	2	2	2
GNATHOBDELLIDA (Leech)	0	0	0	0	1	0	1	0	0	0	0	0	0
LUMBRICULIDA (Aquatic earthworm)	0	0	0	0	0	0	0	0	0	0	0	1	0
EPT Taxa Richness	**34**	**20**	**23**	**13**	**18**	**21**	**14**	**27**	**22**	**9**	**6**	**4**	**5**
Total Taxa Richness	**55**	**33**	**37**	**28**	**34**	**30**	**29**	**42**	**35**	**29**	**13**	**16**	**15**
EPT/Total Taxa Richness(%)	**62**	**61**	**62**	**46**	**53**	**70**	**48**	**64**	**63**	**31**	**46**	**25**	**33**
EPT Abundance	**113**	**57**	**63**	**32**	**59**	**39**	**34**	**85**	**96**	**15**	**15**	**4**	**6**

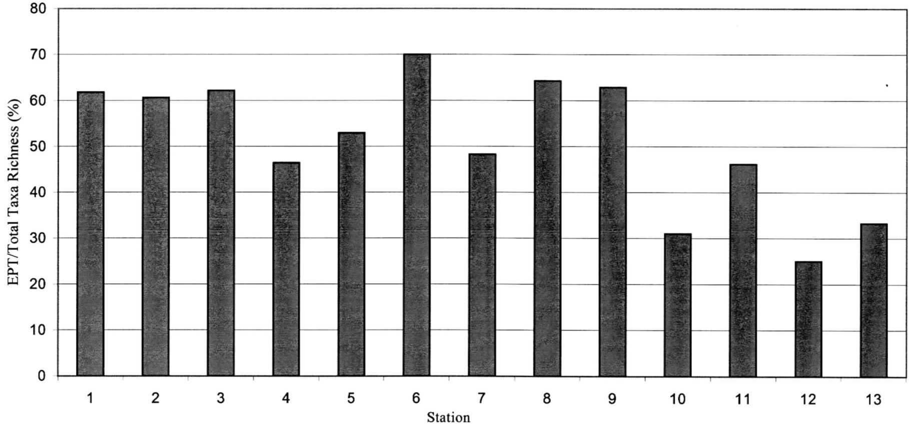


Figure 4. EPT/Total Taxa Richness (%) at Stations along Selai River, Endau-Rompin

relatively higher in the first three upstream stations and then slowly decreased, then peaked at Stations 8 and 9 before declining again.

Of all the groups, Trichoptera scored the highest, with 11 families and 24 genera being identified. Caddisflies were then followed by Plecoptera, which consisted of 8 families and 19 genera, and Ephemeroptera, which composed of 8 families and 18 genera, respectively. Using the Ephemeroptera, Plecoptera and Trichoptera (EPT) insect orders, Che Salmah *et al.* (2001) concluded that Ephemeroptera was the most abundant among the three orders, contributing more than 50 % of the total EPT collected in Krian River basin, Perak. This could be due to the different types of microhabitats available. In terms of taxa richness, the EPT taxa were followed by the Odonata, Diptera and Coleoptera (Table 4). The Coleoptera was a mix of terrestrial and aquatic beetles.

The indicating assemblage EPT was also rich in abundance, fluctuating between 4 and 113 number of individuals. As similarly observed in taxa richness, the EPT abundance peaked at headwaters and tributaries, (Stations 1, 8 and 9); however, the differences in EPT abundance were wider across sites and showed an erratic pattern. The EPT abundance (Figure 5) distinctly showed 3 peaks at Stations 1, 8 and 9 with each station housed well above 80 individual species. Station 1 had the highest abundance with 113 individuals, which was then followed by Stations 9 and 8 with 96 and 85 individuals, respectively. The EPT were moderately abundant, fluctuating from 32 to 63 individuals, at Stations 2 to 7 while they declined in numbers to less than 20 individuals at the last four downstream stations. As compared with the richness, EPT abundance declined abruptly from upstream to downstream of Selai River. Among the EPT, Ephemeroptera was comparatively and randomly abundant

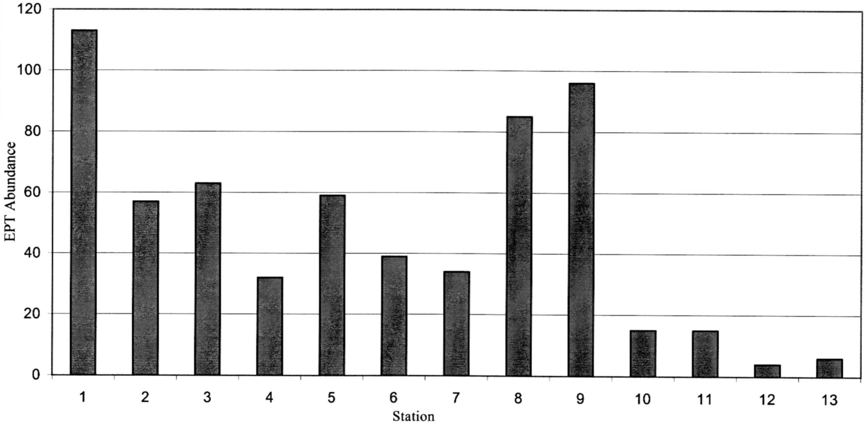


Figure 5. EPT Abundance at Stations along Selai River, Endau-Rompin

across sites and therė are at least 2 to 35 specimens found at each site. Plecoptera was less abundantly or not at all found, fluctuating between 0 to 23 specimens, at the lower segments of the Selai River. This is probably because of the habitat-selective nature of Plecoptera or in another word, it is a steno-ecious species, preferring clean and cool running water. Trichoptera was the dominant species, (modified after definition by Lenat, 1993) and the abundance of caddisflies ranged between 2 to 68 individuals per m^2. Though it was a crude estimation, EPT abundance in this study could be used to provide an ordinal abundance values; rare = 1 – 5 specimens, common = 6 – 10 specimens, and abundant taxon = 11 – 30 specimens at least at a sampling site.

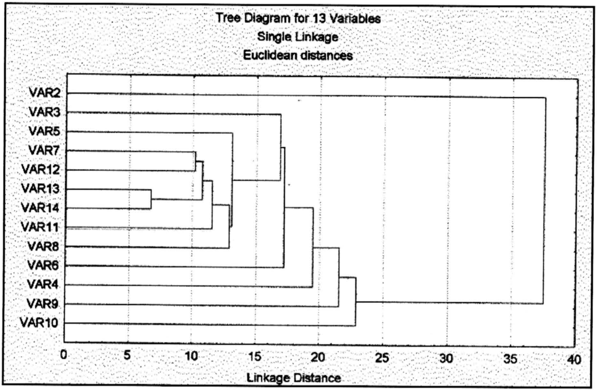
4.3.1.3 Distributional Patterns

The detailed distributional trends of the benthos collected along Selai River are discernible from Tables 4 and 5. The One-Way ANOVA results applied on the transformed data log $(x + 1)$ on abundance provided the subtle difference in distribution among stations. The distributions of Plecoptera ($F = 6.043$, $p = 0.00145$) were different among Stations 1 – 3, 8 and 10 - 13, based on the Newman-Keuls test and also that of Megaloptera ($F = 3.458$, $p = 0.01744$) differed among Stations 2 and 9 (Appendix E). With confirmation needed, *Baetis*, *Heptagenia*, *Chimarra* and *Dysphae* spp distributed widely in all stations. *Etrocorema*, *Neoperla* spp and other stoneflies distributed randomly in Stations 1 – 10 but they were not found at Stations 11 – 13. The distribution of stoneflies was associated with their habitat-related preference for clean and cool running water, and the absence of such steno-ecious species did not indicate that the potamonic lower sites in Selai River were polluted

(Yap, 2003). The aquatic moth and dobsonflies were site-specific and confined in running water with stony substrates. The remaining fauna distributed irregularly without showing any clear distribution pattern. Yap (2003) described the cased micro-caddisflies (*Orthotrichia* and *Oxyethira* spp) as exhibiting an aggregate distribution pattern at the fast-flowing zone, waterfalls and cascades, and seepage over cliff in Selai River.

The distribution pattern of EPT can be roughly visualised from Figures 4 and 5, which fluctuates from upstream (Station 1) to downstream (Station 13). The findings depict a longitudinal distribution pattern of the fauna indicating a declining trend. Other biota like Odonata, Diptera and Coleoptera seemingly demonstrate gradual longitudinal distribution and succession along the river continuum.

The dendrogram (Figure 6) constructed was based on 67 families of benthic macroinvertebrates shows 4 main clusters of stations: Stations 12 and 13 formed a group at a linkage distance of 7; Stations 4, 6, 7, 10 and 11 formed another cluster at a linkage distance of 10 to 13; Stations 2, 3, 5, 8 and 9 formed the third cluster at a linkage distance of 17 to 23; whereas Station 1 as by itself formed the fourth group. The first cluster group represented a lentic or slow-flowing segment, whereas cluster 2 and 3 were a mixed of ripples and pools. The last cluster group was the fast-flowing headwater. However, these similarity measures did not bring out partitions since the stations and tributaries were located along the longitudinal gradient of Selai River. Legendre & Legendre (1998) noted that cluster analyses are not adapted to ecological data and they do not always bring out partitions but they do bring out gradients. In other word, cluster groupings did not conform to river classification but they were instead related to physical river descriptions e.g. water flow.



Legend

Var.2	=	Station 1	Var.9	=	Station 8
Var.3	=	Station 2	Var.10	=	Station 9
Var.4	=	Station 3	Var.11	=	Station 10
Var.5	=	Station 4	Var.12	=	Station 11
Var.6	=	Station 5	Var.13	=	Station 12
Var.7	=	Station 6	Var.14	=	Station 13
Var.8	=	Station 7			

Figure 6. Dendrogram Constructed based on the Family of Macroinvertebrates Showing Clusters of Similar Stations along Selai River and its Tributaries

Estimation of similarity based on 129 genera also produced the same number of cluster groups (Appendix F) and did not deviate significantly from the result based on family.

