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Part I — Distribution and Community Structure of Aquatic Macroinvertebrate Analyses

Part II — 1. The Performance of Biotic Scores and Indices in Assessing Water Pollution: a Case Study in the Pong Catchment of Northeast Thailand

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2. Diversity of Ephemeropteran and Trichopteran Adults

3. Preliminary Keys to Order and to Family of Selected Order of Immature Aquatic Insects of Thailand

By

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การศึกษาความสัมพันธ์ระหว่างสัตว์ไม่มีกระดูกสันหลังหน้าดินในแหล่งน้ำจืดกับปัจจัยคุณภาพสิ่งแวดล้อมในลุ่มน้ำพอง

นฤมล แสงประดับ ธรรยงค์ อินทร์ม่วง ชุติมา หาญจวณิช และจุไรวรรณ อินทร์ม่วง

บทคัดย่อ

ผลการศึกษาสัตว์ไม่มีกระดูกสันหลังหน้าดินด้วยวิธีการเก็บตัวอย่างเชิงปริมาณและตัวอย่างน้ำจากลุ่มน้ำพอง 24 สถานี แม่น้ำชี 3 สถานี จำนวนสถานีละ 6 ซ้ำ ทุก 2 เดือน เป็นระยะเวลา 1 ปี พบโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดินในลำน้ำพองตอนบนซึ่งมีการปนเปื้อนของสารอินทรีย์น้อยมีความหลากชนิดของสัตว์มากกว่าลำน้ำพองตอนล่างที่มีการปนเปื้อนของสารอินทรีย์มากกว่า พบว่าฤดูกาลมีผลมากต่อชนิดและความหนาแน่นของสัตว์ คือในฤดูฝนจะพบจำนวนชนิดและจำนวนตัวของสัตว์ลดลงอย่างมากเนื่องจากเกิดน้ำหลากพัดพาสัตว์ไปกับกระแสน้ำ

การวิเคราะห์ข้อมูลด้วยสถิติวิเคราะห์หลายตัวแปร พบว่าสามารถจัดจำแนกสถานีต่าง ๆ ได้ด้วยข้อมูลองค์ประกอบทางชีวภาพในแต่ละสถานีนั้น และสามารถแสดงปัจจัยทางเคมีฟิสิกซ์ที่มีความสัมพันธ์ต่อคุณภาพน้ำได้ พบตัวอ่อนแมลงชีปะขาวและตัวอ่อนแมลงหนอนปลอกน้ำมากในบริเวณแหล่งน้ำที่มีคุณภาพดี คือมีค่า DO สูง และ BOD ต่ำ พบตัวอ่อนแมลงสองปีก เช่น หนอนแดง (Chironomidae) มากในบริเวณที่มีสภาวะมีการปนเปื้อนของสารอินทรีย์สูง ตัวอ่อนริ้นน้ำกร่อย (*Chaoborus sp.*) พบมากในบริเวณที่มีค่าการนำไฟฟ้าสูง และพบไส้เดือนน้ำจืดซึ่งเป็นสัตว์ที่มีความทนทานมากที่สุดมีปริมาณมากในบริเวณที่มีการปนเปื้อนของสารอินทรีย์สูงมาก การเปรียบเทียบผลการวิเคราะห์ข้อมูลจากตัวอย่างสัตว์ที่เก็บด้วยวิธีเชิงปริมาณและวิธีเชิงคุณภาพ พบว่าการเก็บตัวอย่างด้วยวิธีเชิงปริมาณให้ผลการวิเคราะห์ข้อมูลที่น่าเชื่อถือทางสถิติมากกว่าการเก็บตัวอย่างด้วยวิธีเชิงคุณภาพ และเมื่อเก็บตัวอย่างด้วยวิธีเชิงปริมาณข้อมูลระดับวงศ์ให้ผลการวิเคราะห์เช่นเดียวกับข้อมูลระดับสกุลหรือชนิด

ระบบค่าคะแนน BMWP/ASPT และ/หรือดัชนี EPT และดัชนีความหลากหลาย Shannon-Weiner's index ล้วนเป็นวิธีที่ใช้ได้สำหรับประเมินการเปลี่ยนแปลงคุณภาพของน้ำจากการปนเปื้อนของสารอินทรีย์ แต่เนื่องจากค่าคะแนนระบบ BMWP/ASPT ยังไม่เหมาะสมกับข้อมูลสัตว์ไม่มีกระดูกสันหลังหน้าดินของประเทศไทยนัก ในการศึกษาครั้งนี้ได้พัฒนาดัชนีชีวภาพสำหรับจัดจำแนกคุณภาพแหล่งน้ำจืด 2 แบบ คือ (1) ดัชนีน้ำพอง โดยกำหนดค่าคะแนน 1-10 แก่สัตว์ไม่มีกระดูกสันหลังหน้าดินในระดับวงศ์ตามความทนต่อการเปลี่ยนแปลงสิ่งแวดล้อม โดยใช้ข้อมูลการกระจายและคุณภาพน้ำในลำน้ำพองแต่ละสถานีเป็นหลัก (คะแนนต่ำหมายถึงสัตว์มีความทนทานมากกว่า คะแนนสูงหมายถึงสัตว์มีความทนทานน้อยกว่า) และแบ่งระดับดัชนีในการจัดจำแนกคุณ

ภาพน้ำทางชีวภาพได้ 6 ระดับ และ (2) ดัชนี Q โดยแบ่งสัตว์ออกเป็น 5 กลุ่มตามระดับความทนทานต่อสารอินทรีย์แล้วพิจารณาสัดส่วนของสัตว์แต่ละกลุ่มที่ปรากฏในโครงสร้างของสัตว์ไม่มีกระดูกสันหลังหน้าดินในสถานีหนึ่ง ๆ และสามารถแบ่งระดับคุณภาพแหล่งน้ำได้ 5 ระดับ

นอกจากนี้ยังได้ศึกษาอนุกรมวิธานตัวเต็มวัยของแมลง 3 อันดับ คือ แมลงชีปะขาวพบ 6 วงศ์ 16 ชนิด แมลงสโตนฟลาย 1วงศ์ 1 ชนิด และแมลงหนอนปลอกน้ำ 8 วงศ์ 28 ชนิด ตามลำดับ และได้สร้างรูปวิธานเบื้องต้นระดับอันดับของตัวอ่อนแมลงน้ำ ระดับวงศ์ของตัวอ่อนแมลงชีปะขาว แมลงสโตนฟลาย และแมลงหนอนปลอกน้ำ

A Correlation Study between Freshwater Benthic Macroinvertebrate Fauna and Environmental Quality Factors in Nam Pong Basin Thailand

Narumon Sangpradub, Yanyong Inmuong, Chutima Hanjavanit and Uraiwan Inmuong

Abstract

Six replicates of benthic macroinvertebrate fauna and water chemistry samples were collected by quantitative method at each sampling site along the Pong river (24 sites) and Chi river (3 sites) bimonthly for one year. The results showed that the benthic community structure varies through time and space over the study sites, most benthic taxa were abundant in less impacted upstream waters but declined in downstream water disturbed by heavily organic pollution. The seasonal flooding caused a significant decrease in taxa and the abundance of most benthic groups decreased significantly during the rainy season.

The multivariate analyses were tested and the results revealed that classification of sites based on benthic fauna content and were well related to certain physico-chemical factors of water quality. Certain mayfly and caddisfly larvae were occurring very restricted to good environmental factors (i.e., high DO and low BOD). Dipteran larvae Chironomidae were found in water disturbed with organic pollution and *Chaoborus* sp. occurred in water with high conductivity. Oligochaetes were abundant and tolerated to heavily organic impact pollution. The statistical result of quantitative sampling methods was very significantly higher than the qualitative samples and data at family level provided a same result as generic and species levels.

BMWP/ASPT scores and/or EPT index and diversity indices, Shannon-Weiner's index were significantly correlated to organic water pollution. Due to BMWP/ASPT scores is not fitted to the benthic fauna of Thailand. Therefore, this study develops 2 biotic indices to classify the quality of freshwater as following: (1) Pong index based on family levels of benthic fauna distribution and water quality at each sampling site. The index scores assigned to 1-10 (low scores means strong tolerant groups, high scores means less tolerant groups) and there was 6 classes of biotic groups; (2) Q index based on general patterns of organism tolerance and ratio of presence/absence of organisms in benthic community at sampling sites and this index was classified water quality into 6 categories.

In addition, taxonomical study of adult insects of 3 orders was conducted. The results showed 6 families, 16 species of Order Ephemeroptera, 1 family, 1 species of Order Plecoptera and 8 families, 28 species of Order Trichoptera were recorded, respectively. The preliminary keys to order of aquatic insects and keys to families of Ephemeropteran, Plecopteran and Trichopteran larvae were constructed.

A Research Report on

A Correlation Study between Freshwater Benthic Macroinvertebrate Fauna and Environmental Quality Factors in Nam Pong Basin Thailand

Part I

Distribution and Community Structure of Aquatic Macroinvertebrate Analyses

by

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We also like to extend our grateful thanks to the senior and masters students of Department of Biology, Faculty of Science, Khon Kaen University, in helping us conducting a very hard field works. We are very appreciated to the staff from the Environmental Health Center Region 6, Department of Health, Ministry of Public Health, who also continuously help us in difficult tasks with sampling benthic samples and water chemistry.

Data analysis even with a very rather sophisticated techniques, we like to thank to Dr Peter McQuillan of the Centre for Environmental Studies, University of Tasmania, Australia, the one who simplifies such difficult analyses for us, and guiding us conducting our data analyses.

Many persons out there in the fields aid us finishing our works particularly at the remote countryside, including the staff from the Nam Cheon Conservation Unit, the Royal Thai Forestry Department, we are very thankful to these persons. We also like to thank the villagers at all around the sampling places, they are very pleased to help us handling all of the sampling gears, and kindly participating our sampling operation.

Narumon Sangpradub
Yanyong Inmuong
Chutima Hanjavanit
Uraiwan Inmuong

14 October 1996

Abstract

The study is aimed to conduct a series of research of Thailand aquatic benthic macroinvertebrate fauna. This study result is the first series of research activities which is primarily indicating what findings about our native macroinvertebrate taxa in the northeast region of Thailand. The faunal abundance, community structure and their relationships to environmental factors both in space and time are firstly analyzed and recorded in Thailand. The Pong catchment of northeast Thailand is selected to be the region investigated. Distribution of benthic taxa at a basin wide scale with bimonthly samplings of 27 established locations is extensively examined.

The aquatic macroinvertebrates are sampled, of shallow waters by the US Standard Surber where at deeper waters the US Standard Ekman Grab is used. Six replicates are applied at each sampling site both with fauna and water chemistry samples. The benthic specimen is identified to possibly at lowest taxonomic level by available keys. All of the discovered species are recorded, and establishing them as a specimen collection at Department of Biology, Khon Kaen University, for later uses. Water physicochemical analyses follow the US Public Health Association standard methods. The univariate analyses are used to generalize the benthic taxa variations. Current multivariate analysis methods are applied, in which the benthic taxa are classified by the polythetic divisive clustering (TWINSPAN) and ordinated by the semi-strong hybrid multidimensional scaling (SSH). The relationships between benthic taxa assemblages and environmental factors use the correlation analyses.

The study explores a certain facts of our native benthic macroinvertebrate species which determined by some environmental variables. All species of Perlidae, some Ephemeroptera and Trichoptera species are occurring very restricted to good environmental quality. The physical factors, for examples, discharge, river dimensions, substrate types and turbidity have major influences on benthic taxa assemblages. The BOD, DO and nitrate, phosphate and dissolved chloride ion are chemically revealed to have a very critical effects on benthic taxa communities. The aquatic benthic taxa are temporally and spatially varying in species occurrence and community patterns. There is a clear distinct difference between benthic species and community structure of the impacted and less impacted sites. The benthic taxa, by using both indicator species and community composition, can be effectively applied in quantifying the degrees of environmental impact at a site through time and space.

The multivariate procedures, the TWINSPAN and SSH, are tested, and the results reveal that they can perform effectively in grouping the sites based on faunal content. Moreover, the reference sites can be evidently created by these two techniques. The grouped sites arranged by the TWINSPAN and SSH are well related to certain environmental factors. The intensity of each environmental factor due determine on the benthic community can be drawn from the results of the TWINSPAN and SSH. Critically, the multivariate procedures show the more pristine sites having more diverse species while the severe impacted sites occupying only minute species numbers. This is viewed that the multivariate procedure will be a very much useful tool in quantifying the degree of "biodiversity".

However, what is found by this study is only at a starting stage in this area of research in Thailand. There are yet to be a series of research needed to be done by this study

as to fulfill much understanding about our native macroinvertebrate taxa, which they have never been comprehensively studies before. It is expected that such the next series of this research would conduct a more detailed biological studies of a particular group of these taxa. Also, the appropriate investigations which may include the studies of biotic indices, qualitative sampling approach and even initiating the rapid bioassessment method. All of those need more supports on both by resource persons and research funds. As the country lacks knowledge, experiences and several available techniques in this area of research, overseas experts are also expected to actively institutionally participate and assist our studies.

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1 An overview

This report is aimed, at this stage, to primarily report of what is found in the first year of benthic macroinvertebrate reconnaissance of northeast region Thailand. This research is in fact being one of the pioneer studies in freshwater fauna research of the country, as currently with a very few studies done in Thailand. The result by this report is expected to contribute significant knowledge principally associated with macroinvertebrate fauna existing of the country, particularly in northeastern region of Thailand. Further, faunal distribution pattern is analysed and any feasible correlations between faunal structure and environmental factors are examined.

Certain pattern correlation from data analysis is anticipated to characterise some forms of species being determined by environmental attributes. Some indicator species of Ephemeroptera, Plecoptera and Trichoptera (EPT) for examples are well understood by overseas nature conservation authorities that these species can reveal degrees of "healthy ecosystems". It is almost certainly that wherever any healthy ecosystems existed, these species are relatively much more abundant. Currently, most European and North American nations they adopted a routine programs assessing their water resources towards this end. In response to such notion, this study then needs to generate particular hypotheses in the following years whether we can assess our healthy environment via our native benthic fauna or *vice versa*. Prior to doing this exercise, our native benthic fauna communities have to be surveyed and recorded. Their correlations associated with environmental variables are likewise fundamentally to be understood.

Even a large numbers of document published by overseas researchers, who studying taxonomically about freshwater benthic fauna and their uses in environmental impact assessment, it is of a very limited published papers found to date within Thailand. Knowledge of benthic fauna taxonomy in Thailand is very limited, and thus this causes a hardship for anyone who likes to study benthic species distribution and their abundance at both local and regional scales. More recently, as this approach is internationally becoming one of common tools used in quantifying biological resources availability within a country, and that to a major extent namely "biodiversity", the studies associated with freshwater benthic animals in Thailand have been increasingly received much attention.

Applying benthic fauna both communities and species methods for biologically assessing water resources as practicing internationally, this would be viewed not easily possible application within Thailand as due to such limited preceding available studies. Not only Thailand which faces difficulty in studying this faunal group but also as to many Asian countries which recently Rundle *et al.* (1993) once concluded that knowledge of freshwater invertebrate fauna in Asia is still very scarce in terms of both community ecology and taxonomy.

