# A STUDY OF THE RELATIONSHIP BETWEEN PHYSIO-CHEMICAL PARAMETERS AND BENTHIC MACROINVERTEBRATES IN THE PHACHI RIVER

**NAPHAPORAN VITSAVAKUL**

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT**
**OF THE REQUIREMENTS FOR**
**THE DEGREE OF MASTER OF SCIENCE**
**(TECHNOLOGY OF ENVIRONMENTAL MANAGEMENT)**
**FACULTY OF GRADUATE STUDIES**
**MAHIDOL UNIVERSITY**
**2005**

**ISBN 974-04-6014-3**
**COPYRIGHT OF MAHIDOL UNIVERSITY**

Copyright by Mahidol University

Thesis
Entitled

# A STUDY OF RELATIONSHIP BETWEEN PHYSICO-CHEMICAL PARAMETERS AND BENTHIC MACROINVERTEBRATES IN THE PHACHI RIVER

Miss Naphaporn Vitsavakul
Candidate

Asst. Prof. Raywadee Roachanakanan, Ph.D. (Ecology, Evolution and Systematics)
Major-Advisor

Asst. Prof. Saranya Sucharitakul, M.S. (Applied Statistics)
Co-Advisor

Assoc. Prof. Rassmidara Hoonsawat, Ph.D.
Dean
Faculty of Graduate Studies

Asst. Prof. Raywadee Roachanakanan, Ph.D. (Ecology, Evolution and Systematics)
Chair
Master of Science Programme in Technology of Environmental Management
Faculty of Environment and Resource Studies

Copyright by Mahidol University

Thesis
Entitled

# A STUDY OF RELATIONSHIP BETWEEN PHYSICO-CHEMICAL PARAMETERS AND BENTHIC MACROINVERTEBRATES IN THE PHACHI RIVER

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science
(Technology of Environmental Management)
on
5 April, 2005

Miss Naphaporn Vitsavakul
Candidate

Asst. Prof. Raywadee Roachanakanan, Ph.D.(Ecology, Evolution and Systematics)
Chair

Asst. Prof. Saranya Sucharitakul, M.S.(Applied Statistics)
Member

Mr. Pradit Boontantrapiwat, M.Sc.(Appropriate Technology for Resources Development)
Member

Assoc. Prof. Rassmidara Hoonsawat, Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

Assoc. Prof. Anuchat Poungsomlee, Ph.D.(Human Ecology)
Dean
Faculty of Environment and Resource Studies
Mahidol University

Copyright by Mahidol University

# ACKNOWLEDGEMENT

The success of this thesis can be attributed to the extensive support and assistance from my major advisor, Asst. Prof. Raywadee Roachanakanan, my co-advisors, Asst. Prof. Saranya Sucharitakul and my external advisor, Mr. Pradit Boontantrapiwat for their time correcting my thesis and valuable suggestions. I would like to express my deeply appreciation and sincere gratitude to them for their valuable advice and guidance in this research.

I wish to thank Khun Oradee, the Head of Laboratory for her kindness in giving me a data. And I also wish to thank all officers of the Laboratory for their helpfulness. I am grateful to all the lecturers and staff of the Faculty of Environment and Resource Studies for their support and kindness.

My special thanks are contributed to ET 27 friends especially Leng, Ning, Molly, King, Wan and Aueam for their encouragement and help.

Most of all, I deeply appreciated my beloved family for their love and support. I really could not achieve the graduation without them. The usefulness of this thesis, I dedicate to my father, my mother, my sister and all the teachers who had taught me since my childhood.

Finally, this research work is supported by the grant from the Post-Graduate Education, Training and Research Program in Environmental Science, Technology and Management under Higher Education Development Project of the Commission on Higher Education, Ministry of Education.

Naphaporn Vitsavakul

Copyright by Mahidol University

A STUDY OF THE RELATIONSHIP BETWEEN PHYSICO-CHEMICAL PARAMETERS AND BENTHIC MACROINVERTEBRATES IN THE PHACHI RIVER

NAPHAPORN VITSAVAKUL 4337278 ENTM/M
M. Sc. (TECHNOLOGY OF ENVIRONMENTAL MANAGEMENT)

THESIS ADVISORS: RAYWADEE ROACHANAKANAN, Ph. D. (ECOLOGY, EVOLUTION AND SYSTEMATICS), SARANYA SUCHAITAKUL, M. S. (APPLIED STATISTICS)

## ABSTRACT

The Biotic index based on benthic macroinvertebrates for water quality assessment is used in many countries in Europe, North America and Australia. Studies on taxonomy, community structure, and distribution of benthic macroinvertebrates have been carried out in some parts of Thailand. However, application of the biotic index for rivers in Thailand needs more sampling campaigns to cover all habitats and regions. Furthermore, it is necessary to explore appropriate sampling procedures for physico-chemical parameters and benthic macroinvertebrate samples. Finally, the biotic index based on Belgian Biotic Index (BBI) and Trent Biotic Index (TBI) should be applied to the Phachi River. The objectives of this study are 1) to describe benthic macroinvertebrate communities of samples from the Phachi River; 2) to compare the physico-chemical parameters of river water collected from mid depth and mid width and near the bottom where benthic macroinvertebrate samples are collected; 3) to apply BBI and TBI for water quality assessment of the Phachi River.

The first sampling campaign on the Phachi River was carried out in the rainy season of September 2002 and the hot season of May 2003. Five physico-chemical parameters (i.e. Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), pH, conductivity, water temperature), and current velocity were analyzed and recorded and benthic macroinvertebrate samples were collected along a cross-section of headwaters of the river. Paired-samples t-test was used for comparison of physico-chemical parameters at different sampling sites. Benthic macroinvertebrate samples were sorted out, identified and interpreted by BBI and TBI methods.

75 water samples and 18 benthic macroinvertebrate samples were collected during the first campaign, and 40 water samples and 28 benthic macroinvertebrate samples during the second campaign. The total number of 82 taxa of 12 orders, 44 families, 48 genera and 24 unidentified taxa were found during the rainy season of the first campaign. In the hot season of the second campaign, there were 65 taxa including 14 orders, 38 families, 4 subfamilies, 29 genera and 7 unidentified taxa. For both sampling campaigns, most of benthic macroinvertebrates belonged to Insecta and Mollusca. Among the Insecta, Trichoptera and Ephemeroptera were the best represented taxa. From the first sampling campaign, water quality, classified as Class 2 according to the surface water quality standards of Thailand, was as follows: DO 6.80-8.80 mg/l, BOD 0.15-2.13 mg/l, pH 7.42-8.95, conductivity 140-170 µmhos/cm, water temperature 24.5-26.0ºC. It was found that BOD and water temperature collected from mid depth and mid width were significantly different at the level of 0.05 from those near the bottom of the river (Ho rejected). Water quality of the second sampling campaign was also classified as Class 2 with DO 6.75-8.80 mg/l, BOD 0.68-1.53 mg/l, pH 8.27-8.36, conductivity 265-275 µmhos/cm, water temperature 27.0-28.0ºC. However, BOD and conductivity collected from mid depth and mid width are not significantly different at the level of 0.05 from those near the bottom of the river. BBI and TBI values for both sampling campaigns were from 4-9 and 2-9, respectively. The value of 10 represents very good water quality. Wide range of both indices is owing to the sensitivity to the microhabitats along the cross section. From the study, a new data set of benthic macroinvertebrates of the Phachi River is described. Unidentified taxa suggested further study on taxonomy. Water samplings for physico-chemical parameters do not represent the ones for benthic macroinvertebrates. Therefore, in addition to the conventional method of water sampling at mid width and mid depth, the sampling near the bottom should be carried out when benthic macroinvertebrate samples are collected. BBI and TBI can be used for water quality assessment in Thailand but further studies are needed.

KEY WORDS: BENTHIC MACROINVERTEBRATES/ BIOTIC INDEX/ PHACHI RIVER/ STREAM CROSS-SECTION/ WATER QUALITY ASSESSMENT

65 P. ISBN 974-04-6014-3

Copyright by Mahidol University

การศึกษาความสัมพันธ์ระหว่างเคมี-กายภาพของน้ำกับสัตว์ไม่มีกระดูกสันหลังหน้าดินในแม่น้ำภาชี
(A STUDY OF THE RELATIONSHIP BETWEEN PHYSICO-CHEMICAL PARAMETERS AND BENTHIC MACROINVERTEBRATES IN THE PHACHI RIVER)

นภาพร วิศวกุล 4337278 ENTM/M

วท.ม. (เทคโนโลยีการบริหารสิ่งแวดล้อม)

คณะกรรมการควบคุมวิทยานิพนธ์: เรวดี โรจนกนันท์, Ph.D. (Ecology, Evolution and Systematics), ศรัณยา สุจริตกุล, M.S. (Applied Statistics)

บทคัดย่อ

การใช้สัตว์ไม่มีกระดูกสันหลังหน้าดิน(สัตว์หน้าดิน) เป็นดัชนีชีวภาพในการประเมินคุณภาพน้ำใช้แพร่หลายในหลายประเทศทั้งในยุโรป อเมริกาเหนือ และ ออสเตรเลีย ในประเทศไทยได้มีการศึกษาทางด้านอนุกรมวิธาน โครงสร้างและการกระจายตัวของสัตว์หน้าดินในบางพื้นที่ อย่างไรก็ตามการใช้ดัชนีชีวภาพสำหรับแม่น้ำในประเทศไทยยังต้องมีการศึกษาให้ครอบคลุมอีกหลายพื้นที่ รวมทั้งวิธีในการเก็บตัวอย่างและการนำ Belgiam Biotic Index (BBI) และ Trent Biotic Index (TBI) มาประยุกต์ใช้ ซึ่งในการศึกษานี้ได้นำมาประยุกต์ใช้ในแม่น้ำภาชีและมีวัตถุประสงค์ในการศึกษาคือ 1) ศึกษาลักษณะของสังคมสัตว์หน้าดินในแม่น้ำภาชี 2) เปรียบเทียบคุณภาพน้ำที่เก็บในบริเวณจุดกึ่งกลางความลึกและความกว้างกับบริเวณท้องน้ำ 3) นำ BBIและTBIมาประยุกต์ใช้ในการประเมินคุณภาพ น้ของแม่น้ำภาชี

เก็บตัวอย่างครั้งที่ 1 ในช่วงฤดูฝนเดือนกันยายน 2545 และครั้งที่ 2 ในช่วงฤดูร้อนเดือนพฤษภาคม 2546 ทำการศึกษาทางด้านเคมี-กายภาพ จำนวน 5 พารามิเตอร์ ได้แก่ DO BOD pH conductivity water temperature current flow และ macroinvertebrates การศึกษาในครั้งที่ 1 ในฤดูฝน เดือนกันยายน 2545 เก็บตัวอย่างน้ำจำนวน 75 ตัวอย่าง ตัวอย่างสัตว์หน้าดินจำนวน 18 ตัวอย่าง และ ครั้งที่ 2 ในฤดูร้อน เดือนพฤษภาคม 2546 เก็บตัวอย่างน้ำจำนวน 40 ตัวอย่าง และตัวอย่างสัตว์หน้าดินจำนวน 28 ตัวอย่าง วิเคราะห์ข้อมูลโดยใช้ Independent t-test และ Pair t-test สำหรับข้อมูลด้านเคมี-กายภาพของน้ำ และใช้ Belgium Biotic Index (BBI) และ Trent Biotic Index (TBI) สำหรับข้อมูลสัตว์หน้าดินซึ่งผ่านการจำแนกแล้ว

ผลการศึกษาจากการวิเคราะห์คุณภาพน้ำและการแปรผลสัตว์หน้าดินโดยใช้ BBI และ TBI พบว่า คุณภาพน้ำในภาคตัดขวาง ณ แนวดิ่งที่มีความเร็วของกระแสน้ำใกล้เคียงกัน ค่า DO BOD conductivity และ water temperature ไม่แตกต่างกันอย่างมีนัยสำคัญที่ระดับความเชื่อมั่น 95% นอกจากค่า pH ที่แตกต่างกันอย่างมีนัยสำคัญทางสถิติที่ $p < 0.05$ และเมื่อเปรียบเทียบค่าคุณภาพน้ำในบริเวณต่างแนวดิ่งที่มีความเร็วกระแสน้ำแตกต่างกัน พบว่า มีค่าแตกต่างกันอย่างมีนัยสำคัญ และเมื่อนำค่า DO BOD pH และ water temperature จากการศึกษามาประเมินตามมาตรฐานคุณภาพน้ำแหล่งน้ำของประเทศไทย และการประเมินผลสัตว์หน้าดินโดยใช้ BBI และ TBI พบว่า คุณภาพน้ำจากการแปรผลทั้ง 2 วิธีเป็นไปในทางเดียวกันโดยแปรผันตามลักษณะความเร็วของกระแสน้ำ คือในบริเวณที่กระแสน้ำไหลเอื่อยมีค่าคุณภาพน้ำต่ำกว่าบริเวณที่กระแสน้ำไหลแรงปานกลาง และในบริเวณที่กระแสน้ำไหลแรงมากมีค่าคุณภาพน้ำดีที่สุด ข้อเสนอแนะที่ได้จากการศึกษาในครั้งนี้คือ ในการเก็บตัวอย่างทั้งตัวอย่างน้ำและตัวอย่างสัตว์หน้าดินควรศึกษาลักษณะและวัดความเร็วของกระแสน้ำก่อน รวมทั้งควรเก็บตัวอย่างให้ครอบคลุมตามลักษณะของกระแสน้ำในหน้าตัดขวางของลำน้ำ และควรมีการศึกษาในลักษณะเดียวกันนี้ในแหล่งน้ำที่มีการปนเปื้อนของมลพิษ รวมถึงการศึกษาเพิ่มเติมถึงชนิดของสัตว์หน้าดินที่พบในประเทศไทยซึ่งแตกต่างจาก BBI และ TBI เพื่อนำมาประยุกต์และปรับปรุงให้เหมาะสมกับสิ่งมีชีวิตของประเทศไทย

65 หน้า ISBN 974-04-6014-3

Copyright by Mahidol University

# CONTENTS


| | | Page |
|---|---|---|
| **ACKNOWLEDGEMENT** | | iii |
| **ABSTRACT- ENGLISH** | | iv |
| **ABSTRACT- THAI** | | v |
| **LIST OF TABLES** | | viii |
| **LIST OF FIGURES** | | x |
| **CHAPTER** | | |
| **I** | **INTRODUCTION** | |
| | 1.1 Statement of the problems | 1 |
| | 1.2 Objectives | 3 |
| | 1.3 Hypothesis | 3 |
| | 1.4 Scope of the study | 3 |
| | 1.5 Expected of result | 3 |
| **II** | **LITERATURE REVIEW** | |
| | 2.1 Sampling methods | 5 |
| | 2.2 The relationship between physico-chemical parameters and macroinvertebrates | 8 |
| | 2.3 Biotic index | 12 |
| | 2.4 Respiration mechanisms of aquatic macroinvertebrates in relation to water quality assessment | 19 |
| **III** | **METERIAL AND METHODS** | |
| | 3.1 Study site | 20 |
| | 3.2 Methodology | 21 |
| | 3.3 Identification books | 23 |
| | 3.4 Statistics analysis | 24 |
| | 3.5 Biotic indices | 24 |


Copyright by Mahidol University

# CONTENTS (Continued)


| | | Page |
|---|---|---|
| **IV** | **RESULTS AND DISCUSSIONS** | |
| | 4.1 Description of study area and the sampling campaigns | 29 |
| | 4.2 Physico-chemical parameters of the Phachi River water quality and bottom sediments | 31 |
| | 4.3 Benthic macroinvertebrates | 36 |
| | 4.4 Calculation of the Biotic Index | 44 |
| **V** | **CONCLUSIONS AND RECOMMENDATIONS** | |
| | 5.1 Conclusions | 47 |
| | 5.2 Recommendations | 48 |
| **BIBLIOGRAPHY** | | 49 |
| **APPENDIX** | | 55 |
| **BIOGRAPHY** | | 65 |