4.3.2 Biotic Indices and Scores

4.3.2.1 Tolerance Values: Family- and Genus Biotic Indices (FBI & GBI)

The tolerance values (Appendix I) were adopted, assuming they reflected the tropical conditions experienced by Malaysian taxa. The scheme assigned "0" for sensitive species while "10" for pollution-tolerant species. Accordingly, families like Pteronarcyidae (Plecoptera), Glossosomatidae (Trichoptera), Corydalidae (Megaloptera) and Deuterophlebiidae (Diptera) scored "0" while Chlorolestidae, Lestidae, Libellulidae (Odonata) and Nepidae (Heteroptera) scored "9". The remaining families assumed the intermediate values. For the GBI, *Cinygmula* sp. (Heptageniidae), *Sweitsa* sp. (Chloroperlidae), *Agapetus* sp. (Glossosomatidae), *Helicopsyche* sp. (Helichopsychidae), *Protohermes* sp. (Corydalidae), *Deuterophlebia* sp. (Deuterophlebiidae) scored "0" while *Conchapelopia* sp. (Chironomidae) scored "10". Chutter (1972) designed a comparable scheme for biota of tropical South African streams and rivers.

A total of 54 families and 112 genera of indicating aquatic insects were based on for the calculation of Family Biotic Index (FBI) (Appendix G) and Genus Biotic Index (GBI) (Appendix H), respectively. GBI scores were either close to or slightly lower than those of FBI, suggesting that both scores provided more or less similar indication on the effects of environmental changes on the organisms. The FBI scores ranged from 3.2 to 6.2 while those of GBI ranged from 2.6 to 5.5 (Table 6). Figure 7

Table 6. The Biotic Indices and BMWP Scores Estimated for Stations along Selai River, Endau-Rompin

Biotic Indices / BMWP Score	Stations:	1	2	3	4	5	6	7	8	9	10	11	12	13
Family Biotic Index (FBI)		3.6	3.5	3.2	4.0	3.9	3.5	4.5	3.4	3.9	4.5	4.4	6.2	5.4
Genus Biotic Index (GBI)		3.6	3.0	3.0	3.7	3.3	3.0	5.0	2.6	3.9	4.4	2.9	5.5	5.5
Biological Monitoring Working Party (BMWP)		171	136	114	96	123	122	131	105	148	108	55	45	43
Average Score Per Taxon (ASPT)		7.4	7.2	7.1	6.9	6.8	7.6	6.9	7.5	7.4	6.4	6.9	5.6	5.4

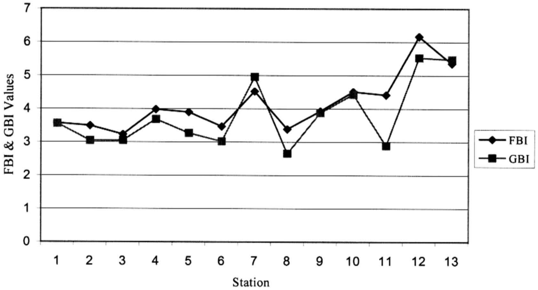


Figure 7. FBI & GBI Values of Aquatic Insects at Stations along the Longitudinal Gradient of Selai River, Endau-Rompin

shows the variations in FBI and GBI scores, generally demonstrating slight increment due to the higher population of tolerant organisms at downstream. Most of the stations were recorded with FBI and GBI values lower than 5.24, except Stations 12 and 13. Station 12 had FBI and GBI values of 6.2 and 5.5 while Station No. 13 had FBI and GBI values of 5.4 and 5.5, respectively.

4.3.2.2 Biological Monitoring Working Party (BMWP) Scores and Schemes

In a reverse manner to the FBI and GBI's scores, the BMWP scheme assigned tolerance score of "10" for pollution-sensitive species and "0" for pollution-tolerant species. As an example, Siphlonuridae, Heptageniidae, Leptophlebiidae, Ephemerellidae, Potamanthidae and Ephemeridae (Ephemeroptera); Taeniopterygidae, Leuctridae, Capniidae, Perlodidae, Perlidae, Chloroperlidae (Plecoptera); Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae, Sericostomatidae (Trichoptera) were assigned with the highest tolerance score of "10" while Oligochaeta (segmented worms) was given a score of "1" (Appendix K). As for Biological Monitoring Working Party (BMWP), this method was based on the absence and presence of families and not the total number of specimens in a particular family or genus as for the FBI or GBI and would be counted once only for a particular family. A total of 41 families of the known indicating species were based on for calculation as tabulated in Table 6 (raw data in Appendix J). The BMWP values ranged from 43 to 171 while the Average Score Per Taxon (ASPT) values ranged from 5.4 to 7.6. Most of the stations recorded scores higher than 100 where Station 1 had the highest score of 171. Stations 11 - 13 as well as Station 4 had BMWP values, which were lower than 100 with a score of 55, 45, 43 and 96, respectively. However, all stations had scored above 4 for the ASPT values. The highest ASPT value was recorded in Station 6 with 7.6 and the lowest was in Station 13. In summary, the biological measures showed a declining pattern from Station 1 to Station 13 (Figures 8a & 8b), due to the increased population size of pollution-tolerant organisms with low tolerance scores. Both schemes agreed with the variations of physical-chemical factors of the study area, especially the levels of dissolved oxygen, pH, PO_4, NO_3, Si_4 concentrations, conductivity and temperature.

4.3.2.3 Comparisons of FBI and GBI with BMWP Schemes

The two biotic indices yielded an opposite trend across the sampling stations. This was because the BMWP and FBI / GBI used the reverse scales in assigning tolerance values of the known indicating species (Appendices I and K). This discernible pattern served as a good criterion for assigning the water quality classification of this river.

From the comparisons of corresponding values at each sampling station (Table 6), the FBI and GBI estimates were more constant than those of BMWP. The latter discriminated clearly the contrast between the upstream stations (Stations 1 – 10) and the downstream stations (Stations 11 – 13). However, the ASPT values were almost constant and did not have predictive value, besides indicating the contribution of each family towards the total BMWP estimations. In order to reduce the subjectivity in the determination on the tolerance of biota to an array of environmental factors, the use of a combination of both or more schemes should be encouraged.

Moreover, since the estimates of both schemes were based on familial and genus levels of macroinvertebrates, the results and conclusions derived should be regarded

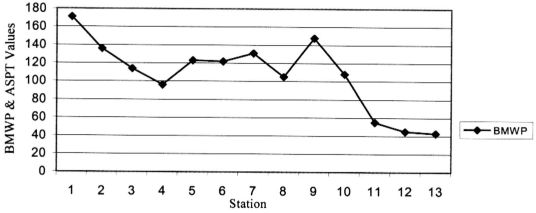


Figure 8a. BMWP Scores of Aquatic Insects At Stations along the Longitudinal Gradient of Selai River, Endau-Rompin

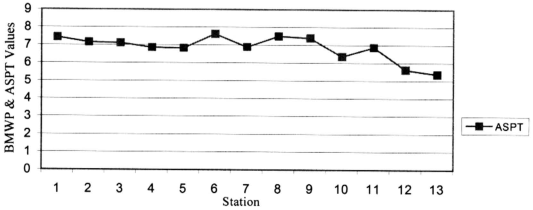


Figure 8b. ASPT Scores of Aquatic Insects At Stations along the Longitudinal Gradient of Selai River, Endau-Rompin

as conservative and preliminary, until the organisms were identified up to species level of taxonomic identification (Furse *et al.*, 1984). This recommendation on the use of FBI estimate in water quality classification had also been made by Che Salmah *et al.* (2001).

4.3.2.4 Water Quality in Comparison with Water Quality Criteria and Standards for Protection of Nature Reserve

With the exception of dissolved oxygen, physical-chemical parameters such as water temperature, conductivity and pH demonstrated a more constant fluctuation patterns and most parameters were at the acceptable levels as compared with the criteria and standards for the protection of natural reserves (Table 7). They suggested an excellent water quality for all stations except Stations 10 and 12 while there were no records on Stations 3, 7 and 11. Dissolved oxygen levels varied considerably, however, it was a direct measure of the oxygen concentration in the flowing water at this lotic and erosional environment, and it was thus selected for comparison with other biological measures in the classification of water quality at the pristine area.

4.3.3 Criteria for Assigning Water Quality Classification

As explored above, the headwaters and tributaries of Selai River were comparatively rich in clean-water EPT taxa, which gradually declined in richness, abundance and diversity as the river meandars downstream. Similarly, the FBI and GBI showed an increasing trend while the BMWP scores showed a decreasing trend.

The five-category ratings in Tables 2 and 3 (Sub-section 4.2.5) were defined in parallel with the five categories of water quality, which were in agreement with the

Table 7. Physical-Chemical Parameters for Assigning Water Quality at Stations Along Selai River, Endau-Rompin

Parameter	Station No. (Present Study & Yap, 2003)													Min & Max	Range Values	Interim Water Quality Std.
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Water temperature (°C)	27.2	25.8	-	25.8	25.8	25.3	-	25.3	26.8	28.5	-	27.2	27.3	25.3-28.5	24.0-26.2	Normal ±2
Conductivity (mSiemen/m)	4.0	5.0	-	2.0	2.0	2.0	-	3.0	5.0	5.0	-	6.0	4.0	2.0-6.0	23.4-49.6	1000
pH	6.86	7.73	-	8.28	8.30	8.27	-	7.93	7.12	6.90	-	6.98	7.78	6.86-8.30	5.02-7.62	6-9
Dissolved oxygen (mg/L)	7.0	8.0	-	7.8	7.8	8.0	-	7.0	8.0	5.2	-	5.0	8.0	5.2-8.0	2.43-8.29	5-7
PO_4 (mg/L)	0.03	0.08	-	0.01	0.06	0.01	-	0.01	0.09	0.06	-	0.09	0.04	0.01-0.09	0.0-0.05	0.2
NO_3 (mg/L)	0.2	0.3	-	0.2	0.5	0.2	-	0.4	0.4	0.4	-	0.6	0.5	0.2-0.6	0.8-4.5	7
Si_4 (mg/L)	0.326	0.804	-	0.183	0.056	0.560	-	0.573	0.889	0.806	-	0.794	0.680	0.056-0.889	0.0-0.17	50
Turbidity (NTU)	← Non-detectable →													-	-	50

Source for Range Values: Mohd Jamil *et al.* , 2002.