Only taxonomy and biology of freshwater mollusc group is at present being well published and available for later study (see more details in Brandt 1974, Upratham *et al* 1995), aquatic insect larva, however, as a major group of benthic living fauna are very rarely documented. Thus, any attempt associated with studying aquatic insects within this country will be very important issue as such that exercise will generate significant knowledge of our native benthic fauna contributing to the country. Of among biological disciplines in Thailand Bimai (1995) reported that aquatic entomology is now at the top priority, and thus the country needs to develop quite a large number of scholars in order to placing them in entomological diversity investigation works.

This study is attempting to investigate distribution of macroinvertebrate fauna and also their taxonomy. Even such approach by this study is rather difficult but with an increasing need for nature conservation in Thailand, this type study is considerably very essential. Most recently Inmuong *et al.* (1996) noted that the biological method by using benthic macroinvertebrate fauna is proved to be an effective tool in assessing water pollution degrees in Thailand. However, what they concluded is from the data collected limited to only one of the waterways and they recommended that a catchment wide study is still needed. Unlike international practices, biological methods other than coliform bacterial counts have never been employed to assess water quality in Thailand. This study may be viewed as the first attempt of the country in investigating whether benthic macroinvertebrate communities would characterise a reliable information relating to various environmental stresses. Further, knowledge of benthic fauna taxonomy and community is anticipated to be initially subsequently achieved by this study, and that their applications to ecosystems and water resource conservations can later be applied.

The term "benthic macroinvertebrate fauna" used here, and as agreement to what stated elsewhere, is referred to aquatic faunal groups consisting mainly of insect larvae, molluscs, crustaceans and aquatic earthworms. All of these fauna some spend all of their life in waters, and others inhabit partly in waters while their adult stage living on terrestrials. These aquatic fauna may be grouped by orders i.e. Ephemeroptera, Plecoptera, Trichoptera, Odonata, Hemiptera, Diptera, Coleoptera, Megaloptera, Lepidoptera, Isopoda, Decapoda, Mollusca and Oligochaeta. Nevertheless, none of these fauna are well understood in Thailand, it is only a few number of papers currently available which relating to Trichopteran adults studied in Chiang Mai Thailand by some investigators (see for examples in Chantaramongkol and Malicky 1989, Malicky and Chantaramongkol 1993). At larval stage, largely there is only a few preliminary studies appeared recently as being the fourth-year student projects and some are master's theses (for examples in Rajchapakdee 1992, Thanee 1994, Panreansaen 1995).

A basin-wide scale study by looking at a distribution of aquatic fauna in Thailand has never been existed so far even current publications revealed that this approach can be applied as one of the major tool in measuring local and regional biodiversity. In addition to this, information from these faunal distributions can be used to assess degrees of biological (environmental) integrity (quality) of the lands, as similar to what are practicing in UK and USA (see for examples in Loeb and Spacies 1994, Bunce 1994). Moreover, benthic macroinvertebrate fauna method is currently included in the standardised methods in assessing water quality impacts by human and natural disturbances in North American and most European countries, or even develop them to be the biotic scores available for ecosystems quality classification, all of these approaches are lately summarized by Rosenberg and Resh (1993).

This study is then tailoring to meet what is lacking in this area of research within the country by firstly attempting to reconnaissance distribution of benthic fauna at a catchment scale. The Pong river catchment locating in northeast Thailand is selected to be the site investigated.

Secondly, state-of-the-art of data analysis techniques are also used to characterise data pattern which later can be applied for interpreting the research results. It should be noted that such available techniques are also worthy to test whether they would probably be working when applying in the Thai environment. It is also expected that the results from these spatial and temporal surveys by this study will considerably contribute the facts of the numbers and species of aquatic fauna inhabiting within this catchment. Also, most importantly, it will be significantly leading to the development of knowledge and understanding of our native aquatic macroinvertebrates.

2 Sampling site description

Twenty-seven sampling sites are established from upstream highlands and downstream lowlands, and all of the sites are locating spreading over the Pong catchment. Fig. 1 shows detailed locations of the sampling sites. All of the sampling sites lie between 16° 00′-17° 15′ N and 101° 15′-103° 15′ E with altitudes range from 600 to 100 M.S.L. Three main rivers are sampled namely the Pong, Cheon and Chi. Upstream sites are H01-H04 which of the Cheon river and P01-P03 of the Pong river, where stations N01-N05 and P04-P05 are locating in the intermediate zone of the Cheon and Pong rivers, respectively. Other sites (P06-P15 and C01-C03) are classified as downstream lowland sites.

Among all sites, the site H01 (Hin Lek Fai) is the only site which having minimal human perturbation as it locates in the Nam Nao National Park while the other sites are received various degrees of impacts through the year from both human and natural disturbances. The lower sites, particularly the sites which locating close to city boundary, are relatively much more disturbed than the upper sites.

The upstream lands are modified mainly for agricultural farms, while the lower downstream sites are of mixed extensively uses for rice and cassava fields, large to small industrial establishments and community residences.

River waters of the catchment are regulated and abstracted for agricultural, industrial and community uses, particularly of along the lower parts of the river length. Channel morphology of both the Pong and Cheon rivers are relatively narrow at upstream highlands with comparatively rapid current, while their channels become much wider at lowland downstream with somewhat slow speed. The river depths are shallower at upstream and relatively deeper at lowland sites.

Vegetation community along the river banks are relatively dense at upstream while downstream zones the riparian flora are growing rather sparsely. Except the site H01, all of the remaining sites the river banks are modified for planting crops and or partly being cruising ramp. At some river stretches, the banks are well protected by vegetation community and thus less soil erosion can be observed, for examples at sites P08 and P09. In contradictory, at upstream sites where the banks are heavily modified, for examples at sites H02 (Huay Chan), H03 (Tad Fa), P01 (Na Noi), P03 (Pa Nokao), surface run-off from the lands to river waters are immense.

The Pong river originates from the seepage spring which locating almost at the center of the Phu Kradueng National Park. The first site of the Pong river P01 locates approximately 30 km. from that origin. The subsequent sites of the Pong river locate all throughout the river length till the last station P15 (Kok Noi) which is 315 km. from the river origin. The Pong river drains southwesterly passing through agricultural lowlands, industrial areas and various communities, i.e. district towns, suburbs and city centers.

The Cheon river originates from the Nam Nao National Park, the first sampling station H01 locates 35 km. from the river origin in which the waters upflowing from underneath the Tham Yai cave. The Cheon river flows southwesterly through extensive corn fields at highlands and large lowland rice fields, and eventually draining into the Pong reservoir.

The water networks of the lower catchment where beyond the Ubolratana Dam forming into only one main channel also namely "the Pong". The Pong river is eventually joined by the Chi river at about the vicinity where locating immediately above the Mahasarakam Dam (see Fig.1).

The flowing waters of the lower Pong catchment are almost entirely regulated and influenced by three Dams operations, the Ubolratana Dam, the Nong Whai Weir and the Mahasarakam Dam. Thus, the fluctuation of the lower Pong water levels are mostly depending on the functions of those three Dams.

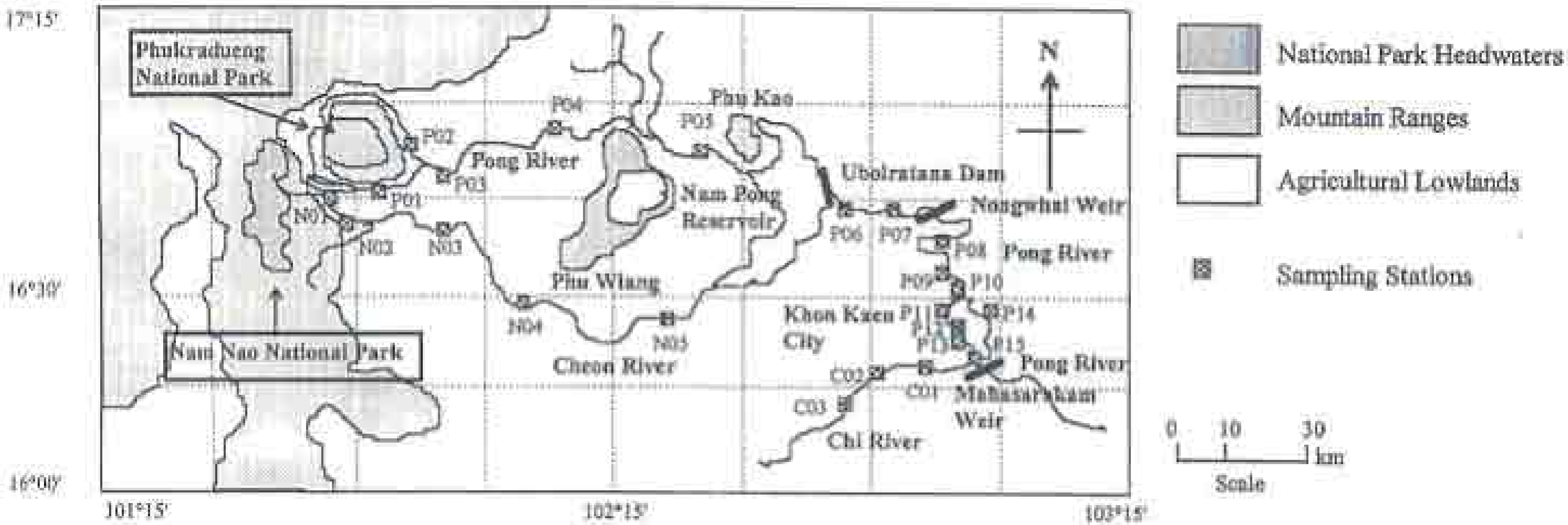


Figure 1 Location map of sampling sites across the Pong catchment.

3 Material and methods

Six replicates (sampling units) are sampled at each sampling sites following the replicate numbers caculation method recommended by Elliot (1978). A certain stretch of river waters at each sampling site with approximately 100 m. length is marked and that six replicates are sampled randomly at this stretch. Sampling both benthic fauna and water chemistry is conducted bimonthly, from October 1995 to August 1996.

Benthic fauna are sampled following the methods recommended by Davies (1994). 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 waters at downstream sites. The boat is also used to sample animals and water chemistry of that deeper waters. Sampling river waters uses 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. All of water chemistry analyses follow the standard methods described in APHA (1992).

Benthic samples (fauna plus sediments) recovered are beforehand preserved with 90% ethyl alcohol and kept in polyethylene plastic bags which later brought to the laboratory. Sieving benthic fauna uses the US Standard Sieve with 500 µm. mesh size screen. Benthic samples are then placed on white trays and sorted by eyes using the forceps. The specimens are preserved with 70% ethyl alcohol contained in vials and eventually labeled. All of the specimens are tried to identify them till to possibly at lowest taxonomic level, and further keeping and establishing them as a specimen collections for later references at Department of Biology, Khon Kaen University.

All available keys are used, these are of the North American Keys (Lehmkuhl 1979, McCafferty 1983, Merrit and Cummins 1984), European Keys (Edington and Hildrew 1981, Wallace *et al.* 1990), Chinese Keys (Morse *et al.* 1994), Malayan Keys (Fernando and Cheng 1963) and Thai Keys (available only mollusc) (Brandt 1974, Upratham *et al* 1995). Most of faunal specimens can be identified at best lowest taxonomy to generic level by using these keys.

4 Data analyses

As faunal data are from two capture equipment sources, the Surber and the Grab, thus the average organism density per square meter is calculated prior to applying any statistical analyses.

Data analyses use both univariate and multivariate techniques. All data are statistically examined, and transformation is applied when necessary as to improve normality. Water chemistry and faunal variables are generally described and compared by conventional univariate analyses, both parametric and non-parametric procedures (e.g. ANOVA, regression, Kruskal-Wallis etc.).

All multivariate data analyses use the software PATN (Belbin 1995). The sampling sites are classified using Polythetic Divisive Hierachical Clustering method, namely Two-Way INdicator SPecies ANalysis (TWINSPAN) in PATN, these classification results are based on faunal family composition at a site. Also, all of the sites are ordinated using Semi-Strong Hybrid Multidimensional Scaling Method (SSH).
Significant associations between the TWINSPAN grouped sites and environmental attributes are employed the Kruskal-Wallis test. Spatially and temporally correlation between the SSH axes and environmental variables at a site is analyzed using the Pearson-Product Moment method. The vectors of species (families) and environmental variables are created by the PCC option in PATN. These vectors will be featuring the influences of the attributes (faunal families or environmental variables) relating to the sites' position of the plot.

Initial assumption should be made here is that all of the faunal data used for multivariate analyses are limited to using only family level data (present and absent). However, some forms of analysis results will use faunal data at generic level. The "genus" here also means "species" where the voucher system is established to differentiate all specimens collected. The multivariate data analysis is aimed at seeking for a generation of data structure of macroinvertebrate fauna as which varying by time and space. Such faunal data results created by the multivariate procedures will be later analyzed for any relationships between taxa inhabiting versus environmental variables.

5 Results

5.1 Spatial and temporal variations of macroinvertebrate fauna

Sixty-four families with one hundred thirty species are explored and recorded by this study from five sampling occasions during October 1995 to June 1996. The numbers of families and species are higher at the upper sites and these numbers decrease significantly at downstream sites. Sampling benthic fauna in February 1996 apparently yields comparatively highest average numbers of both faunal species and individuals.

Abundance of macroinvertebrate fauna of all five sampling occasions is markedly varying by time and space. Of all 27 sites investigated, the density of individuals of macroinvertebrate fauna, on the average, ranges from 2334.16 to 4946.91 organism/m^2 which the maximum occurs in February and the minimum in April (Table 1). Fig.2 shows the abundance of macroinvertebrate fauna of all 27 sampling sites.

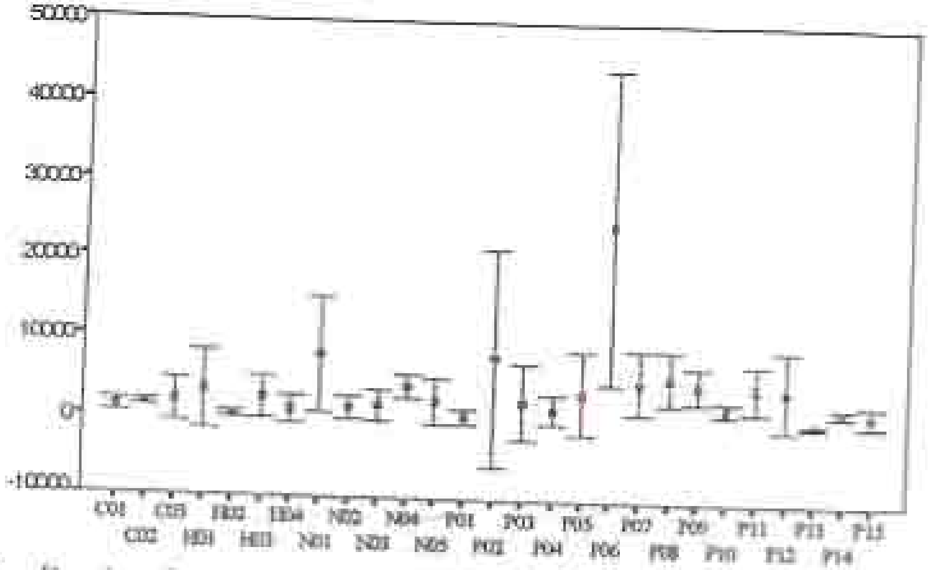


Figure 2 Density of macroinvertebrate organisms from all sampling occasions at all sites of the Pong catchment (±95% Confident Interval).