Copyright by Mahidol University

# LIST OF TABLES


| Table | Page |
|---|---|
| 2.1 The table suggests that current measurement change by width of stream. | 7 |
| 2.2 Comparing different ranges of Saprobic Water Quality Classes (SWQC) with some Biotic Index methods applied to Nepalese streams (modified from Moog and Graf, 1994 unpublished). | 17 |
| 2.3 Transformation scales used in converting the BMWP and BMWP/ASPT. | 18 |
| 3.1 Standard table to determinate the biotic index. (The standard table of Tuffery and Verneaux, 1968) | 25 |
| 3.2 The interpretation of the biotic indices. | 26 |
| 3.3 The Trent Biotic Index: Part 1 Classification of biological samples. | 27 |
| 4.1 Sampling line and number of sampling sites on the 1st campaign | 30 |
| 4.2 Sampling line and number of sampling sites on the 2nd campaign | 31 |
| 4.3 Physico-chemical parameters of 18 sampling stations of the Phachi River in Rachaburi Province on 1st campaign (7 – 8 September 2002) 32 | 32 |
| 4.4 Paired samples t-test for physico-chemical parameters of the 1st campaign | 33 |
| 4.5 Physico-chemical parameters of ten sampling stations of the Phachi River in Rachaburi Province on the 2nd campaign (25 May 2003) | 34 |
| 4.6 Paired samples t-test for physico-chemical parameters of the 2nd campaign | 35 |
| 4.7 Characteristics of bottom sediments of the Phachi River in Rachaburi Province during the 2nd campaign (25 May 2003) | 35 |
| 4.8 Taxa list and distribution of macroinvertebrates among 18 sampling sites of the Phachi River in Rachaburi Province during the 1st sampling campaign (6 – 8 September 2002) | 37 |
| 4.9 Taxa list and distribution of macroinvertebrates among seven sampling sites of the Phachi River in Rachaburi Province during the 2nd sampling campaign (24 – 25 May 2003) | 42 |


Copyright by Mahidol University

# LIST OF TABLES (Continued)


| Table | Page |
|---|---|
| 4.10 Calculation results of Belgian Biotic Index and Trent Biotic Index for the 1st sampling campaign | 45 |
| 4.11 Calculation results of Belgian Biotic Index and Trent Biotic Index for the 2nd sampling campaign | 46 |


Copyright by Mahidol University

# LIST OF FIGURES

**Figure** **Page**

3.1 The Study Site on The Phachi river 20

Copyright by Mahidol University

# CHAPTER I
# INTRODUCTION

## 1.1 State of the Problems

Water quality studies are required for establishing baseline condition, setting quality criteria and standard, monitoring temporal changes, and determining the impacts of specific projects and developments. Water quality represents a term associated with the composite analysis of physical, chemical, and biological parameters (Hauer and Lamberti, 1996). Chemical variables of water quality as such are indeed instantaneous in time. Therefore they provide only a "momentary" picture of the degree of pollution (De Pauw, 1988). However, streams, rivers, wetlands, and lakes are home for many small animals called macroinvertebrates. These animals generally include insects, crustaceans, molluses, arachnids and annelids. These animals live in the water for all or part of their lives so their survival is related to the water quality. Macroinvertebrates are sensitive to different chemical and physical conditions. If there is a change in the water quality, perhaps because of a pollutant entering the water, or a change in the flow downstream of a dam, then the macroinvertebrate community will also change. Therefore, the richness of macroinvertebrate community composition in a stream can be used to provide an estimate of stream health (Ribbons of Blue, 2001). The biological assessments with macroinvertebrates, translated as biotic indices, have the advantage to integrate the water quality over a period of time. In fact they can be considered as multispecies field bioassays for water quality assessment (De Pauw, 1988). Chemical and biological monitoring are complementary and therefore are necessary in water quality assessment (De Pauw, 1988). At present the application of biotic index for water quality assessment is widespreadly used in Europe, USA and Australia

Copyright by Mahidol University

In Thailand, physical and chemical factors of river water quality have been studied for more than 30 years and they are set as the national surface water quality standard. On the other hand biological factors especially macroinvertebrates have been studied and applied to use for water quality assessment in Thailand by Vongprasert R. (1990), Boonsom J. (1975), Sangpradub N., Inmuong Y. et al. (1996), Sangpradub N., Inmuong Y. et al. (1997), Green World Foundation (1999), Inmuong Y. et al. (1996), Phaphong (1996), and Sangpradub N. (n.d.). Once the government authority was trying to develop and apply macroinvertebrates to the national surface water quality standard but with lack of specialists in various taxonomic groups and sampling campaigns covering different habitats and regions in Thai watercourses, the project was cancelled. However, more researchers in Thailand are interested in working on macroinvertebrates especially on taxonomy. Sampling campaigns in some small rivers and application of macroinvertebrates to the existing national surface water quality standard are still in need. Also Belgian Biotic Index (BBI) and Trent Biotic Index (TBI) are used.

In this study the Phachi River in Rachaburi province of the west of Thailand was a study site. This will be the first sampling campaign in the river. According to Notification of the National Environment Board No 8 (1994) the standard water sampling method in lotic habitat for chemical and physical parameters is carried out at mid width and mid depth. While taking water sampling for macroinvertebrates is carried out near the bottom of the river where these organisms live (American Public Health Association, 1995 and American Public Health Association, 1998). It is necessary to find out the possible locations of water samples for both physico-chemical parameters and macroinvertebrates and to make a suggestion based on the data obtained from this study. Owing to increasing popularity of biotic index all around the world therefore there will be a possibility to include macroinvertebrates into the national surface water quality standard. In the study two biotic indices i.e. Belgian Biotic Index (BBI) and Trent Biotic Index (TBI) are applied to the Phachi River.

Copyright by Mahidol University

## 1.2 Objectives

1.2.1 To describe benthic macroinvertebrate communities of samples from the Phachi River.

1.2.2 To compare the physico-chemical factors of river water between mid depth and mid width and near the bottom where macroinvertebrate samples are collected.

1.2.3 To apply Belgian Biotic Index (BBI) and Trent Biotic Index (TBI) to macroinvertebrate samples collected from the Phachi River.

## 1.3 Hypothesis

This Thesis study the relationship of water quality in cross-section varies to the location of the same section. The parameters are studying DO, BOD, conductivity, pH and water temperature. The hypotheses are that

"The water samples at mid depth and mid width and water samples at the bottom are non-difference of quality."

## 1.4 Scope of the study

1.4.1 Both physico-chemical parameters of water samples and macroinvertebrate samples are collected along a cross-section at headwaters in the Phachi River.

1.4.2 Five physico-chemical parameters i.e. DO, BOD, pH, conductivity and water temperature along a cross-section of the Phachi River are collected.

1.4.3 This study is conducted in rainy and dry seasons.

## 1.5 Expected of result

1 To obtain information on the macroinvertebrate community in headwaters of the Phachi River

2 To make a suggestion on the suitable water sampling locations for physico-chemical parameters and macroinvertebrates in Thailand

Copyright by Mahidol University

3 To develop a biotic index for Thai water quality based on Belgian Biotic Index (BBI) and Trent Biotic Index (TBI).



Copyright by Mahidol University

# CHAPTER II
# LITERATURE REVIEW

## 2.1 Sampling Methods

### 2.1.1 Macroinvertebrates

Vongprasert (1990) used sampling equipment by handnet in Bang Pakong River, and the sampling effort covered the river stretch of 10 – 20 m with a limited period of 5 minutes. Some researches in Thailand sampled for six replicates (sampling units) are sampled at each sampling sites following the replicate numbers calculation method recommended by Elliot (Sangpradub, Inmuong, Hanjavanit and Inmuong, 1996, Sangpradub et al., 1997a, Sangpradub et al., 1997b). Inmuong and Sangpradub (1996) a uniform stretch of river waters at each sampling site with approximately 100 m length is marked and those six replicates are sampled randomly at this stretch. Sampling benthic fauna is conducted bimonthly. Sampling equipment for recovering benthic fauna at upstream sites uses the US Standard Surber Sampler with 0.30*0.30 m opening and 500 μm mesh size. The US Standard Ekman Grab with 0.15*0.15 m opening is used to sample benthic animals in deeper water at downstream sites. The boat is also used in sampling animals of that deeper water.

De Pauw (1983), De Pauw (1988), De Pauw and Vanhooren (1983), Zampraa-Munoz, Sainz-Cartero, Sancher-Ortega and Alba-Tercedor (1995) and Ribbons of Blue (2001) used a kick sample technique by handnet in shallow. And surber samples is the most common and popular method in sample benthic macroinvertebrates by Kerans and Karr (1994), Krueger and Waters (1983), Death and Winterbourn (1995). De Pauw and Vanhooren (1983) used to sample macroinvertebrates by handnet for river stretch of 10 to 20 m in a limited period of

Copyright by Mahidol University

time, from 3 minutes for watercourse less than 2 m wide up to 5 minutes for larger rivers.

Representative sampling is sampling in such a manner that the data collected accurately and precisely portrays the actual or true environmental conditions. When at a site, it is essential to conduct a site assessment. This will produce a visual health evaluation of the site and reveal the habitats present. If the habitat composition at a site is 50% channel, 30% riffle, and 20% emergent vegetation, then the sampling effort should involve sampling in the channel 50% of the time, at the riffle 30% of the time and around the emergent vegetation 20% of the time. This method takes into consideration both sampling effort, site habitat variation and allows for the collection of the maximum diversity of macroinvertebrates (Ladle, n.d.).

In designing a sampling program it may be apparent to sample each of the habitats individually to ascertain habitat variability of macroinvertebrate communities. In this situation the participants will sample individually at each habitat for the prescribed sampling time of 5 minutes. From the site survey information already attained, a comparison can be made using the habitat composition and the macroinvertebrates identified in each sample (Ribbons of Blue, 2001).

### 2.1.2 Physico-chemical parameters

Physico-chemical parameters are collected as integrated water samples by using the Van Don Bottle at mid-depth water column where the faunal sampling unit located. River flow-rate is also measured at mid-depth range of the river channel (Sangpradub et al., 1996). Water physico-chemistry data are concurrently collected on the same date of benthic fauna sampling (Sangpradub et al., 1997 and APHA, 1992).

For the number of times measurements are made, as a rule two passes are made in a round trip over the same crossing line in measuring water dept and two current measurements are there by taken as well as each measurement point. When there is a flood, for example, and there are great changes in water level and current, these limits do not apply (Free University of Brussels, n.d.).

Copyright by Mahidol University

The current measuring lines, as a rule are to be selected at even intervals in the direction of the crossing line on a vertical plane including the crossing line. Generally, the standard proportion of water surface width to the spaces in the current measuring line is given in the following table. However, when the shape of the cross-section or the current range is complicated, the distance of the measuring lines can be reduced. When precision measurement is required, the distance of the measurement lines in the following table can be cut in half (Free University of Brussels, n.d.).

Table 2.1 The table suggests that current measurement change by width of stream.

| Water surface width (B) m | Distance of water depth measurement (M) m | Distance of current measurements (N) m |
|---|---|---|
| 10 Less than | Percentage of water surface width 10 – 15 % | N = M |
| 10 – 20 | 1 | 2 |
| 20 – 40 | 2 | 4 |
| 40 – 60 | 3 | 6 |
| 60 – 80 | 4 | 8 |
| 80 – 100 | 5 | 10 |
| 100 – 150 | 6 | 12 |
| 150 – 200 | 10 | 20 |
| 200 More than | 15 | 30 |

Current measurement takes place at selected points, which are 20 percent and 80 percent of the water depth in the vertical current measurement line. When water depth is shallow, rather than selecting on the basis of water surface, the measurement point can be set at 60 percent of water depth. When precision measurement is necessary as a rule point can be selected every 20 cm (Free University of Brussels, n.d.).

The water depth measurement line is established both over the current measurement line, which is within the boat direction surface and includes the crossing line and is in the center of the two current measurement lines. On both shorelines, one

Copyright by Mahidol University

of the water depth measurement lines is established at each of the respective outer sides of the current measurement line (Free University of Brussels, n.d.).

## 2.2 The relationship between physico-chemical parameters and macroinvertebrates

### 2.2.1 Dissolved Oxygen

The measurement of dissolved oxygen is one of the most frequently used and the most important of all chemical methods available for the investigation of the aquatic environment. Dissolved oxygen provides valuable information about the biological and biochemical reaction going on in waters; it is a measure of one of the important environmental factors affecting aquatic life and of the capacity of water to receive organic matter without causing nuisance.

Oxygen gas dissolves freely in freshwaters. Oxygen may be added to the water from the atmosphere or as a by-product of photosynthesis from aquatic plants and is utilized by many respiratory biochemical, as well as by inorganic chemical reactions. The concentration of dissolved oxygen in water depends also on temperature, pressure, and concentrations of various ions (Wetzel and Likens, 2000). Oxygen is vital for life and is often in short supply in freshwaters so it must diffuse in from the air. It can therefore have a huge effect on the distribution and abundance of freshwater taxa. The concentration of oxygen is very dependent on water temperature. The relationship is negative with higher concentrations of oxygen found at lower temperatures. Photosynthesis and respiration are the two major biological processes that alter the concentrations of oxygen in freshwater. The amount of oxygen used for respiration in some habitats can be staggering. Lotic taxa also tend to have higher metabolic rates than the lentic counterparts due to the increased oxygen availability. The influence of current on the ability of invertebrates to survive low oxygen concentrations has been convincingly demonstrated in a number of laboratory experiments. The stonefly *Hesperoperla pacifica* experienced 100% mortality in low oxygen water at a current velocity of 1.5 cm/s and no mortality in the same water when the current velocity was 7.6 cm/s.

Copyright by Mahidol University

### 2.2.2 Temperature

Temperature is one of the most important physical variables that affects the distribution, abundance, behavior and morphological adaptations of freshwater organisms Water temperature varies with respect to geographical location and habitat. The average temperature range in temperate rivers is between 0 to 25 $^{o}$C. In still water, especially small ponds this temperature range may be even greater The exact timing of growth, reproduction and senescence depends upon many and complicated factors including predation risk and resource availability. The difficulty of predicting life cycles is well illustrated by the freshwater Oligochaetes in the family Naididae. Their typical life cycle involves hatching in the spring, reproducing vegetatively throughout the summer and early autumn and reproducing sexually in late august. The sexual products are large diapause eggs that are senescent over the winter (Ladle, n.d.).

### 2.2.3 Flow

Life in a fluid is very different to life in a gas and imposes many physical and physiological constraints on an organism. This is most obvious in the stream ecosystem where the flow rate effects many aspects of the abiotic and biotic environment including the dispersion of toxic compounds in the environment. Biologists have long believed that water as a medium and current as a force strongly determine ecological distributions and shape anatomical and behavioral adaptations.

Aquatic invertebrates exhibit a number of anatomical features that apparently enhance their ability to move about, or minimize their likelihood of being swept away:

1. Attached
    - silk and other sticky secretions - blackfly, zebra mussels, etc.
    - hooks and suckers - Blepharocerid larvae have six ventral suckers that allow them to move over rocks in fast current
2. Non-attached
    - Body shapes that are dorso-ventrally flattened or streamlined - Baetid mayflies, bullheads.

Obviously, the flow conditions experienced by large or small organisms or an organism on the stream bed and one in the middle of the stream are quite different.

Copyright by Mahidol University

The exact flow regime is dependent on both the substrate and the water velocity and generally turbulence increases with increasing substrate size and increasing water velocity.

This is exceedingly difficult. Especially for organisms living on or near the surface of the substrate. At the interface of a solid and a fluid the velocity of the two is identical. This is known as the no-slip condition. This means that water in contact with a non-eroding surface has zero velocity. Because surface water can move quite rapidly (the fluid-gas interface) there is a gradient in velocity as one approaches the bottom and sides of streams. This decrease of velocity with depth produces a region of shear, known as the boundary layer. The upper limit of which is where the speed of the current is no longer influenced by the presence of the stream bottom. Very close to the bottom there may be a viscous sublayer where shear stress is zero and flow is greatly reduced. This should not be confused with the boundary layer and the terms are not interchangeable. The idea that there may be a thin layer of low flow near the bottom of streams has aroused the interest of ecologists at least since the turn of the century. This was based on the dorsally compressed shape of many stream invertebrates (Ladle, n.d.).

The segregation of two species of caddis larvae between fast and slow flowing rivers is a classic example of the specialization of organisms to flow conditions. *Hydropsyche instrabilis* preferred to flow of 15-100 cm/s while *Plectrocnemia conspersa* preferred to flow of 0-20 cm/s

These insects are both suspension feeders, capturing food particles from the water column using nets spun of silk. A comparison of net morphology reveals further adaptations: the hydropsychids's net was rigidly supported, streamlined and not damaged by fast currents The polycentropodid's net was flimsier and ruptured if the current was increased from 10 cm/s to 25 cm/s.

Copyright by Mahidol University

### 2.2.4 Substrate / Sediment

Substrate is the name given for the material that organisms live in, on or around. Substrate is a complex aspect of the freshwater environment. It may vary from the large stones and boulders found in mountain streams to the fine silts and clays found in slow flowing rivers, ponds and lakes to the macrophytes and algae common everywhere. In the lotic environment flow is the chief determinant of substrate together with mineral substrate composition. Organic detritus may be found in conjunction with mineral material and may strongly influence the organisms response to the substrate. There are also many types of purely organic substrate from minute fragments up to particles the size of tree trunks.

