

2

**USING BENTHIC MACROINVERTEBRATE COMMUNITY  
FOR WATER QUALITY CLASSIFICATION WITH NOTES  
ON THE CADDISFLY LARVAE (TRICHOPTERA) IN A  
RIVER, ENDAU-ROMPIN FOREST RESERVE, MALAYSIA**

By

CHAN VOON SENG

BEING A DISSERTATION PRESENTED IN PARTIAL  
FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF

MASTER OF TECHNOLOGY  
(ENVIRONMENTAL MANAGEMENT)

INSTITUTE OF POSTGRADUATE STUDIES  
UNIVERSITY OF MALAYA  
KUALA LUMPUR  
2004



## ABSTRACT

The study aims to characterise the community of benthic macro-invertebrates and to use the structure metric as a biotic index criterion for assigning water quality classification in a pristine stream of the Endau-Rompin Forest Reserve, Johore, Malaysia. To this end, an inventory of benthic fauna was established; the composition, taxa richness and abundance of the macro-invertebrate populations, particularly the dominant insect groups Ephemeroptera-Plecoptera-Trichoptera (EPT) were studied. The distributional patterns within groups were also analysed and tested statistically for any significant difference. The benthic macro-invertebrate populations of Selai River were sampled in three occasions during dry periods using visual-hand picking and kick-net collection methods at thirteen stations. The organisms were sorted and identified to family and generic levels using standardised identification keys. Physical-chemical parameters and hydrological regime of the organisms' habitats were qualitatively recorded to understand the micro-habitats of the invertebrates. The biological measures including EPT taxa richness and abundance, Hilsenhoff's Family Biotic Index (FBI) and Lenat's Genus Biotic Index (GBI), the Biological Monitoring Working Party (BMWP) scoring systems and some physical-chemical variables were compared and integrated to define the water quality ratings of Selai River.

Selai River, a headwater of Endau River, had a rich and considerably diverse macro-invertebrate population, comprising 129 genera in sixty-seven families in thirteen orders. The community was dominated by the clean-water insect-groups EPT (11.76-32.58 %) and Odonata (11.76 % of the dominants). The One-way ANOVA

results on the abundance data of all benthos indicated subtle difference in the distribution of Plecoptera ( $F=6.043$ ,  $p<0.05$ ) and Megaloptera ( $F=3.458$ ,  $p<0.05$ ). The cluster analysis based on single linkage clustering model yielded a dendrogram showing four clusters of the thirteen stations: they are groups of lentic, mixed ripples and pools, ripples, and lotic habitats. The FBI values (ranging from 3.2 to 6.2) and those of GBI (ranging from 2.6 to 5.5) fluctuated closely to each other and provide similar indication on the gradient and/or environmental changes along the river. The BMWP values ranged from 43 to 171 scores, depicting the same trend in water quality changes as the FBI and GBI schemes. In comparison with DO, pH,  $PO_4$ ,  $NO_3$ ,  $Si_4$  concentrations, conductivity and temperature, these biotic indices were compared and ranked to provide a “median” class for each station. The class categories along the thirteen stations of Selai River varied from Class I (excellent) to Class III (slightly polluted water quality). The classification results, although regarded as conservative, described an acceptable status that is within the National Water Quality Standards for the protection of nature reserve.

Among the indicating insect assemblage, Trichoptera (caddisflies) predominated in richness and abundance and this dominance prompted interest and study on some biological aspects of some hydropsychids, a philopotamid and a stenopsychid which were abundantly collected during this short-term study.