The minimum organism per m^2 belongs to the site P13 (Pra Kuae) in June 1996, 44.44 organism/m^2 , while the site P06 (Nong Tae) has the maximum density in the same month, 49333.33 organism/ m^2. There is a very much different in density values of individuals when comparing them by bimonthly samplings ($F_{(26,108)}$=4.4167, P<0.001). Table 1 shows more details the density of individuals and species of all five sampling occasions.

Table 1....... Bimonthly average individual densities and species numbers by combining all of the sampling sites.

Month	Density of organisms (Mean ± SD)	Number of species (Mean ± SD)	Number of sites (N)
October, 1995	3111.52 ± 6059.26	7.77 ± 3.42	27
December, 1995	4331.68 ± 5879.22	9.70 ± 6.23	27
February, 1996	4946.91 ± 4541.81	10.15 ± 7.18	26
April, 1996	2334.15 ± 2617.66	7.38 ± 4.04	26
June, 1996	4230.86 ± 9297.67	8.29 ± 6.38	27

SD = Standard deviation

All of the faunal abundance measured by density shows very high deviations in values. The most deviated density level is in June sampling occasion (Table 1). This may be largely due to the effects of flooding during monsoon season. While in February, the late cool month, the faunal density indicates less variation. However, as all of the density values appeared in Table 1 are still highly deviations, thus it implies that the faunal density of all sites at each sampling month is very intensively varied.

Species abundance is also very diverse from upstream to downstream locations (Fig. 3). The ANOVA test shows a very significant bimonthly variation of species numbers ($F_{(26,130)}$=8.37, p<0.0001). The maximum species number occurs since ever sampling is 29 species, which is at site H03 in December 1995, and at H04 in June 1996. Of among 29 benthic species inhabited at H03 in December 1995, the major taxa are Trichoptera plus Ephemeroptera species which accounting for 12 species of the total species numbers. The site H04 in June, that similar highest taxa number, 29, also belongs to these groups, but they increase in numbers with each of 8 Trichoptera and Ephemeroptera species has been found.

The site H03 (Tad Fa) locates almost at the top of the south Nam Nao valley, 620 M.S.L., where most of the lands have been cleared for corn fields. Vegetation strips along the stream bank are relatively plenty and thus becoming a buffer zone for aquatic faunal reproduction. Still, patchy of trees can be observed locating sparsely on this land. The water of this site is relatively clear during December and February with comparatively low levels of biochemical oxygen demand (BOD), averaging 1.77 and 4.25 mg/L, and high dissolved oxygen (DO) levels, with the mean 7.8 and 7.65 mg/L. The waters also have rather steady low current speed at this time of the year with approximately 0.16 and 0.00 m/s (non detectable by the flow meter).

The site H03, like other sites, has a certain trend of species numbers fluctuated throughout the year. The species number increases from October with 14 species found till reaching the maximum number 29 species in December 1995 and lastly the species numbers begin to decrease with a minimum of 13 species found in April 1996. The last sampling month in June the number of species found is increased up to 23 species.

Once at a sampling time in December 1995, one organism of the trichopteran goerid *Goera sp.* is explored from six replicates in this site. This is the rare species which is not normally found in lowland areas. The other sensitive species found are of the mayflies groups, these are heptageniid *Heptagenia* sp., (7.41 specimen/m^2) leptophlebiid *Choroterpes* sp. (14.81 specimen/m^2) and two ephemerids *Litobrancha* sp. (3.70 specimen/m^2) and *Ephemera* sp. (22.22 specimen/m^2).

It should be noted that the above assigned sensitive taxa may be troublesome to southeast Asian tropical environment. Grading sensitivity of those taxa groups are preliminarily following the ranges of tolerant values of each faunal family and the score are given to a group of families, thus finally leading to establishing several similar indices for categorizing these faunal families, for examples, the scores as appeared in Hilsenhoff (1988), BMWP (Spellerberg 1991) and Chessman (1995). Those scores are in fact similar in nature and they appear to be widely accepted by many countries, for instances, in continental Europe, South African countries, some states of U.S.A., (for examples, Maine, Oregon, Ohio, Idaho) and Australiasian plus some south pacific countries. However, such a consensus of the scores of among those countries is indeed resulting from the agreement as those countries have extensively studies their native macroinvertebrates, and in particular the ecotoxicology have been tested against each of benthic faunal family.

This study, at this stage, is then considerably likely to lend the above categorized families by which using them for generalizing our macroinvertebrate taxa in relation to environmental factors. Major reason is that our discovery reveals a certain facts of findings the occurrence of those families are principally determined by different environmental qualities, and this is largely following the overseas notes. In other words, the sensitive taxa are frequently found in the pristine areas or at the good environmental quality sites, the more tolerant taxa are normally discovered widespread, and only a certain family found at the severe polluted sites.

We find that most of the scored taxa mentioned above are likely to be applied in our environment, but there seems to be a limitation of using that scores in some taxa. For examples, we are getting into the doubtful score of ephemerid taxa, where these groups are classified as sensitive species in the continental Europe, but rather they do not appear to be categorized as the sensitive species in the some countries, for examples, Australia (see Chessman 1995). By this study, we discover these taxa rather widespread in our catchment, especially in rainy season at some lowland sites. It may be worth to have a further study about this type of taxa whether they are very much sensitive or not such as in the tropical environment.

As mentioned earlier that we often find these taxa group in lowlands especially during flooding period, particularly at when relatively cleaner waters become available but not absolutely good quality as such. This may be the case in raising the point of recategorizion these taxa score into the rather moderate tolerant taxa as in the tropical zone, rather than putting them into the very pristine high quality environment, as appeared in other countries. However, many research needed to be done within tropical countries associated with this issue. What are doing here, it is just a tentative record for our country by lending some available scores from overseas for generalizing our results that we have been discovered.

When considering the variations of macroinvertebrate species across the catchment. A more widespread trichopteran species found from this site H03 to other lowland upstream sites is *Ecnomus* sp. (Ecnomidae) and *Polycentropus* sp. (Polycentropodidae) while Ephemeroptera species are *Ephemera* sp., (Ephemeride) *Baetis* spp. (Baetidae) and *Litobrancha* sp (Ephemeride). Hydropsychidae is another trichopteran family which inhabiting almost everywhere particularly at the site having not very much pollution.

The most abundant organism of trichopteran species at H04 in June 1996 is hydropsychid *Ceratopsyche* sp. with its density 20.37 specimen/m^2. Two well known sensitive trichopteran taxa are also discovered at this site, these are leptocerid, *Triaenodes* sp. (11.11 specimen/m^2) and molannid, *Molanna* sp.(1.85 specimen/m^2). The highest mayflies taxa density occurred at this site is ephemerid *Ephemera* sp., (88.89 specimen/m^2). Apart from ephemerid taxa itself which included in the high sensitive mayflies species, this site also has the fragile sensitive heptageniid, *Heptagenia* sp. (46.30 specimen/m^2).

This site, H04, is just returned from drought, particularly at the very dry period February to April, and the waters are only available about a month or so. Referring to the density values and sensitive taxa above, this site is rather more enhancing microhabitats for the mayflies species reproduction during this time of the year. This site also has very much shading, and the substrate is mainly bed rocks. Subsequently, certain mayflies larvae are greatly abundance.

The most severe impacted site is P13 which had highest BOD (see more details in Appendix 2) since it is greatly affected by organic pollution discharged from Khon Kaen city, it is much obvious that Diptera Chironomidae is the only major taxa dwelling in this site (see Appendix 1). Plafkin *et al.* (1989) documented that Chironomidae is the specific taxa can be used to characterise organic pollution.

The site H02 (Huay Chan) even receives markedly impacts by surface run-offs from nearby corn fields, it is almost always discovering *Sialis* sp. (Sialidae) inhabiting at this site of all sampling occasions. It is worthy to note that all of the three sampling sites where finding these megalopterans are rather locating at high altitude and the weather at these sites is quite cool all year round. The possible hypothesis may probably be raised here is that whether the climate and landscape are far conditioning flourishing this type of taxa rather than the water pollution *per se*.

The occurrences of other faunal groups except caddisflies, mayflies and stoneflies are rather widespread both at highlands and lowlands.. Hemiptera fauna, for examples, *Tenagobia* sp. (Corixidae) and *Rhyacobates* sp. (Gerridae) are abundant at edgewaters in almost all sites.

Odonatan Gomphidae family found mostly elsewhere, Coenagrionidae, is mainly discovered only limited to upstream places

Coleoptera groups especially riffle beetles Elmidae *Stenelmis* sp., *Hexacylloepus* sp. and *Cleptelmis* sp. are also plentiful at upstream sites where scarce at downstream reaches. Coleopteran Gyrinid especially the shiny *Dineutus* sp. and water-penny Psephenidae are only inhabiting at upstream clean waters.

Another rarest aquatic insect taxa is Megaloptera. Two families of Megaloptera are explored here Sialidae alderflies and Corydalidae dobsonflies. Only three sites H02, H03, H04 are found Megaloptera fauna dwelling. Two species are recorded here *Sialis* sp. (Sialidae) and *Neochauliodes* sp. (Corydalidae), the first species is discovered frequently where inhabiting at sites H02 and H03 while the latter species is limited to site H04.

Unlike North American and European researchers, for examples as in Lehmkuhl (1979), who document that the blackflies dipteran Simuliidae larvae are very common and widespread in their waters, by this study, in contrast, this faunal group is found dwelling only at upstream clean water highlands. Only one Simulid species is discovered so far which is *Simulium* sp. This family is inhabiting in clean waters (Hellawell 1978). Common craneflies (Tipulidae) is another dipteran taxa explored where inhabiting only at upstream sites.

Another interesting dipteran taxa phenomenon is that the occurrence of the phantom midge *Chaoborus* sp.(Chaoboridae). This taxa is found being very tolerant to high level of BOD, conductivity and total dissolved solids (TDS). As a high level of both conductivity and TDS in this study is mainly from chloride content (see Appendix 2). In fact, the causes of chloride contamination in water bodies are from both domestic and natural induces.

The sites locating close to the city, for examples, P12 (Lueng Plei), P13 (Pra Kuea) and P14 (Ta Hin) are impacted by community sewage discharges, and these sites also have comparatively high BOD and TSS values.

High chloride levels of other sites, i.e. C01 (Don Bom), C02 (Ta Pra) and C03 (Ton), are influenced by natural cause which mainly resulting from rock weathering, as some parts of the land are geomorphologically bearing by rock salts. Even waters are affected by critical contaminants from human and natural induces, however, the *Chaoborus* sp can dwell tolerantly to high chloride, BOD and TSS contents, and thus being one of among indicator species associating with pollution found by this study.

Of all dipteran taxa, at this stage, it can be summarised that both Chironomidae and Chaoboridae are highly tolerant to gross organic pollution and heavy dissolved solids. Further, it is more interesting that from all of sampling occasions there have never been found any *Chaoborus* sp. existing in all upper catchment sites except N05 (Nong Pai) and P05 (Kok) which are the last upper sites locating immediately above the Ubolratana Dam. More specifically, in June 1996, the most impacted site P13 discovers only *Chaoborus* sp. dwelling.

5.2 Sites comparison

All of the sampling sites can be divided, according to their locations, into the upper and lower catchment sites, the upper sites are H's and N's of the Cheon river and P01-P05 of the Pong river, whereas the remaining sites (P06-P15 and C01-C03) are classified as the lower catchment sites. The statistical t-test shows a significant difference between the faunal density of the upper and lower catchment sites ($t_{(181)}$-5.38, $p<0.001$).

The upper watershed grouped sites have an average 10.94 species occupying whereas on the average only of 6.28 species inhibiting in the lowland sites. When considering the trend of the species deposited at all sites, it is obviously clear that the sites of the upper Cheon river particularly H01, H03 and H04 have far greater numbers of species than of the Pong (P's) and the Chi rivers (C's), Fig.3. Both sites of the Cheon river H03 and H04 have outnumbers of species more than any other sites.

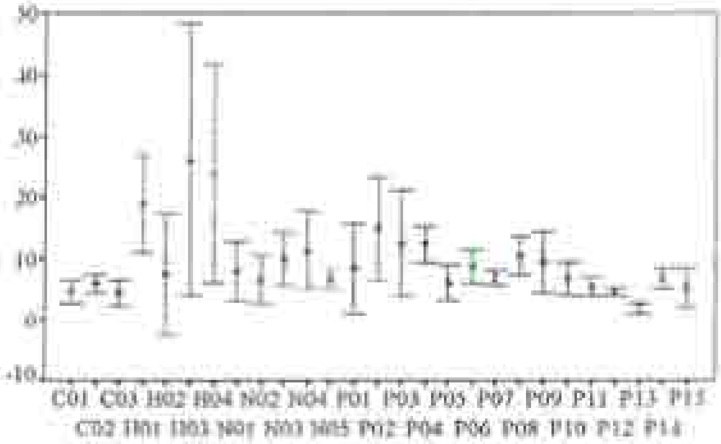


Figure 3 Average number of species abundance of all 27 sampling sites (±95% Confident Interval)

Even the two sites H03 and H04 have comparatively higher numbers of species assemblage but their temporal range of species of these two sites are distinctively large. The site H01, in contrast, has a rather less deviated species numbers, and also the mean species number is also comparatively high. The site H02 even locates in the same plain of the H's sites but this site is severely affected by land modifications for corn fields, thus the number of species appears markedly decreasing. The mean species of H02 is approximately similar to any lowland sites which having extensive impacts from human activities.

The statistical t-test shows no significant difference between the upper Pong river sites (P01-P05) and the Cheon river sites (H01-H04 and N01-N05)($t_{(86)}$ = 1.05, P>0.05

and $t_{(66)}=-0.38$, $P>0.05$). Even the mean species number of the Cheon sites (Mean=15.64) is comparatively higher than the Pong sites (Mean=10.92), but the number of species of the Cheon sites is fairly deviated with its higher standard deviation (SD=12.04) than that of the upper Pong sites (SD=5.88).

The site which having minimal deviation of species number is H01 (Fig.3). This site also reveals a rather consistent species numbers inhabiting through all sampling regimes (see also Appendix 1). The rarest benthic taxa plecopteran family Perlidae is very often found at this site. Two species wished to be recorded here, *Neoperla* sp. and *Phanoperla* sp. These "common stoneflies" are evidently known to occur limited to a high environmental quality. The occurrences of Perlidae taxa are also somewhat restricted to some sites, i.e. P01, P02, P03, P04, H01 and N01 (Wat Thamkayasit), where P04 (Huay Sainang) is the lowermost site which found this taxa inhabiting (see Fig.1 and also Appendix 1).