**Characteristic Fauna of Major substrate categories**

The great majority of aquatic invertebrates live in close association with the substrate. They can be broadly grouped in relation to their preferred substrate

**Rock Taxa (Lithophilous)**

Many species are equally common on stones of all sizes while a few are highly restricted in their size preferences: Larvae of the water penny (Psephenidae) occur mainly on the underside of rocks, often under boulders during torrential flow. Pyralid moth larvae hide under silken covers formed in depressions in rocks. Freshwater sponges (Spongillidae) are found attached to large rocks because they are slow growing and require high temporal stability of their substrate

**Sand Taxa (Psammophilous taxa)**

Sand is considered a poor substrate, especially for macroinvertebrates, due to its instability and because the tight packing of the sand grains both reduces the amount of organic detritus and oxygen. The meiofauna (invertebrates passing through the mesh of a 0.5mm) sieve can be very abundant e.g. rotifers, oligochaetes, early instar chironomids, nematodes and copepods. Macroinvertebrates are rare but present: the dragonfly larvae *Lestinogomphus africanus* found buried deep in sandy bottomed pools in India survives by possessing an elongated respiratory siphon that pokes out of

Copyright by Mahidol University

the sand into the relatively oxygen rich water. The Mayfly larvae *Dolania* has hairs that keep the grains of sand off its body

**Wood Taxa (Xylophilous taxa)**

Wood appears to be a substrate rather than food with only very specialized organisms feeding on it e.g. the beetle *Lara avara.* Woody substrate is especially important in the headwater streams of forested areas, where 25-50% of the streambed is wood and wood created habitat. It is also very important in lowland rivers where 70% of the substrate is sand and wood provides the only stable substrate

## 2.3 Biotic Index

Benthic macroinvertebrates are animals inhabiting the substratum of lakes, streams, estuaries, and marine waters. They may construct attached cases, tubes, or nets that they live on or in, or roam freely over rocks, organic debris, and other substrates during all or part of their life cycle.

Freshwater macroinvertebrates are ubiquitous; even the most polluted or environmentally extreme lotic environments usually contain some representatives of this diverse and ecologically important group of organisms. Macroinvertebrates are considered by definition to be visible to the unaided eye and retained on a U.S. Standard No. 30 sieve (0.595 mm openings) (APHA, 1992 and APHA, 1995).

However, the early life stages of many macroinvertebrates pass through mesh openings that are this size. Because these early stages are important in understanding species specific life histories, trophic relations, secondary production and a multitude of other ecological relationships, there has been a general trend among stream ecologists to use collecting methods employing finer-meshed collecting nets (e.g., 125 to 250 μm).

Examples of benthic macroinvertebrates are crayfish, snails and aquatic insects like mayflies, caddisflies and dragonflies. Benthic macroinvertebrates do not

Copyright by Mahidol University

have the mobility of fish so they cannot swim in and out of areas with polluted water. When they are eliminated from a section of a stream because of some pollutant, they will not return for at least one generation. Some organisms are very sensitive to pollutants and that others can tolerate very polluted conditions. For example, mayflies which are very sensitive to pollutants, do not show-up in benthic samples collected from polluted water. Aquatic worms and midges tolerate high levels of organic pollution and are very abundant in soft organic deposits found on stream bottoms located downstream of ineffective animal waste treatment facilities. The organisms collect will tell the history of that stream.

Macroinvertebrates are the preferred organisms for water quality studies for several reasons:

1. Differential susceptibility to pollutants
   - respond to wide range
   - respond quickly
   - capable of a graded response
2. Present in most lotic habitats
   - abundant
   - easy to catch
   - taxonomy well established (though difficult at species level)
3. Relatively sedentary
   - representative of local conditions
4. Relatively long life span
   - long enough for record of environmental quality
5. Heterogeneous
   - numerous phyla and trophic levels

Ladle (n.d.) defines the biotic index approach to bioassessment as one, which combines diversity on the basis of certain taxonomic groups with the pollution indication of individual species or higher taxa or groups into a single index or score. Numerous biotic indices have been developed as described below.

Copyright by Mahidol University

### 2.3.1 Trent Biotic Index (TBI)

The Trent Biotic Index was perhaps the first true biotic index of water quality. It was originally devised for the Trent River Authority area but has since been adapted for use in many other countries and forms the basis for all modern indices and scores. Organisms are collected from all available habitats through kicknet sampling. Identification is down to family, genus or species depending upon the organism, but they are not enumerated.

### 2.3.2 Chandler Biotic Score

This was worked out for upland rivers in Scotland. Chandler's score is theoretically an improvement on the TBI because it includes a measure of abundance and incorporates a more detailed list of macroinvertebrates. The score is determined by identifying the organisms present, determining the abundance classification each group, and then selecting the appropriate points for that group. The points for all groups are added together to give a site score. Points scored increase with increasing abundance for sensitive groups and decrease with increasing abundance for tolerant groups.

### 2.3.3 Biological Monitoring Working Party (BMWP) – Score

The Biological Monitoring Working Party was set up in 1976 to develop a standardized system for assessing the biological quality of Rivers in Great Britain. It was designed to provide an overall view of the conditions of rivers and canals and of the discharges to them and to show the effectiveness of pollution control policies ISO (1984). BMWP developed a standardized score that was a simplification of the Chandler Score. All organisms were identified to family level for uniformity. Families with similar pollution tolerances were grouped together. Abundance was eliminated because it was time consuming and had only a small effect on the score values.

### 2.3.4 The Average Score Per Taxon (ASPT)

Both the BMWP and Chandler's Score are often divided by the number of taxa thereby making it independent of the number of taxa counted.

Copyright by Mahidol University

**2.3.5 Belgiam Biotic Index (BBI)**

Since 1979, The Belgiam Biotic Index method is based on the analysis of aquatic macroinvertebrates sampled with a handnet, combines the advantages of the methods of Woodiwiss (1964) used in the U.K. and Tuffery and Verneaux (1968) in France. In 1983 – 1984, BBI, first described by De Pauw and Vanhooren (1983) was revised by the subcommission "Biological methods" of the commission "Water analyses" of the Belgiam Institute for Normalisation; it was adopted as a national standard (NBNT 92-402,1984), (Refer to De Pauw, 1988).

BBI method is derived from the French Indice Biotique (IB) which is in turn derived from the TBI. The IB differs from the TBI in that it:

- includes a greater number of indicator taxa
- splits the mayflies into the *Ecdynurids* and others
- divides the caddis into cased and uncased
- does not separate *Nais* from other Naidids
- does not separate *Baetis* from other Ephemeroptera
- does not consider taxonomic units represented by single individuals

The BBI then modified this so:

- sampling was by handnet only
- nematodes are excluded
- chironomids divided into 2 groups

- those in the thummi-plumosus group and those not

- identification generally at genus or family level

The determination of the Belgium Biotic Index occurs in three phases:

1. Sampling of macroinvertebrates in a ten to twenty meter stretch of the watercourse by means of a handnet (mesh size of minimum 300 and maximum 500 μ m); to obtain comparable results, the sampling effort has been set a three minutes for watercourses less than two meters wide and five minutes for larger rivers;

Copyright by Mahidol University

2. Sorting and identification of the sampled organisms up to the desired taxonomic level (presence, family, genus) designated as systematic units.

3. Calculation of the biotic index by means of the modified standard table of Tuffery and Verneaux (1968); this table has a double horizontal and vertical entrance, one for the faunistic groups (in decreasing order of sensitivity) and one for the number of systematic units expressing the diversity. The BBI splits faunistic groups into 7 groups related to their perceived pollution tolerance. The row chosen from the table is the one corresponding to the most sensitive faunistic group in the sample. The column chosen depends upon the number of systematic units present in the sample.

4. The biotic index may vary from 10 to 0. The higher the value, the more sensitive groups and systematical units are present in the water. The minimum biotic index of 0 (very gross pollution) is attained when all groups of macroinvertebrates, except the Eristalinae, are absent. If the biotic index equals 5 or less, this not only means that the water is polluted, but that a critical situation is reached (Refer to De Pauw, 1988).

The following methods have been modified and compared after transformations to water quality classes based on Table 2.2 BBI with single findings included (+1) and BMWP Score with the Abundance factor included (+Ab). Similarly, original BMWP Scores and BMWP/ASPT values obtained after calculation are compared by different transformations i.e., either based on Coring & Küchenhoff (1994) or Anglian Water Authority (1986). The conversion scales for harmonization of the methods used in changing the water quality classes to the equivalent saprobic water quality classes for the above mentioned methods applied to the Nepalese streams are as tabulated in Tables 2.2 and 2.3 (Subodh, n.d.).

Copyright by Mahidol University

Table 2.2 Comparing different ranges of Saprobic Water Quality Classes (SWQC) with some Biotic Index methods applied to Nepalese streams (modified from Moog and Graf, 1994 unpublished).

| SWQC | Woodiwiss (1964) TBI | Woodiwiss (1978) EBI | Verneaux and Tuffery (1968) IB |
|---|---|---|---|
| I | 10 | 15 , 14 | 10 |
| I - II | 9 | 13 , 12 | 9 |
| II | 8 , 7 | 11 , 10 | 8 , 7 |
| II - III | 6 , 5 | 9 , 8 , 7 | 6 , 5 |
| III | 4 , 3 | 6 , 5 | 4 , 3 |
| III - IV | 2 | 4 , 3 | 1 , 2 |
| IV | 1 | 2 , 1 | 0 |

### 2.3.5 Comparisons of different indices

TBI Vs Chandler's Index and ASPT

Murphy (1978) studied a range of polluted and unpolluted sites in Welsh rivers. He showed the Chandler ASPT to have the least temporal variability, thus allowing the best spatial discrimination. Both Chandler and TBI values were reduced at headwater sites while the Chandler ASPT values were high suggesting high water quality.

BMWP score Vs BMWP /ASPT

Armitage et al. (1983) studied different unpolluted sites that varied in their physical and chemical characteristics. Scores varied considerably. ASPT showed a steady decline from upland to lowland range of environmental features. Predictive equations based on multiple regression using physical and chemical parameters explained 65% of the variance in ASPT and only 22% of score.

Copyright by Mahidol University

BMWP Vs Chandler

Pinder et al. (1987) studied at chalk stream and found; BMWP score stabilized after fewer replicates than Chandler score. BMWP/ASPT was more sensitive to small changes in pollution status. BMWP/ASPT was best correlated with direct chemical measurements. Chandler/ASPT consistently failed to agree with other indices.

Pinder and Farr (1987) concluded that BMWP/ASPT was the best system although they recommended removing the Oligochaeta and Chironomidae from the system since these are large groups in which species vary dramatically in their pollution tolerance. Their inclusion, therefore, has the effect of decreasing ASPT without contributing to the score. After eliminating these groups they gained better site discrimination.

Table 2.3 Transformation scales used in converting the BMWP and BMWP/ASPT.

| Based on Anglian water authority, 1986 (after modification) | Based on Coring and Küchenhoff, 1994 (after modification) | | SWQC |
|---|---|---|---|
| BMWP | BMWP | BMWP/ASPT | |
| > 151 | > 151 | 8.00-10.00 | I |
| 101-150 | > 151 | 7.00-7.90 | I-II |
| 51-100 | 101-150 | 5.50-6.90 | II |
| 26-50 | 51-100 | 4.00-5.49 | II-III |
| 7-25 | 26-50 | 2.50-3.90 | III |
| 1-6 | 0-25 | 1.01-2.49 | III-IV |
| - | - | 1 | IV |

Copyright by Mahidol University

## 2.4 Respiration mechanisms of aquatic macroinvertebrates in relation to water quality assessment

Macroinvertebrates are proved to be the most valuable groups for biological surveillance of water quality because these are both more sensitive and objective. In defining these faunistic groups to assess water quality by biotic index, the ordering concept is mainly based on their respiration mechanisms in aquatic environment (refer to Vongprasert, 1990). For example, Plecoptera, one of the most sensitive indicators, completely depends on oxygen concentration in the water whereas the rat-tailed maggot can survive in the very low oxygen level because it has an extensive breathing tube to reach the water surface. Therefore, it is very important and useful to understand the respiration mechanism of their organisms. In very large rivers, where lotic as well as lentic habitats may be present, differences in transversal distribution of the benthic macroinvertebrates (Gaschignard et al., 1983, refer to De Pauw et al., 1986).

Copyright by Mahidol University

# CHAPTER III
# MATERIAL AND METHODS

## 3.1 Study site

The selected study site is the upstream part of Phachi River in Rachaburi province, located on N 1486048 E 0530629 in UTM System and the elevation 171 m above mean sea level. The Phachi River is a small and old stream running from Tanow Sri mountain range. It passes through Rachaburi province in a distance of about 80 km. The study site is covered with dense vegetations of tall grasses and big trees. The bottom of the stream is soft sediment.

A B

C D

Figure 3.1 The Study Site on The Phachi river

A : The Phachi river above Study Site, B : The Study Site,

C : Sampling water for physico-chemical and D : Measure of depth

Copyright by Mahidol University

## 3.2 Methodology

### 3.2.1 Physico-chemical sampling and measurements

This study measures the water quality in across section of stream for two seasons; which are rainy and dry seasons. The first time on rainy season (6 – 8 September 2002); measures width and depth of stream and sampling lines for physico-chemical parameters every 0.5m from water surface in the vertical line and every 1.25m from riverside. Total numbers of sample on 1st campaign are 75 samples for physico-chemical parameters of 18 vertical lines

The second on dry season (24 – 25 May 2003); proportion width of stream every 3m from riverside as 7 lines in the vertical. Physico-chemical parameters are sampled at the vertical lines numbers of 1, 3, 5 and 7 at the bottom while at the vertical lines numbers of 2, 4, 6, these parameters are sampled at mid depth and the bottom for 4 replicates. The current measures by two-point method; which are 20 percent and 80 percent of the water depth at the vertical line. The conductivity, pH, transparency, water-temperature, air-temperature, width, depth, and current velocity are measured in situ by portable instruments. DO and BOD are sampled by Kemmerer sampler and are analyzed by azide modification of Iodometric method (District of Health,1996 and APHA,1998). Total numbers of sample on 2nd campaign are 40 samples for physico-chemical parameters.

### 3.2.2 Macroinvertebrates sampling

Benthic macroinvertebrate samples are taken by Ekman Grab with 15 *15 cm opening. The 1st campaign is sampled all 18 location for 3 replicates and combine 1 sample. Total numbers of sample on 1st campaign are 18 samples for macroinvertebrates. The 2nd campaign is sampled all 7 location for 4 replicates as 28 samples. In situ, the samples are cleaned as much as possible by removing most of the mud, stones, leaves and debris. All the material collected is transferred to plastic bags and preserved in situ with ethanol alcohol 95%. Proper sieving of the sample and sorting of the organisms is done in a laboratory. First, the sample is rinsed and washed

Copyright by Mahidol University

with a water jet over a stack of sieves with different mesh sizes (No.10, 20, 30) (De Pauw, 1983). The coarse debris are removed and the organisms retained on each sieve are transferred to white plastic sorting trays (30 × 50 cm). The bottom of a sorting tray is divided into squares in order to facilitate the systematical examination of the material collected (De Pauw, 1983). The organisms are sorted out the samples by forceps. The animals are transferred into small bottle (7 to 10 ml) and grouped roughly according to major taxonomic groups. For conservation, concentration of 70 percent ethanol is used (Hauer and Lamberti, 1996).

**3.2.3 Sediment texture analysis (simple method)**

The sediment in bottom is habitat of the macroinvertebrates and so that effect for varies taxa of macroinvertebrates. Measurements of sediment concentration important information about stream system that has direct significance for aquatic biota (Hauer and Lamberti, 1996). This study analyses sediment in bottom by simple method adept form Khtesanee (1996). A simple method to estimate the percent sand silt and clay in sediment and determine it textures. Each;

1. Get a tall slender jar 1,000 ml and a plastic bigger 250 ml.
2. Fill the sediment sample in a bigger to 250 ml.
3. Fill a tall slender jar to 250 ml with sediment form a plastic bigger.
4. Add water to 1,000 ml and shake the sediment water mix till the sediment is all mixed up in the water.
5. Put the slender on a table and let the sediment settle out for 1-minute mark the level of sediment on the jar. This is sand portion (X) in the sediment.
6. Wait 10-minutes and mark the level of the sediment in the jar. The difference between the bottom mark which is the sand, and the second mark up is the silt portion (Y) of the sediment.
7. To transfer the water mixed above the second mark to imhoff cone and let for 24 hours mark the level of sediment on the imhoff cone. This is clay portion (Z) of sediment.
8. Calculate the percent sand, silt and clay by measuring the depth of sediment by equation ;

Copyright by Mahidol University

100% of sediment = X+Y+Z

X = portion of sand

Y = portion of silt

Z = portion of clay

## 3.3 Identification books

The following books are used in identification of the specimens.

1. Needham J.G. and Needam P.R. (1962). A guide to the study of fresh-water biology. San Fracisco. Holden-day.

2. Victor S. and Michael, Q. (1986). Blackwell habitat field guides invertebrate animals of freshwater. Hong Kong. Basil Blackwell.