Source for Interim National Water Quality Standards for Malaysia: DOE-UM, 1986.

more comprehensive physical-chemical data (Yap, 1997; DOE-UM, 1986). This scheme was also adopted in this present study in an attempt to compare the water conditions of the habitats of the indicating species and the general water quality of Selai River. Table 8 lists the possible water quality classes based on six different measures that consisted of the percentage of EPT taxa richness, EPT abundance, FBI, GBI, BMWP scores, dissolved oxygen (DO), pH, PO_4, NO_3, Si_4 concentrations, conductivity and temperature at each station. The class categories along the 13 stations varied from Class I to Class V. Due to the small sample size of this short-term study, the results were quite conservative but generally, they gave an acceptable overall rating for the thirteen stations, ranging from Class I to Class III. Stations 1 – 10 were ranged from Class I to II while Stations 11 – 13 were classified as Class III if justified by dissolved oxygen. However, if more parameters were based on, about 50 % of the sampling stations had their classification results upgraded.

From the comparison, the FBI and GBI results gave rise to less stringent classes as compared the remaining measures. However, the EPT taxa richness and abundance results were more stringent as they indicated lower classes of water quality especially towards the potamonic lower stations. By comparison, the BMWP scheme appeared to give a more reliable water quality ratings to avoid an under estimation of quality or worst-case scenario.

On a preliminary basis, the Selai River could be classified between Classes I and III with good-fair to excellent water quality. The headwaters were found to be excellent while the potamonic lower sites were fairly- to slightly polluted in water quality. Similar conclusions were reported in earlier studies in Endau regions (Lim, 1987; Yap, 2003).

Table 8. Proposed Classification of Water Quality at Stations along Selai River, Endau-Rompin

Criterion	Station No.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
EPT Taxa Richness (%)	II	II	II	III	II	I	III	II	II	III	III	IV	III
EPT Abundance	I	III	III	IV	III	IV	IV	II	II	V	V	V	V
FBI	I	I	I	I	I	I	I	I	I	I	I	III	I
GBI	I	I	I	I	I	I	I	I	I	I	I	II	II
BMWP	I	II	II	III	II	II	II	II	II	II	III	IV	IV
Dissolved oxygen (mg/L)	I	I	-	I	I	I	-	I	I	IIB	-	IIB	I
Overall Rating (Median Value)	**I**	**I**	**II**	**II**	**I**	**I**	**II**	**II**	**II**	**II**	**III**	**III**	**III**
pH	I	I	-	I	I	I	-	I	I	I	-	I	I
PO_4 (mg/L)	I	I	-	I	I	I	-	I	I	I	-	I	I
NO_3 (mg/L)	I	I	-	I	I	I	-	I	I	I	-	I	I
Si_4 (mg/L)	I	I	-	I	I	I	-	I	I	I	-	I	I
Water temperature (°C)	I	I	-	I	I	I	-	I	I	I	-	I	I
Conductivity (mSiemen/m)	I	I	-	I	I	I	-	I	I	I	-	I	I
Overall Rating (Median Value)	**I**	**I**	**II**	**I**	**I**	**I**	**II**	**I**	**I**	**I**	**III**	**II**	**I**

CHAPTER 4

THE COMMUNITY OF BENTHIC MACROINVERTEBRATES IN SELAI RIVER AND THE USE OF ITS STRUCTURE METRIC AS A CRITERION FOR WATER QUALITY CLASSIFICATION

4.1 INTRODUCTION

Benthic macroinvertebrates are common inhabitants in freshwater environment. They have been long recognised as an intermediate source for the transferring of contaminant in aquatic ecosystems from one trophic level to another higher level. Among these, the aquatic insects that are commonly found and successfully inhabit the pristine environment are the Ephemeroptera, Plecoptera and Trichoptera (EPT). The composition and distributional pattern of the EPT are determined by their tolerance to an array of environment factors (Morse *et al.*, 1994). EPT have been proposed to be good indicators of water quality in pristine areas (Lenat, 1993). This group has been studied in Krian River Basin in Malaysia (Che Salmah *et al.*, 2001). The taxa richness of this sub-category has been described as a reliable metric and this idea will be further illustrated in this present study results.

4.2 METHODOLOGY

4.2.1 Field Study

Intensive and comprehensive sampling works were carried out during the second and third trips. The second trip was carried out in October 2002, just before the monsoon season and the third trip was in May 2003, after the monsoon but had intermittent wet spell during the trip.

4.2.1.1 Sampling of Fauna

Bottom-dwelling macroinvertebrate samples were collected using kick sampling and visual collection methods depending on the site conditions and accessibility. Basically, the choice of using which method for sampling purposes was determined primarily by the site accessibility, substrate types (stony against sandy or silty) on the river beds and vegetation types on the littoral areas. A kick net was used for sampling at stations where the water was deep enough, about knee-deep, and also clear from obstructions such as rocks and branches in order to sample the planktonic and bottom-living life forms. It was employed at all the stations except S2, S3 and S4. The rocky and rugged riverbeds of S2 and S3 make the sampling of benthic macroinvertebrates using kicking method quite impossible. At S4, the small and shallow stream with stony bottom is too shallow to allow the use of kick net.

The kick net used for semi-quantitative sampling is a rectangular bag with a dimension of 40 cm long x 40 cm wide x 60 cm deep and nylon netting of 30 μm mesh size. During the sampling exercise, the kick net was held vertically with the mouth facing the on-coming current by a field personnel. At the same time, another field personnel, by using feet or a stick, continuously disturbed a defined area of 1 m^2 just immediately upstream of the net for approximately 3 minutes. Through these actions, the benthic macroinvertebrates would be dislodged from its hiding places and trapped into the kick net with the assistance of the water current. After the 3 minutes duration, the contents were gently washed into one corner with the flowing water before discharging all the contents into a sieve by turning the net inside out. The size of the sieve was 15 cm x 18 cm with a mesh size of 1 mm. Dead leave, twigs and other debris were removed before emptying the bottom-living macro-organisms into plastic containers. These plastic containers contained 70 - 95 % alcohol for preservation purposes. The 70 - 95 % alcohol preservative would kill most of the living macro-organisms instantly in order to prevent smaller animals from being eaten up by the larger, carnivorous animals when putting them together inside the same container. Any macro-organisms left in the sieve would be hand picked using a pair of forceps or by bare hand.

Besides the kick net, hand rubbing on stones or gravel and picking within the designated 1 m^2 area was also employed during the sampling works. This visual and hand-picking method was best used in shallow and stony or rocky area where kick net could not be used. The bottom living macro-organisms were hand picked using a pair of forceps or by bare hand into plastic containers containing 70 - 95 % alcohol preservative.

The combined methods of kick net collection and visual-hand picking at each station were consistently carried out for a period of two hours and at least three replicates were taken. There were four field personnel sampling at each station and each personnel worked within their designated 1 m^2 area. Plastic containers with specimens for each station were labeled clearly before storing them into a bigger plastic container to prevent spillage of preservative during transportation. Traveling from base camp to forested hilly sampling stations S1 – S8 was by foot while S9 – S13 using 4 x 4 wheel-drive vehicles.

4.2.1.2 Measurement of Water Quality Parameters

Several water quality parameters were measured to investigate the characteristics of microhabitats that possibly influenced the distribution of benthic macroinvertebrates in the river basin. They were also used to justify the reliabilities of scores of biological indices derived from the data collected. The physical-chemical parameters taken during the field trips were water temperature (°C), conductivity (mSiemen/m), pH, dissolved oxygen (mg/l), PO_4 (mg/l), NO_3 (mg/l), Si_4 (mg/l) and turbidity (NTU). These parameters were measured using the HACH DR/2000 Direct Spectrophotometer.

Besides the primary data of in-situ measurement, secondary data were also taken into consideration. These secondary data were obtained during the Endau-Rompin Heritage Expedition (Phase II) carried out by UM-Endau National Park Research Team in 2002 and Yap (2004). The additional parameter recorded and published was water turbidity.

Qualitative observations on the water conditions and its surrounding were made and recorded. Water and environmental conditions (Table 1) such as depth and width of water bodies, its flow rate, substrate conditions (e.g: boulders, rocky bed) and the microhabitats were recorded on a typical field record sheet reproduced from Chapman *et al.*, (1996)(Appendix L).

4.2.2 Sorting and Laboratory Analysis

In the laboratory, the benthic macroinvertebrates were sorted out in petri dishes and identified to the order level using standard identification keys as soon as possible within two days. The animals were then placed into different plastic containers or glass vials according to their orders for permanent storage. After the sorting exercise was completed, these containers or vials were then labeled accordingly and placed into a bigger plastic container before storing them in the refrigerator or freezer.

The second round of identification exercise was carried out to identify the organisms as far as possible to family and genus levels using identification keys detailed in Brinkhurst and Jamieson (1971), Wells (1991), and Morse *et al.* (1994) as references in order to maintain taxonomic-level consistency. Dissecting and compound microscopes, Olympus SZ40 and BH-2, were used for identification and counting, using appropriate magnification on minute and important features. This exercise was repeated for all the samples collected and the results were systematically tabulated for the analyses on its community structure and distribution.

4.2.3 Data Processing

After the identification exercise was completed, populations of benthic macroinvertebrates at stations along Selai River were tabulated from the inventory data of second and third trips. From these data, the mean population ($\bar{x}$) of benthic macroinvertebrates at each station and their standard deviations (s), composition (by orders), taxa richness and relative abundance of dominant taxa were computed. The standard deviation's values (Appendix C) would indicate precision of sampling and answer the possible errors like whether the sampling frequency is adequate or how many samplings are required.

The community structure of the benthic macroinvertebrates collected was expressed by composition (%), total taxa richness (total number of genera of all organisms collected) and Ephemeroptera–Plecoptera–Trichoptera (EPT) taxa richness (total number of genera of EPT collected). It was then expressed in proportion of EPT (expressed in % of total taxa of all organisms collected) and EPT abundance (total number of EPT individuals collected). The composition of benthic macroinvertebrates at stations along Selai River was computed by the summation of total number of individuals of a particular order from S1 to S13 and then divided with the grand total of the total number of individuals of all orders. From the species composition, pie chart was drawn to indicate the main groups in the community and also the most dominant species throughout the routine sampling exercise.

Since the Ephemeroptera - Plecoptera - Trichoptera (EPT) were recognised as good and reliable water quality indicators (Lenat, 1988 & 1993), their taxa richness (percentage) and abundance along the 13 stations were calculated. The abundance data of all benthos was log (x + 1) transformed to ensure homogenity of the means and variances. The transformed abundance data of all organisms was subjected to One-Way ANOVA to detect any significant difference between stations. The STATISTICA® Version 5.0 software was used. The Newman-Keuls test was done on any significant dependent variables. In addition, cluster analysis was run to detect any similarity or any possible out-groups between stations. The basic model used was the single linkage clustering (Legendre & Legendre, 1998), applying on the number of families and genera as a comparison.