The Perlidae is found quite limited to a certain times and places of the year. It is also obvious that this taxa likes to dwell in cool and clean waters. Whenever such that environmental quality prevailing, there may be a high probability to find this taxa, and almost certainly that this type of condition will be available at the upper catchment sites. The weather at these upper sites are much cooler than any other sites, and the waters are mostly impacted by natural disturbance.

The most striking maximum number of the perlid taxa caught is at Wat Thamkayasit site in December 1995 when found a total of Perlidae *Neoperla* sp. 77 specimens from all of six replicates combined. The water at this site in December is quite clear and rather steady slowly flowing, and the waters are about just to recover from flooding storms. At P04 in October 1995, one specimen of *Neoperla* sp. is discovered at this site, the weather is relatively cool and again the water column is quite clean. There have never been any Perlidae existing at lower catchment sites as ever samplings.

The upper Cheon river sites (H01-H04) has no significant difference in faunal density when compared to the lower Cheon sites (N01-N05)($t_{(41)}=-1.99$, $P>0.05$), but the species number of the upper sites is significantly greater than the lower sites ($t_{(41)}=2.84$, $P<0.01$). The site H01 is relatively pristine conserved and administered by the Nam Nao National Park. The mean number of species in H01 is less than H03 and H04, which the latter two are classified as the National Reserve Lands managed by the Nam Cheon Upstream Conservation Unit. This part of the lands is largely used for growing crops, mainly corns and chili. The sites H01 to H04 are locating at the altitudes ranging from 610 to 780 M.S.L. As the site H01 has less species number than H03 and H04, this may be resulting from the stream orders. Ward (1992) finds that the very pristine sites of the first or second stream orders are often found less numbers of macroinvertebrate species than the sites of the later stream orders. In contradictory to the H's sites, taxa abundance decreases markedly in N's sites due to the fact that the lands have been cleared seasonally for growing crops and having very few percent of forest cover.

There has no significant difference in both density and species numbers between the upper Cheon river sites (H01-H04) and the uppermost Pong sites (P01-P03) ($t_{(17)}=0.06$, P.0.05 and $t_{(31)}=1.16$ $P>0.05$, respectively). The species composition of the upper Cheon river sites is similar to the sites P01-P03, but it differs from the lower Cheon river sites (N01-N05) as due to their different physical environment, for examples, depth and

substrate types (see Appendix 2). Ward (1992) documented that one of the major factors determining the distribution of aquatic insects is the substrate types.
The mayflies nymph *Heptagenia* sp., Trichoptera larvae Calamoceratidae, Goeridae, Psychomyiidae, Philopotamidae and Hydroptilidae are normally found in these upper sites. These taxa usually occur in clean water (Hellawell 1978, Ward 1992).

The lower Cheon river sites (N01-N05) and the upper Pong river sites (P01-P05), which locating in similar altitude, have no significant difference in both organism density and species numbers ($t_{(48)}$=1.76, P>0.05 and $t_{(48)}$=-1.23, P>0.05, respectively). However, the taxa composition is quite difference which many ephemeropterans and trichopterans disappear in the lower Cheon river sites. The hypothesis merged here may be that whether physical environmental conditions possibly play more important role than the chemical parameters.

The site P04 and P05, which locate in the intermediate zone of the Pong river, have taxa composition similar to the lower Cheon river sites, and the numbers of individuals in both sites are not different ($t_{(33)}$=1.2, P>0.05 and $t_{(33)}$=-0.22, P>0.05, respectively). They are mainly composed of mayflies nymphs Baetidae and Caenidae, caddisflies larvae Hydropsychidae, Ecnomidae and Polycentropodidae and also riffle beetle Elmidae, in which all of these taxa are widespread in all sampling sites.

The numbers of individuals in Chi river sampling sites are not different from the lower Pong river sites, but the diptera Chaoboridae is more abundant in the Chi river sites.

Among the lower Pong river catchment sites, the site P13 is the most severe impacted site. Bloodworms (Diptera, Chironomidae) and Oligocheate are frequently found in this site, this is featuring its severe pollution condition as confirming to the results stated by many researchers (for examples, Hellawell 1978, Pinder 1986, Plafkin *et al.* 1989, Ward 1992 and Williams and Feltmate 1992).

However the sites P08 (Kood Namsai) and P09 (Bueng Kae) show some improvements of water quality which characterized by the increases of both animal densities and species numbers. The sensitive mayflies *Heptagenia* sp. including other mayflies nymphs and caddisflies larvae, which found in the upper Pong river catchment sites, are also presented in these two sites. Less soil erosion in these sites can be observed, this is due to the existing riparian vegetation stretch along stream bank which acting as a buffer zone preventing the land despoliation. Williams and Feltmate (1992) document that many overseas research confirmed that it is necessary to left a 30 m. of riparian community along the river bank as being a buffer zone to prevent the soil erosion and sediment deposition into the stream, which consequently protecting stream macroinvertebrate community from that disturbance.

The density of macroinvertebrates in the lower Pong river sites (P06-P15) does not differ to the sites P08 and P09 ($t_{(38)}$=-1.43, P>0.05) but the number of fauna is significantly difference ($t_{(38)}$=-2.83, P<0.01). The common mayflies, Baetidae, Caenidae, trichopteran families, Hydropsychidae, Ecnomidae and Polycentropodidae, the riffle beetle Elmidae and the widespread dipteran, Chironomidae and Ceratopogonidae are inhabiting in these sites. Chaoboridae the phantom midges larva is widely distributed in all sites except the site P11. The fauna abundance increase markedly in site P08 and P09 as previously mentioned. The present of sensitive mayfly Heptageniidae and cranefly Tipulidae indicates that the environment of this grouped sites is better than the rest sites of the lower catchment part.

The lower Pong river sites and the Chi river sites (C01 to C03) have no significant difference in both organism density and species number ($t_{(63)}$=1.97, P>0.05 and $t_{(63)}$=1.62, P>0.05, respectively). Both individual and taxa numbers in the lower Pong river sites are more diverse than those of the Chi river.

Regarding the absence of common taxa in some sites, for examples, as clearly appeared in sites H02 and N's, such condition indicated that these sites are very vulnerable. It is also found that the higher levels of suspension solid, soil erosion and chemical disturbances all have critical effect on aquatic insect communities, by reducing species diversity and significantly changing species composition (Williams and Feltmate 1992).

5.3 Indicator taxa

An overview

Indicator species related to environmental pollution is widely applied elsewhere (Rosenberg and Resh 1993). The study discovers some facts about our native indicator taxa that generally agreed to such overseas application. This study shows that the aquatic macroinvertebrates which are possibly initially used as biotic indicators in the Pong catchment are some families of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata, Diptera, Oligochaeta and Decapoda. A brief description of what are found about our indicator taxa will be delineated. The occurrence of indicator taxa groups associating with various sites will be described.

Aquatic insects

Mayflies

From the study, sensitive organism of Ephemeroptera is Heptageniidae which is one of the most sensitive aquatic insects (Hellawell 1978). This taxa disappears from highland sites where disturbance occurs. Leptophlebiidae is widely spread in the upper catchment sites, and also in some highland sites. It is absent in the lower catchment sites, and in some highland sites which the lands are extensively modified for agricultural purposes, with a very few riparian strips exist. Among the widespread taxa, the Baetidae is less tolerance than other mayfly nymphs, i.e. Caenidae and Ephemeridae. The Baetidae is categorized as one of the most tolerant mayflies (Hellawell 1978, Brittain 1982).

Stoneflies

Perlidae is the only one family of Plecoptera which is found limited to a cool and clean waters. It appears in the upper catchment sites H01, P01 to P04 and N01, but it is more abundant in the site H01. As the stoneflies like to present in a pristine areas, thus the stoneflies are then used to characterize the degree of environmental quality (Hellawell 1978).

Caddisflies

Trichoptera larvae of families Goeridae, Leptoceridae and Hydroptilidae are mainly found in rocky substrates. They are absent in the disturbed sites, for examples, the sites H02, P01, P05 and the N's sites. The net-spinning caddisflies Hydropsychidae and Polycentropodidae are in contradictory to those three mayflies species in which having quite a large tolerance range to water contamination. In some lowland sites, for examples, at P08, P14 and P15, some Hydropsychidae, Polycentropodidae and Ecnomidae species are explored. These sites are in fact classified as mild to moderate perturbation. Once when the sites are heavily organic impacted, none of these taxa are found. Mackay and Wiggins (1979) and Edington and Hildrew (1981) state that *Hydropsyche* and *Cheumatopsyche* of the family Hydropsychidae are the first caddisflies taxa to reappear when the water quality of the polluted sites improved. These two genera are also the last caddis taxa that will disappear from the polluted sites.

Water beetles

The whiriligig beetle Gyrinidae only inhabits in the upper clean highland sites and disappears from highland sites where disturbances occur. This beetle may be an indicator fauna of the highland. Riffle beetles Elmidae are widely distribution, but they do not inhabit in the severely polluted sites. Whenever the elmids reappear it could indicate that the environmental condition is markedly recovered.

Dragonflies

The clubtail dragonflies Gomphidae are widely distribution, but they do not inhabit in severely polluted sites. Whenever this fauna presents, it may imply the improvement of environmental condition.

True Flies

The cranefly Tipulidae inhabits in less polluted sites, this may show a possibility of using it as indicator species. The bloodworms Chironomidae can tolerate to very severe polluted site (P13). The chironomid can be used as a biotic indicator for organic content increasing (Pinder 1986, Ward 1992, Williams and Feltmate 1992). The bitting midges Ceratopogonidae appears in almost all sites except the poorest oxygenated site (P13). The phantom midge Chaoboridae is found abundant in lower catchment sites especially of the Chi sites. This taxa is found being very high tolerant to high level of BOD, conductivity and TDS. High levels of both conductivity and TDS in this study is mainly from both domestic and natural induces, the chloride content shares the major part of these two values.

Non-aquatic insects

Freshwater earthworms

The freshwater earthworms Oligocheata are found in all sampling sites, and more specifically they are greatly abundant in a very severe polluted site (P13). This fauna can be used as an indicator taxa for polluted aquatic environment.

Freshwater shrimp

The freshwater shrimps *Macrobrachium lanchesteri* has a wide range toleration to water impairment and it is also absent in many glossy polluted sites.

From the finding results of indicator taxa, certain associations with indicator taxa and aquatic environment can be concluded. The most sensitive organisms are Heptageniidae and Gyrinidae, which are only found in very clean (unpolluted) waters. Leptophlebiidae and Psephinidae inhabit in clean waters with less disturbed environment. Baetidae, Caenidae, Ephemeridae, Hydropsychidae, Ecnomidae, Polycentropodidae, Elmidae, Gomphidae, Tipulidae and Palaemonidae present in moderately polluted sites. The appearance abundant numbers of Ceratopogonidae and Chaoboridae shows that these taxa could tolerate to severe water pollution. While the presence of massive number of Chironomidae and Oligochaeta also indicate the grossly heavily organic water pollution.

5.4 Macroinvertebrate fauna variations implicated by multivariate data analyses

Prior to documenting all multivariate data analysis results explored by this study, some important preliminary premises associating with these data analysis methods should be addressed here. These are as followings.

Firstly, the macroinvertebrate faunal data of all sampling sites presented here, as the first year of investigation, use only presence (1) and absence (0) of family level data. Handling data analysis techniques through all multivariate analysis procedures are partly assisted by Dr Peter McQuillan, University of Tasmania, Australia. All of the methods used for these data analyses are conforming to whatever techniques currently applied in community ecology studies as appeared in most update international journals. Indeed, such methods are very much too new to the Thai academicians. Even all of that methods are proved very successful in analyzing biological data of both local and regional fauna and flora distributions at any parts of the world, nevertheless they have never been intensively tested within Thailand.

Secondly, the classification method employed here, the TWINSPAN (Two-Way INdicator SPecies ANalysis), is one of the classification methods originally created by Cornell University in 1979, and this effective method is currently being used by many biological investigators. The dendrograms from TWINSPAN are then drawn and further providing indicator families (species) that conditioning the dichotomy split levels. Not only the grouped sites produced by the TWINSPAN dendrogram are ecologically comparatively profitable, but those indicator species revealed by the TWINSPAN also show *a priori* species classification related to environmental variables.

Thirdly, the Semi-Strong Hybrid Multidimensional Scaling (SSH) which is claimed to be the most effective ordination method to date (Belbin 1995) applying here will reflect all of the sites based on their faunal composition. The ordination results produced by the SSH will then display these data patterns in multidimensional aspect. The plots between the axes will indicate the positions of the sites in the space biplot. The biplots created by the SSH will feature the proximities of the sites based on their similarity (or dissimilarity). For this instance, the paired sites with maximum dissimilarity are separated far apart in the plots, while the more similarity sites are located close to each other. Such proximity of the sites revealed by the SSH biplot will then allow us to group the sites in the biplot.

Fourthly, as those two methods both produce grouping of the sites, in this aspect the grouped sites created by the TWINSPAN can be seeked for their concordancy through a certain axes biplot of SSH. In this manner, the precise separation of the sites grouping can be reconfirmed *vice versa* through the two methods. This is thus leading high robustness of the sites separation which characterising a certain set of sites based on their similar faunal attributes.

Fifthly, the faunal families assemblage at a site of all sampling stations of each sampling month will also be ordinated, and leading to the positions of different families in those SSH biplots which relating to the site space. The vectors can then be drawn in such these biplots where showing the directions of the families relating to the sites' position in the biplot.

Sixthly, correlations between faunal data and physicochemical factors are explored by examining any merging relationships between the ordination axes and those environmental variables. Variations of physicochemical parameters according to the TWINSPAN grouped sites are also able to be delineated.

Lastly, the bimonthly physicochemical data of the sampling sites are ordinated by the SSH and their directions associated with the sites' position in the same plot are presented as the vectors. These vectors radiated via the centroid of the plot will show the directions and influences of various environmental factors relating to the sites' position in that plot.

All of the correlation analyses handling are tested for statistical significant by the Monte-Carlo Randomization, this test method is conducted through the available procedure in the PATN software.

5.5 Bimonthly sites and species classifications and ordinations

October 1995

The first data set is of October sampling month, the sites are classified and grouped by the TWINSPAN into four main grouped sites (Fig.4a). The grouped sites retained as shown in Fig.4a are the grouped sites divided by the TWINSPAN at level 2 which are very much comparatively ecological meaningful. Important indicator families which are used to split the sites grouping are also shown in Fig.4a. Among those indicator families, interestingly, on the positive side (n=16) of the first division indicator families are Oligochaete and Ceratopogonidae. On the other hand, the negative side (n=11) the indicator families are Elmidae, Gomphidae, Caenidae, Palaemonidae and Leptoceridae. Of the first split sites here, following the indicator families, it is more clearer that the sites locating on the negative side are much less impacted and having a relatively more numbers of environmental sensitive families than the positive side.