3. Hellawell J. M. (1989). Biological indicators of freshwater pollution and environment management (Pollution monitoring series). NY. Elsevier science publishers.

4. Giller P.S. and Malmqvist B. (2001). The biology of streams and rivers. N.Y. Oxford University Press

5. Hauer F.R. and Lamberti. G.A. (1996). Methods in stream ecology. San Diego. Academic press.

6. Dennis M. Lehmkuhl (1979). How to know the aquatic insects. Wm. C. Brown Company Publishers.

7. Dudgeon D. (1999) Tropical Asian Streams Zoobenthos, Ecology and Conservation. Hohg Kong university Press.

8. Richard W. Merritt and Kenneth W. Cummins (1996). An Introduction to the Aquatic Insects of North America. (3rd ed.). Kendall/Hunt Publishing Company.

9. John C. Morse , Yang Lianfang and Tian lixin (1994). Aquatic Insects of China Useful for Monitoring Water Quality. Nanjing Agricultural University Printing House.

10. W. Patrick McCafferty and Arwin V. Provonsha (1981). Aquatic Entomology. The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives Halliday Lithograph.

Copyright by Mahidol University

11. Fitter R. and Manuel R.(1986). Collins Field Guide to Freshwater Life. William Collins Sons & Co Ltd.

## 3.4 Statistics analysis

SPSS program is used for analysis physico-chemical parameters in this study with Paired samples t-test between at mid width-mid depth and the bottom of the study. The 1st campaign, take data to average of the middle line No.9 and 10 for mid depth and mid width spot. The bottom value is the data near the bottom of 18 vertical line. The 2nd campaign, the data of mid depth and mid width is same spot and the bottom value is the data near the bottom of 7 vertical line.

## 3.5 Biotic indices

Two index systems i.e. BBI (De Pauw and Vanhooren, 1983) and TBI (Hellawell, 1989) are used to assess the biological water quality of cross-section in this study. The determination of the biotic is based on the standard table (Table 3.3) of Tuffery & Verneaux (1968) having a double horizontal and vertical entrance, one for the faunistic groups and one for the number of systematic units (refer to De Pauw and Vanhooren, 1983).

The standard table of Tuffery&Verneaux (1968) (Table 3.1), the horizontal partitioning corresponds to the observed faunistic groups, ranked from 1 to 7 with regard to decreasing environmental requirements or increasing tolerance to pollution (= column I). The most sensitive groups such as Plechoptera, cased Trichoptera and Ephemeroptera are found at the top of the table. The most tolerant species are found at the base of the table: Tubificidae, Chironomidae of the *Thummi-plumosus* group, Syrphidae (Eristalinae). Intermediate groups are Gammaridae, Asellidae, Sphaeridae and Odonata (De Pauw and Vanhooren, 1983).

Copyright by Mahidol University

For the first three faunistic groups (1 to 3) it is necessary to know if there are 1, 2 or more systematic units present in the sample (Column II). Depending on what is the case, the first or the second row is chosen (De Pauw and Vanhooren, 1983).

The vertical partitioning corresponds with classes of diversity, i.e. the number of systematic units found in the sample (De Pauw and Vanhooren, 1983).

Table 3.1 Standard table to determinate the biotic index. (The standard table of Tuffery&Verneaux, 1968)

| I<br>Faunitis groups present | II | III<br>Total numbers of systematic units | | | | |
|---|---|---|---|---|---|---|
| | | 0 - 1 | 2 - 5 | 6 - 10 | 11 - 15 | 16 and more |
| | | Biotic index | | | | |
| 1.Plechoptera or Ecdyonuridae (=Heptageniidae) | 1.several S.U.* | - | 7 | 8 | 9 | 10 |
| | 2.only 1 S.U. | 5 | 6 | 7 | 8 | 9 |
| 2.Cased Trichoptera | 1.several S.U. | - | 6 | 7 | 8 | 9 |
| | 2.only 1 S.U. | 5 | 5 | 6 | 7 | 8 |
| 3.Ancylidae or Ephemeroptera Except Ecdyonuridae | 1.more than 2 S.U | - | 5 | 6 | 7 | 8 |
| | 2.2 or < 2 S.U. | 3 | 4 | 5 | 6 | 7 |
| 4.Aphelocheirus or Odonata or Gammaridae or Mollusca (except Sphaeridae) | all S.U. mentioned 0 above are absent | 3 | 4 | 5 | 6 | 7 |
| 5.Asellus or Hirudinea or Sphaeridae or Hemiptera (except Aphelocheirus) | all S.U. mentioned 0 above are absent | 2 | 3 | 4 | 5 | - |
| 6.Tubificidae or Chironomidae of the *Thummi-plumosus group* | all S.U. mentioned 0 above are absent | 1 | 2 | 3 | - | - |
| 7.Eristalinae (=Syrphidae) | all S.U. mentioned 0 above are absent | 0 | 1 | 1 | - | - |

S.U. : number of systematic units observed of this faunistic group.

Copyright by Mahidol University

The interpretation of the biotic indices, the highest biotic index (10) is indicative of good water quality or absence of pollution. As the value of the index decreased, the water quality deteriorates (De Pauw and Vanhooren, 1983).

Table 3.2 The interpretation of the biotic indices.

| Class | Biotic index | Color | Significance |
|---|---|---|---|
| I | 10 - 9 | blue | lightly or unpolluted |
| II | 8 – 7 | green | slightly polluted |
| III | 6 – 5 | yellow | moderately polluted - critical situation |
| IV | 4 – 3 | orange | heavily polluted |
| V | 2 – 0 | red | very heavily polluted |

In order to synthesize the results, the 10 indices can be ranged in 5 quality classes, which may be visualized by different colors. Eventually the 0 value indicating a complete absence of bio-indicators may be visualized by a black color (De Pauw and Vanhooren, 1983).

Copyright by Mahidol University

Table 3.3 The Trent Biotic Index : Part 1 Classification of biological samples.

| Key indicator Groups | Diversity of fauna | Total number of groups (see Part 2) present | | | | |
|---|---|---|---|---|---|---|
| | | 0 - 1 | 2 - 5 | 6 - 10 | 11 - 15 | 16 + |
| | | Biotic index | | | | |
| Plecoptera nymphs present | - More than one species | - | VII | VIII | IX | X |
| | - One species only | - | VI | VII | VII | IX |
| Ephemeroptera nymphs present | - More than one species [a] | - | VI | VII | VIII | IX |
| | - One species only [a] | - | V | VI | VII | VIII |
| Trichoptera larvae present | - More than one species [b] | - | V | VI | VII | VIII |
| | - One species only [b] | IV | IV | V | VI | VII |
| *Gammarus* present | - All above species absent | III | IV | V | VI | VII |
| *Asellus* present | - All above species absent | II | III | IV | V | VI |
| Tubificid worms and or Red larvae present | - All above species absent | I | II | III | IV | - |
| All above types | Some organisms Such as *Eristalis tenax* not requiring dissolved oxygen may be present | 0 | I | II | - | - |

[a] *Baetis rhodani* exclued

[b] *Baetis rhodani* (Ephem.) is counted in this section for the purpose of classification.

The Trent Biotic Index: Part 2 Groups of defined.

The term “Group” here denotes the limit of identificationwhich can be reached without resorting to lengthy techniques. Groups are as follows:

1.Each species of Platyhelminthes (flatworms)

2.Annellida (worms) excluding *Nais*

3.*Nais* (worms)

4. Each species of Hirudinea (leeches)

5. Each species of Mollusca (snils)

6. Each species of Crustacea (log-louse, shrimps)

7. Each species of Plecoptera (stone-fly)

8.Each genus of Ephemeroptera (mayfly) excluding *Baetis rhodani*

9.*Baetis rhodani* (mayfly)

10.Each family of Trichoptera (caddis-fly)

Copyright by Mahidol University

11. Each species of Neuroptera larvae (alder-fly)

12.Family Chironomidae (midge larvae) except *Chironomus thummi*(=riparius)

13. *Chironomus thummi* (blood worms)

14.Family Simuliidae (black – fly larvae)

15. Each species of other fly larvae

16. Each species of Coleoptera (beetles and beetle larvae)

17. Each species of Hydracarine (water mites)

Copyright by Mahidol University

# CHAPTER IV
# RESULTS AND DISCUSSIONS

## 4.1 Description of study area and the sampling campaigns

### 4.1.1 Study area

The study area was situated in a protected area of dense forest in Ratchaburi Province. The sampling campaigns were carried out at the upland section of the Phachi River with both banks covered with pristine dense vegetations of tall grasses and big trees. A Buddhist monastery area was situated on the right of the riverbank. There were only few houses in the vicinity. Big rocks emerging from the water surface were found near the study area.

### 4.1.2 The 1st sampling campaign

On the 1st campaign at the end of the rainy season (6 – 8 September 2002) seven water quality parameters were studied. A cross section of study area was divided into 18 vertical lines and water quality was sampled every 0.50 m from the water surface to the bottom. Therefore the total number of seventy-five sampling sites were established. It rained and was windy during the campaign period.

### 4.1.3 The 2nd sampling campaign

On the 2nd campaign at the end of dry seasons (24 – 25 May 2003) seven water quality parameters were studied. For the 2nd campaign, the same cross section of study area was divided into seven vertical lines and ten sampling sites were established. The total numbers of samples on 2nd campaign were forty samples (four replicates per 1 sampling site). Also the river regime was categorized into three zones as low, moderate and high according to the rate of current velocity. Land use and cover was similar to the condition described for the 1st campaign. However according to the

Copyright by Mahidol University

different season from the 1st campaign, during the 2nd campaign it did not rain and the water flow sometimes appeared to be slow and stagnant.

Table 4.1 Sampling line and number of sampling sites on the 1st campaign

| Line | Width (m) | Depth (m) | Number of sampling sites for physico-chemical parameters | current velocity |
|---|---|---|---|---|
| 1 | 1.25 | 1.5 | 2 | - |
| 2 | 2.50 | 1.8 | 3 | 2 |
| 3 | 3.75 | 2.0 | 3 | - |
| 4 | 5.00 | 2.0 | 3 | 2 |
| 5 | 6.25 | 2.0 | 3 | - |
| 6 | 7.50 | 2.0 | 3 | 2 |
| 7 | 8.75 | 2.0 | 3 | - |
| 8 | 10.00 | 2.2 | 4 | 2 |
| 9 | 11.25 | 2.5 | 4 | - |
| 10 | 12.50 | 2.9 | 5 | 2 |
| 11 | 13.75 | 3.1 | 5 | - |
| 12 | 15.00 | 3.3 | 6 | 2 |
| 13 | 16.25 | 3.4 | 6 | - |
| 14 | 17.50 | 3.5 | 6 | 2 |
| 15 | 18.75 | 3.5 | 6 | - |
| 16 | 20.00 | 3.1 | 5 | 2 |
| 17 | 21.25 | 3.0 | 5 | - |
| 18 | 22.50 | 2.2 | 3 | 2 |
| | | | Total 75 | 18 |

Line 1 was the first line located from 1.25 m of the west bank of the Phachi River (facing the river mouth) and Lines 2 and others were 1.25 m width from the next one along the cross section line to the east bank.

(-) = Not measured

Copyright by Mahidol University

Table 4.2 Sampling line and number of sampling sites on the 2nd campaign

| Line | Width (m) | Depth (m) | Number of sampling sites for physico-chemical parameters | | current velocity |
|---|---|---|---|---|---|
| | | | Bottom | Mid depth | |
| 1 | 3 | 1.50 | 4 | - | - |
| 2 | 6 | 1.60 | 4 | 4 | 2 |
| 3 | 9 | 1.90 | 4 | - | - |
| 4 | 12 | 2.60 | 4 | 4 | 2 |
| 5 | 15 | 2.90 | 4 | - | - |
| 6 | 18 | 3.15 | 4 | 4 | 2 |
| 7 | 21 | 2.70 | 4 | - | - |
| Total | | | 28 | 12 | 6 |

Line 1 was the first line located from 1.25 m of the west bank of the Phachi River (facing the river mouth) and Lines 2 and others were 1.25 m width from the next one along the cross section line to the east bank.

(-) = Not measure

## 4.2 Physico-chemical parameters of the Phachi River water quality and bottom sediments

### 4.2.1 The 1st sampling campaign

The results of the 1st campaign showed that DO values were in the range from 6.80 to 8.80 mg/L, BOD from 0.15 to 2.13 mg/L, pH from 7.42 to 8.95, conductivity from 140 to 170 μmhos/cm, water temperature from 24.5 to 26.0 °C, water depth from 1.5 to 3.5 m, current velocity for low zone in the range from 0 to 0.027 m/s, moderate zone from 0.035 to 0.1 m/s and high zone from 0.25 to 0.43 m/s (Table 4.3). The current velocity near the west bank was rather stagnant to low and increasing towards the east bank however the maximum current velocity was at Station 13 and decreasing but it was still considered high. Regardless of current velocity, DO values in all stations were high. When compared the results with Water Quality Standard of Thailand (Notification of the National Environment Board No.8, 1994), it was found that most physico-chemical parameters can be classified in the Class 2 except BOD values of Station 2 with the values over 2 mg/L (showed in Table 4.3).

Copyright by Mahidol University

Table 4.3 Physico-chemical parameters of 18 sampling stations of the Phachi River in Rachaburi Province on 1st campaign (7 – 8 September 2002)

| Parameter / Station of Line | DO (mg/L) | BOD (mg/L) | pH | Conductivity (μmhos/cm) | Water temperature (°C) | Current velocity (m/s) | Water depth (m) |
|---|---|---|---|---|---|---|---|
| 1 | 8.00 | 1.62-1.75 | 8.83-8.95 | 159-170 | 25.6-26.2 | n.d. | 1.5 |
| 2 | 7.80-7.90 | 0.83-2.13 | 8.63-8.75 | 155-162 | 25.1-26.0 | - | 1.8 |
| 3 | 7.75-7.85 | 1.15-1.47 | 8.62-8.71 | 168-170 | 25.5-25.7 | n.d. | 2.0 |
| 4 | 7.60-8.35 | 1.27-1.70 | 8.65-8.81 | 164-170 | 25.5-25.6 | - | 2.0 |
| 5 | 8.0-8.25 | 0.35-0.90 | 8.71-8.78 | 165-168 | 25.5-25.6 | 0.027 | 2.0 |
| 6 | 7.80-8.50 | 0.31-1.11 | 8.74-8.81 | 164-170 | 25.5-25.6 | - | 2.0 |
| 7 | 7.55-7.80 | 0.43-0.70 | 8.79-8.88 | 160-169 | 25.5 | 0.035 | 2.0 |
| 8 | 7.30-7.75 | 1.03-1.45 | 8.69-8.89 | 164-165 | 25.5-25.6 | - | 2.2 |
| 9 | 7.45-8.10 | 0.15-1.34 | 8.61-8.76 | 162-169 | 25.5-25.7 | 0.105 | 2.5 |
| 10 | 7.50-7.70 | 0.18-1.09 | 8.58-8.75 | 163-170 | 25.5 | - | 2.9 |
| 11 | 7.25-7.60 | 0.45-1.75 | 8.64-8.81 | 160-168 | 25.3-25.5 | 0.247 | 3.1 |
| 12 | 7.35-8.20 | 0.0-0.83 | 8.64-8.77 | 164-169 | 25.3-25.5 | - | 3.3 |
| 13 | 6.80-7.55 | 0.52-1.25 | 8.47-8.64 | 140-168 | 24.8-25.3 | 0.433 | 3.4 |
| 14 | 7.10-7.60 | 0.44-1.05 | 7.42-7.81 | 151-160 | 24.5-24.9 | - | 3.5 |
| 15 | 7.30-8.40 | 0.75-1.38 | 7.90-8.36 | 158-161 | 24.6-24.7 | 0.371 | 3.5 |
| 16 | 7.30-7.80 | 0.0-0.95 | 8.29-8.48 | 159-160 | 24.6-25.1 | - | 3.4 |
| 17 | 7.60-7.80 | 0.19-1.04 | 8.46-8.50 | 160-162 | 25.0-25.1 | 0.270 | 3.0 |
| 18 | 8.05-8.80 | 0.57-0.95 | 8.60-8.62 | 164-168 | 25.1-25.4 | - | 2.2 |

n.d. = non detectable

(-) = Not measure

The total numbers of sampling on the 2nd campaign were 40 samples and were less than the 1st campaign (75 samples). Because the results (DO and BOD) of station follow the vertical line from surface water to bottom calculated by correlation and found that no difference observed significant at 95% confidential level. But the results were calculated follow the width of river showed that difference significant level at the 0.05. Many Site stations follow the width of river were differed in a flow rate. The correlation showed significant difference ($\alpha$=0.05) between DO, BOD, pH and conductivity among the location of current velocity zone (Tables 4.2 and 4.3). The difference of current velocity rate affected to water quality in the cross-section of river. Thus, the sampling on the 2nd campaign was considered and changed to be a

Copyright by Mahidol University

new sampling plan by follow the current velocity and closed up the location of benthic sampling (APHA, 1998).