## ABSTRAK

Kajian ini bertujuan untuk meninjau komuniti invertebrata-makro “benthic” dan menggunakan struktur metrik sebagai kriteria indeks biotik untuk pengelasan kualiti air sebuah sungai yang tidak tercemar di Hutan Simpanan Endau-Rompin, Johor, Malaysia. Pada akhir kajian, satu senarai fauna “benthic” telah dihasilkan dan komposisi, kekayaan taxa serta lebih populasi-populasi invertebrata-makro, khususnya, kumpulan serangga dominan iaitu Ephemeroptera-Plecoptera-Trichoptera (EPT) juga dikaji. Corak-corak penyebaran dalam kumpulan juga dianalisis dan diuji secara statistik untuk sebarang perubahan yang penting. Sampel populasi invertebrata-makro “benthic” di Sungai Selai diambil sebanyak tiga kali ketika tempoh kering dengan menggunakan kaedah lihat dan kutip serta persampelan tendang di tiga belas buah stesyen sampel. Kesemua organisma-organisma tersebut diasingkan dan dikenalpasti sehingga ke tahap famili dan genus dengan menggunakan kekunci piawai pengenalpastian. Parameter kimia-fizikal dan juga rejim hidrologikal habitat-habitat organisma dicatat secara kualitatif untuk memahami habitat-mikro invertebrata-invertebrata tersebut. Pengukuran biologi termasuk kekayaan dan lebih taxa EPT, Indeks Biotik Famili Hilsenhoff (FBI) dan Indeks Biotik Genus Lenat (GBI), sistem pengukuran “Biological Monitoring Working Party” (BMWP) serta sebahagian variasi kimia-fizikal dibanding dan disatukan untuk mentakrifkan kadar kualiti air di Sungai Selai.

Sungai Selai, sebahagian hulu Sungai Endau, kaya dengan pelbagai populasi invertebrata-makro, mengandungi 129 “genera” dalam 67 famili yang terdiri daripada 13 “order”. Komuniti tersebut didominasi oleh kumpulan serangga air-

bersih EPT (11.76-32.58 %) and Odonata (11.76 % daripada yang dominan). Keputusan sehala ANOVA ke atas data lebih kesemua bentuk menunjukkan perbezaan yang tidak ketara dalam penyebaran Plecoptera ( $F=6.043$ ,  $p<0.05$ ) dan Megaloptera ( $F=3.458$ ,  $p<0.05$ ). Analisis berkelompok berdasarkan model “single linkage clustering” menghasilkan satu dendrogram di mana stesyen-stesyen ini dikelompokkan kepada 4 kelompok: iaitu kumpulan berhabitat air tenang, antara tenang dan berpusar, berpusar, serta air deras. Nilai-nilai FBI (dalam lingkungan 3.2 hingga 6.2) dan GBI (dalam lingkungan 2.6 hingga 5.5), mempunyai perubahan julat yang ketara namun menghasilkan petunjuk yang sama ke atas perubahan kecerunan dan/atau alam sekitar di sepanjang sungai. Nilai-nilai BMWP dalam lingkungan 43 hingga 71 mata, memaparkan haluan yang sama dalam perubahan kualiti air sebagaimana dengan skim FBI dan GBI. Berbanding dengan kepekatan oksigen terlarut (DO), pH,  $PO_4$ ,  $NO_3$ ,  $Si_4$ , konduktiviti dan suhu, indeks biotik ini dibanding dan ditentukan kedudukannya untuk menyediakan kelas pertengahan untuk setiap stesyen. Kategori kelas kesemua 13 stesyen di sepanjang Sungai Selai berbeza daripada Kelas I (sangat baik) hingga Kelas III (kualiti air yang sedikit tercemar). Keputusan klasifikasi, walau dianggap konservatif, menghuraikan satu status yang berada di dalam lingkungan Piawai Kualiti Air Kebangsaan untuk perlindungan simpanan alam semulajadi.

Di kalangan perkumpulan serangga petunjuk, Trichoptera (caddisflies) adalah dominan dalam kekayaan dan lebihan, dan dominasi ini menarik minat dan kajian ke atas sebahagian aspek biologi sebilangan “hydropsychids”, “philopotamid” dan “stenopsychid” yang dikumpul dengan banyak sepanjang kajian jangka-pendek ini.

## ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere appreciation to my Supervisor, Assoc. Professor Dr. Yap Siaw Yang, for her continuous encouragement, patience and guidance throughout the course of this study, for which it would not have completed without her generous assistance. It has been a great experience working under her supervision as she constantly shared her invaluable experience and knowledge in many fields.