Table 2 indicates the average physicochemical profiles of the grouped sites A to D. The grouped sites A have comparatively less average values of all physicochemical parameters, this is excluded the DO value where the average DO shows a markedly higher level than the rest grouped sites. When referring to DO and BOD values of the two group sites (A plus B versus C plus D) there is a clear differentiation of BOD values between these two grouped sites, as the TWINSPAN negative end has the mean DO value 6.38 mg/L, whereas the positive end has 4.41 mg/L. The BOD of the negative side is averaging 1.18 mg/L, while the positive direction is 1.6 mg/L.

Table 2 Average values of selected physicochemical varibales in October 1995.

Environmental variables	Grouped sites			
	A	B	C	D
Air temp.(°C)	25.47	31.21	30.56	30.70
Water temp. (°C)	25.33	27.48	29.11	28.20
Velocity (m/sec)	0.50	0.85	0.73	0.43
Width (m)	5.67	29.38	56.67	32.57
Depth (m)	0.43	3.74	7.04	3.51
Discharge (cu.m/sec)	1.10	49.05	212.60	32.50
Alkalinity (mg/L)	77.33	103.50	84.44	89.43
Conductivity (microS/cm)	141.53	199.26	211.69	215.17
TDS (mg/L)	114.50	167.06	155.98	129.94
TSS (mg/L)	159.00	70.39	40.58	74.19
Ortho-P (mg/L)	0.02	0.06	0.05	0.05
Nitrate (mg/L)	0.13	0.19	0.19	0.44
DO (mg/L)	6.73	6.03	4.84	3.97
BOD (mg/L)	1.27	1.09	1.29	1.91

There have been a marked differences of certain environmental values between the TWINSPAN grouped sites (A to D) when testing them by the Kruskal-Wallis. These are river width ($H=11.43$, $P<0.01$), depth ($H=11.02$, $P<0.05$), discharge ($H=16.19$, $P<0.001$) and DO ($H=8.38$, $P<0.05$). This is indeed the major environmental variables that discriminating the TWINSPAN grouped sites. All of the first three variables are increasing from grouped sites A to B, and further to the other end. On the other hand, the DO is reducing from A to D. Such these variation results will later be tested for correlations between the ordination axes and all of the environmental variables. Moreover, if the axes of the ordination plot reveal any conform correlation results to such of the TWINSPAN, then it can be concluded that those certain environmental variables are commonly affirmatively relating to faunal groups of interest.

The second level is splitted into two grouped sites at each end. Baetidae and Leptophlebiidae (-) and Tipulidae (+) are indicator families are used to divide the first group sites (n=11). These families indeed reflect the more subtle environmental changes of among sensitive families. The Baetidae, with only limited to some species in this group, while the others have a large range of toleration, and Leptophlebiidae are very much sensitive to pollution, the Tipulidae, however, is relatively more tolerant when compared to the former groups.

The second level split of the other group (n=16) is divided by indicator families Polycentropodidae (-) and Hydropsychidae (-). Of these less sensitive sites, it can yet make a comparison between these sites, the negative end at this level (n=9) is consisting all of the sites which having family members moderate sensitivity to pollution, these sites also indicate quite a diverse macroinvertebrate fauna inhabiting than of the other end (n=7). This latter site, the major faunal group found is mainly Diptera which is more tolerant to water pollution. Preliminary conclusion according to sites classification by the TWINSPAN in October is that the sites are well successfully classified by the TWINSPAN as grouping them into less impacted to much impaired sites, and these grouped sites can be also simply correspondingly expressed by chemical variables.

Fig 4b shows certain positions of the sites arranged in the space and the most clearest grouping of the sites according to the TWINSPAN is the biplot from the SSH between axis1 and axis3. The sites can be grouped into four major grouped sites (Fig 4b). The most well separation is of the last grouped sites (D) where having relatively much water pollution than the others. Fig 4c also exhibits the families assemblage arrangement in relation to the sites' position (Fig 4b). The occurrence of all families in the biplot with respect to the site-pollution classification are clearly apparent, Fig. 4c. Most cleaner water macroinvertebrate fauna required occur limited to the grouped sites A and B. These are, for examples, Leptophlebiidae (LEP), Hydroptilidae (HYDT), Simuliidae (SIM), Sialidae (SIA) and Perlidae (PER). It is very obvious that these family groups never occur in the grouped sites C and D. This is also in contrast to Oligochaete (OLI) which is most abundant in the grouped site D and never exist in the grouped sites A and B.

Correlations between ordination axes and environmental variables by the Pearson-Product Moment reveal that axis1 negatively correlates to discharge ($r = -0.52$, $t_{(25)} = 3.06$, $P<0.01$) and positively relates to turbidity ($r = 0.49$, $t_{(25)} = 2.85$, $P<0.01$) and TSS ($r = 0.44$, $t_{(25)} = 2.48$, $P<0.05$). Axis3 is greatly significantly negatively related to DO ($r = -0.76$, $t_{(25)} = 5.92$, $P<0.001$) and positively associated with water temperature ($r = 0.53$, $t_{(25)} = 3.14$, $P<0.01$), width ($r = 0.47$, $t_{(25)} = 2.67$, $P<0.05$), depth ($r = 0.51$, $t_{(25)} = 3.01$, $P<0.01$) and discharge ($r = 0.43$, $t_{(25)} = 2.35$, $P<0.05$). There is no relationship between axis2 and any water quality variables.

As the results from Kruskal-Wallis shown earlier that four main environmental variables are contributed to the variation of the TWINSPAN grouped sites, the SSH axes also still reveal a consistent result to TWINSPAN output. It now can be concluded that in October these four environmental variables are primarily conditioning the existence of the faunal groups which dividing by the TWINSPAN analysis.

To be much more clear about the correlation of family-site and environmental variables, this can be shown by grasping two extreme environmental variables, i.e. discharge and DO. The former is highly relating to axis1 ($P<0.01$), this can be seen in Fig 4b that the trend of discharge is increasing from the right to the left hand side of the plot. Fig 4c shows some facts of benthic animals with much susceptible to discharge positioning on the right end of the plot whereas the animals capable of resisting to high discharge are placed on the far left, for examples, the families Polycentropodidae and Ecnomidae. Such this explanation associating with environmental variables and SSH axes would then be applied to interpret the results onwards unless otherwise not mentioned.

The DO level is very much significantly related to axis3 ($P<0.001$). The DO value is apparently reducing from the bottom to the top along axis3 of the plot. Fig 4c reveals a certain fact associating with this DO profile by reflecting the distinctively different benthic families positioning along axis3, the families require high dissolved oxygen, for examples, Leptophlebiidae, Leptoceridae, Heptageniidae and Perlidae, as in Fig. 4c, are clearly placed towards the bottom end of the plot while the less sensitive families to DO level are positioned at the upper part of the plot. This is also showing how the environmental variables are relating to the particular fauna and the TWINSPAN grouped sites.

Fig.4d shows the vectors of environmental variables radiating from the centroid, and relating to the sites' position. The most outstanding features about physicochemical variables which selected to present here are BOD, width, depth and nitrate. These varaibles are pointing towards the impacted sites which having less number of animals deposited. In contrast, the sites with more animal numbers are located in the opposite end of these vectors. The DO, alkalinity and TDS vectors are obviously running across the sites with high numbers of animals assemblage, and they are all locating at upstream. Also, at this month the upstream sites show being influenced by the TSS, turbidity, velocity levels, and thus these variables never affect the downstream sites such as P12, P13 and P15

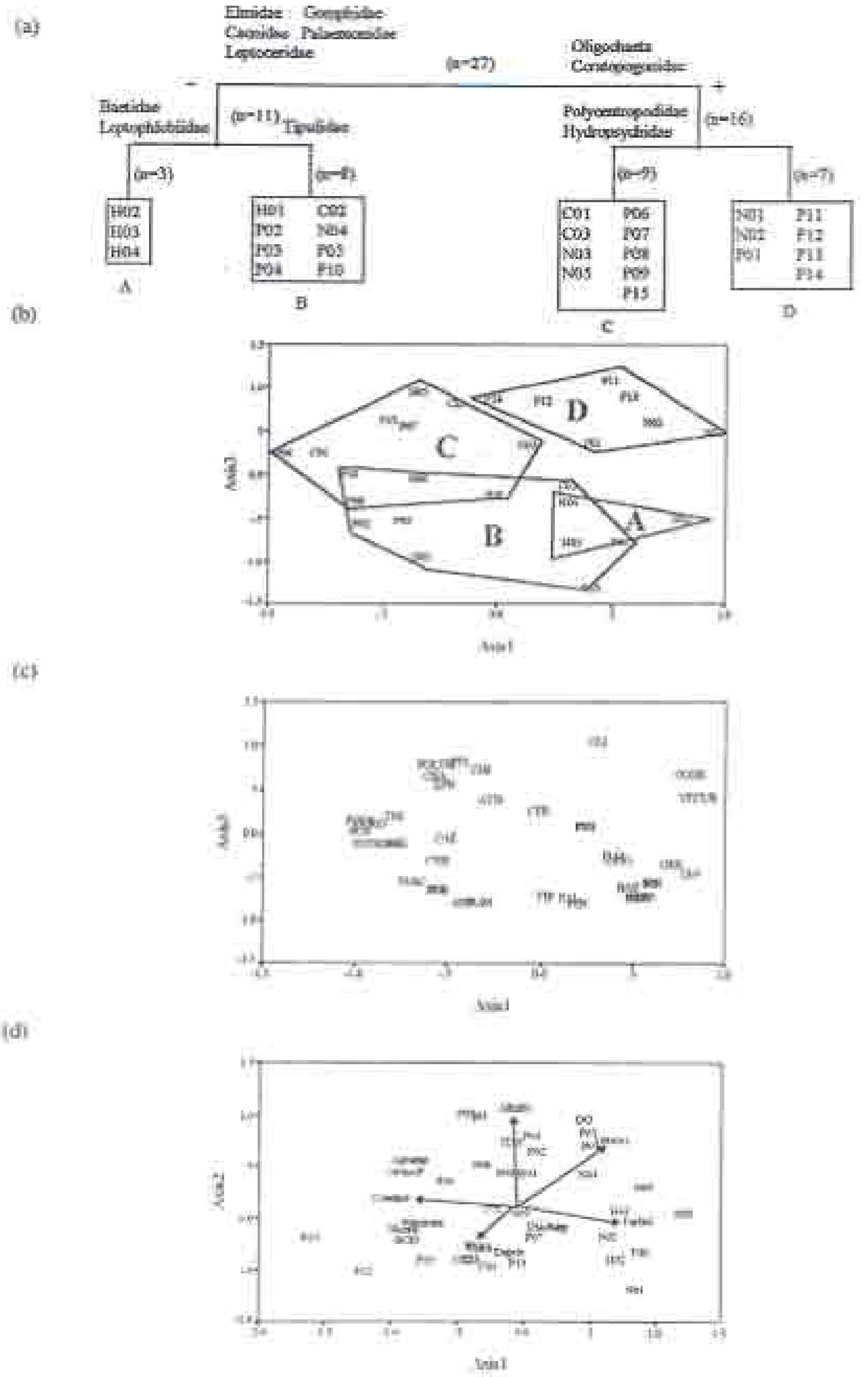


Figure 4 Classification and ordination analyses (October 1995).
(a) Results from TWINSPAN analysis.
(b) Axis1 vs. Axis3 biplot of sampling sites by SSH ordination.
(c) Axis1 vs. Axis3 biplot of macroinvertebrate fauna by SSH ordination.
(d) Axis1 vs. Axis2 biplot of physicochemical variable by SSH ordination.

December1995.

Unlike the October phenomena which features a late rainy condition and that still receiving a dramatic flooding effects, in December the water environment is considerably returning to rather static state. The TWINSPAN and SSH can both successfully classify the sites into five major groups A, B, C, D and E, as shown in Fig 5a and Fig 5b.

The indicator families conditioning the split of the first TWINSPAN level are Baetidae (-), Gomphidae (-), Leptophlebiidae (-) and Tipulidae (-) with no positive side family indication. The second level of the negative side (n=9) is then splited into two main grouped sites A (n=5) and B (n=4) with only family Elmidae (-) is an indicator, Fig 5a. Indicator family on the positive side (n=18) is Chaoboridae (+) and on the negative side is Polycentropodidae which dividing the sites into two grouped sites, C (n=10) and D plus E (n=8) sites. The third level is a split between the sites D (n=5) and E (n=3) which indicator species is Ephemeridae (-).

All of the sites divided by the TWINSPAN at the first level on the negative end are locating at upstream areas, except the site P09. These sites have more macroinvertebrate faunal numbers than other remaining sites. Since the site P09 is included within the uppermost highland sites, this is mainly from its family numbers content. This site has certain indicator families inhabited, i.e. Gomphidae and Elmidae. These families are in fact also used to characterise a relatively less polluted waters.

Table3 shows some distinctive physicochemical values comparing between the grouped sites A to E. The grouped sites A and B, referring to Table3, have less impacts from physical factors, i.e. velocity, depth, discharge, turbidity and TSS, while the remaining grouped sites are notably disturbed by these environmental factors. The average DO and BOD levels of the sites also reveal some facts of chemical variables associating with the TWINSPAN grouped sites, i.e. the grouped sites A and B have distinctively average high DO and low BOD values.

Table 3 Average values of selected physicochemical variables in December1995.

Environmental variables	**Grouped sites**				
	A	B	C	D	E
Velocity (m/sec)	0.86	0.40	0.22	0.27	0.25
Depth (m)	0.34	0.21	3.05	4.06	3.56
Discharge (cu.m/sec)	3.74	1.31	29.08	52.07	40.57
Alkalinity (mg/L)	160.8	128	135.4	114.4	4.782
Turbidity (NTU)	9.98	9.08	15.08	14.80	14.94
TSS (mg/L)	7.84	5.40	20.80	30.88	25.84
Nitrate (mg/L)	0.08	0.03	0.44	0.12	0.28
DO (mg/L)	8.00	7.96	6.10	7.25	6.67
BOD (mg/L)	2.06	1.78	3.60	2.18	2.89

Seven environmental variables reveal being major contribution to the variation of the TWINSPAN grouped sites. The result from Kruskal-Wallis test portrays these prime variables, they are water temperature ($H=11.49$, $P<0.05$), velocity ($H=10.19$, $P<0.05$), width ($H=12.13$, $P<0.05$), depth ($H=17.63$, $P<0.01$), discharge ($H=12.93$, $P<0.05$), nitrate ($H=11.16$, $P<0.05$) and DO ($H=12.86$, $P<0.05$). These seven environmental parameters are thus accounting for the differentiation of the grouped sites according to the TWINSPAN analysis, Fig.5a.