Table 4.4 Paired samples t-test for physico-chemical parameters of the 1st campaign

| Parameters | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Std.Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| DO | 0.0422 | 0.2597 | 0.0612 | -0.0870 | 0.1714 | 0.690 | 17 | 0.500 |
| BOD | -0.2967 | 0.4552 | 0.1073 | -0.5230 | -0.0700 | -2.765 | 17 | 0.013 |
| pH | 0.1011 | 0.2468 | 0.0582 | -0.0220 | 0.2238 | 1.738 | 17 | 0.100 |
| Conductivity | -1.4444 | 4.3720 | 1.0305 | -3.6186 | 0.7297 | -1.402 | 17 | 0.179 |
| Water temperature | 0.2000 | 0.3634 | 0.0856 | 0.0193 | 0.3807 | 2.335 | 17 | 0.032 |

The result of 1st campaign corrected only mid depth and mid width value and the bottom value. And these value calculated by Paired samples t-test, and show that the DO, pH and Conductivity value at mid depth and mid width and the bottom are not difference at 95% confidence level. BOD and Water temperature values at the same Site are difference at 95% confidence level.

### 4.2.2 The 2nd sampling campaign

Forty water samples from ten sampling stations were examined with DO values in the range from 6.75 to 8.00 mg/L, BOD from 0.68 to 1.53 mg/L, pH from 8.27 to 8.36, conductivity from 265 to 275 μmhos/cm, water temperature from 27.0 to 28.0°C, water depth from 1.5 to 3.15 m, current velocity for low zone in the range from 0 to 0.02 m/s, moderate zone from 0.05 to 0.075 m/s and high from 0.085 to 0.16 m/s (Table 4.5). The high current velocity was still near the east bank of the river. Although the 2nd sampling campaign was in the dry season, the water quality can be classified in the Class 2.

Copyright by Mahidol University

Table 4.5 Physico-chemical parameters of ten sampling stations of the Phachi River in Rachaburi Province on the 2nd campaign (25 May 2003)

| Parameter / Station of Line | DO (mg/L) | BOD (mg/L) | pH | Conductivity (μmhos/cm) | Water temperature (°C) | Current velocity (m/s) | Depth (m) |
|---|---|---|---|---|---|---|---|
| 1 | 7.02 | 1.17 | 8.30 | 270.0 | 27.5 | n.d. | 1.50 |
| 2 | 7.08 | 1.12 | 8.30 | 270.0 | 27.5 | 0.020 | 1.60 |
| (2) | (7.25) | (0.94) | (8.30) | (273.0) | (27.5) | ( - ) | (0.80) |
| 3 | 7.10 | 1.21 | 8.28 | 273.0 | 27.5 | 0.050 | 1.90 |
| 4 | 7.02 | 1.14 | 8.28 | 271.0 | 27.5 | 0.075 | 2.60 |
| (4) | (7.05) | (0.68) | (8.29) | (272.0) | (27.5) | ( - ) | (1.30) |
| 5 | 7.38 | 0.94 | 8.28 | 270.0 | 27.0 | 0.160 | 2.90 |
| 6 | 7.12 | 1.03 | 8.32 | 267.5 | 27.5 | 0.150 | 3.15 |
| (6) | (7.30) | (1.20) | (8.34) | (269.0) | (27.0) | ( - ) | (1.60) |
| 7 | 7.20 | 0.97 | 8.30 | 273.5 | 28.0 | 0.085 | 2.70 |

(2), (4) and (6) = Stations at mid depth of Lines 2, 4 and 6

(…) = Values from the samples at mid depth of station

n.d. = non detectable

(-) = Not measure

The 2nd campaign was calculated in statistic value, Paired samples t-test, from 5 parameters of water quality (DO, BOD, Conductivity pH and Water temperature) between the mid depth and the bottom station. The results showed significance level 95% and accept *H*o for DO, Conductivity and Water temperature but rejection *H*o for BOD and pH (*H*o: μ1=μ2). Then, 3 parameters (DO, Conductivity and Water temperature) were not different with the significance level of this test at 0.05 (Table 4.6).

Copyright by Mahidol University

Table 4.6 Paired samples t-test for physico-chemical parameters of the 2nd campaign

| Parameters | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Std.Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| DO | -0.0810 | 0.1259 | 0.0476 | -0.1979 | 0.0350 | -1.711 | 6 | 0.138 |
| BOD | -0.1843 | 0.1050 | 0.0397 | -0.2814 | -0.0870 | -4.643 | 6 | 0.004 |
| pH | -0.0110 | 0.0090 | 0.0034 | -0.0200 | -0.0031 | -3.361 | 6 | 0.015 |
| Conductivity | 1.2143 | 2.0332 | 0.7685 | -0.6661 | 3.0947 | 1.580 | 6 | 0.165 |
| Water temperature | 0.0000 | 0.2887 | 0.1091 | -0.2670 | 0.2670 | 0.000 | 6 | 1.000 |

From this study, the result of physico-chemical parameter had different between on the 1st campaign and the 2nd campaign. Average value of DO, pH and current velocity of the 2nd campaign decreased from the 1st campaign but BOD, conductivity and water temperature indicated the increasing value. There were showed those less trends of water quality than the 1st campaign. In general, the actual amount of oxygen present is related to the character of the current, the water temperature, and the presence of respiring plants and animals (Maitland, 1978).

Table 4.7 Characteristics of bottom sediments of the Phachi River in Rachaburi Province during the 2nd campaign (25 May 2003)

| Station | % Sand | % Silt | % Clay |
|---|---|---|---|
| 1 | 51.06 | 48.51 | 0.43 |
| 2 | 54.23 | 45.19 | 0.57 |
| 3 | 72.97 | 26.53 | 0.50 |
| 4 | 73.88 | 25.70 | 0.42 |
| 5 | 57.79 | 41.80 | 0.41 |
| 6 | 61.79 | 37.61 | 0.60 |
| 7 | 91.57 | 7.33 | 1.10 |

Copyright by Mahidol University

The bottom sediments were collected during the 2nd campaign for all stations (Table 4.7). Sand was the major component of the bottom sediments. This is owing to the sampling area was in the upland river. It was found that current velocity had an effect on the composition of the bottom sediment. While the current velocity of the east bank are higher than the west bank thus the combination percentage of silt and clay at the west bank is higher than that at the east bank

## 4.3 Benthic macroinvertebrates

### 4.3.1 The 1st sampling campaign

On the 1st sampling campaign at the end of the rainy season (6 – 8 September 2002), 67 taxa of 12 orders, 43 families, 48 genera and unidentified 18 taxa were found from 16 sampling sites along a cross section of the Phachi River (Table 4.10). Sites 11 and 13 could not sample because the bottoms were stone plates. Plechoptera, Ephemeroptera, Trichoptera, Odonata, Coleoptera, Diptera, Heteroptera, Ostracoda, Oligochaeta, Mesogastropoda, Basommatophora and Veneroida were identified. Most of the macroinvertebrates belonged to the class Insecta (42 taxa), followed by mollusca (14 taxa). Among the Insecta, the best represented (considering on family and genus levels) were Trichoptera (8 families, 8 genera and 5 unknown genera) and Ephemeroptera (6 families and 10 genera). The order of Mollusca contained 4 families and 10 genera of Mesogastropoda and most of taxa were under Thiaridae. The effect of current velocity regime on diversity can be observed in the study. The highest number of 28 and 21 taxa were found in Sites 10 and 17 with high current velocity; 10 to 14 taxa in Sites 5 to 8 with moderate current velocity and 6 taxa in Site 2 with low current velocity. The most three important orders of clean water quality were Plechoptera, Ephemeroptera and Trichoptera (EPT) were found in sampling sites with high current velocity (Sites 9 to 18).

Copyright by Mahidol University

Table 4.8 Taxa list and distribution of macroinvertebrates among 18 sampling sites of the Phachi River in Rachaburi Province during the 1st sampling campaign (6 – 8 September 2002)

| Taxa \ Sampling site on line | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **O.Plechoptera** | | | | | | | | | | | | | | | | | | |
| F.Chloroperlidae - *Kathroperia sp.* | | | | | | | | | | | | | | | A | | | |
| **O.Trichoptera** | | | | | | | | | | | | | | | | | | |
| Trichoptera pupa | | B | | | | | D | | | | | B | | | B | | B | |
| F.Leptoceridae - *G.Unk* | | | | | | | | | A | | | B | | | | | | |
| - *Setodes incertus* | | | | | | | | | | | | | | B | | A | | |
| - *Oecetis sp.* | | | | | | | | | | | | | | | A | | | |
| - *Triaenodes sp.* | | | | | | | | | | | | | | | | | B | |
| F.Helicopsychidae - *Helicopsyche sp.* | | | | | | | B | B | | A | | | | | A | | | A |
| F.Polycentropodidae - *Polycentropus sp.* | | | | | | | | | | A | | | | | | | | |
| - *Neureclipsis sp.* | | | | | | | | | | | | | | | | | | B |
| F.Hydropsychidae - *G.Unk* | | | | | | | | | | A | | | | A | | | | |
| F.Dipseudosidae - *G.Unk* | | | | | | | | A | | | | | | | | | | |
| F.Hydroptilidae - *G.Unk* | | | | | | | | | A | | | | | | | | | |
| - *Ochrotrichia sp.* | | | | | | | | | | | | | | | | | | A |
| F.Limnephilidae - *G.Unk* | | | | | | | | | | | | | | | | A | | |
| F.Odontoceridae - *G.Unk* | | | | | | | | | | | | | | | | B | | |
| - *Marilia sp.* | | | | | | A | | | | | | | | | | | | |
| **O.Ephemeroptera** | | | | | | | | | | | | | | | | | | |
| F.Ephemeridae - *G.Unk* | | | | | | | | | | B | | | | | | | | |
| - *Ephemera sp.* | | | | | | | B | C | | | | | | A | B | B | B | |
| F.Baetidae - *G.Unk* | | | | | | | | | | A | | B | | | | | A | |
| - *Platybaetis sp.* | | | | | | | | | | B | | | | | | | | |
| - *Centroptilum sp.* | | | | | | | | | | B | | | | | | | | |

Copyright by Mahidol University

Table 4.8 Taxa list and distribution of macroinvertebrates among 18 sampling sites of the Phachi River in Rachaburi Province during the 1st sampling campaign (6 – 8 September 2002) (Continued)

| Taxa \ Sampling site on line | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **O.Ephemeroptera (continue)** | | | | | | | | | | | | | | | | | | |
| F.Leptophlebiidae - *G.Unk* | | | | | A | | | | | | | | | | | | | |
| - *Choroterpides sp.* | | | | A | | A | | | | | | A | | | | | B | A |
| - *Thraulus sp.* | | | | | | | | | C | E | | | | | | B | | |
| F.Caenidae - *Caenocaulis sp.* | | | | | A | | | | B | B | | | | | | | | |
| - *Caenodes sp.* | | | | A | | | | | | A | | | | | | | | |
| - *Brachycercus sp.* | | | | | B | | | | | | | | | | | | | |
| F.Siphlonuridae - *Ameletus sp.* | | | | | A | | | | | | | | | | | | | |
| F.Neoephemeridae - *Potamanthellus sp.* | | | | | | | | | | | | A | | | | | | |
| **O.Odonata** | | | | | | | | | | | | | | | | | | |
| F.Libellulidae - *G. Unk* | | | | | | | | | | B | | | | | | | | |
| - *Pseudothemis sp.* | | | | | | | | | | A | | | | | | | | |
| F.Gomphidae - *G. Unk* | | | | | | A | | | | | | | | | | | | |
| - *Ophiogomphus sp.* | | | | A | | | | | | | | A | | | | | | |
| - *Melligomphus sp.* | | | | A | | | | | | | | | | | | | | |
| - *Leptogomphus sp.* | | | | | | | | | | A | | | | | | | | |
| - *Paragomphus sp.* | | | | | | | | | | | | | | | | | A | |
| F.Aeshnidae - *G. Unk* | | | | | | | | | | B | | | | | | | | |
| **O.Coleoptera** | | | | | | | | | | | | | | | | | | |
| - Coleoptera adult | | | | | | | | | | | | | | | B | | A | |
| F.Elmidae / Elminthidae - *G.Unk* | | A | | | | B | | B | B | A | | B | | | C | C | A | B |
| - *Promoresia sp.* | | | | B | C | | | | | B | | | | B | | | | |
| F.Psephenidae - *G.Unk* | | | | B | | | | | A | | | | | | | | | |
| - *Eubrianax sp.* | | | | | | | | | | | | A | | | | | | |
| F.Scirtidae - *G.Unk* | | | | | | | | | | | | | | | | A | | |

Copyright by Mahidol University

Table 4.8 Taxa list and distribution of macroinvertebrates among 18 sampling sites of the Phachi River in Rachaburi Province during the 1st sampling campaign (6 – 8 September 2002) (Continued)

| Taxa \ Sampling site on line | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **O.Coleoptera (continue)** | | | | | | | | | | | | | | | | | | |
| F.Hydrophilidae – *G.Unk* | | | | | | | | | | | | | | | B | B | | |
| F.Dytiscidae - *G.Unk* | | B | | | | | | | A | B | | | | | | | | |
| F.Melyridae - *Endeodes sp.* | | | | | | | | | | | | | | | | | A | |
| **O.Diptera** | | | | | | | | | | | | | | | | | | |
| F.Chironomidae – *G.Unk* | B | B | B | B | A | | | | | A | | B | | | | A | | B |
| - *Orthocladius sp.* | | | | | | | | A | | | | | | | | A | | |
| - *Chironomus sp.* | | | | | | | | | | | | | | A | | | | |
| F.Ceratopogonidae – *G.Unk* | | | | | A | B | B | | | B | | | | B | B | | B | B |
| - *Bezzia sp.* | | | | | | | | | | | | B | | | | | | |
| F.Athericidae – *G.Unk* | | | | | A | | | | B | | | | | | | | | |
| - *Atrichops sp.* | | | A | | | | | | | | | | | | | | | |
| **O.Heteroptera / Hemiptera** | | | | | | | | | | | | | | | | | | |
| F.Micronectidae - *Micronecta sp.* | | | | | | | | | | | | | | | | | A | |
| F.Helotrephidae - *G.Unk* | | | | | | | | | | | | | | | | A | | |
| F.Unk | | | | | | | | | A | | | | | | | | | |
| **O.Ostracoda** | | | | | | | | | | | | | | | | | | |
| F.Cypridae – *G.Unk* | | | | | | | | | | | | | | | | | A | |
| - *Candona candida* | | | | | | | | B | | | | | | | | | | |
| - *Herpetocypris reptans* | | | | | | | | | | B | | | | | | | | |
| F.Darwinulidae – *G.Unk* | | A | | | | | | | | | | | | | | | | |
| F.Unk | | | | | A | | B | | | | | | | | | | | |
| **O.Oligochaeta** | | | | | | | | | | | | | | | | | | |
| F.Naidae/ F.Naididae | | | | A | | | C | | B | C | | A | | | | B | | |
| F.Enchytracidae | | | | | | | | | | | | B | | | | | | |

Copyright by Mahidol University

Table 4.8 Taxa list and distribution of macroinvertebrates among 18 sampling sites of the Phachi River in Rachaburi Province during the 1st sampling campaign (6 – 8 September 2002) (Continued)

| Taxa \ Sampling site on line | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **O.Oligochaeta (continue)** | | | | | | | | | | | | | | | | | | |
| F.Tubificidae | | | | | | | | | | C | | | | | | | | |
| F.Lumbriculidae | | | | B | | | | | B | | | | | | | | | |
| F.Unk | | | | | A | B | | | | | | | | | B | | B | |
| **O.Mesogastropoda** | | | | | | | | | | | | | | | | | | |
| F.Thiaridae - *G.Unk* | | | | D | C | | E | D | | C | | | | | D | | E | |
| - *Thiara sp.* | B | C | B | A | | B | | B | C | | | C | | B | | D | | B |
| - *Brotia sp.* | | | B | | | | | | | | | | | | | | | B |
| - *Syrmylasma sp.* | | C | | | | B | | | | | | B | | | | | | |
| -*Tarebia sp.* | | | | | | B | B | B | A | A | | B | | A | A | | A | A |
| -*Melanoides sp.* | | C | B | | | B | | B | A | | | B | | | B | | A | A |
| - *Sermyla sp.* | | | | | | | | B | A | | | | | B | | B | A | |
| -*Syrmyla sp.* | | | | | | | | | | | | | | | C | | | |
| F.Ampullariidae *Pila sp.* | A | | | B | C | B | A | B | B | B | | A | | | B | B | B | A |
| F.Assiminaidae - *Paludinella sp.* | | | | | | | | | | | | | | | B | | | |
| F.Pleuroceridae - *Elimia sp.* | | | | | | | | | C | | | | | | | B | A | C |
| **O.Basommatophora** | | | | | | | | | | | | | | | | | | |
| Sub F.Planorbinae - *Gyraulus sp.* | A | | | | | B | | C | B | B | | A | | | A | | C | A |
| F.Lymnaeidae - *Radix sp.* | | | | | | | | | A | | | | | | | | | A |
| **O.Veneroida** | | | | | | | | | | | | | | | | | | |
| F.Corbiculidae | | | | | | | | | | | | B | | | | B | | |
| - *Corbicula sp.* | | C | | C | C | C | C | C | C | B | | | | B | C | | C | B |
| **-** *Batissa similis* | | | | | | | | | | A | | | | | | | | |

A = 1 organism; B = 2-10 organisms; C = 11-50 organisms; D = 51-100 organisms; E = 101-1000 organisms

Copyright by Mahidol University

### 4.3.2 The 2nd sampling campaign

During the 2nd sampling campaign at the end of dry season (24 – 25 May 2003), 14 orders, 41 families, 35 genera and unidentified 20 genera (Table 4.11) were found. Plechoptera, Ephemeroptera, Trichoptera, Odonata, Coleoptera, Diptera, Heteroptera, Ostracoda, Oligochaeta, Mesogastropoda, Basommatophora, Veneroida, Decapoda and Heterodonta were identified. Most of the macroinvertebrates belonged to the class Insecta (39 taxa), followed by mollusca (13 taxa). Among the Insecta, the best represented (considering on family and genus levels) were Trichoptera (7 families, 4 genera and 4 unknown genera) and Ephemeroptera (4 families 6 genera and 1 unknown genera). The order of Mollusca contained 6 families 1 unknown family 10 genera and 2 unknown genera. The most taxa of Mesogastropoda were under Thiaridae. The highest number of taxa showed in Sites 6 and 7 (29 and 28 taxa, respectively), followed by Sites 3, 1, 4 and 5 (22, 21, 21 and 21 taxa, respectively), and Site 2 (19 taxa). The EPT were also found in sampling sites with high current velocity. All these sites were proposed to be the representative for good water quality.