4.2.4 Biotic Indices

The EPT taxa richness, (in percentage) and abundance were required to provide information for the classification and ratings of water quality along Selai River.

4.2.4.1 Tolerance Values of Family- and Genus Biotic Indices (FBI & GBI)

A tolerance score system for both the Family- and Genus Biotic Indices (FBI and GBI) based on aquatic insects was adopted with modifications from the list of

Hilsenhoff (1988) and Lenat (1993) to reflect the tropical conditions of Malaysia. The formula for the FBI and GBI is:

$$\text{FBI and GBI} = \sum x_i \,.\, t_i / n \quad \text{.........................(1)}$$

where; x_i = the number of individuals (x) in a particular family or genus (i)

t_i = the tolerance value of the family or genus (i)

n = the total number of organisms in the sample

From the inventory data on benthic macroinvertebrates, the numbers of known indicator species of each family were multiplied with their respective assigned tolerance values ranging from 0 to 10. These products were then summed to be further divided by the total number of individuals found in the population to obtain the values of FBI. The FBI values for each station were then tabulated. As for the GBI values for each station, the same steps were taken for computation, but in this level, the tolerance scores published by Lenat (1993) were used with slight modifications to consider the eco-region differences. The modified biotic index ranking system used in North Carolina Standard sampling program (Lenat, 1993) for water quality classification was adopted and reproduced in Table 2 for the Endau-Rompin River hilly landscape.

4.2.4.2 Biological Monitoring Working Party (BMWP) Scores

The tolerance scores of organisms used in the Biological Monitoring Working Party (BMWP) method that had been published (Chapman *et al.*, 1996) were adopted and reproduced in for this study (Appendix K). The scoring scheme has been standardised by the International Organisation for Standardisation (ISO) and can be used to reflect the impact of pollution on water bodies. This method is based on the absence and presence of species and not the total number of specimens in a particular family or genus as for the FBI or GBI.

The families present in each station were ticked off once even if more than one species occurred for a particular family. For example, there were 15 individuals of Baetidae collected at Station 1 (Appendix J) but the score for that particular family was counted only once. The scores for all the families then were summed up to give the BMWP values. Table 3 shows an empirical BMWP category for the water quality of Malaysian rivers, which could be adopted for Endau-Rompin rivers.

The formula used in this BMWP scheme is:

$$\text{BMWP Values} = \sum t_i \qquad \text{.........................(2)}$$

where; t_i = the tolerance score of the family (i)

The Average Score Per Taxon (ASPT) was considered in order to minimise the effect of sampling size and effort on the results computed using this BMWP method. The ASPT score was obtained by dividing the BMWP score by the total number of taxa or family found in each station.

Therefore, the formula employed is:

$$\text{ASTP} = \sum t_i / n \qquad \text{.........................(3)}$$

where; t_i = the tolerance score of the family (i)

n = the total number of families present disregarding the number of individuals

In the interpretation of results, the BMWP value greater than 100 while the ASPT value greater than 4 are categorised as good water quality indication. The water quality classification based on BMWP method for assigning water quality ratings of Selai River was adopted from the ratings used by the Department of Environment on Langat River (DOE, 1999).

4.2.5 Criteria for Assigning Water Quality Classification

A classification scheme and water quality rating that considered the possible bias of eco-region difference and that suits the scenario of the hilly area of Endau River (Yap, 2003) was adopted for the present study (reproduced as Tables 2 and 3). The biotic index criteria for assigning water quality in hilly country published by Lenat (1993) was analysed and followed. The data obtained on EPT taxa richness (%), abundance (total number of EPT individuals), and FBI / GBI and BMWP scores for each station of Selai River were matched with the five categories of the published classification scheme to establish the likely water quality classes of Selai River and its tributaries.

Water quality data were used as benchmarks to conclude the overall ratings, principally based on median class. This was aimed to improve the subjectivity in the semi-qualitative classifying approach for water quality management decision.

Table 2. Community Structure and Biotic Index Criteria for Assigning Water Quality Ratings Appropriate for Endau River Hilly Areas (Lenat, 1993; Yap, 2003).

Biotic Count / Index Criteria				**Water Quality Ratings**	
EPT Taxa			***Biotix Index Ratings***		
Richness		Abundance	*FBI and GBI*		
No.	%				
>31	>70	>100	*<5.24*	**I.**	Excellent
24-31	50-69	75-99	5.25-5.95	**II.**	Good
16-23	30-49	50-74	5.96-6.67	**III.**	Good-fair
8-15	10-29	25-49	6.68-7.70	**IV.**	Fair
0-7	<9	0-24	>7.71	**V.**	Poor

Table 3. BMWP Categories for Assigning Water Quality Classification Ratings of Malaysian Rivers (DOE, 1999).

BMWP Categories	Water Quality Ratings
> 150	**I.** Excellent water quality, no treatment necessary for water supply
101 – 150	**II.** Good quality, requires conventional treatment
51 – 100	**III.** Slightly polluted, requires conventional treatment
17 – 50	**IV.** Moderately polluted to polluted, requires extensive treatment
0 – 16	**V.** Heavily polluted, requires extensive treatment

4.3 RESULTS AND DISCUSSIONS

Mean populations of benthic macroinvertebrates (Table 4) at Stations 1 to 13, along Selai River, Endau-Rompin Forest Reserve, Johor, were derived from the data of benthic macroinvertebrates' populations of Trip 2 and Trip 3 (Appendix A & Appendix B). The preliminary data of the first trip was excluded from the calculation, though the information served as a basis for the subsequent selection of a comprehensive set of the 13 sampling stations.

4.3.1 Benthic Macroinvertebrate Population

4.3.1.1 Species Composition

The number of species recorded was high. There were 67 families and 129 genera of benthic macroinvertebrates being identified. Generally, the overall inventory data on benthic macroinvertebrates of Table 4 indicates that the Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) and Odonata (damselflies & dragonflies) were found abundantly as compared with the remaining groups, such as Coleoptera (aquatic beetles), Diptera (2-winged true-flies), Decapoda (prawns & crabs) and Gastropoda (freshwater snails). These four main orders contributed approximately 78.5 % of the total number of species throughout the routine sampling. The remaining 21.5 % was contributed by the other 9 orders.

Table 4 and Figure 3, derived from Appendix D, present the species composition of the fauna where Ephemeroptera constituted 207 individuals (22.33 %), Plecoptera 109 individuals (11.76 %), Trichoptera 302 individuals (32.58 %) and Odonata 109 individuals (11.76 %). These four abundant taxa significantly contributed towards the bulk of the population. Among this indicating assemblage, Trichoptera was the dominant species in terms of numbers, suggesting the possibility of a rich diversity. The relative importance of Trichoptera in running waters had been recognised and well studied. Caddisflies has been a subject of interest and massive data on their occurrence and habitats were presented in the proceedings of the International Symposia on Trichoptera since 1974 when the first symposium was held in Lyon, France (Bournaud & Tachet, 1986). The Coleoptera and Diptera made up 5.50 and 5.29 % respectively. The remaining groups had an overall percentage fluctuating between 0.11 % and 3.88 %.

In the order of Ephemeroptera, the Baetidae and Heptageniidae families were the more dominant taxa where genera *Baetis* and *Heptagenia* spp predominated and can be found in most of the thirteen stations. The Plecoptera was not well represented as compared with the Ephemeroptera and Trichoptera. The restriction of Plecoptera larvae to clean and cool running water could be one of the main reasons while small samples taken during field works could also contributed to this low collection. Among the Plecoptera, Perlidae was the most dominant family, with the highest count totaling 43 individuals. The *Neoperla* sp. was found to have the highest numbers with 13 individuals and occurred in most upstream stations. Past studies had showed that some genera among the Perlidae are quite tolerant of warm, silty and eutrophicated habitats (Harper, 1994). In the order of Trichoptera, the Hydropsychidae was recorded with seven genera while the genus *Chimarra* sp. of the Philopotamidae, was the most dominant species with a count of 129 individuals. It also had the highest occurrence frequency and was recorded in all the stations except Station 12, suggesting an omnipresent caddisfly.

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin.

Macroinvertebrates	Stations:	1	2	3	4	5	6	7	8	9	10	11	12	13
EPHEMEROPTERA (Mayflies)														
Baetidae	*Baetis*	3	2	1	1	2	2	8	2	7	1	0	1	1
	Centroptilum	11	0	0	0	0	0	0	0	0	0	0	0	0
	Cloeon	0	0	0	0	0	0	0	0	1	3	1	0	1
	Pseudocloeon	1	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	*Caenis*	0	0	1	0	0	1	2	0	0	2	2	1	0
Ephemerellidae	*Serratella*	0	0	0	0	0	0	3	0	2	0	0	0	0
Heptageniidae	*Cinygma*	1	0	1	0	2	3	0	1	0	0	0	0	0
	Cinygmula	0	0	0	0	0	1	0	0	0	0	2	0	0
	Heptagenia	7	5	4	6	4	7	4	10	17	1	7	0	0
	Nixe	1	1	0	1	0	0	0	3	2	0	0	0	0
	Rhithrogena	2	0	0	0	0	0	0	0	0	0	0	0	0
Isonychiidae	*Isonychia*	1	0	0	0	4	1	0	2	0	0	0	0	0
Leptophlebiidae	*Choroterpes*	0	0	0	0	1	0	0	0	0	0	0	0	0
	Habrophlebiodes	1	1	1	1	1	2	1	3	1	0	0	0	0
	Leptophlebia	0	0	1	0	0	0	0	1	2	1	1	0	0
Potamanthidae	*Potamanthus*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Rhoenanthus	0	0	0	0	4	1	0	1	0	0	0	0	0
Siphlonuridae	*Siphlonurus*	1	5	3	3	1	1	0	0	3	0	0	0	0
	Sub-total	**30**	**14**	**12**	**12**	**19**	**19**	**18**	**23**	**35**	**8**	**13**	**2**	**2**
PLECOPTERA (Stoneflies)														
Chloroperlidae	*Sweitsa*	0	0	0	0	0	0	0	1	1	0	0	0	0
Nemouridae	*Mesonemura and*	0	0	0	0	0	0	0	0	1	0	0	0	0
	Indonemura	0	0	0	0	0	0	0	0	0	0	0	0	0
Peltoperlidae	*Cryptoperla*	0	0	0	0	0	0	0	0	2	0	0	0	0
	Peltoperlopsis	1	1	3	0	0	0	0	0	0	0	0	0	0
Perlidae	*Etrocorema*	3	2	2	0	0	0	0	2	3	0	0	0	0
	Neoperla	0	2	2	0	1	1	1	2	3	1	0	0	0
	Phanoperla	1	1	1	0	3	1	0	5	0	0	0	0	0
	Tetropina	2	1	0	2	0	0	1	0	0	0	0	0	0
Perlodidae	*Arcynopteryx*	0	2	2	0	0	0	1	1	1	0	0	0	0
	Isoperla	0	0	1	0	1	0	1	1	0	0	0	0	0
	Pictetiella	1	0	0	0	0	0	0	0	0	0	0	0	0
	Skwala	0	2	0	0	0	0	0	4	0	0	0	0	0
	Stavsolus	0	1	1	0	1	1	0	6	0	0	0	0	0
Pteronarcyidae	*Pteronarcys*	0	0	0	0	0	1	0	0	0	0	0	0	0
Styloperlidae	*Cerconychia*	0	0	0	1	0	0	0	0	0	0	0	0	0
Taeniopterygidae	*Strophopteryx*	1	1	2	0	1	1	1	1	2	0	0	0	0
	Taeniopteryx	4	0	1	0	1	1	0	0	0	0	0	0	0
	Taenionema & Mesyatsia	2	0	1	0	1	4	0	0	1	0	0	0	0
	Sub-total	**15**	**13**	**16**	**3**	**9**	**10**	**5**	**23**	**14**	**1**	**0**	**0**	**0**
TRICHOPTERA (Caddisflies)														
Ecnomidae	*Ecnomus*	1	0	0	0	0	0	0	0	3	1	0	1	2
Glossosomatidae	*Agapetus*	3	0	0	0	0	0	0	0	0	0	0	0	0
Helicopsychidae	*Helicopsyche (case)*	0	0	0	1	0	0	0	0	0	0	0	0	0
Hydropsychidae	*Aethalopsyche*	0	0	0	0	0	0	2	0	0	0	0	1	0
	Ceratopsyche	1	1	0	0	0	0	0	4	0	0	0	0	0