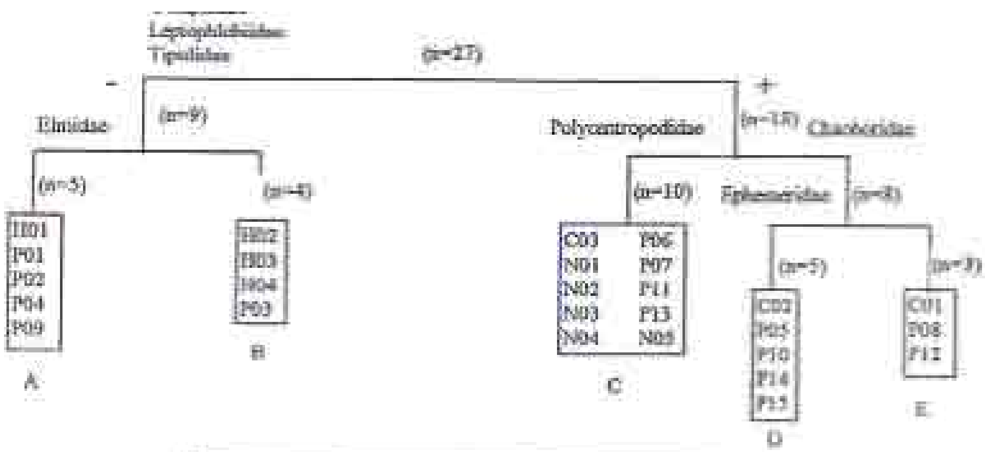
The best ordination result corresponding to the TWINSPAN groups is revealed by the biplot between axis2 and axis3. Five major groups can be drawn from the plot A, B, C, D and E, Fig.5b. The grouped sites A and B are the sites with less disturbed while the grouped sites C, D and E are rather much impacted.

There are six environmental attributes which relating to axis1, these are conductivity ($r = -0.44$, $t_{(25)} = 2.48$, $P<0.05$), water temperature ($r = -0.45$, $t_{(25)} = 2.53$, $P<0.05$), velocity ($r = 0.58$, $t_{(25)} = 3.54$, $P<0.01$), phosphate ($r = -0.40$, $t_{(25)} = 2.19$, $P<0.05$), nitrate ($r = -0.59$, $t_{(25)} = 3.72$, $P<0.01$) and DO ($r = 0.70$, $t_{(25)} = 4.92$, $P<0.001$). Axis2 is associated only with water temperature ($r = 0.44$, $t_{(25)} = 2.43$, $P<0.05$), and aixs3 is correlated with width ($r = 0.67$, $t_{(25)} = 4.52$, $P<0.001$), depth ($r = 0.78$, $t_{(25)} = 6.28$, $P<0.001$), discharge ($r = 0.59$, $t_{(25)} = 3.58$, $P<0.01$), TSS ($r = 0.53$, $t_{(25)} = 3.11$, $P<0.01$) and water temperature ($r = 0.53$, $t_{(25)} = 3.09$, $P<0.01$).

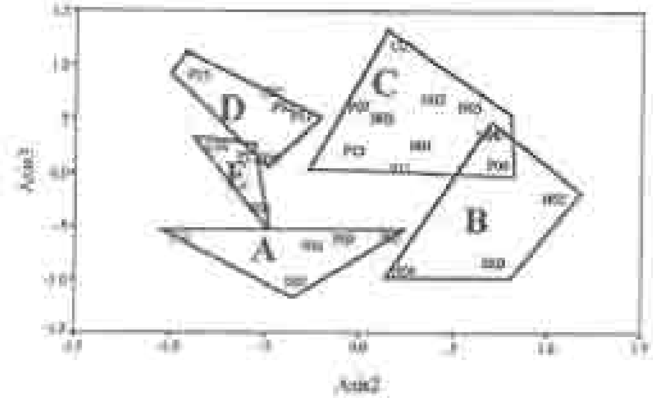
All of the seven variables used to differentiate the TWINSPAN grouped sites shown above are included in the SSH axes correlations. It is also worthy to note that the associations delineated by the SSH axes are obviously including more numbers of environmental factors than merely the ones which conforming to the TWINSPAN's variables. Thus, the SSH correlations are likely to show more robustness by embracing additional environmental variables other merely from that appearing in the TWINSPAN. In other words, the correlation between the SSH axes and environmental factors thus renders a more efficient detection of environmental changes along the space rather than by the TWINSPAN.

Fig.5c indicates the positions of macroinvertebrate families in the space, their places are indicated in correspondingly to the positions of the sites in Fig.5b. The grouped sites A and B reveal having more numbers of sensitive families than any other grouped sites. The directions of sensitive families of the grouped sites A and B can be apparently seen from the vectors of the plot in Fig.5c, and that most of sensitive families are extended to the bottom of the plot. These families lined to the bottom end are never found in the opposite direction sites, i.e. grouped sites D and E. In contrast, it is also very obvious that families Oligochaete (OLI) and Chaoboridae (CHA), which indicated by the vectors, only exist limited to the grouped site C where these sites are extensively polluted.

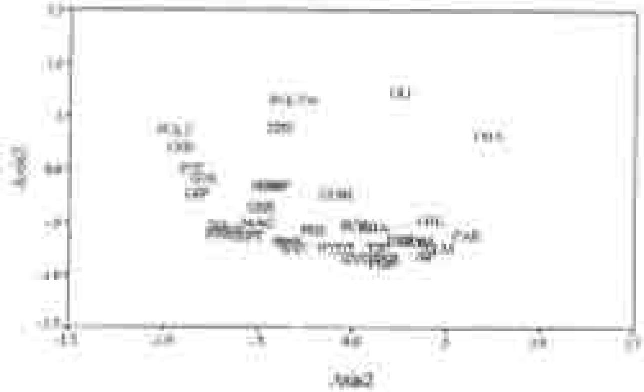
Correlations between environmental variables and the sites can be seen from the vectors radiated as shown in Fig.5d. Most of the polluted sites are influenced by high levels of BOD, turbidity, TSS and other physical morphological features of the river, i.e. discharge, width and depth. The grouped sites A and B locate in the opposite direction of these environmental vectors. The alkalinity and DO vectors however line across most of the sites in groups A and B. Such that influences of the alkalinity and DO vectors to the TWINSPAN grouped sites are also similar to the results revealed in October investigating month.



(b)



(c)



(d)

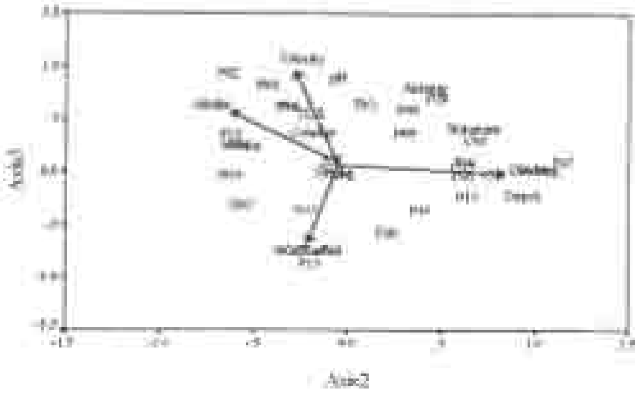


Figure 5 Classification and ordination analyses (December 1995).
(a) Results from TWINSPAN analysis.
(b) Axis2 vs. Axis3 biplot of sampling sites by SSH ordination.
(c) Axis2 vs. Axis3 biplot of macroinvertebrate fauna by SSH ordination.
(d) Axis2 vs. Axis3 biplot of physicochemical variables by SSH ordination.

February 1996

All of the investigated sites are divided into four major groups, A to D, according to the TWINSPAN analysis, Fig.6a. Only two families, i.e. Gomphidae (-) and Baetidae (-) are the indicator families used to split at the first level, with no positive family indicator. At the negative end the sites are splited into two main groups, A (n=5) and B (n=4), which indicator families are Elmidae (-), Psephenidae (-) and Ecnomidae (+).

On the positive direction (n=17), the sites are divided into two levels. The first level consists of two main grouped sites, i.e. C plus D (n=14) and E (n=3). The only indicator family used to split the sites at this first level is Ecnomidae (+).

Most of the sites in groups A and B locate at upstream lands, except two sites, P06 and P08, which locating downstream below the Ubolratana Dam. These two downstream sites at this month, unlike previous months, found having more numbers of faunal families dwelling. Gomphidae, Libellulidae, Ecnomidae, Caenidae and Polycentropodidae are common families discovered inhabiting at these two sites, whereas these families are not explored in any other lower sites.

The grouped sites C and D are rather disturbed sites, where the sites group C, which consisting of the maximum members of 14 sites, are to a larger extent impaired. Ceratopogonidae and Chironomidae families are extensively abundant here. The grouped sites D however is not very much disturbed, the faunal families being tolerant from mild to moderate pollutions can be found at these sites, for examples, Ecnomidae, Caenidae and Gyrinidae.

What is essential to note here is that the site P13 is not included in any specified groups and this site is far well separated from the remaining sites. This site in fact has only pollution preferential family deposited-the Chironomidae. During sampling occasion the eutrophication occurs profoundly at this site which can easily be seen by eyes with very much heavy abundance of unicellular algae *Anacystis* sp.

Table 4 shows some important environmental factors which relating to the TWINSPAN grouped sites. There is a certain differentiation of environmental variables between the grouped sites A plus B and C plus D. The two grouped sites obviously have different levels of temperature, turbidity and TSS. Also, the grouped site A, which containing the maximum numbers of benthic families, has minimal water depth and discharge when compared to the other groups, but this group has an average high value of alkalinity.

The most impacted sites in terms of BOD value is the grouped sites C which has the BOD value, averaging 2.30 mg/L, whereas the other sites have lower BOD levels. At this sampling month, the DO value of the grouped site A is at comparatively highest value, averaging 7.61 mg/L. Similarly, all of the sites in this sampling occasion also reveal high DO values, in which DO of each site is equal or greater than 7.00 mg/L.

The site P13, itself, is at this time, experiencing severe impacts from water pollution. The two nutrients eutrophic factors measured by orthophosphate (P) and nitrate (N) are rising up as highest levels at 1.4 mg/L and 20.0 mg/L, respectively. The BOD level is also reaching at highest value of 9.26 mg/L, this is almost maximum BOD level as compared to any sampling sites investigated in this month. Indeed, it is one of the most severe cases in light of water pollution consideration where this site exhibiting a clear evidence of only discovering the family Chironomidae dwelling with a very few numbers of specimens found (five individuals from six replicates). What is finding here in this case associating with the animals, it is also consistent to what the chemical variables exhibited.

Table 4 Average values of selected physicochemical variables in February 1996.

Environmental variables	Grouped sites			
	A	B	C	D
Water temp. (°C)	21.72	21.66	24.44	24.69
Depth (m)	0.21	2.60	3.77	1.54
Discharge (cu.m/sec)	0.24	52.23	37.01	16.72
Alkalinity (mg/L)	178.00	122.00	127.50	88.00
Turbidity (NTU)	9.03	3.91	19.12	104.26
TSS (mg/L)	6.72	3.55	14.51	29.47

To be more rigorous analysis rather than presenting the general trend as appeared in Table 4, there are five environmental factors being contributed to the discrimination of the TWINSPAN grouped sites. The results shown by the Kruskal-Wallis test are width ($H = 10.59$, $P<0.05$), depth ($H = 12.40$, $P<0.01$), discharge ($H = 11.23$, $P<0.05$), turbidity ($H = 9.24$, $P<0.05$) and phosphate ($H = 8.93$, $P<0.05$). This is apparently indicating that channel morphology is yet having a very much effects on the differentiation of the TWINSPAN grouped sites.

The biplot from the SSH, as in Fig. 6b, is also conforming to the result analysed by the TWINSPAN. A and B, the grouped sites with less disturbed, are also well separated from the grouped sites C and D. Disregarding the site P13, the grouped sites C at which relatively impacted are locating towards the bottom of the plot while the less impaired sites are placed at the upper part.

Significant associations when relating the SHH axes with environmental variables appear statistically only limited to two axes, i.e. axis 1 and axis 3 with no correlation occurred to axis 2. Axis 1 is significantly related to water temperature ($r = -0.58$, $t_{(24)} = 3.53$, $P<0.01$), width ($r = -0.72$, $t_{(24)} = 5.03$, $P<0.001$), depth ($r = -0.79$, $t_{(24)} = 6.20$, $P<0.001$), discharge ($r = -0.72$, $t_{(24)} = 4.92$, $P<0.001$), turbidity ($r = -0.41$, $t_{(24)} = 2.18$, $P<0.05$) and TSS ($r = -0.56$, $t_{(24)} = 3.32$, $P<0.01$). Axis 3 is markedly correlated with only one environmental variable, i.e. depth ($r = 0.43$, $t_{(24)} = 2.35$, $P<0.05$).

The correlation results of the SSH shown above is mostly compromising to the analysis produced by the Kruskal-Wallis of the TWINSPAN. It remains one of the environmental variables, i.e. phosphate, not being included in the SSH associations. This is in fact the phosphate variation between the TWINSPAN grouped sites analysed by the Kruskal-Wallis is rather statistically interval marginal with the H value = 8.92, and thus leading to no statistical significant in the SSH correlation output by the Pearson-Product Moment method. Additional advantage should be noted here is that even the environmental variables cannot be detected by the TWINSPAN grouped sites analysis through Kruskal-Wallis, the SSH results are able to fill this gap by embodying all of significant variables relating to the site-space.

Fig. 6c also indicates the family vectors corresponding to the sites arranged in Fig. 6b. It is clearly that Chaoboridae and Oligochaete have much influences on the grouped sites C which correspondingly shown by the SSH plot in Fig. 6b. Interestingly, these two taxa never exist in the grouped sites A. All of the faunal families occur in the upper part of the plot at where the grouped sites A and B locating, this indicates that the grouped sites A and B are likely relatively being less disturbed.

In contrast to the impacted sites, much more numbers of animals are clearly locating at the upper part of the plot in Fig. 6c. Psychomyiidae, Sialidae, Elmidae, Calamoceratidae, Philopotamidae, for examples, are inhabiting at the less polluted grouped sites A and B. The moderated impaired grouped sites D (N04, P09 and P11) are explored having some families dwelling, for examples, Gyrinidae, Palaemonidae, Caenidae and Ecnomidae.

Fig. 6d shows the vectors drawn from the centroid indicating the effects of environmental variables relating to the sites' position. At this late cooler month, February, dissolved mineral ions measured by conductivity and TDS values show relatively high concentrations at the upstream sites, particularly at P01, P02 and P03. This is mainly due to lower level of river waters. Apart from these mineral salts, alkalinity and to a lesser extent the DO have influential effects on the upper sites which can be seen from the upper left hand of the plot in Fig. 6d.

Still, at the lower sites the discharge and river channel dimensions expense the large effects on those sites which shown at the lower right hand side of the plot, Fig. 6d. This is thus leading to a higher levels of turbidity and TSS as previously shown by the SSH axes-environment correlations.