The Order differed between the 1st and 2nd sampling campaign was Decapoda and Heterodonta.

Oligochaeta and Cnironomidae are lentic community and supports by the decaying organic matter in the sediments (Maitland, 1978), but this study found them where lotic and lentic habitats and supports by the sand in sediments to both campaign.

Copyright by Mahidol University

Table 4.9 Taxa list and distribution of macroinvertebrates among seven sampling sites of the Phachi River in Rachaburi Province during the 2nd sampling campaign (24 – 25 May 2003)

| Taxa \ Sampling site on line | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **O.Plechoptera** | | | | | | | |
| F.Perlidae - *G.Unk* | | | | A | | | |
| **O.Trichoptera** | | | | | | | |
| Trichoptera pupa | | A | | | | | B |
| F.Leptoceridae - *G.Unk* | | | | | A | | B |
| - Parasetodes sp. | | | | | | B | |
| F.Helicopsychidae - *Helicopsyche sp.* | A | | | | | | A |
| F.Polycentropodidae - *Polycentropus sp.* | | | | | | | A |
| F.Rhyacophilidae - *G.Unk* | A | | | | | | |
| F.Psychomyiidae - *G.Unk* | | | A | | | | |
| F.Ecnomidae - *G.Unk* | | | | | | | A |
| F.Odontoceridae pupa | | | | | | A | |
| F.Odontoceridae - *G.Unk* | | | | | | B | |
| - *Marilia sp.* | | | | | | | B |
| **O.Ephemeroptera** | | | | | | | |
| F.Ephemeridae - *Ephemera sp.* | | | | | B | C | C |
| F.Baetidae - *G.Unk* | | | | | | A | |
| F.Leptophlebiidae - *Choroterpides sp.* | | | | | | | B |
| - *Choroteres sp.* | | | | | | | B |
| F.Caenidae - *Caenocaulis sp.* | | | | | A | A | A |
| - *Caenodes sp.* | | | A | | | | |
| - *Caenis sp.* | | | | A | A | B | |
| **O.Odonata** | | | | | | | |
| F.Libellulidae - *Libellula sp.* | | | | | | | A |
| - *Macrothemis sp.* | | | | | B | B | |
| F.Gomphidae - *Ophiogomphus sp.* | | | | | | | A |
| - *Melligomphus sp.* | A | | | | | | |
| F.Unk | | | | A | | | |
| **O.Coleoptera** | | | | | | | |
| F.Elmidae / Elminthidae | | B | B | C | D | D | C |
| Sub F.Elmidinae | A | | | | | | |
| F.Psephenidae | | C | | | | A | A |
| F.Gyrinidae | | | | | | | A |
| F.Limnichidae | | | B | | | B | |
| **O.Diptera** | | | | | | | |
| F.Chironomidae | C | C | D | D | C | D | D |
| *Chironomus sp.* | | | | | A | | |
| *Cricotopus sp.* | | | | | A | | |
| Sub.F.Tanypodinae | A | A | B | | | | A |
| Sub.F.Diamesinae | | C | | | | | |
| F.Culicidae | | | | | | A | A |
| F.Ceratopogonidae | B | B | C | B | B | C | C |
| *Bezzia sp.* | | | | | | B | |
| *Dasyhelea sp.* | | | | A | | | |
| F.Athericidae | | | | A | | A | |

Copyright by Mahidol University

Table 4.9 Taxa list and distribution of macroinvertebrates among seven sampling sites of the Phachi River in Rachaburi Province during the 2nd sampling campaign (24 – 25 May 2003) (Continued)

| Taxa \ Sampling site on line | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **O.Heteroptera / Hemiptera** | | | | | | | |
| F.Tipulidae | A | | | | | | |
| F.Corrixidae | | | C | C | | | |
| **O.Ostracoda** | | | | | | | |
| F.Cypridae | A | | | | | | |
| *Candona candida* | | | A | | | B | B |
| *Notodromas* | | B | B | B | | A | |
| *Herpetocypris* | | B | | B | C | | B |
| **O.Oligochaeta** | | | | | | | |
| F.Naidae/ F.Naididae | B | | C | | C | C | B |
| *-Naris sp.* | B | | A | | | | |
| *- Dero sp.* | B | | | | | | |
| F.Enchytracidae | | B | B | | B | C | |
| F.Tubificidae | | | | | | | B |
| F.Unk | | B | C | B | B | B | B |
| **O.Mesogastropoda** | | | | | | | |
| F.Thiaridae | C | B | C | D | E | E | E |
| *Thiara sp.* | C | B | C | B | | B | B |
| *Brotia sp.* | C | B | | B | | | |
| *Syrmylasma sp.* | | | C | B | | B | |
| *Tarebia sp.* | | B | A | B | B | B | |
| *Melanoides sp.* | C | C | | B | B | | |
| F.Ampullariidae | | | B | | | | |
| *Pila sp.* | A | B | | A | B | A | |
| **O.Basommatophora** | | | | | | | |
| F.Planorbinae - *Polyphylis sp.* | | | | | | A | |
| Sub F.Planorbinae - *Gyraulus sp.* | A | A | | B | C | B | C |
| **O.Veneroida** | | | | | | | |
| F.Corbiculidae - *Corbicula sp.* | B | C | A | B | C | C | C |
| F.Unk | | | A | | | | |
| **O.Heterodonta** | | | | | | | |
| F.Sphaeriidae | C | | | | | | |
| **O.Decapoda** | | | | | | | |
| F.Palaemonidae | A | | A | | B | | |

A = 1 organism; B = 2-10 organisms; C = 11-50 organisms; D = 51-100 organisms; E = 101-1000 organisms

Copyright by Mahidol University

## 4.4 Calculation of the Biotic Index

From the data in Table 4.10, it could be seen that so many taxa found only 1 individual. This might be to due to the inefficiency of sample collection. From this reason the calculation of the biotic index was carried out in two ways. First results represented the calculation considering even 1 individuals as a systematic unit and the second results followed the reference method of 2 organisms or more as a systematic unit. The results are given in Table 4.10 for the 1st sampling campaign and Table 4.11 for the 2nd sampling campaign. The results were calculated by two index systems i.e. BBI (APHA, 1995, Subodh, n.d.) and TBI (De Pauw and Vanhooren, 1983) that were used to assess the biological water quality of cross-section in study site.

The 1st sampling campaign, the results from Table 4.11 calculated by BBI & TBI. The trend of results followed on the same way. The low flow zone (Sites 1-4) had been 4 and 6 points, that comparison with biotic index were Class III and Class IV their presented moderately to heavily polluted. The medium flow zone (Sites 5 to 8) was 7 and 8 point (Class II), they are presented slightly polluted. And high flow zone (Sites 9 to 18) was 9 point (Class I), they're presented lightly or unpolluted except Site 14 got 7 point (Class II) showed slightly polluted.

The 2nd sampling campaign, calculated data by BBI and TBI showed in Table 4.12. Sites 1, 4, 6 and 7 were comparable 9 point, their presented Class I lightly. For Sites 2, 3 and 5 were given 8 point, their presented Class II slightly polluted.

Copyright by Mahidol University

Table 4.10 Calculation results of Belgian Biotic Index and Trent Biotic Index for the 1st sampling campaign

| (I) Site Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (II) | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 |
| (III) Total Systematic | 4 2 | 9 7 | 5 4 | 13 7 | 13 5 | 13 10 | 10 9 | 14 12 | 20 11 | 28 17 | 19 12 | 10 6 | 18 13 | 17 11 | 21 10 | 16 8 |
| (IV) Calculation based on the standard table of Tuffery & | 4 4 | 6 6 | 4 4 | 6 5 | 7 4 | 7 5 | 7 5 | 8 7 | 9 6 | 9 8 | 9 8 | 9 7 | 9 7 | 9 7 | 9 7 | 9 6 |
| (V) Calculation from IV by Biotic Index (Class I-V; | 4 4 | 3 3 | 4 4 | 3 3 | 2 4 | 2 3 | 2 3 | 2 2 | 1 3 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 3 |
| (VI) Calculation based on Trent | 4 4 | 5 5 | 2 2 | 8 5 | 8 5 | 7 2 | 6 6 | 7 7 | 9 8 | 9 9 | 9 7 | 9 7 | 9 7 | 9 8 | 9 7 | 8 5 |

(II) 1 =; total number of taxa based on even 1 or more than 2 organisms in each taxon = 1 systematic unit

2 = total number of taxa based on 21 or more than 2 organisms in each taxon = 1 systematic unit

Copyright by Mahidol University

Table 4.11 Calculation results of Belgian Biotic Index and Trent Biotic Index for the 2nd sampling campaign

| Sampling site | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| (II) | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 | 1 2 |
| (III) Total Systematic units | 21 11 | 19 16 | 22 14 | 21 13 | 21 16 | 29 20 | 28 18 |
| (IV) Calculation based on the standard table of Tuffery & Verneaux (1968) | 9 6 | 8 7 | 8 6 | 9 6 | 8 7 | 9 9 | 9 9 |
| (V) Calculation from IV by Biotic Index (Class I – V) | 1 3 | 2 2 | 2 3 | 1 3 | 2 2 | 1 1 | 1 1 |
| (VI) Calculation based on Trent Biotic Index | 8 4 | 7 4 | 8 4 | 9 4 | 9 8 | 9 9 | 9 9 |

(II) 1 = total number of taxa based on even 1 or more than 2 organisms in each taxon = 1 systematic unit
2 = total number of taxa based on 2 or more than 2 organisms in each taxon = 1 systematic unit

From this study of a cross-section at the Phachi River on the 1st and 2nd sampling campaigns, total number of 82 and 65 taxa were found respectively. There were 28 taxa, which were common to both sampling campaigns. The 1st sampling campaign is more benthic macroinvertebrates than the 2nd sampling campaign and more diversity too, but there is less order of benthic macroinvertebrate than the 2nd sampling campaign. When comparing the taxa in this study with the standard table for determination of the Belgian Biotic index (De Pauw and Vanhooren, 1983), there were 13 taxa on the 1st campaign and 9 taxa on the 2nd sampling campaign did not appeared in the standard table therefore, the same 4 taxa to both campaign for different 14 taxa. These were 9 taxa on the 1st sampling campaign (6 taxa of Coleoptera; Promoresia sp., Eubrianax sp., Scirtidae, Hydrophilidae, Dytiscidae, Dytiscidae, melyridae, and 3 taxa of Ostracoda; Darwinulidae, Cypridae (unknown genus, unknown family) and 5 taxa on the 2nd sampling campaign (3 taxa of Coleoptara; Sub Family Elmidinae, Gyrinidae, Limnichidae, 1 Notodromas taxon of Ostracoda, and 1 Palaemonidae taxon of Decapoda)). This study showed low flow zone because there are less taxa than moderate and high flow zone. When considering both sampling campaigns, it was showed the means capable of sampling for benthic macroinvertebrates.

Copyright by Mahidol University

# CHAPTER V
# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

From this study of water quality in cross-section area and macroinvertebrates both two campaign indicated that;

### 5.1.1 The physico-chemical parameters

The 1st campaign, Paired samples t-test statistical test shows that DO, pH, and Conductivity at mid depth and mid width and the bottom is not statistical variation in 95% confidential. The BOD and Water temperature are different at mid depth and mid width and the bottom. The comparison among sampling station, BOD at low flow velocity at station 1 to 4 is higher than at higher flow velocity station. Especially in BOD at 1 station is 1.68 mg/l classified in category 3 in Water Quality Standard of Thailand. Others are classified to category 2 that BOD not exceed 1.50 mg/l. DO is not statistical variation in all stations. Do is higher than 6.0 mg/l that can be classified in category 2 indicated that water quality is in a good level. The ph value is in the standard range between 5 to 9 that all creature can survivor in this pH condition.

The 2nd campaign, when being statistical test by Paired samples t-test; DO, Conductivity and Water temperature values are not differential at 95% confidential. The BOD and pH values are significant variation. But the pH value is in the range of 5 to 9. When compared to The Water Quality Standard of Thailand, the river quality can be classified in category 2 at all stations.

Copyright by Mahidol University

### 5.1.2 The Biotic index

BBI and TBI applications to indicate water quality which sampling by Ekman grab in the cross-section line of river stream founds some creatures outer specify in BBI and TBI such as Ostracoda and Oligochaeta. However; from the comparison by remarking the results; the remark from two samplings are similar. There is lower remark at the low water flow velocity than at medium and high water flow velocity. Classification by Biotic Index interpretation shows the same results that synchronize with physico-chemical water quality interpretation by Water Quality Standard of Thailand also. Water Quality assessment by macroinvertebrates sampling should take sample at the same vertical point as physico-chemical sampling. Further more; in the case of deep water and steep bank, Ekman grab method should replace Hand-net method in clouding BBI and TBI application with Water Quality Standard of Thailand.

## 5.2 Recommendation

From this study, strongly recommend that water flow velocity have a significant affect to whole cross-section area of water stream. This results can be recommended that in physico-chemical water sampling, should take sample covered all zones of water stream and sampling spot should be in the depth of at least 50 cm from water surface when water stream is depth less than 4 meter. Further more, should be take sample from 2 banks.

1 Sites study and check the water stream velocity should be done before studying the water quality.

2 Sampling of water and macroinvertebrates should be covered all variation of cross-section area of water stream.

3 Should implement the same method for polluted river to compare the results.

4 Should have more macroinvertebrates study in Thailand different from BBI and TBI method for appropriated implementation in Thailand fauna.

Copyright by Mahidol University

# BIBLIOGRAPHY

American Public Health Association (APHA). (1992). **Standard Methods For the Examination of water and waste water (18th ed.)**. American Public Health Association. Washington DC.

American Public Health Association (APHA). (1995). **Standard Methods For the Examination of water and waste water (19th ed.)**. American Public Health Association, Washington, DC.

American Public Health Association (APHA). (1998). **Standard Methods For the Examination of water and waste water (20th ed.)**. American Public Health Association. Washington DC.

Dudgeon D. (1999) **Tropical Asian Streams Zoobenthos, Ecology and Conservation**. Hohg Kong University Press.

Death R. G. and Winterbourn M. J. (1995). Diversity patterns in stream benthic invertebrate communities: the influence of habitat stability. **Ecology**. Vol 76. Issue 5. 1446 – 1460.

De Pauw N. (1988). Biological assessmsnt of surface water quality: The Belgian experience in Proceding of Riva del Garda Palazzo dei Congress 28-29 April 1988. 195-212

De Pauw N. and Vanhooren G. (1983). Method for biological quality assessment of watercourses in Belgium. **Hydrobiologia**. 100, 153-168.

Lehmkuhl D. M. (1979) **How to know the aquatic insects**. Wm. C. Brown Company Publishers.