My sincere thanks to Professor Dr. Haji Mohamed Abdul Majid (Dean of Science Faculty) and Professor Dr. Lim Ah Lan for their advice and words of encouragement.

I would also like to thank Mr. Ponniah, Mr. Naggapan, Ms. Khairin Yahya and Ms. Chan Yoke Mui for their contributions during the field trips. A special thank to En. Mohamad Adli Mansor of Endau-Rompin Base Camp and Perbadanan Taman Negara Johor for their assistance and permission to use the base camp's facilities throughout the field sampling works.

Many thanks and grateful acknowledgements to IPS, University of Malaya, for the research grant, Vote F: F0155/2003B, given to me to ease the financial burden incurred throughout this project and also to the academic and administrative staff for rendering their services for the completion of this study.

# CONTENTS

	<b>Page</b>
TITLE .....	i
ABSTRACT .....	ii
ACKNOWLEDGEMENTS .....	vi
CONTENTS .....	vii
LIST OF TABLES .....	xii
LIST OF FIGURES .....	xiii
LIST OF PLATES .....	xiv
LIST OF EQUATIONS .....	xv
<b>CHAPTER 1: INTRODUCTION .....</b>	<b>1</b>
1.1 WATER QUALITY MANAGEMENT .....	2
1.1.1 Water Quality Monitoring Programme .....	3
1.1.2 Quality Assurance .....	4
1.2 APPROACH OF BIOLOGICAL ASSESSMENT AND MONITORING....	5
1.2.1 Concept of Biological Assessment and Monitoring .....	5
1.2.2 Use of Biological Assessment and Monitoring Programme .....	7
1.2.3 Biological Monitoring Techniques .....	9
1.2.4 Macroinvertebrate-Based Monitors and Assessment .....	10
1.3 OBJECTIVES OF THE STUDY .....	11
<b>CHAPTER 2: LITERATURE REVIEW .....</b>	<b>13</b>
2.1 RIVER CONTINUUM CONCEPT .....	13

2.2	ECOLOGY OF AQUATIC INSECT .....	14
2.2.1	Habitat Affiliation, Habit and Distributional Pattern .....	14
2.2.2	Aquatic Insect Orders – Ephemeroptera, Plecoptera and Trichoptera (EPT) Group vs Odonata as Water Quality Indicator Taxon .....	15
2.3	WATER QUALITY CLASSIFICATION USING EPT METRIC AND MACROINVERTEBRATE-BASED BIOTIC INDICES .....	16
2.4	WATER QUALITY .....	17
2.4.1	Natural Factors Influencing Water Quality of Pristine River .....	17
	(a) <i>Climate</i> .....	18
	(b) <i>Watershed characteristics</i> .....	19
	(c) <i>Microbiological growth</i> .....	19
2.4.2	Human-Induced Factors Influencing Water Quality of Pristine River .....	20
2.5	ENDAU-ROMPIN FOREST RESERVE .....	21
2.6	ECOLOGY OF TRICHOPTERA (CADDISFLIES) .....	24
2.6.1	The Life Cycle and History of Trichoptera .....	24
	(a) <i>The Egg Stage</i> .....	25
	(b) <i>The Larva</i> .....	26
	(c) <i>The Pupa</i> .....	27
2.6.2	General Description of External Morphology .....	28
2.6.3	Movement, Feeding and Respiration .....	28
	(a) <i>Movement</i> .....	28
	(b) <i>Feeding</i> .....	29
	(c) <i>Respiration</i> .....	29
2.6.4	The Economic Importance of Trichoptera .....	30
2.6.5	Potential Use of Trichoptera as Water Pollution Indicator .....	32
2.6.6	Habitat Affiliation, Distribution and Seasonal Abundance of Trichoptera .....	33
	<b>CHAPTER 3: STUDY AREA AND SAMPLING STATIONS .....</b>	<b>35</b>
3.1	STUDY AREA .....	35