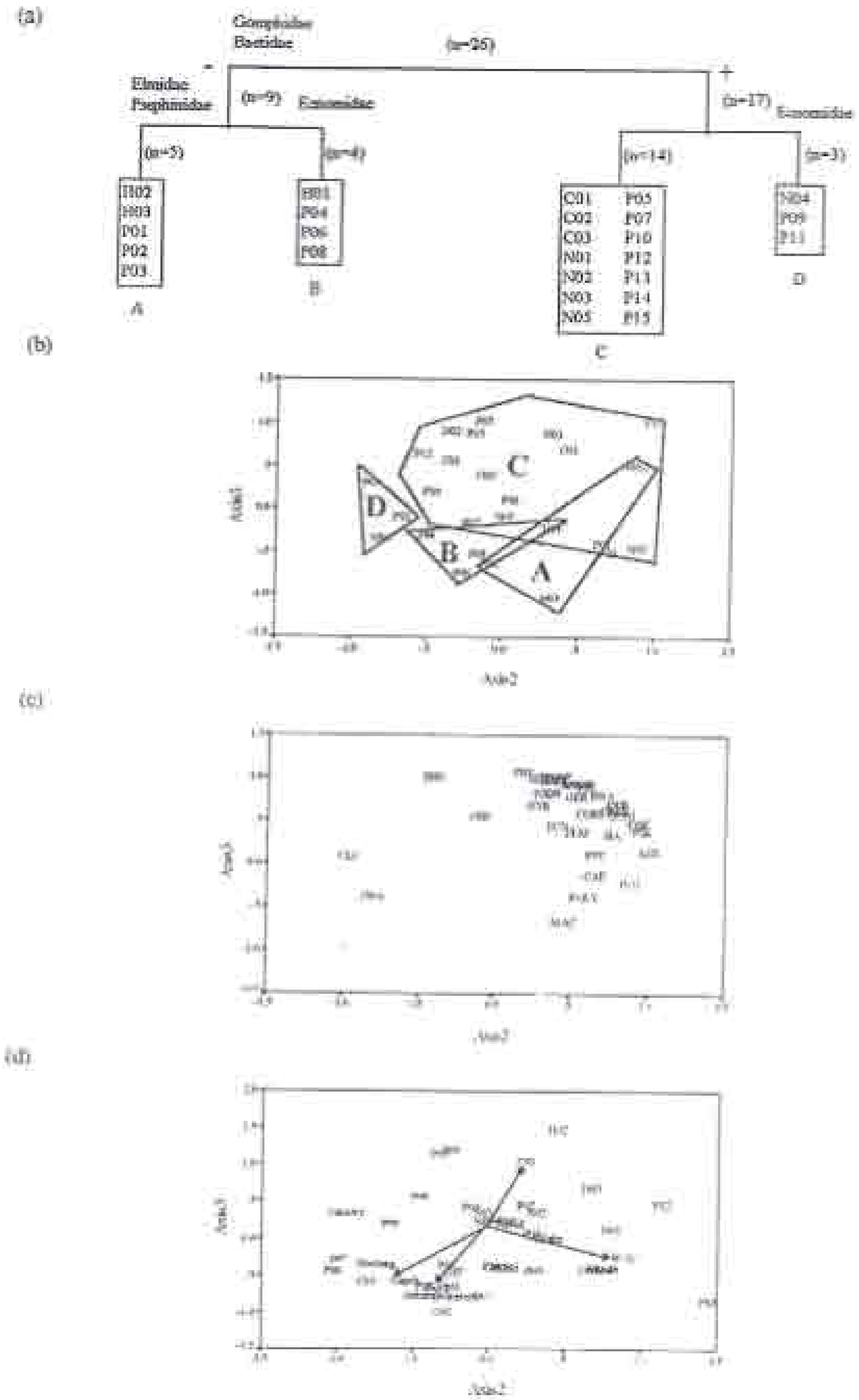


Figure 6 Classification and ordination analyses (February 1996).
(a) Results from TWINSPAN analysis.
(b) Axis2 vs. Axis3 biplot of sampling sites by SSH ordination.
(c) Axis2 vs. Axis3 biplot of macroinvertebrate fauna by SSH ordination.
(d) Axis2 vs. Axis3 biplot of physicochemical variable by SSH ordination.

April 1996

As this month is the hottest month, the TWINSPAN has much ability to classify the sites into more groups, i.e. up to five groups A to F as shown in Fig. 7a. The first level is splitted into two grouped sites A plus B plus C (n=16) and D plus E (n=10) by four indicator families Polycentropodidae (-), Elmidae (-), Gomphidae (-) and Chaoboridae (+). The sites on the negative end are relatively less impaired whereas the other end receives considerable organic pollution impacted.

On the negative side, the second level is further splitted into two main groups A (n=6) and B plus C (n=10) at which the indicator families are Elimidae (-), Ceratopogonidae (+) and Polycentropodidae (+). The third level split is a separation between the grouped sites (n=5) and C (n=5), at this division the only indicator family is Ecnomidae (-).

Of the positive end (n=10), two main groups are created D (n=7) and E (n=3) by which using two indicator families, Ceratopogonidae (-) and Chaoboridae (+). These grouped sites are extensively polluted which are mainly from human activities. There is a very few benthic animals found at these sites. For examples, the sites P15, H02 and C01 all are discovering only two families of fauna inhabiting which are mainly dipterans. The most diverse faunal families found, in contrast, are of the grouped sites A, and to a minor extent of the grouped sites B and C.

Table 5 shows some discrete important environmental trends. Much interestingly, such trends can be seen a very far differentiation of the sites grouped A and the remaining grouped sites. Effects of river channel morphology are still conditioning the upper sites condition as similar to other previous investigating months. The water temperature of the sites grouped A is, on the average, lower than the lower grouped sites. Occasional storms occurring during this month lead to relatively high levels of turbidity and TSS.

However, this situation cannot be referring to organic pollution origin, but rather it is very much involved mainly from siltation caused by natural induce. The grouped sites D and E, on the other hand, even feature low values of turbidity and TSS they both have high BOD levels when compared to the grouped sites A. Alkalinity is also found comparatively reaching at higher levels at the grouped sites A, this is similar to the relative high trends of alkalinity of this grouped sites in previous sampling months.

Table 5 Average values of selected physicochemical variables in April 1996.

Environmental variables	**Grouped sites**				
	A	B	C	D	E
Water temp. (°C)	27.88	28.80	26.71	30.75	30.41
Velocity (m/sec)	0.46	0.21	0.34	0.12	0.12
Width (m)	9.32	45.20	33.80	40.60	46.67
Depth (m)	0.45	3.31	2.06	4.22	2.91
Discharge (cu.m/sec)	1.80	29.67	15.92	18.20	14.97
Alkalinity (mg/L)	110.67	86.40	79.20	92.80	94.00
Conductivity (microS/cm)	226.27	210.78	175.62	785.61	611.53
TDS (mg/L)	149.87	138.67	117.06	611.01	407.10
Turbidity (NTU)	120.70	30.10	30.04	62.56	96.35
TSS (mg/L)	166.17	26.50	29.40	38.57	53.50
BOD (mg/L)	1.38	1.72	1.34	2.91	2.46

Significant variations of environmental factors across the TWINSPAN groups show four variables which are distinctively different by the Kruskal-Wallis test. Velocity is significantly highly variated ($H = 14.91$, $P<0.01$), the other three diverse factors are width ($H = 11.37$, $P<0.05$), depth ($H = 10.50$, $P<0.01$) and discharge ($H = 11.76$, $P<0.01$).

Even Table 5 reveals a markedly different values of several physicochemical variables, but the variation of within TWINSPAN groups is evidently greater than of the between groups. In this instance, it is thus leading to no significantly statistical variation occurred from among the groups tested. Such this phenomenon occurs in most of the sampling months tested as presented so far, where the general physicochemical trend is varying obviously but the test shows only some values being statistically significantly different, due explanations associated with that case can be made similar to this case by determining the extent to which whether the off-set variation within or between groups which one is greater than the other.

The result from the SSH plot is also clearly exhibiting a well separation of the sites in concordance with the grouped sites shown by the TWINSPAN, Fig. 7b. The grouped sites A, B and C are locating towards the bottom of the plot while the other two groups D and E being extended to the top of the plot. The farthest group, E, with severely impacted is located at the uppermost of the plot. It is essential to note here that as the site H02 is indeed apparently separated from the other sites on the SSH plot, and also it is well splitted from the grouped D at the third level (+) of the TWINSPAN analysis. What logical intention in this aspect is to retain the grouped sites at the second split level of the positive side of the dendrogram, as this for lending them to implying a more ecological meaningful sense.

All three axes are related to environmental factors. Axis 1 is correlated with velocity ($r = 0.55$, $t_{(25)} = 3.23$, $P<0.01$), depth ($r = -0.43$, $t_{(25)} = 2.21$, $P<0.05$), discharge ($r = -0.47$, $t_{(25)} = 2.54$, $P<0.05$), alkalinity ($r = 0.59$, $t_{(25)} = 3.60$, $P<0.01$) and nitrate ($r = 0.64$, $t_{(25)} = 4.212$ $P<0.001$). Axis 2 is associated with velocity ($r = -0.41$, $t_{(25)} = 2.22$, $P<0.05$), width ($r = 0.58$, $t_{(25)} = 3.56$, $P<0.01$), depth ($r = 0.59$, $t(_{(25)}) = 3.62$, $P<0.01$) and discharge ($r = 0.55$, $t_{(25)} = 3.12$, $P<0.01$). Only two variables are correlated to axis 3, i.e. conductivity ($r = 0.43$, $t_{(25)} = 2.37$, $P<0.05$) and TDS ($r = 0.44$, $t_{(25)} = 2.36$, $P<0.05$). Such these correlations reveal physical environments, for examples, velocity, depth and discharge, still being major factors disturbing the sites.

Families distributed along the sites in the space, Fig. 7b, are very much evident according to their directions radiated. Important families show certain directions extending to the left hand side of the plot, which is very much indeed corresponding to the grouped sites in Fig. 7b. All of the families in that direction are never found existing in any sites of the different ends. These families are, for examples, Elmidae (ELM), Philopotamidae (PHI), Leptophlebiidae (LEPT), and Heptageniidae (HEP). Chaoboridae (CHA) and Chironomidae (CHI), even the former family is discovered inhabiting at almost all sites but its direction is moving towards the grouped sites E, and the Chaoboridae is forwarded to the upper part of the plot where the grouped sites E located.

Of among the sites which considering having moderate impacts, the grouped sites B and C, the Polycentropodidae (POLY), Dytiscidae (DYT), Potamantidae (POT) and Oligochaete (OLI) are the common families showing apparently a distinctive location in relation to these grouped sites.

Regarding the variations of environmental variables across the sites, it is noticeably that the grouped sites A are less influenced by any physicochemical variables. Nevertheless, it is just only the amount of nutrients, phosphate and nitrate, that might be the case as can be seen from the right hand side of the plot, Fig. 7d. This grouped sites have average values of both nutrient variables, 0.38 mg/L and 1.11 mg/L, respectively. It is expected that such high nutrient levels will be resulting from first occasional run-offs diffused from the agricultural lands in this area.

The BOD vector runs across the sites N02, PO9 and moving forward to the directions where the sites P12 and P13 located. This can show the direction of organic pollution occurred across the sites in the space. The sites locating at the upper right hand of the plot also indicate encountering much disturbances from natural cause, which can be seen by the TSS and turbidity vectors lining upon them.

A very intense levels of conductivity is also occurring in this sampling month. The sites C01, C02 and C03 have highest ranges of conductivity from 1218.50 microS/cm to 1690.33 microS/cm. In fact, these sites belong to the Chi river and when the water level decreasing, particularly in April, the high levels of conductivity and TDS would be expected. Of the very high conductivity values prevailing at these sites, only four families found being able to inhabit, these are; Chaoboridae, Ceratopogonidae, Oligochaete and Chironomidae. Chloride from rock weathering is the main cause of this chemical pollutant. It is observed that of among other taxa, Chaoboridae is the one that is much tolerant to high levels of chloride.

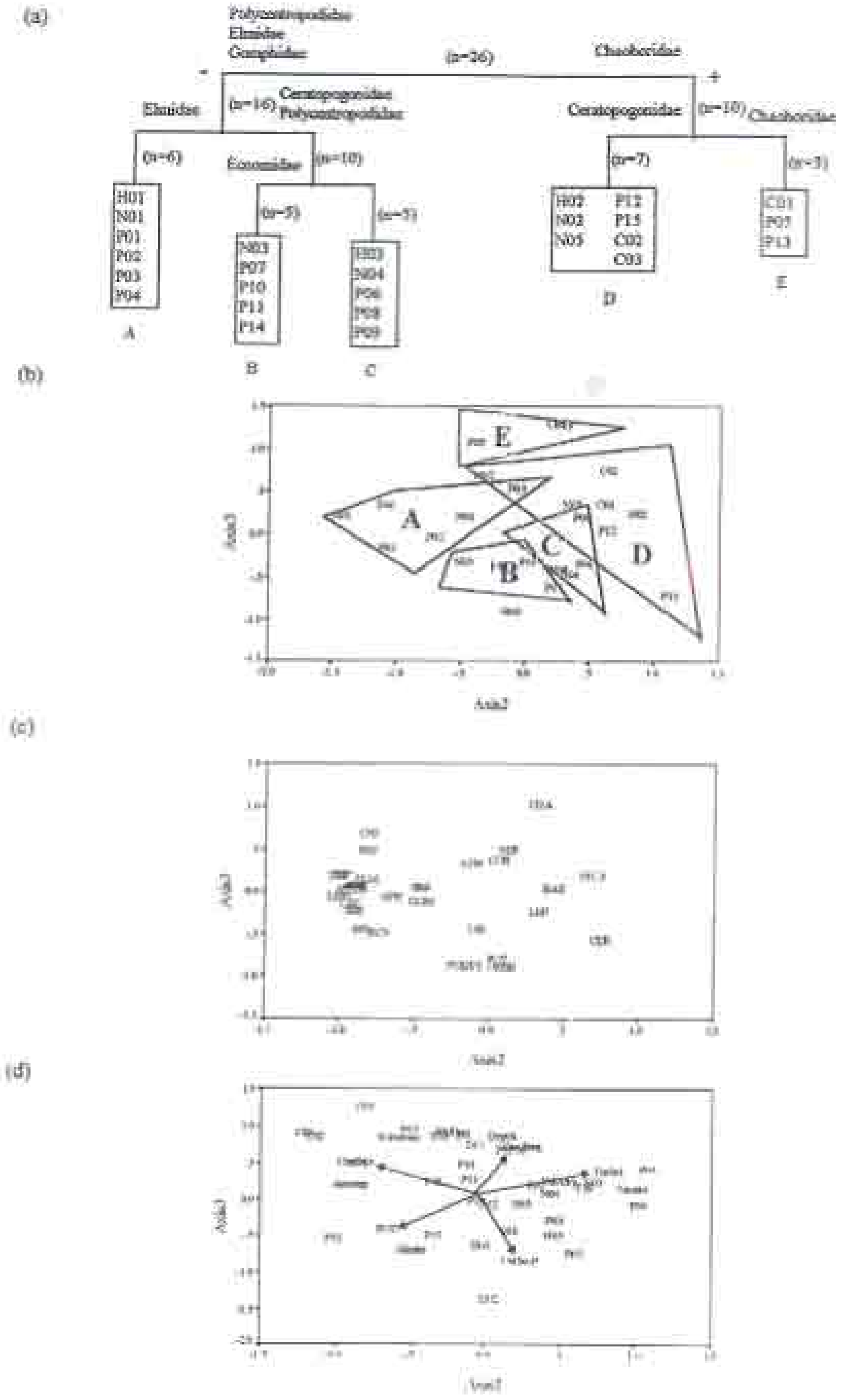


Figure 7 Classification and ordination analyses (April, 1996).
(a) Results from TWINSPAN analysis.
(b) Axis2 vs. Axis3 biplot of sampling sites by SSH ordination.
(c) Axis2 vs. Axis3 biplot of macroinvertebrate fauna by SSH ordination.
(d) Axis2 vs. Axis3 biplot of physicochemical variable by SSH ordination.