Fitter R. and Manuel R. (1986). **Collins Field Guide to Freshwater Life**. William Collins Sons and Co Ltd.

Giller P.S. and Malmqvist B. (2001). **The biology of streams and rivers**. New York. Oxford University Press Inc.

Hauer F.R. and Lamberti G.A. (editors) (1996). **Methods in stream ecology**. San Diego. Academic Press.

Copyright by Mahidol University

Hawkins C. P., Murphy M. L.and Anderson N. H. (1982). Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in cascade range streams of Oregon. **Ecology**. Vol 63. Issue 6. 1840-1856.

Hellawell J. M. (1978). **Biological surveillance of rivers**. Medmenham and Stevenage, Water Research Centre.

Hellawell J. M. (1989). **Biological indicators of freshwater pollution and environment management (Pollution monitoring series)**. NY. Elsevier science publishers.

Morse J. C., Yang Lianfang and Tian lixin (1994) **Aquatic Insects of China Useful for Monitoring Water Quality**. Nanjing Agricultural University Printing House.

Kerans B. L. and Karr J. R. (1994). A benthic index of biotic integrity (B-IBI) for river of the Tennessee Valley. **Ecological Applications**. Vol 4. Issue 4. 768-785.

Krueger C. C. and Waters T. F. (1983). Annual production of macroinvertebrates in three streams of different water quality. **Ecology**. Vol 64. Issue 4.840-850.

Needham J. G. and Needam P. R. (1962). **A guide to the study of fresh-water biology**. San Fracisco. Holden-day.

Nemerow N. L. (1991). **Stream estuary and ocean pollution (2nd ed.).** New York. Van Nostrand Reinhold.

Notification of the National Environment Board No 8 (1994). published in the Royal Government Gazette. Vol 111. Part 16. Dated February 24. BE. 2537.

Giller P. S. and Malmqvist. B. (2001). **The biology of streams and rivers**. N.Y. Oxford University Press

Ribbons of Blue. (2001). **Waterwatch Macroinvertebrate Sampling Guidelines Version 1.1 September**.

Merritt R. W. and Cummins K. W. (1996) **An Introduction to the Aquatic Insects of North America**. **(3rd ed.)**. Kendall/Hunt Publishing Company.

Rosenberg D. M. and Resh V. H. (1993). **Freshwater biomonitoring and benthic macroinvertebrates**. New York: Chapman and Hall, Inc.

Copyright by Mahidol University

Sangpradub N., Inmuong Y., Hanjavanit C. and Inmuong U. (1996). **A correlation Study between freshwater benthic macroinvertebrate fauna and environmental quality factors in Nam Pong Basin Thailand. Part 1 distribution and community structure of aquatic macroinvertebrate analyses**. Khon Kaen University.

Sangpradub N., Inmuong Y., Hanjavanit C. and Inmuong U. (1996). **A correlation study between freshwater benthic macroinvertebrate fauna and environmental quality factors in Nam Pong Basin Thailand. Part 2 effect of headwater catchment degradation on water quality and benthic macroinvertebrate community in Northeast Thailand**. Khon Kaen University.

Sangpradub N., Inmuong Y., Hanjavanit C. and Inmuong U. (1997). **A correlation study between freshwater benthic macroinvertebrate fauna and environmental quality factors in Nam Pong Basin Thailand. Part 2 the performance of biotic scores and indices in assessing water pollution: a case study in the Pong catchment of north-east Thailand**. Khon Kaen University.

Sharma S. and Moog O. (n.d.). **The use of Biotic Index and score methods in biological water quality assessment of the Nepalese Rivers**.

Victor S. and Michael Q. (1986). **Blackwell habitat field guides invertebrate Animals of freshwater.** Hong Kong. Basil Blackwell.

Vongprasert R. (1990). **Application of biotic index for water quality assessment of rivers in tropical countries: case studies in Thailand and Indonesia**. Master in Environmental Sanitation. Centre for Environmental Sanitation. University of Ghent.

McCafferty P. W. and Provonsha A. V. (1981). **Aquatic Entomology. The Fishermen's and Ecologists' Illustrated Guide to Insects and Their Relatives**. Halliday Lithograph.

Wetzel R. G. and Likens G. E. (2000). **Limnological analyses**. **(3rd ed.)**. New York. Springer-Verlag.

Woodiwiss F. S. (1964). The biological system of Stream classification used by the Trent River Board. Chemy. Indust.11.443-447

Copyright by Mahidol University

Zampra-Munoz C., Sainz-Cartero C. E., Sancher-Ortega A. and Alba-Tercedor J. (1995). Are biological index BMPW' and ASPT' and their significance regarding water quality seasonally dependent? factors explaining their variations. **Water Resources**. Vol 29. No 1. 285-290.

กรมส่งเสริมคุณภาพสิ่งแวดล้อม. (2541). **ฐานข้อมูลคำศัพท์ด้านสิ่งแวดล้อม**. กระทรวงวิทยาศาสตร์ เทคโนโลยีและสิ่งแวดล้อม. กรุงเทพฯ.

กรมอนามัย. (2539). **คู่มือการตรวจวิเคราะห์คุณภาพสิ่งแวดล้อมในห้องปฏิบัติการ**. กระทรวงสาธารณสุข. กรุงเทพฯ.

จันดา วงษ์สมบัติ. (2541). **ผลกระทบจากการถางป่าริมฝั่งลำธารต่อโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดินในแหล่งน้ำจืด**. วิทยานิพนธ์ปริญญาวิทยาศาสตรมหาบัณฑิต สาขาวิชาชีววิทยา. บัณฑิตวิทยาลัย มหาวิทยาลัยขอนแก่น.

เจียมจิตต์ บุญสม. (2518). **การศึกษาสัตว์หน้าดินในแม่น้ำเจ้าพระยาโดยใช้วัตถุล่อ**. ปริญญานิพนธ์วิทยาศาสตรมหาบัณฑิต. บัณฑิตวิทยาลัย. มหาวิทยาลัยเกษตรศาสตร์.

ชิตชล ผลารักษ์. (2536). **การศึกษากลุ่มแมลงในบางท้องที่ของสวนพฤกษศาสตร์ภาคเหนือ (แม่ลา) จังหวัดเชียงใหม่**. การค้นคว้าแบบอิสระเชิงวิทยานิพนธ์ วิทยาศาสตรมหาบัณฑิต. บัณฑิตวิทยาลัย มหาวิทยาลัยเชียงใหม่.

ณรรฐพล วัลลีย์ลักษณ์. (ม.ป.ป.). **ตัวอ่อนของแมลงเล่ม 2**. ภาควิชากีฏวิทยา มหาวิทยาลัยเกษตรศาสตร์.

ทิพย์นันท์ งามประหยัด. (2542). **ความชุกชุม ความหลากหลายของสัตว์หน้าดินและคุณภาพน้ำในแม่น้ำเจ้าพระยา**. วิทยานิพนธ์ปริญญาวิทยาศาสตร์มหาบัณฑิต. สาขาวิทยาศาสตรสิ่งแวดล้อม บัณฑิตวิทยาลัย มหาวิทยาลัยเกษตรศาสตร์.

นฤมล แสงประดับ. (มปป). **การใช้สัตว์หน้าดินในการบ่งชี้คุณภาพน้ำ**. ภาควิชาชีววิทยา คณะวิทยาศาสตร์. มหาวิทยาลัยขอนแก่น.

นฤมล แสงประดับ, ยรรยงค์ อินทร์ม่วง, ชุติมา หาญจวณิช และอุไรวรรณ อินทร์ม่วง. (2538). **การศึกษาความสัมพันธ์ระหว่างสัตว์ไม่มีกระดูกสันหลังหน้าดินกับปัจจัยคุณภาพสิ่งแวดล้อมในลุ่มน้ำพอง**. ขอนแก่น. คณะวิทยาศาสตร์ มหาวิทยาลัยขอนแก่น.

นิตยา เลาหะจินดา. (2528). **นิเวศวิทยา**. ภาควิชาสัตววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยเกษตรศาสตร์.กรุงเทพฯ: อมรการพิมพ์.

Copyright by Mahidol University

นันทนา คชเสนีย์. (2539). **คู่มือปฏิบัติการนิเวศวิทยาน้ำจืด**. จุฬาลงกรณ์มหาวิทยาลัย. กรุงเทพฯ.

บังอร แถวโนนงิ้ว. (2539). **คุณภาพน้ำ ชนิด และปริมาณของสัตว์หน้าดินในแม่น้ำแม่กลอง**. วิทยานิพนธ์ ปริญญาวิทยาศาสตรมหาบัณฑิต สาขาวิชาชีววิทยา. บัณฑิตวิทยาลัย มหาวิทยาลัยเกษตรศาสตร์.

พรทิพย์ ปั่นเจริญ. (2529). **รายงานการสำรวจสภาพนิเวศวิทยาในแม่น้ำท่าจีน**. โครงการศึกษาและวิจัยคุณภาพน้ำในแม่น้ำสายหลักท่าจีน. กรุงเทพฯ: ฝ่ายคุณภาพน้ำ กองมาตรฐานคุณภาพสิ่งแวดล้อม.

พรรณศรี เชิดชูพันธ์เสรี. (2522). **การศึกษาอิทธิพลของระดับน้ำที่มีต่อความอุดมสมบูรณ์ของสัตว์หน้าดินในอ่างเก็บน้ำเขื่อนอุบลรัตน์ จังหวัดขอนแก่น**. วิทยานิพนธ์ปริญญาวิทยาศาสตรมหาบัณฑิต สาขาวิชาสัตววิทยา. บัณฑิตวิทยาลัย มหาวิทยาลัยเกษตรศาสตร์.

มูลนิธิโลกสีเขียว. (2542). **คู่มือหาชื่อสัตว์เล็กน้ำจืด**. กรุงเทพฯ. แปลน พริ้นท์ติ้ง จำกัด.

ยรรยง อินทร์ม่วง, นฤมล แสงประดับ และ อุไรวรรณ อินทร์ม่วง. (2539). **การตรวจสอบคุณภาพน้ำแม่น้ำแบบใหม่โดยใช้ดัชนีร่วมทางฟิสิกส์ เคมี และชีววิทยา** (River Water Quality A New Assessment Method by Integrating Physicochemical and Biological Variables with Multivariable Analyses). ขอนแก่น. โครงการสนับสนุนองค์กรเอกชนสาธารณประโยชน์ ของกระทรวงสาธารณสุข.

รัชฎาภรณ์ กิตติวรเชฏฐ์ และเสาวคนธ์ วัลลีย์. (2535). การศึกษาชนิดของสัตว์หน้าดินที่พบในแม่น้ำพอง แม่น้ำชี และแม่น้ำมูล หลังวิกฤตน้ำเสีย. **วารสารการประมง**. 4 (3): 935-942.

วิลาสินี วัฒนาวงศ์ดอน. (2539). **การศึกษาเบื้องต้นสัตว์ไม่มีกระดูกสันหลังขนาดใหญ่ในบึงหนองเอียดมหาวิทยาลัยขอนแก่น**. ซีเนียร์โปรเจค. ภาควิชานิเวศวิทยาสิ่งแวดล้อม คณะวิทยาศาสตร์ มหาวิทยาลัยขอนแก่น.

ศุภชัย สิทธิเลิศ. (2528). ชนิด ปริมาณ และการกระจายของสัตว์หน้าดินในแม่น้ำท่าจีน. วิทยานิพนธ์ปริญญาวิทยาศาสตรมหาบัณฑิต สาขาวิทยาศาสตร์สิ่งแวดล้อม. บัณฑิตวิทยาลัย มหาวิทยาลัยเกษตรศาสตร์.

สมสุข มัจฉาชีพ. (2528). นิเวศวิทยา. กรุงเทพฯ: เจริญรัฐการพิมพ์.

อลงกรณ์ ผาผง. (2539). **การทดสอบการให้ค่าคะแนนแก่สัตว์ไม่มีกระดูกสันหลังหน้าดินเพื่อติดตามคุณภาพน้ำ**. ซีเนียร์โปรเจค. ภาควิชานิเวศวิทยาสิ่งแวดล้อม คณะวิทยาศาสตร์. มหาวิทยาลัยขอนแก่น.

Copyright by Mahidol University

อิสระ ธานี. (2537). **การศึกษาสัตว์ไม่มีกระดูกสันหลังหน้าดินในห้วยพรมแล้ง อุทยานแห่งชาติน้ำหนาว จังหวัดเพชรบูรณ์**. ซีเนียร์โปรเจค. ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยขอนแก่น.

Copyright by Mahidol University

# APPENDIX

Copyright by Mahidol University

# Appendix A

Table 1. Physico-chemical parameter in crossection of Phachi River on 1st campaign.

| Parameter / Location | DO (mg/L) | BOD (mg/L) | pH | conduct (μmhos/cm) | water temperature (°C) | depth (m) | Average current flow (cm/s) |
|---|---|---|---|---|---|---|---|
| 1(1) | 8.00 | 1.62 | 8.95 | 159 | 26.2 | 0.5 | 0 |
| 1(2) | 8.00 | 1.75 | 8.83 | 170 | 25.6 | 1.0 | - |
| 2(1) | 7.80 | 1.28 | 8.65 | 162 | 25.5 | 0.5 | - |
| 2(2) | 7.80 | 2.13 | 8.75 | 162 | 25.1 | 1.0 | - |
| 2(3) | 7.90 | 0.83 | 8.63 | 155 | 26.0 | 1.5 | - |
| 3(1) | 7.85 | 1.15 | 8.71 | 168 | 25.5 | 0.5 | 0 |
| 3(2) | 7.75 | 1.47 | 8.64 | 170 | 25.7 | 1.0 | - |
| 3(3) | 7.85 | 1.42 | 8.62 | 168 | 25.6 | 1.5 | - |
| 4(1) | 8.35 | 1.27 | 8.65 | 165 | 25.5 | 0.5 | - |
| 4(2) | 7.90 | 0 | 8.65 | 164 | 25.6 | 1.0 | - |
| 4(3) | 7.60 | 1.70 | 8.81 | 170 | 25.5 | 1.5 | - |
| 5(1) | 8.10 | 0.49 | 8.78 | 168 | 25.5 | 0.5 | 2.7 |
| 5(2) | 8.00 | 0.9 | 8.76 | 165 | 25.6 | 1.0 | - |
| 5(3) | 8.25 | 0.35 | 8.71 | 168 | 25.6 | 1.5 | - |
| 6(1) | 7.80 | 0.31 | 8.81 | 169 | 25.5 | 0.5 | - |
| 6(2) | 8.50 | 0.79 | 8.80 | 170 | 25.6 | 1.0 | - |
| 6(3) | 8.20 | 1.11 | 8.74 | 164 | 25.5 | 1.5 | - |
| 7(1) | 7.70 | 0.43 | 8.88 | 162 | 25.5 | 0.5 | 3.5 |
| 7(2) | 7.55 | 0.59 | 8.82 | 160 | 25.5 | 1.0 | - |
| 7(3) | 7.80 | 0.70 | 8.79 | 169 | 25.5 | 1.5 | - |
| 8(1) | 7.65 | 1.03 | 8.69 | 165 | 25.5 | 0.5 | - |
| 8(2) | 7.30 | 1.45 | 8.79 | 165 | 25.5 | 1.0 | - |
| 8(3) | 7.75 | 1.06 | 8.89 | 165 | 25.6 | 1.5 | - |
| 8(4) | 7.65 | * | 8.77 | 164 | 25.6 | 2.0 | - |
| 9(1) | 7.90 | 1.34 | 8.76 | 164 | 25.7 | 0.5 | 10.5 |
| 9(2) | 8.10 | 0.92 | 8.68 | 162 | 25.6 | 1.0 | - |