3.2	SAMPLING FREQUENCY .....	35
3.3	DESCRIPTION OF SAMPLING STATIONS .....	37
<b>CHAPTER 4: THE COMMUNITY OF BENTHIC MACRO- INVERTEBRATES IN SELAI RIVER AND THE USE OF ITS STRUCTURE METRIC AS A CRITERION FOR WATER QUALITY CLASSIFICATION .....</b>		<b>48</b>
4.1	INTRODUCTION .....	48
4.2	METHODOLOGY .....	48
4.2.1	Field Study .....	48
	4.2.1.1 <i>Sampling of Fauna</i> .....	49
	4.2.1.2 <i>Measurement of Water Quality Parameters</i> .....	50
4.2.2	Sorting and Laboratory Analysis .....	51
4.2.3	Data Processing .....	52
4.2.4	Biotic Indices .....	53
	4.2.4.1 <i>Tolerance Values of Family- and Genus Biotic     Indices (FBI &amp; GBI)</i> .....	53
	4.2.4.2 <i>Biological Monitoring Working Party (BMWP) Scores</i> .....	54
4.2.5	Criteria for Assigning Water Quality Classification .....	56
4.3	RESULTS AND DISCUSSIONS .....	59
4.3.1	Benthic Macroinvertebrate Population .....	59
	4.3.1.1 <i>Species Composition</i> .....	59
	4.3.1.2 <i>Community Structure: Taxa Richness and Abundance</i> .....	67
	4.3.1.3 <i>Distributional Patterns</i> .....	72
4.3.2	Biotic Indices and Scores .....	75
	4.3.2.1 <i>Tolerance Values: Family- and Genus Biotic Indices     (FBI &amp; GBI)</i> .....	75

4.3.2.2 <i>Biological Monitoring Working Party (BMWP) Scores and Schemes</i> .....	77
4.3.2.3 <i>Comparisons of FGI and GBI with BMWP Schemes</i> .....	78
4.3.2.4 <i>Water Quality in Comparison with Water Quality Criteria and Standards for Protection of Nature Reserve</i> .....	80
4.3.3 <i>Criteria for Assigning Water Quality Classification</i> .....	80
<b>CHAPTER 5: SOME BIOLOGICAL ASPECTS OF CADDISFLIES</b> .....	<b>84</b>
5.1 INTRODUCTION .....	84
5.2 METHODOLOGY .....	84
5.3 RESULTS AND DISCUSSIONS .....	85
<b>CHAPTER 6: CONCLUSION AND RECOMMENDATIONS</b> .....	<b>96</b>
<b>REFERENCES</b> .....	<b>100</b>
<b>APPENDICES</b>	
Appendix A: Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin – Trip 2, 11/10/2002 to 14/10/2002 ....	105
Appendix B: Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin – Trip 3, 02/05/2003 to 04/05/2003 ....	109
Appendix C: Standard Deviation of Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin .....	113
Appendix D: Composition of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin .....	117
Appendix E: Newman-Keuls Test .....	118
Appendix F: Dendrogram Constructed based on the Genera of Macroinvertebrates Showing Clusters of Similar Stations along Selai River and its Tributaries .....	120

Appendix G: Populations of Benthic Macroinvertebrates at Stations along Selai River used for Estimation of Family Biotic Index (FBI) .....	121
Appendix H: Populations of Benthic Macroinvertebrates at Stations along Selai River used for Estimation of Genus Biotic Index (GBI) .....	123
Appendix I: Tolerance Values (Ranging from 0 to 10) for FBI and GBI based on Aquatic Insects of Selai River at the Endau-Rompin National Park .....	126
Appendix J: Absence and Presence of Populations of Benthic Macroinvertebrates at Stations along Selai River used for Estimation of BMWP .....	129
Appendix K: The Biological Scores Allocated to Groups of Organisms by the Biological Monitoring Working Party (BMWP) Score .....	131
Appendix L: Typical Field Record Sheet for Biological Sampling and Ecological Surveys .....	132