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates	**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Diplectrona	1	6	1	0	0	0	0	4	1	0	0	0	0
	Hydropsyche	4	2	1	0	16	1	3	2	1	0	0	0	0
	Amphipsyche	0	0	0	0	0	0	0	1	0	0	0	0	0
	Potamyia	0	0	1	2	0	0	0	8	1	0	0	0	0
Hydroptilidae	*Orthotrichia(+cases)*	22	0	0	0	0	0	0	0	0	0	0	0	0
	Oxyethira (+ cases)	7	0	0	1	0	0	0	0	0	0	0	0	0
	Stactobia	1	0	0	0	0	0	0	0	0	0	0	0	0
	Ugandatrichia	2	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	*Leptocerus*	1	0	0	0	0	0	0	0	0	0	0	0	0
Limnephilidae	*Arctopora*	0	1	0	0	0	0	0	0	0	0	0	0	0
	Dicosmoecus	3	0	1	1	0	1	0	0	0	0	0	0	0
Philopotamidae	*Chimarra*	17	19	30	10	13	2	5	4	22	4	2	0	1
	Dolophilodes	0	0	1	0	0	0	0	1	0	0	0	0	0
	Wormaldia	0	0	0	0	0	0	0	1	0	0	0	0	0
Polycentropodidae	*Nyctiophylax*	1	0	0	0	0	0	0	0	0	0	0	0	0
Psychomyiidae	*Psychomyia*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Tinodes	0	1	0	0	0	0	0	0	0	0	0	0	0
Stenopsychidae	*Stenopsyche*	0	0	0	0	2	2	1	13	0	0	0	0	0
	Sub-total	**68**	**30**	**35**	**17**	**31**	**10**	**11**	**39**	**47**	**6**	**2**	**2**	**4**
ODONATA, ZYGOPTERA (Damselflies)														
Amphipterygidae	*Philoganga*	0	1	0	2	0	0	0	1	0	1	0	0	0
Calopterygidae	*Neurobasis*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Vestalis	0	0	1	0	1	0	0	0	0	0	0	0	0
Chlorocyphidae	*Libellago*	1	0	0	0	0	0	0	0	0	0	0	0	0
	Rhinocypha	0	0	0	0	0	0	0	0	0	0	0	1	0
Chlorolestidae	*Megalestes*	0	0	0	0	1	0	0	0	1	0	0	1	1
	Sinolestes	0	0	0	0	0	0	0	0	0	0	0	1	0
Euphaeidae	*Anisopleura*	1	0	1	0	1	0	0	0	0	0	0	0	0
	Dysphae	13	15	2	5	0	2	0	6	9	8	0	0	1
	Euphaea	0	0	0	1	0	0	0	0	0	0	0	0	0
Lestidae	*Indolestes*	0	0	0	0	0	0	0	0	0	1	1	0	0
Megapodagrionidae		1	0	0	1	0	0	0	0	0	0	0	0	0
ODONATA, ANISOPTERA (Dragonflies)														
Aeshnidae	*Boyerla*	0	1	0	0	0	0	0	0	0	0	0	0	0
Cordulegastridae	*Cordulegaster*	0	0	0	1	0	0	0	0	0	0	0	0	0
Corduliidae	*Epitheca*	0	1	0	0	0	0	0	0	0	0	0	0	0
	Idionyx	1	1	0	0	0	0	1	0	0	0	0	0	0
Gomphidae	*Labrogomphus*	0	0	0	0	0	0	0	2	0	1	0	0	0
	Leptogomphus	0	0	1	0	0	0	0	0	0	0	0	0	0
	Merogomphus	0	0	1	0	0	0	0	0	0	1	0	1	1
	Macrogomphus	0	0	0	0	1	1	0	2	0	0	0	0	1
Libellulidae	*Orthetrum*	0	0	0	0	0	0	1	0	0	0	0	0	0
Macromiidae	*Macromia*	0	0	0	0	3	1	0	0	0	0	0	0	0
	Sub-total	**18**	**19**	**6**	**10**	**7**	**4**	**2**	**11**	**10**	**12**	**1**	**4**	**4**
LEPIDOPTERA (Aquatic moths)														

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates	Stations:	1	2	3	4	5	6	7	8	9	10	11	12	13
Pyralidae, Nymphulinae	*Elophila*	1	0	0	0	0	1	1	1	0	0	0	0	0
	Eoophyla	4	0	0	0	0	0	0	2	1	0	0	0	0
	Eristena	1	0	0	0	0	0	0	0	0	0	0	0	0
	Nymphula	0	0	0	0	0	0	0	0	0	1	0	0	0
	Sub-total	**6**	**0**	**0**	**0**	**0**	**1**	**1**	**3**	**1**	**1**	**0**	**0**	**0**
MEGALOPTERA (Alderflies/ Dobsonflies)														
Corydalidae	*Protohermes*	3	3	2	0	0	0	1	1	0	0	0	0	0
HETEROPTERA (Aquatic bugs)														
Gelastocoridae	*Nerthra*	0	0	0	0	0	0	0	0	0	0	0	1	0
Gerridae	Subfamily-Halobatine	1	1	0	0	2	1	0	0	1	0	0	0	0
Helotrephidae	*Distotrephes*	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	*Hydrometra*	0	0	0	0	0	0	0	0	0	0	1	0	0
Nepidae	*Cercometus*	0	0	0	0	0	0	0	0	0	0	0	1	0
	Ranatra	0	0	0	0	1	0	1	0	0	0	0	0	0
Veliidae	*Rhagovelia*	0	0	0	0	0	1	0	0	1	0	0	0	0
	Sub-total	**2**	**1**	**0**	**0**	**3**	**2**	**1**	**0**	**2**	**0**	**1**	**2**	**0**
COLEOPTERA (Aquatic beetles)														
Elmididae/Elmidae	*Dryopomorphus*	0	0	0	0	1	0	0	0	0	0	0	0	0
	Ordobrevia	0	0	0	1	0	0	0	0	0	0	0	0	0
	Pseudamophilus	0	0	0	2	0	0	0	0	0	0	0	0	0
Gyrinidae	*Dineutus*	0	0	1	1	0	0	0	0	0	3	0	0	0
	Porrorhynchus	0	1	0	0	0	0	0	0	2	0	0	0	0
Haliplidae	*Haliplus*	0	0	0	0	0	0	0	0	0	0	0	3	0
Hydrophilidae	*Anacaena*	0	0	0	0	0	0	0	0	0	0	0	0	1
	Paracymus	0	0	0	0	0	0	0	0	0	1	0	0	0
Psephenidae	*Eubrianax*	3	0	1	2	0	0	2	0	5	3	1	0	0
	Mataeopsephus	5	2	0	1	0	1	1	1	1	0	0	0	0
Scirtidae	*Cyphon*	0	0	0	0	0	0	0	0	0	1	0	0	0
	Prionocyphon	0	0	0	0	0	0	0	0	1	1	0	0	0
	Scirtes	0	0	0	0	0	0	0	0	0	1	0	0	0
Staphylinidae	*Staphylinid larva*	0	0	0	0	0	0	0	0	0	1	0	0	0
	Sub-total	**8**	**3**	**2**	**7**	**1**	**1**	**3**	**1**	**9**	**11**	**1**	**3**	**1**
DIPTERA (2-wing true flies)														
Chaoboridae	*Chaoborus*	0	0	0	1	0	0	0	0	0	0	0	0	0
Chironomidae	*Ablabesmyia*	0	0	0	0	0	0	0	0	0	0	0	0	1
	Chironomus	1	1	2	0	0	0	3	1	0	0	0	0	1
	Cryptochironomus	0	0	0	0	0	0	0	0	0	1	0	0	0
	Conchapelopia	0	0	0	0	0	0	0	0	0	1	0	0	0
Other sub-family	Tanypodinae	0	0	0	0	1	0	2	0	0	1	0	0	1
Deuterophlebiidae	*Deuterophlebia*	0	0	1	0	0	0	0	0	0	0	0	0	0
Simuliidae	*Prosimulium*	0	0	0	1	0	0	0	0	0	0	0	0	0
	Simulium	0	0	2	1	0	0	6	0	1	5	0	0	0
Stratiomyidae	Stratiomys	1	0	1	0	0	0	0	1	0	0	0	0	0
Tipulidae	*Holorusia*	0	0	0	0	0	0	0	0	0	1	0	0	0
	Prionocera & Tipula	1	1	0	0	1	0	1	0	0	0	0	0	0