Copyright by Mahidol University

Table 1. Physico-chemical parameter in crossection of Phachi River on 1st campaign. (Continued)

| Parameter / Location | DO (mg/L) | BOD (mg/L) | pH | conduct (µmhos/cm) | water temperature (°C) | depth (m) | Average current flow (cm/s) |
|---|---|---|---|---|---|---|---|
| 9(3) | 7.75 | 0.15 | 8.61 | 169 | 25.5 | 1.5 | - |
| 9(4) | 7.45 | 0.44 | 8.72 | 168 | 25.6 | 2.0 | - |
| 10(1) | 7.50 | 1.09 | 8.69 | 169 | 25.5 | 0.5 | - |
| 10(2) | 7.70 | 0.45 | 8.58 | 163 | 25.5 | 1.0 | - |
| 10(3) | 7.60 | 0.18 | 8.75 | 165 | 25.5 | 1.5 | - |
| 10(4) | 7.60 | 0.56 | 8.69 | 168 | 25.5 | 2.0 | - |
| 10(5) | 7.65 | * | 8.74 | 170 | 25.5 | 2.5 | - |
| 11(1) | 7.60 | 1.46 | 8.75 | 165 | 25.5 | 0.5 | 24.67 |
| 11(2) | 7.25 | 0.7 | 8.76 | 168 | 25.4 | 1.0 | - |
| 11(3) | 7.50 | 1.75 | 8.81 | 160 | 25.4 | 1.5 | - |
| 11(4) | 7.55 | 0.62 | 8.74 | 168 | 25.4 | 2.0 | - |
| 11(5) | 7.60 | 0.45 | 8.64 | 168 | 25.3 | 2.5 | - |
| 12(1) | 7.35 | 0.83 | 8.76 | 168 | 25.4 | 0.5 | - |
| 12(2) | 7.50 | 0 | 8.70 | 164 | 25.4 | 1.0 | - |
| 12(3) | 7.90 | 0.64 | 8.72 | 165 | 25.3 | 1.5 | - |
| 12(4) | 7.55 | 0.71 | 8.66 | 169 | 25.4 | 2.0 | - |
| 12(5) | 8.29 | 0.45 | 8.77 | 168 | 25.4 | 2.5 | - |
| 12(6) | 7.90 | * | 8.64 | 169 | 25.5 | 3.0 | - |
| 13(1) | 7.20 | 0.52 | 8.63 | 164 | 25.2 | 0.5 | 43.33 |
| 13(2) | 6.80 | 0.59 | 8.57 | 165 | 25.3 | 1.0 | - |
| 13(3) | 7.40 | 1.22 | 8.52 | 165 | 25.3 | 1.5 | - |
| 13(4) | 7.45 | 1.05 | 8.64 | 168 | 25.1 | 2.0 | - |
| 13(5) | 7.55 | 1.25 | 8.61 | 164 | 25.2 | 2.5 | - |
| 13(6) | 7.40 | * | 8.47 | 140 | 24.8 | 3.0 | - |
| 14(1) | 7.10 | 1.05 | 7.42 | 151 | 24.9 | 0.5 | - |
| 14(2) | 7.35 | 0.80 | 7.46 | 152 | 24.7 | 1.0 | - |

Copyright by Mahidol University

Table 1. Physico-chemical parameter in crossection of Phachi River on 1st campaign. (Continued)

| Parameter / Location | DO (mg/L) | BOD (mg/L) | pH | conduct (μmhos/cm) | water temperature (°C) | depth (m) | Average current flow (cm/s) |
|---|---|---|---|---|---|---|---|
| 14(3) | 7.50 | 0.83 | 7.62 | 152 | 24.9 | 1.5 | - |
| 14(4) | 7.60 | 0.44 | 7.71 | 158 | 24.7 | 2.0 | - |
| 14(5) | 7.40 | 0.56 | 7.74 | 159 | 24.6 | 2.5 | - |
| 14(6) | 7.50 | 0.69 | 7.81 | 160 | 24.5 | 3.0 | - |
| 15(1) | 7.40 | 1.38 | 7.90 | 160 | 24.6 | 0.5 | 37.14 |
| 15(2) | 7.85 | 1.05 | 8.91 | 160 | 24.6 | 1.0 | - |
| 15(3) | 7.80 | 1.20 | 8.11 | 158 | 24.7 | 1.5 | - |
| 15(4) | 7.30 | 1.20 | 8.14 | 160 | 24.6 | 2.0 | - |
| 15(5) | 8.40 | 1.29 | 8.36 | 160 | 24.7 | 2.5 | - |
| 15(6) | 7.65 | 0.75 | 8.30 | 161 | 24.7 | 3.0 | - |
| 16(1) | 7.65 | 0.42 | 8.29 | 160 | 24.6 | 0.5 | - |
| 16(2) | 7.75 | 0 | 8.48 | 160 | 24.8 | 1.0 | - |
| 16(3) | 7.30 | 0.65 | 8.41 | 160 | 24.7 | 1.5 | - |
| 16(4) | 7.30 | 0.48 | 8.36 | 159 | 24.6 | 2.0 | - |
| 16(5) | 7.80 | 0.95 | 8.48 | 159 | 25.1 | 2.5 | - |
| 17(1) | 7.80 | 1.04 | 8.48 | 161 | 25.1 | 0.5 | 27.0 |
| 17(2) | 7.60 | 0.77 | 8.46 | 161 | 25.1 | 1.0 | - |
| 17(3) | 7.70 | 1.0 | 8.47 | 161 | 25.0 | 1.5 | - |
| 17(4) | 7.60 | 0.88 | 8.50 | 162 | 25.0 | 2.0 | - |
| 17(5) | 7.70 | 0.19 | 8.50 | 160 | 25.0 | 2.5 | - |
| 18(1) | 8.15 | 0.57 | 8.62 | 168 | 25.4 | 0.5 | - |
| 18(2) | 8.80 | 0.95 | 8.62 | 165 | 25.2 | 1.0 | - |
| 18(3) | 8.05 | 0.59 | 8.60 | 164 | 25.1 | 1.5 | - |

Copyright by Mahidol University

Table 2. Physico-chemical parameter in crossection of Phachi River on 2nd campaign.

| Parameters / Location | DO (mg/L) | BOD (mg/L) | pH | Conduct | Water Temp. (°C) | Depth (m) | Depth* (m) | Average current flow (cm/s) |
|---|---|---|---|---|---|---|---|---|
| 1(1) | 7.10 | 1.14 | 8.30 | 270 | 27.5 | 1.2 | 1.5 | 0 |
| 1(2) | 7.10 | 0.90 | 8.30 | 270 | 27.5 | 1.2 | - | - |
| 1(3) | 7.15 | 1.35 | 8.30 | 270 | 27.5 | 1.2 | - | - |
| 1(4) | 6.75 | 1.31 | 8.30 | 270 | 27.5 | 1.2 | - | - |
| 2(1) | 7.20 | 1.28 | 8.30 | 270 | 27.5 | 1.3 | 1.6 | 2.0 |
| 2(2) | 7.00 | 0.90 | 8.30 | 270 | 27.5 | 1.3 | - | - |
| 2(3) | 7.10 | 1.18 | 8.30 | 270 | 27.5 | 1.3 | - | - |
| 2(4) | 7.00 | 1.13 | 8.30 | 270 | 27.5 | 1.3 | - | - |
| 2B(1) | 7.10 | 1.01 | 8.30 | 273 | 27.5 | 0.8 | 1.6 | - |
| 2B(2) | 7.10 | 0.68 | 8.30 | 273 | 27.5 | 0.8 | - | - |
| 2B(3) | 7.50 | 0.97 | 8.30 | 273 | 27.5 | 0.8 | - | - |
| 2B(4) | 7.30 | 1.11 | 8.30 | 273 | 27.5 | 0.8 | - | - |
| 3(1) | 7.20 | 1.21 | 8.30 | 273 | 27.5 | 1.6 | 1.9 | 5.0 |
| 3(2) | 7.00 | 0.86 | 8.30 | 273 | 27.5 | 1.6 | - | - |
| 3(3) | 7.10 | 1.53 | 8.30 | 273 | 27.5 | 1.6 | - | - |
| 3(4) | 7.10 | 1.24 | 8.30 | 273 | 27.5 | 1.6 | - | - |
| 4(1) | 7.00 | 1.09 | 8.30 | 272 | 27.5 | 2.3 | 2.6 | 7.5 |
| 4(2) | 7.00 | 1.15 | 8.30 | 270 | 27.5 | 2.3 | - | - |
| 4(3) | 7.10 | 1.03 | 8.30 | 271 | 27.5 | 2.3 | - | - |
| 4(4) | 7.00 | 1.27 | 8.30 | 271 | 27.5 | 2.3 | - | - |
| 4B(1) | 7.00 | 0.90 | 8.29 | 272 | 27.5 | 1.3 | 2.6 | - |
| 4B(2) | 7.15 | 0.62 | 8.29 | 272 | 27.5 | 1.3 | - | - |
| 4B(3) | 7.05 | 0.85 | 8.29 | 272 | 27.5 | 1.3 | - | - |
| 4B(4) | 7.00 | 0.34 | 8.29 | 272 | 27.5 | 1.3 | - | - |

Copyright by Mahidol University

Table 2. Physico-chemical parameter in crossection of Phachi River on 2nd campaign. (Continued)

| Parameters / Location | DO (mg/L) | BOD (mg/L) | pH | Conduct | Water Temp. (°C) | Depth (m) | Depth* (m) | Average current flow (cm/s) |
|---|---|---|---|---|---|---|---|---|
| 5(1) | 8.00 | 1.26 | 8.28 | 270 | 27.0 | 2.6 | 2.9 | 16.0 |
| 5(2) | 7.10 | 0.96 | 8.29 | 270 | 27.0 | 2.6 | - | - |
| 5(3) | 7.20 | 0.78 | 8.29 | 270 | 27.0 | 2.6 | - | - |
| 5(4) | 7.20 | 0.76 | 8.29 | 270 | 27.0 | 2.6 | - | - |
| 6(1) | 6.80 | 1.18 | 8.30 | 265 | 27.5 | 2.85 | 3.15 | 15.0 |
| 6(2) | 7.40 | 0.97 | 8.33 | 270 | 27.5 | 2.85 | - | - |
| 6(3) | 7.10 | 1.12 | 8.32 | 268 | 27.5 | 2.85 | - | - |
| 6(4) | 7.20 | 0.86 | 8.32 | 268 | 27.5 | 2.85 | - | - |
| 6B(1) | 7.40 | 1.16 | 8.36 | 268 | 27.0 | 1.6 | 3.15 | - |
| 6B(2) | 7.30 | 1.18 | 8.33 | 270 | 27.0 | 1.6 | - | - |
| 6B(3) | 7.20 | 1.52 | 8.34 | 269 | 27.0 | 1.6 | - | - |
| 6B(4) | 7.30 | 0.94 | 8.34 | 269 | 27.0 | 1.6 | - | - |
| 7(1) | 7.10 | 1.32 | 8.31 | 275 | 28.0 | 2.4 | 2.7 | 8.5 |
| 7(2) | 7.30 | 1.08 | 8.28 | 272 | 28.0 | 2.4 | - | - |
| 7(3) | 7.20 | 0.85 | 8.30 | 274 | 28.0 | 2.4 | - | - |
| 7(4) | 7.20 | 0.64 | 8.31 | 274 | 28.0 | 2.4 | - | - |

Depth* = Depth of river from the surface of water to the bottom at location

B = Sampling at mid depth of vertical line

Copyright by Mahidol University

Table 3.1 Table of Paired samples t-test (1st campaign)

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | MDO1 | 7.8500 | 18 | .0000 | .0000 |
| | BDO1 | 7.8078 | 18 | .2597 | 6.121E-02 |
| Pair 2 | MBOD1 | .5500 | 18 | .0000 | .0000 |
| | BBOD1 | .8467 | 18 | .4552 | .1073 |
| Pair 3 | MPH1 | 8.7200 | 18 | .0000 | .0000 |
| | BPH1 | 8.6189 | 18 | .2468 | 5.817E-02 |
| Pair 4 | MCON1 | 163.5000 | 18 | .0000 | .0000 |
| | BCON1 | 164.9444 | 18 | 4.3720 | 1.0305 |
| Pair 5 | MTEMP1 | 25.5500 | 18 | .0000 | .0000 |
| | BTEMP1 | 25.3500 | 18 | .3634 | 8.565E-02 |

Copyright by Mahidol University

Table 3.2 Table of Paired samples t-test (1st campaign)

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | MDO1 - BDO1 | 4.222E-02 | .2597 | 6.121E-02 | -8.7E-02 | .1714 | .690 | 17 | .500 |
| Pair 2 | MBOD1 - BBOD1 | -.2967 | .4552 | .1073 | -.5230 | -7.0E-02 | -2.765 | 17 | .013 |
| Pair 3 | MPH1 - BPH1 | .1011 | .2468 | 5.817E-02 | -2.2E-02 | .2238 | 1.738 | 17 | .100 |
| Pair 4 | MCON1 - BCON1 | -1.4444 | 4.3720 | 1.0305 | -3.6186 | .7297 | -1.402 | 17 | .179 |
| Pair 5 | MTEMP1 - BTEMP1 | .2000 | .3634 | 8.565E-02 | 1.929E-02 | .3807 | 2.335 | 17 | .032 |

Copyright by Mahidol University

Table 4.1 Table of Paired samples t-test (2nd campaign)

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | MIDDEPTB | 1.0800 | 3 | .0000 | .0000 |
| | BOTTOMB | .8167 | 3 | .2650 | .1530 |
| Pair 2 | MIDDEPTP | 8.7600 | 3 | .0000 | .0000 |
| | BOTTOMP | 8.6367 | 3 | .1704 | 9.838E-02 |
| Pair 3 | MIDDEPTC | 163.0000 | 3 | .0000 | .0000 |
| | BOTTOMC | 165.2767 | 3 | 2.6307 | 1.5188 |
| Pair 4 | MIDDEPTT | 25.5000 | 3 | .0000 | .0000 |
| | BOTTOMT | 25.3667 | 3 | .3215 | .1856 |
| Pair 5 | MIDDEPTD | 7.6200 | 3 | .0000 | .0000 |
| | BOTTOMD | 7.7767 | 3 | .1704 | 9.838E-02 |
| Pair 6 | MDO2 | 7.0500 | 7 | .0000 | .0000 |
| | BDO2 | 7.1314 | 7 | .1259 | 4.758E-02 |
| Pair 7 | MBOD2 | .9000 | 7 | .0000 | .0000 |
| | BBOD2 | 1.0843 | 7 | .1050 | 3.969E-02 |
| Pair 8 | MPH2 | 8.2900 | 7 | .0000 | .0000 |
| | BPH2 | 8.3014 | 7 | 8.997E-03 | 3.401E-03 |
| Pair 9 | MCON2 | 272.0000 | 7 | .0000 | .0000 |
| | BCON2 | 270.7857 | 7 | 2.0332 | .7685 |
| Pair 10 | MTEM2 | 27.5000 | 7 | .0000 | .0000 |
| | BTEM2 | 27.5000 | 7 | .2887 | .1091 |

Copyright by Mahidol University

Table 4.2 Table of Paired samples t-test (2nd campaign)

Paired Samples Test

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | MIDDEPTB - BOTTOMB | .2633 | .2650 | .1530 | -.3950 | .9217 | 1.721 | 2 | .227 |
| Pair 2 | MIDDEPTP - BOTTOMP | .1233 | .1704 | 9.838E-02 | -.2999 | .5466 | 1.254 | 2 | .337 |
| Pair 3 | MIDDEPTC - BOTTOMC | -2.2767 | 2.6307 | 1.5188 | -8.8117 | 4.2583 | -1.499 | 2 | .273 |
| Pair 4 | MIDDEPTT - BOTTOMT | .1333 | .3215 | .1856 | -.6652 | .9319 | .718 | 2 | .547 |
| Pair 5 | MIDDEPTD - BOTTOMD | -.1567 | .1704 | 9.838E-02 | -.5799 | .2666 | -1.593 | 2 | .252 |
| Pair 6 | MDO2 - BDO2 | -8.1E-02 | .1259 | 4.758E-02 | -.1979 | 3.500E-02 | -1.711 | 6 | .138 |
| Pair 7 | MBOD2 - BBOD2 | -.1843 | .1050 | 3.969E-02 | -.2814 | -8.7E-02 | -4.643 | 6 | .004 |
| Pair 8 | MPH2 - BPH2 | -1.1E-02 | 8.997E-03 | 3.401E-03 | -2.0E-02 | -3.1E-03 | -3.361 | 6 | .015 |
| Pair 9 | MCON2 - BCON2 | 1.2143 | 2.0332 | .7685 | -.6661 | 3.0947 | 1.580 | 6 | .165 |
| Pair 10 | MTEM2 - BTEM2 | .0000 | .2887 | .1091 | -.2670 | .2670 | .000 | 6 | 1.000 |

Copyright by Mahidol University

# BIOGRAPHY


| | |
|---|---|
| **NAME** | Miss Naphaporn Vitsavakul |
| **DATE OF BIRTH** | 20 December 1963 |
| **PLACE OF BIRTH** | Bangkok, Thailand |
| **INSTITUTIONS ATTENDED** | Khon Kaen University, 1990:<br>Bachelor of Science (Public Health)<br>Sukhothai Thammathirat Open University, 1995:<br>Bachelor of Communication Arts<br>Mahidol University, 2004:<br>Master of Science (Technology of Environmental Management) |
| **POSITION&OFFICE** | Environmental Center Region 6 Nonthaburi, Nonthaburi, Thailand<br>Position: Environmentist<br>Tel. 02-9688398<br>E-mail: gartae_na@hotmail.com |
| **HOME ADDRESS** | 715/12 Soi Pornpipat Parnnok Road, Bangchalor Bangkoknoi, Bangkok, Thailand<br>Tel.02-4123106 |


Copyright by Mahidol University