## LIST OF TABLES

	<b>Page</b>
Table 1: Description of Sampling Stations .....	40
Table 2: Community Structure and Biotic Index Criteria for Assigning Water Quality Ratings Appropriate for Endau River Hilly Areas .....	57
Table 3: BMWP Categories for Assigning Water Quality Classification Ratings of Malaysian Rivers .....	58
Table 4: Mean Populations of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin .....	61
Table 5: Taxa Richness of Benthic Macroinvertebrates at Stations along Selai River, Endau-Rompin .....	68
Table 6: The Biotic Indices and BMWP Scores Estimated for Stations along Selai River, Endau-Rompin .....	76
Table 7: Physical-Chemical Parameters for Assigning Water Quality at Stations along Selai River, Endau-Rompin .....	81
Table 8: Proposed Classification of Water Quality at Stations along Selai River, Endau-Rompin .....	83

## LIST OF FIGURES

	<b>Page</b>
Figure 1: Peninsular Malaysia: Location of Endau-Rompin National Park .....	23
Figure 2: Endau-Rompin: Location of Sampling Stations .....	33
Figure 3: Taxa Composition of Benthic Macroinvertebrates along Selai River, Endau-Rompin .....	65
Figure 4: EPT/Total Taxa Richness (%) at Stations along Selai River, Endau-Rompin .....	69
Figure 5: EPT Abundance at Stations along Selai River, Endau-Rompin .....	71
Figure 6: Dendrogram Constructed based on the Family of Macroinvertebrates Showing Clusters of Similar Stations along Selai River and its Tributaries .....	74
Figure 7: FBI & GBI Values of Aquatic Insects at Stations along the Longitudinal Gradient of Selai River, Endau-Rompin .....	76
Figure 8a: BMWP Scores of Aquatic Insects at Stations along the Longitudinal Gradient of Selai River, Endau-Rompin .....	79
Figure 8b: ASPT Scores of Aquatic Insects at Stations along the Longitudinal Gradient of Selai River, Endau-Rompin .....	79
Figure 9: Hydropsychidae: <i>Hydropsyche</i> sp. ....	89
Figure 10: Hydropsychidae: <i>Ceratopsyche</i> sp. ....	90
Figure 11: Hydropsychidae: <i>Cheumatopsyche</i> sp. ....	91
Figure 12: Hydropsychidae: <i>Potamyia</i> sp. ....	92
Figure 13a: Philopotamidae: <i>Chimarra</i> sp. ....	93
Figure 13b: Philopotamidae: <i>Chimarra</i> & <i>Wormaldia</i> spp. ....	94
Figure 14: Stenopsychidae: <i>Stenopsyche</i> sp. ....	95

## LIST OF PLATES

	<b>Page</b>
Plate 1: Takah Pandan Waterfall (S1) .....	41
Plate 2: Anak Selor River (S2) .....	41
Plate 3: Kuala Selor (S3) .....	42
Plate 4: Downstream of Air Batu Dinding Waterfall (S4) .....	42
Plate 5: Lubuk Tapah (S5) .....	43
Plate 6: Next to Base Camp (S6) .....	43
Plate 7: Opposite of Base Camp (S7) .....	44
Plate 8: Downstream of Base Camp (S8) .....	44
Plate 9: Ketiau Padi River (S9).....	45
Plate 10: Tengkeboh River (S10) .....	45
Plate 11: Upstream of Kelembai River (S11) .....	46
Plate 12: Downstream of Kelembai River (S12) .....	46
Plate 13: Nearby Aboriginal Settlement (S13).....	47

## LIST OF EQUATIONS

	<b>Page</b>
Equation 1: The formula for the FBI and GBI: .....	54
FBI and GBI            = $\sum x_i \cdot t_i / n$	
Equation 2: The formula for the BMWP scheme: .....	55
BMWP Values            = $\sum t_i$	
Equation 3: The formula for the ASPT score: .....	55
ASTP                      = $\sum t_i / n$	