Table 4. Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates		**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
	Triogma		2	0	0	0	0	0	0	3	0	1	0	0	0
	Sub-total		**5**	**2**	**6**	**3**	**2**	**0**	**12**	**5**	**1**	**10**	**0**	**0**	**3**
DECAPODA (Prawns & crab)															
Palaemonidae	*Macrobrachium*		2	0	0	0	1	1	1	1	4	0	1	3	0
	Palaemonetes		1	0	0	0	1	0	0	1	0	0	0	0	0
Potamoidea (Freshwater crab)			0	1	1	0	1	0	1	0	1	0	1	1	0
	Sub-total		**3**	**1**	**1**	**0**	**3**	**1**	**2**	**2**	**5**	**0**	**2**	**4**	**0**
GASTROPODA (Freshwater snails)															
Lymnaeidae 1	*Lymnaea*		0	0	0	2	2	1	4	1	0	2	2	3	1
Lymnaeidae 2			2	4	1	2	1	0	0	1	1	0	3	2	1
	Sub-total		**2**	**4**	**1**	**4**	**3**	**1**	**4**	**2**	**1**	**2**	**5**	**5**	**2**
GNATHOBDELLIDA (Leech)															
Hirudinidae			0	0	0	0	1	0	1	0	0	0	0	0	0
LUMBRICULIDA (Aquatic earthworm)															
Lumbriculidae			0	0	0	0	0	0	0	0	0	0	0	1	0

Note: Station 1, Takah Pandan is the reference point of the rhithronic headwaters. Station 11, Upstream of a tributary Kelembai River is the reference point for the potamonic lower part of Selai River.

For the corresponding standard deviation of mean populations, refer Appendix C.

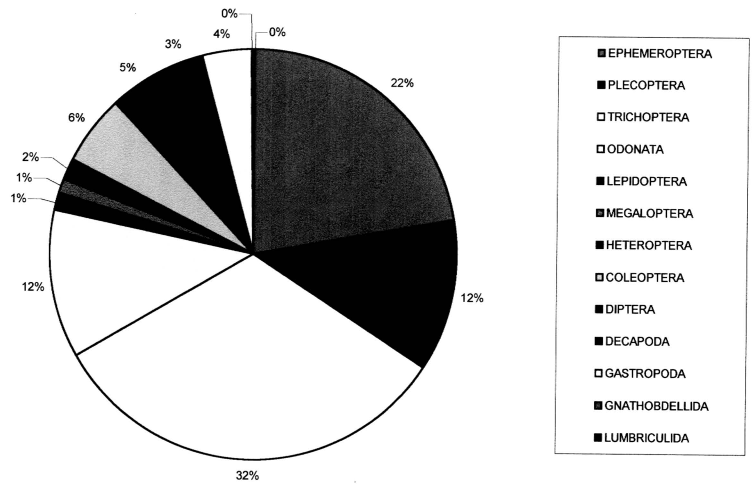


Figure 3. Taxa Composition of Benthic Macroinvertebrates along Selai River, Endau-Rompin

With the exception of Euphaeidae, the odonates were not very well represented when compared with the Ephemeroptera and Trichoptera. The damselfly, Euphaeidae, was well represented especially the *Dysphae* sp. which was recorded in considerable numbers in most of the stations while the dragonfly, such as Gomphidae, was collected in a lesser number. The poor collection of the odonates in the present short-term study is attributable to the small samples taken. The population size of the odonates can be expected to increase considerably if more samplings are to be carried out in this pristine riverine environment. An earlier study on adult and larval biology of Odonata reported 12 families consisting of 32 species being collected from about 11 tributaries of the Endau River (Norma-Rashid in UM-Endau National Park Research Expedition 2002 Newsletter). In this early study, Libellulidae was reported to be the dominant family, constituting 32 % while Euphaeidae and Gomphidae each constituted 9 % of the total odonate populations. Another study conducted in the standing water body of Tasik Bera, Pahang recorded 59 species where Libellulidae was also reported to be the dominant family, constituting 66.5 % of the total collection of Odonata. Gomphidae was found to be moderately represented with 7.1 % while Euphaeidae were poorly represented with less than 1 % (Norma-Rashid *et al.*, 2001) in the lentic system. This study which took about 32 months confirmed that more samplings were required in order to have a more accurate representation of the odonates or other insects inhabiting in the semi-riverine environment and riparian vegetation. The difference in population size of the odonates, besides sampling errors, could be due to the lotic condition prevailing in Selai River and Endau River while Tasik Bera is a mix of lotic and lentic environment in which aquatic insects abound.

Other orders that contributed to the remaining percentage of the species composition were Lepidoptera (aquatic moths), Megaloptera (alderflies/ dobsonflies), Heteroptera (aquatic bugs), Coleoptera (aquatic beetles), Diptera (2-winged true-flies), Decapoda (prawns & crabs), Gastropoda (freshwater snails), Gnathobdellida (leeches) and Lumbriculida (aquatic earthworms). Individuals of these orders were recorded in much lower numbers.

4.3.1.2 Community Structure: Taxa Richness and Abundance

The taxa richness of benthic macroinvertebrates at the 13 stations along Selai River, Endau-Rompin Forest Reserve was tabulated in Table 5. The values indicate the number of the genera of 13 orders. In addition, Table 5 gives an easy assessment on the dominant groups, their frequency of occurrence and also abundance. The square matrix consisting of 13 groups (orders) and 13 sampling stations indicates an interesting pattern of fluctuation in the number of genera of each group. It allows a comparison on the richness of taxa along the river to be made. The total taxa richness fluctuated between 13 and 55 genera. The relative importance of the Ephemeroptera - Plecoptera - Trichoptera (EPT) taxa richness was certainly portrayed, ranging from 4 to 34 genera and representing 25 % to 70 % of total taxa richness. As indicated in Figure 4, EPT/Total Taxa Richness (%) values were higher than 60 % in Stations 1, 2, 3, 6, 8 and 9. The EPT/Total Taxa Richness (%) values of Stations 4, 5, 7 and 11 were recorded at intermediate proportion (approximately 50 %) while the rest were in low proportion. Station 12 harboured the lowest EPT taxa richness with 25 %. This pattern was well expected at the downstream site due to the predominance of Odonata and non-insect fauna. The richness of EPT were

Table 5. Taxa Richness of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin

Macroinvertebrates	**Stations:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Group														
EPHEMEROPTERA (Mayflies)		11	5	7	5	8	9	5	8	8	5	5	2	2
PLECOPTERA (Stoneflies)		8	9	10	2	7	7	5	9	8	1	0	0	0
TRICHOPTERA (Caddisflies)		15	6	6	6	3	5	4	10	6	3	1	2	3
ODONATA(Damselflies & Dragonflies)		6	5	5	5	5	3	2	4	2	5	1	4	4
LEPIDOPTERA (Aquatic moths)		3	0	0	0	0	1	1	2	1	1	0	0	0
MEGALOPTERA (Alder/Dobsonflies)		1	1	1	0	0	0	1	1	0	0	0	0	0
HETEROPTERA (Aquatic bugs)		2	1	0	0	2	2	1	0	2	0	1	2	0
COLEOPTERA (Aquatic beetles)		2	2	2	5	1	1	2	1	4	7	1	1	1
DIPTERA (2-wing true flies)		4	2	4	3	2	0	4	3	1	6	0	0	3
DECAPODA (Prawns & Crab)		2	1	1	0	3	1	2	2	2	0	2	2	0
GASTROPODA (Freshwater snails)		1	1	1	2	2	1	1	2	1	1	2	2	2
GNATHOBDELLIDA (Leech)		0	0	0	0	1	0	1	0	0	0	0	0	0
LUMBRICULIDA (Aquatic earthworm)		0	0	0	0	0	0	0	0	0	0	0	1	0
EPT Taxa Richness		**34**	**20**	**23**	**13**	**18**	**21**	**14**	**27**	**22**	**9**	**6**	**4**	**5**
Total Taxa Richness		**55**	**33**	**37**	**28**	**34**	**30**	**29**	**42**	**35**	**29**	**13**	**16**	**15**
EPT/Total Taxa Richness(%)		**62**	**61**	**62**	**46**	**53**	**70**	**48**	**64**	**63**	**31**	**46**	**25**	**33**
EPT Abundance		**113**	**57**	**63**	**32**	**59**	**39**	**34**	**85**	**96**	**15**	**15**	**4**	**6**

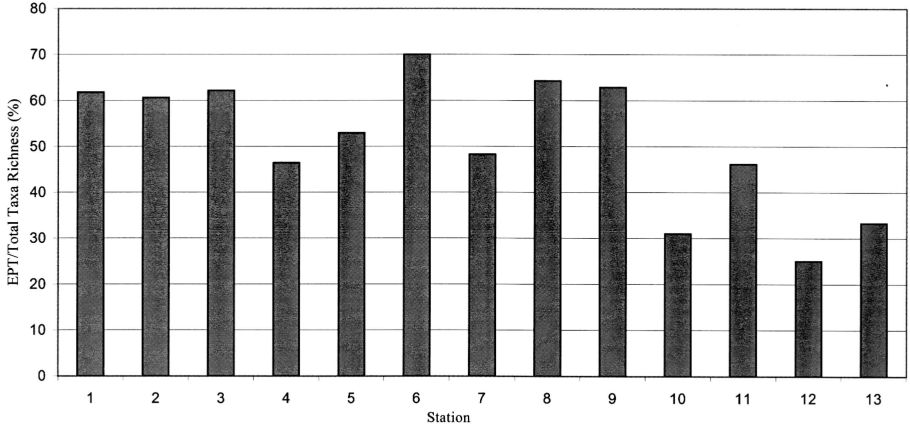


Figure 4. EPT/Total Taxa Richness (%) at Stations along Selai River, Endau-Rompin

relatively higher in the first three upstream stations and then slowly decreased, then peaked at Stations 8 and 9 before declining again.

Of all the groups, Trichoptera scored the highest, with 11 families and 24 genera being identified. Caddisflies were then followed by Plecoptera, which consisted of 8 families and 19 genera, and Ephemeroptera, which composed of 8 families and 18 genera, respectively. Using the Ephemeroptera, Plecoptera and Trichoptera (EPT) insect orders, Che Salmah *et al.* (2001) concluded that Ephemeroptera was the most abundant among the three orders, contributing more than 50 % of the total EPT collected in Krian River basin, Perak. This could be due to the different types of microhabitats available. In terms of taxa richness, the EPT taxa were followed by the Odonata, Diptera and Coleoptera (Table 4). The Coleoptera was a mix of terrestrial and aquatic beetles.

The indicating assemblage EPT was also rich in abundance, fluctuating between 4 and 113 number of individuals. As similarly observed in taxa richness, the EPT abundance peaked at headwaters and tributaries, (Stations 1, 8 and 9); however, the differences in EPT abundance were wider across sites and showed an erratic pattern. The EPT abundance (Figure 5) distinctly showed 3 peaks at Stations 1, 8 and 9 with each station housed well above 80 individual species. Station 1 had the highest abundance with 113 individuals, which was then followed by Stations 9 and 8 with 96 and 85 individuals, respectively. The EPT were moderately abundant, fluctuating from 32 to 63 individuals, at Stations 2 to 7 while they declined in numbers to less than 20 individuals at the last four downstream stations. As compared with the richness, EPT abundance declined abruptly from upstream to downstream of Selai River. Among the EPT, Ephemeroptera was comparatively and randomly abundant

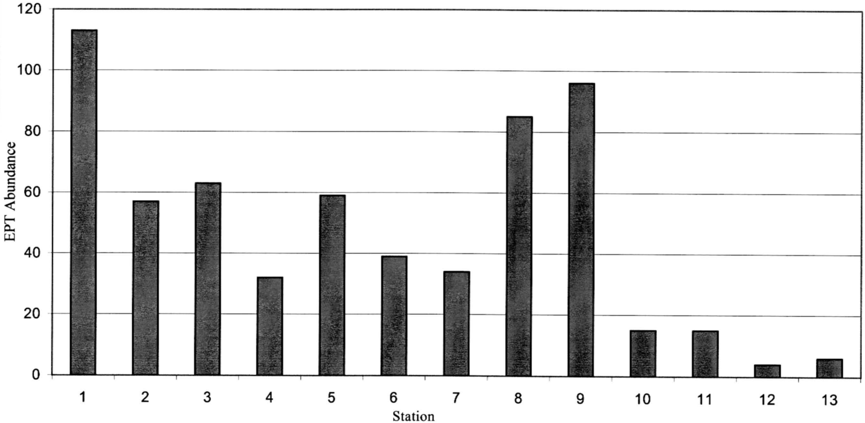


Figure 5. EPT Abundance at Stations along Selai River, Endau-Rompin

across sites and there are at least 2 to 35 specimens found at each site. Plecoptera was less abundantly or not at all found, fluctuating between 0 to 23 specimens, at the lower segments of the Selai River. This is probably because of the habitat-selective nature of Plecoptera or in another word, it is a steno-ecious species, preferring clean and cool running water. Trichoptera was the dominant species, (modified after definition by Lenat, 1993) and the abundance of caddisflies ranged between 2 to 68 individuals per m^2. Though it was a crude estimation, EPT abundance in this study could be used to provide an ordinal abundance values; rare = 1 – 5 specimens, common = 6 – 10 specimens, and abundant taxon = 11 – 30 specimens at least at a sampling site.

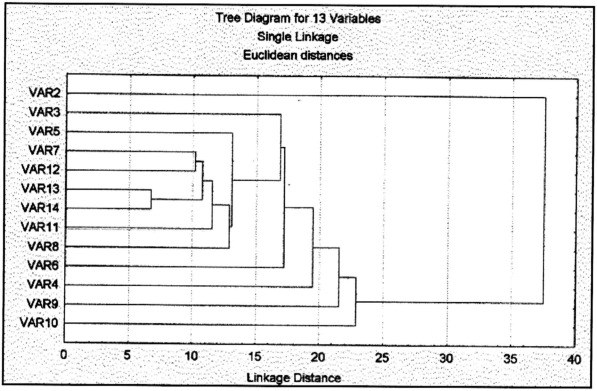
4.3.1.3 Distributional Patterns

The detailed distributional trends of the benthos collected along Selai River are discernible from Tables 4 and 5. The One-Way ANOVA results applied on the transformed data log $(x + 1)$ on abundance provided the subtle difference in distribution among stations. The distributions of Plecoptera ($F = 6.043$, $p = 0.00145$) were different among Stations 1 – 3, 8 and 10 - 13, based on the Newman-Keuls test and also that of Megaloptera ($F = 3.458$, $p = 0.01744$) differed among Stations 2 and 9 (Appendix E). With confirmation needed, *Baetis*, *Heptagenia*, *Chimarra* and *Dysphae* spp distributed widely in all stations. *Etrocorema*, *Neoperla* spp and other stoneflies distributed randomly in Stations 1 – 10 but they were not found at Stations 11 – 13. The distribution of stoneflies was associated with their habitat-related preference for clean and cool running water, and the absence of such steno-ecious species did not indicate that the potamonic lower sites in Selai River were polluted

(Yap, 2003). The aquatic moth and dobsonflies were site-specific and confined in running water with stony substrates. The remaining fauna distributed irregularly without showing any clear distribution pattern. Yap (2003) described the cased micro-caddisflies (*Orthotrichia* and *Oxyethira* spp) as exhibiting an aggregate distribution pattern at the fast-flowing zone, waterfalls and cascades, and seepage over cliff in Selai River.

The distribution pattern of EPT can be roughly visualised from Figures 4 and 5, which fluctuates from upstream (Station 1) to downstream (Station 13). The findings depict a longitudinal distribution pattern of the fauna indicating a declining trend. Other biota like Odonata, Diptera and Coleoptera seemingly demonstrate gradual longitudinal distribution and succession along the river continuum.

The dendrogram (Figure 6) constructed was based on 67 families of benthic macroinvertebrates shows 4 main clusters of stations: Stations 12 and 13 formed a group at a linkage distance of 7; Stations 4, 6, 7, 10 and 11 formed another cluster at a linkage distance of 10 to 13; Stations 2, 3, 5, 8 and 9 formed the third cluster at a linkage distance of 17 to 23; whereas Station 1 as by itself formed the fourth group. The first cluster group represented a lentic or slow-flowing segment, whereas cluster 2 and 3 were a mixed of ripples and pools. The last cluster group was the fast-flowing headwater. However, these similarity measures did not bring out partitions since the stations and tributaries were located along the longitudinal gradient of Selai River. Legendre & Legendre (1998) noted that cluster analyses are not adapted to ecological data and they do not always bring out partitions but they do bring out gradients. In other word, cluster groupings did not conform to river classification but they were instead related to physical river descriptions e.g. water flow.



Legend

Var.2	=	Station 1	Var.9	=	Station 8
Var.3	=	Station 2	Var.10	=	Station 9
Var.4	=	Station 3	Var.11	=	Station 10
Var.5	=	Station 4	Var.12	=	Station 11
Var.6	=	Station 5	Var.13	=	Station 12
Var.7	=	Station 6	Var.14	=	Station 13
Var.8	=	Station 7			

Figure 6. Dendrogram Constructed based on the Family of Macroinvertebrates Showing Clusters of Similar Stations along Selai River and its Tributaries

Estimation of similarity based on 129 genera also produced the same number of cluster groups (Appendix F) and did not deviate significantly from the result based on family.

4.3.2 Biotic Indices and Scores

4.3.2.1 Tolerance Values: Family- and Genus Biotic Indices (FBI & GBI)

The tolerance values (Appendix I) were adopted, assuming they reflected the tropical conditions experienced by Malaysian taxa. The scheme assigned "0" for sensitive species while "10" for pollution-tolerant species. Accordingly, families like Pteronarcyidae (Plecoptera), Glossosomatidae (Trichoptera), Corydalidae (Megaloptera) and Deuterophlebiidae (Diptera) scored "0" while Chlorolestidae, Lestidae, Libellulidae (Odonata) and Nepidae (Heteroptera) scored "9". The remaining families assumed the intermediate values. For the GBI, *Cinygmula* sp. (Heptageniidae), *Sweitsa* sp. (Chloroperlidae), *Agapetus* sp. (Glossosomatidae), *Helicopsyche* sp. (Helichopsychidae), *Protohermes* sp. (Corydalidae), *Deuterophlebia* sp. (Deuterophlebiidae) scored "0" while *Conchapelopia* sp. (Chironomidae) scored "10". Chutter (1972) designed a comparable scheme for biota of tropical South African streams and rivers.

A total of 54 families and 112 genera of indicating aquatic insects were based on for the calculation of Family Biotic Index (FBI) (Appendix G) and Genus Biotic Index (GBI) (Appendix H), respectively. GBI scores were either close to or slightly lower than those of FBI, suggesting that both scores provided more or less similar indication on the effects of environmental changes on the organisms. The FBI scores ranged from 3.2 to 6.2 while those of GBI ranged from 2.6 to 5.5 (Table 6). Figure 7

Table 6. The Biotic Indices and BMWP Scores Estimated for Stations along Selai River, Endau-Rompin

Biotic Indices / BMWP Score	Stations: 1	2	3	4	5	6	7	8	9	10	11	12	13
Family Biotic Index (FBI)	3.6	3.5	3.2	4.0	3.9	3.5	4.5	3.4	3.9	4.5	4.4	6.2	5.4
Genus Biotic Index (GBI)	3.6	3.0	3.0	3.7	3.3	3.0	5.0	2.6	3.9	4.4	2.9	5.5	5.5
Biological Monitoring Working Party (BMWP)	171	136	114	96	123	122	131	105	148	108	55	45	43
Average Score Per Taxon (ASPT)	7.4	7.2	7.1	6.9	6.8	7.6	6.9	7.5	7.4	6.4	6.9	5.6	5.4

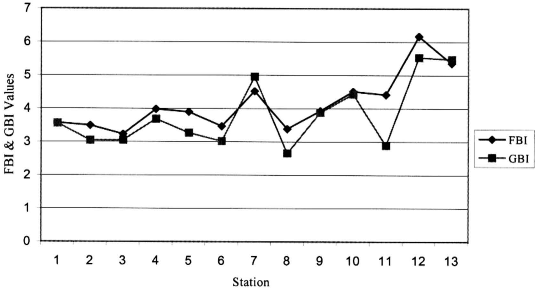


Figure 7. FBI & GBI Values of Aquatic Insects at Stations along the Longitudinal Gradient of Selai River, Endau-Rompin

shows the variations in FBI and GBI scores, generally demonstrating slight increment due to the higher population of tolerant organisms at downstream. Most of the stations were recorded with FBI and GBI values lower than 5.24, except Stations 12 and 13. Station 12 had FBI and GBI values of 6.2 and 5.5 while Station No. 13 had FBI and GBI values of 5.4 and 5.5, respectively.

4.3.2.2 Biological Monitoring Working Party (BMWP) Scores and Schemes

In a reverse manner to the FBI and GBI's scores, the BMWP scheme assigned tolerance score of "10" for pollution-sensitive species and "0" for pollution-tolerant species. As an example, Siphlonuridae, Heptageniidae, Leptophlebiidae, Ephemerellidae, Potamanthidae and Ephemeridae (Ephemeroptera); Taeniopterygidae, Leuctridae, Capniidae, Perlodidae, Perlidae, Chloroperlidae (Plecoptera); Leptoceridae, Goeridae, Lepidostomatidae, Brachycentridae, Sericostomatidae (Trichoptera) were assigned with the highest tolerance score of "10" while Oligochaeta (segmented worms) was given a score of "1" (Appendix K). As for Biological Monitoring Working Party (BMWP), this method was based on the absence and presence of families and not the total number of specimens in a particular family or genus as for the FBI or GBI and would be counted once only for a particular family. A total of 41 families of the known indicating species were based on for calculation as tabulated in Table 6 (raw data in Appendix J). The BMWP values ranged from 43 to 171 while the Average Score Per Taxon (ASPT) values ranged from 5.4 to 7.6. Most of the stations recorded scores higher than 100 where Station 1 had the highest score of 171. Stations 11 - 13 as well as Station 4 had BMWP values, which were lower than 100 with a score of 55, 45, 43 and 96, respectively. However, all stations had scored above 4 for the ASPT values. The highest ASPT value was recorded in Station 6 with 7.6 and the lowest was in Station 13. In summary, the biological measures showed a declining pattern from Station 1 to Station 13 (Figures 8a & 8b), due to the increased population size of pollution-tolerant organisms with low tolerance scores. Both schemes agreed with the variations of physical-chemical factors of the study area, especially the levels of dissolved oxygen, pH, PO_4, NO_3, Si_4 concentrations, conductivity and temperature.

4.3.2.3 Comparisons of FBI and GBI with BMWP Schemes

The two biotic indices yielded an opposite trend across the sampling stations. This was because the BMWP and FBI / GBI used the reverse scales in assigning tolerance values of the known indicating species (Appendices I and K). This discernible pattern served as a good criterion for assigning the water quality classification of this river.

From the comparisons of corresponding values at each sampling station (Table 6), the FBI and GBI estimates were more constant than those of BMWP. The latter discriminated clearly the contrast between the upstream stations (Stations 1 – 10) and the downstream stations (Stations 11 – 13). However, the ASPT values were almost constant and did not have predictive value, besides indicating the contribution of each family towards the total BMWP estimations. In order to reduce the subjectivity in the determination on the tolerance of biota to an array of environmental factors, the use of a combination of both or more schemes should be encouraged.

Moreover, since the estimates of both schemes were based on familial and genus levels of macroinvertebrates, the results and conclusions derived should be regarded

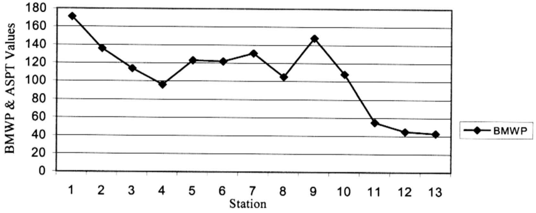


Figure 8a. BMWP Scores of Aquatic Insects At Stations along the Longitudinal Gradient of Selai River, Endau-Rompin

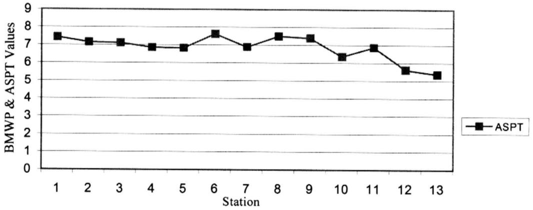


Figure 8b. ASPT Scores of Aquatic Insects At Stations along the Longitudinal Gradient of Selai River, Endau-Rompin

as conservative and preliminary, until the organisms were identified up to species level of taxonomic identification (Furse *et al.*, 1984). This recommendation on the use of FBI estimate in water quality classification had also been made by Che Salmah *et al.* (2001).

4.3.2.4 Water Quality in Comparison with Water Quality Criteria and Standards for Protection of Nature Reserve

With the exception of dissolved oxygen, physical-chemical parameters such as water temperature, conductivity and pH demonstrated a more constant fluctuation patterns and most parameters were at the acceptable levels as compared with the criteria and standards for the protection of natural reserves (Table 7). They suggested an excellent water quality for all stations except Stations 10 and 12 while there were no records on Stations 3, 7 and 11. Dissolved oxygen levels varied considerably, however, it was a direct measure of the oxygen concentration in the flowing water at this lotic and erosional environment, and it was thus selected for comparison with other biological measures in the classification of water quality at the pristine area.

4.3.3 Criteria for Assigning Water Quality Classification

As explored above, the headwaters and tributaries of Selai River were comparatively rich in clean-water EPT taxa, which gradually declined in richness, abundance and diversity as the river meandars downstream. Similarly, the FBI and GBI showed an increasing trend while the BMWP scores showed a decreasing trend.

The five-category ratings in Tables 2 and 3 (Sub-section 4.2.5) were defined in parallel with the five categories of water quality, which were in agreement with the

Table 7. Physical-Chemical Parameters for Assigning Water Quality at Stations Along Selai River, Endau-Rompin

Parameter	Station No. (Present Study & Yap, 2003)													Min & Max	Range Values	Interim Water Quality Std.
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Water temperature (°C)	27.2	25.8	-	25.8	25.8	25.3	-	25.3	26.8	28.5	-	27.2	27.3	25.3-28.5	24.0-26.2	Normal ±2
Conductivity (mSiemen/m)	4.0	5.0	-	2.0	2.0	2.0	-	3.0	5.0	5.0	-	6.0	4.0	2.0-6.0	23.4-49.6	1000
pH	6.86	7.73	-	8.28	8.30	8.27	-	7.93	7.12	6.90	-	6.98	7.78	6.86-8.30	5.02-7.62	6-9
Dissolved oxygen (mg/L)	7.0	8.0	-	7.8	7.8	8.0	-	7.0	8.0	5.2	-	5.0	8.0	5.2-8.0	2.43-8.29	5-7
PO_4 (mg/L)	0.03	0.08	-	0.01	0.06	0.01	-	0.01	0.09	0.06	-	0.09	0.04	0.01-0.09	0.0-0.05	0.2
NO_3 (mg/L)	0.2	0.3	-	0.2	0.5	0.2	-	0.4	0.4	0.4	-	0.6	0.5	0.2-0.6	0.8-4.5	7
Si_4 (mg/L)	0.326	0.804	-	0.183	0.056	0.560	-	0.573	0.889	0.806	-	0.794	0.680	0.056-0.889	0.0-0.17	50
Turbidity (NTU)	← Non-detectable →													-	-	50

Source for Range Values: Mohd Jamil *et al.*, 2002.

Source for Interim National Water Quality Standards for Malaysia: DOE-UM, 1986.

more comprehensive physical-chemical data (Yap, 1997; DOE-UM, 1986). This scheme was also adopted in this present study in an attempt to compare the water conditions of the habitats of the indicating species and the general water quality of Selai River. Table 8 lists the possible water quality classes based on six different measures that consisted of the percentage of EPT taxa richness, EPT abundance, FBI, GBI, BMWP scores, dissolved oxygen (DO), pH, PO_4, NO_3, Si_4 concentrations, conductivity and temperature at each station. The class categories along the 13 stations varied from Class I to Class V. Due to the small sample size of this short-term study, the results were quite conservative but generally, they gave an acceptable overall rating for the thirteen stations, ranging from Class I to Class III. Stations 1 – 10 were ranged from Class I to II while Stations 11 – 13 were classified as Class III if justified by dissolved oxygen. However, if more parameters were based on, about 50 % of the sampling stations had their classification results upgraded.

From the comparison, the FBI and GBI results gave rise to less stringent classes as compared the remaining measures. However, the EPT taxa richness and abundance results were more stringent as they indicated lower classes of water quality especially towards the potamonic lower stations. By comparison, the BMWP scheme appeared to give a more reliable water quality ratings to avoid an under estimation of quality or worst-case scenario.

On a preliminary basis, the Selai River could be classified between Classes I and III with good-fair to excellent water quality. The headwaters were found to be excellent while the potamonic lower sites were fairly- to slightly polluted in water quality. Similar conclusions were reported in earlier studies in Endau regions (Lim, 1987; Yap, 2003).

Table 8. Proposed Classification of Water Quality at Stations along Selai River, Endau-Rompin

Criterion	**Station No.**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
EPT Taxa Richness (%)	II	II	II	III	II	I	III	II	II	III	III	IV	III
EPT Abundance	I	III	III	IV	III	IV	IV	II	II	V	V	V	V
FBI	I	I	I	I	I	I	I	I	I	I	I	III	I
GBI	I	I	I	I	I	I	I	I	I	I	I	II	II
BMWP	I	II	II	III	II	II	II	II	II	II	III	IV	IV
Dissolved oxygen (mg/L)	I	I	-	I	I	I	-	I	I	IIB	-	IIB	I
Overall Rating (Median Value)	**I**	**I**	**II**	**II**	**I**	**I**	**II**	**II**	**II**	**II**	**III**	**III**	**III**
pH	I	I	-	I	I	I	-	I	I	I	-	I	I
PO_4 (mg/L)	I	I	-	I	I	I	-	I	I	I	-	I	I
NO_3 (mg/L)	I	I	-	I	I	I	-	I	I	I	-	I	I
Si_4 (mg/L)	I	I	-	I	I	I	-	I	I	I	-	I	I
Water temperature (°C)	I	I	-	I	I	I	-	I	I	I	-	I	I
Conductivity (mSiemen/m)	I	I	-	I	I	I	-	I	I	I	-	I	I
Overall Rating (Median Value)	**I**	**I**	**II**	**I**	**I**	**I**	**II**	**I**	**I**	**I**	**III**	**II**	**I**