June 1996.

This is the last sampling month of the study when entering the early phase of tropical monsoon period, the TWINSPAN can still be capable of separating the sites into five major groups. Fig. 8a indicates the TWINSPAN groups A to E. The first level firstly divided the sites into two groups A (n=1) and the other group (n=26), the indicator family is Sialidae (-). On the positive end the sites are further separated at the second level which dividing the sites into two main groups, B plus C (n=17) and D plus E (n=9), at which the indicator families are Hydropsychidae (+) and Tipulidae (+).

On the negative side of the second level which later dividing the sites into two sub-groups B (n=1), C (n=16), the indicator family is Chironomidae (+). On the positive end the sites are splitted into two sub-groups, D (n=6) and E (n=3), Baetidae (-), Ceratopogonidae (-) and Heptageniidae (-).

The grouped sites D and E are less impacted sites while the other sites are very much affected by mainly natural disturbances. Of among all sites, the sites H03 and H04 are greatly abundant with many benthic faunal families while the site H02 has only one taxa discovered-the Sialidae. The site P13 is explored also having only one family inhabiting, the Chaoboridae.

Certain feasible comparisons of the sites due to water physicochemical variations can be made within this investigating month. At first sight, of the TWINSPAN groups A and B, in fact each group consists of only one site, i.e. H02 and P13, respectively. These two sites are well separated by both the TWINSPAN dendrogram (Fig. 8a) and the SSH plot (Fig. 8b). Even they both have far different values of BOD, TDS, DO, nitrate, conductivity, alkalinity, discharge and depth, these two sites however reveal visually impacted in which each of them has only one faunal family dwelling. The site H02 of upstream highlands where the lands nearby have been cleared, thus considerable amount of surface soils being discharged into water bodies. Such fine earth is later partly suspending and its considerable amount passing to downstream. The remaining suspended residues are eventually sinking to the stream bed. This leads to a substantial modification of this habitat and that not suitably for benthic fauna assemblage, even this site has a considerable amount of DO which is as high at 6.53 mg/L. Such high level of DO, however, is in fact largely from the reaeration caused by water current.

The site P13, in contrast, is clearly indicated the impacts which originating from human sources. As this site locates within city boundary and with a very extremely high BOD level, 12.80 mg/L., consequently such this water environment is not providing suitable habitat for most benthic animal larvae. Also as noted earlier that Chaoboridae is more tolerant to high level of conductivity and this appears to be another confirm case that the site P13 in this month show such similar phenomena, i.e. discovering only family Chaoboridae inhabiting and the measured conductivity is at greatly high value.

Possibly six main water chemistry variables can be drawn to compare between the grouped sites C, D and E, these are pH, conductivity, TDS, turbidity, TSS, DO and BOD, Table 6. The most abundant faunal families occurring at the grouped sites D, and these grouped sites have relatively low turbidity and TSS levels when compared to the other two grouped sites. The grouped sites D also have a markedly highest level of DO, 6.95 mg/L., and lowest level of BOD, 1.03 mg/L.

Similarly to the grouped sites D, the grouped sites E also have higher levels of DO and lower level of BOD, Table 6, this grouped sites likewise have higher numbers of faunal families inhibiting. However, the water quality of the grouped sites D are still superior to the grouped sites E, as when they appear with lower levels of turbidity, TSS, conductivity and pH. One special note to the grouped sites C is that they all have higher value of discharge, which is averaging 34.64 cu.m/sec.

Table 6. Average values of selected environmental variables in June 1996

Environmental variables	Grouped sites				
	A	B	C	D	E
Velocity (m/sec)	0.28	0.12	0.33	0.43	0.56
Depth (m)	0.21	1.20	3.33	1.15	0.71
Discharge (cu.m/sec)	0.25	8.35	34.64	23.41	5.88
pH	8.20	8.60	8.21	7.69	7.95
Alkalinity (mg/L)	36.00	130.00	90.50	92.00	102.67
Conductivity (microS/cm)	62.43	311.20	220.95	167.16	182.94
TDS (mg/L)	41.60	222.13	148.10	111.34	120.08
Turbidity (NTU)	62.00	24.00	118.52	25.17	117.25
TSS (mg/L)	31.50	38.50	94.19	15.33	131.08
Ortho-P (mg/L)	ND	0.40	0.03	0.03	0.03
Nitrate (mg/L)	0.10	1.10	0.42	0.40	0.38
DO (mg/L)	6.53	2.80	6.12	6.95	6.50
BOD (mg/L)	1.23	12.80	2.05	1.03	1.59

ND = non detectable

Velocity ($H = 9.74$, $P<0.05$), depth ($H = 11.94$, $P<0.05$), discharge ($H = 9.64$, $P<0.05$) and TDS ($H = 10.64$, $P<0.05$) are four main variables significantly related to the TWINSPAN grouped sites as being revealed by the Kruskal-Wallis test.

The SSH plot as shown in Fig. 8b reveals a well-defined grouping of the sites in the space. The sites H02 and P13 are far separated from the rest, they both have a marked impacts occurring but by different sources as mentioned earlier. The most cleaner water quality sites, group D, and being abundantly colonised by most aquatic larvae are extending the right hand side of the plot. Its closet neighbors locating a little northward to the plot is the grouped sites E which have subordinate numbers of faunal families to the grouped sites D. The grouped sites C are locating approaching to the bottom of the plot.

Only two SSH axes, axis1 and axis2, are correlated with several physicochemical factors. Axis1 is significantly related to velocity ($r = 0.42$, $t_{(25)} = 2.27$, $P<0.05$), pH ($r = -0.60$, $t_{(25)} = 2.27$, $P<0.01$), phosphate ($r = -0.42$, $t_{(25)} = 2.26$, $P<0.05$), DO ($r = 0.67$, $t_{(25)} = 4.39$, $P<0.001$), width ($r = -0.49$, $t_{(25)} = 2.73$, $P<0.05$), depth ($r = -0.50$, $t_{(25)} = 2.79$, $P<0.05$) and BOD ($r = -0.44$, $t_{(25)} = 2.39$, $P<0.05$). Axis3 is associated with air temperature ($r = 0.54$, $t_{(25)} = 3.15$, $P<0.01$), water temperature ($r = 0.70$, $t_{(25)} = 4.74$, P<0.001), width (r = 0.60, $t_{(25)}$ = 3.67, P<0.01), depth (r = 0.54, $t_{(25)}$ = 3.16, P<0.01), discharge (r = 0.66, $t_{(25)}$ = 4.25, P<0.001), conductivity (r = 0.65, $t_{(25)}$ = 4.17, P<0.001) and TDS (r = 0.64, $t_{(25)}$ = 4.05, P<0.001).

This month is characterizing as the first month of rainy season of the region and thus leading to almost all physicochemical variables rising up at high levels. Surface run-offs can be observed everywhere, and subsequently contributing to high levels of environmental variables measured in most of the waterways. The SSH axes are then appearing to be significantly correlated with several variables.

Fig. 8c shows the family vectors extending to several directions which in fact relating to the sites in Fig. 8b. It is very apparent that much more numbers of families are directed to the grouped sites D and E. The indicator families forwarded to the grouped sites D are, for examples, Potamantidae (POT), Heptageniidae (HEP), Elmidae (ELM), Leptophlebiidae (LEPT), Calamoceridae (CAL), Corydalidae (COR) and Molannidae (MOL). The second highest abundant family is of group E, where the vectors also indicate a larger numbers of indicator families, these are, for instances, Leptoceridae (LEP), Hydropsychidae (HYD), Caenidae (CAE) and Curculionidae (CUR).

The grouped sites C which are influenced by discharge show a certain types of indicator families which most of them prefer deeper waters. These are, for instances, Ecnomidae (ECN), Polycentropodidae (POLY) and Potamantidae (POT). Some pollution indicator families are also extending to this end, for examples, Oligochaete (OLI), Ceratopogonidae (CER) and Chironomidae (CHI). The family Chaoboridae (CHA) is obviously pointed forward to the site P13, where the Sialidae (SIA) is lined directly to the site H02.

There are some certain correlations between ordination axes and environmental variables, which some of the variables significantly associating with axis1. There is no significant association between physicochemical parameters with axis2.

The ordination axis1 is very highly positively correlated with DO (r = 0.65, $t_{(25)}$ = 4.26, P<0.001). This is indeed corresponding to whatever the sites are arranged in the plot, the sites having lower levels of DO are placed on the left hand side of the plot, while the high DO sites located on the opposite end. The pH is strongly negatively associated with Axis1 (r = -0.60, $t_{(25)}$ = 3.71, P<0.01). The trend of pH is then increasing from the right to the left of the plot along axis1.

Other environmental factors which negatively correlated with axis1 are air temperature (r = -0.38, $t_{(25)}$ = 2.08, P<0.05), phosphate (r = -0.41, $t_{(25)}$ = 2.26, P<0.05), width (r = -0.49, $t_{(25)}$ = 2.73, P<0.05), depth (r = -0.47, $t_{(25)}$ = 2.65, P<0.05) and BOD (r = -0.46, $t_{(25)}$ = 2.65, P<0.05), while water velocity is positively associated with axis1 (r = 0.42, $t_{(25)}$ = 2.29, P<0.05).

The influence of physicochemical variables due on the sites is shown in Fig. 8d. Most of the environmental factors do affect most of the sites where locating at the bottom of the plot. At the upper part of the plot where more numbers of faunal families flourishing, these sites are comparatively less impacted by environmental factors. In other words, the sites at the upper part of the plot have low level (intensity) of environmental variables.

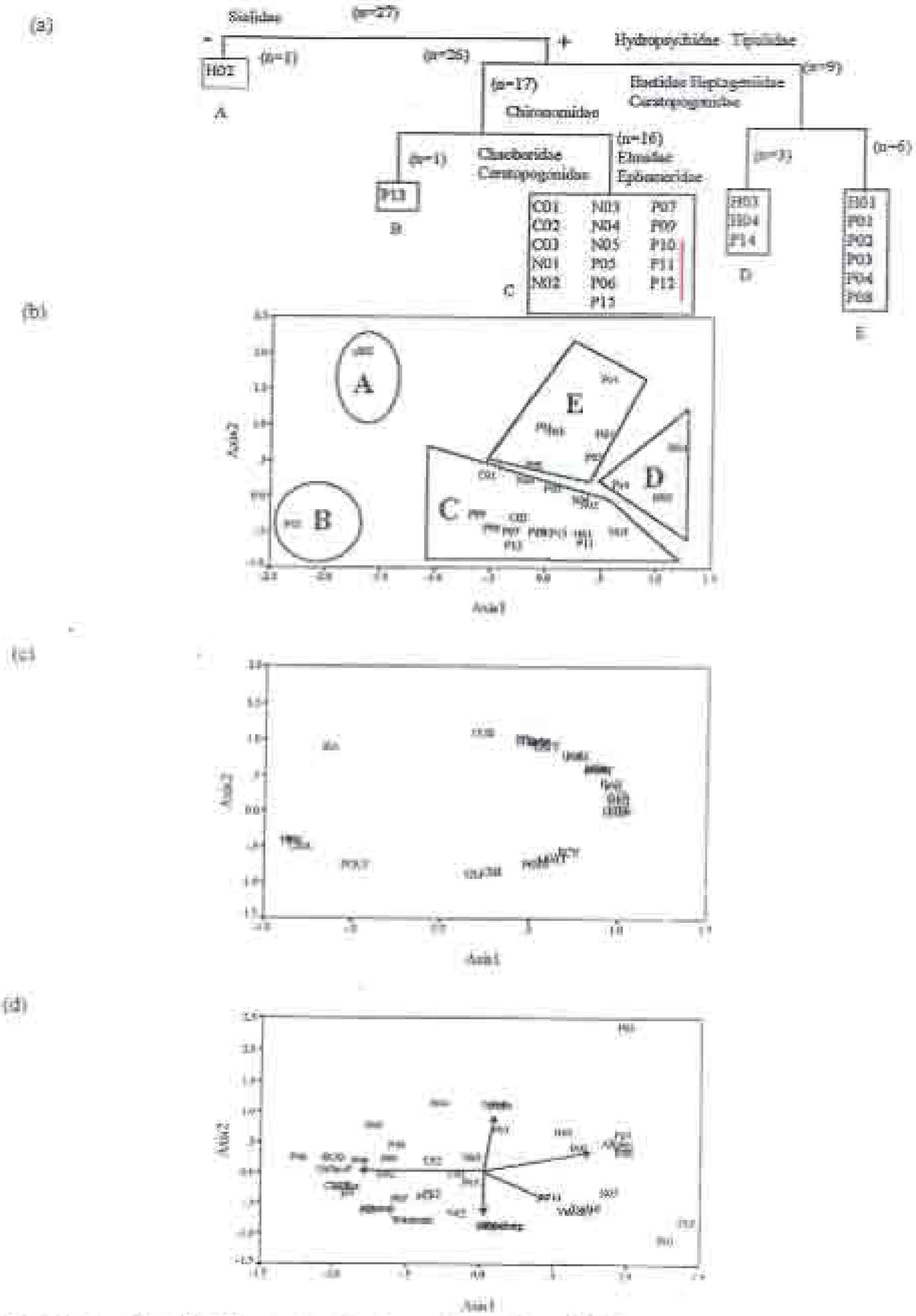


Figure 8 Classification and ordination analyses (June 1996).
(a) Results from TWINSPAN analysis.
(b) Axis2 vs. Axis3 biplot of sampling sites by SSH ordination.
(c) Axis2 vs. Axis3 biplot of macroinvertebrate fauna by SSH ordination.
(d) Axis2 vs. Axis3 biplot of physicochemical variable by SSH ordination

6 Concluding remarks and discussions

6.1 Benthic macroinvertebrate species distribution

Distribution of benthic macroinvertebrate species are varying through various types of landscape in the Pong catchment. The upstream lands have more numbers of benthic species, and becoming less abundance at lowland areas. The two prime factors which determining the existence of benthic species are (1) habitat specification and (2) habitat disturbance.

(1) Habitat specification

Certain benthic species inhabiting at a site is the first issue to be discussed here. This is the case of habitat specification preferential for particular species. For examples, most of the sensitive Ephemeroptera, Trichoptera and Plecoptera taxa are abundant at upstream highlands. The stream reach uplands are relatively shallow with the average minimal depth less than 0.50 m. The water quality of these upland sites are relatively clean with less levels of contaminants. The stream beds of the upstream sites are mixed but mainly underlain by bed rock, boulder and cobble. Also at those sites, along the stream banks, shading is largely provided by the abundant trips of native vegetation. All these habitat characteristics are preferred by certain aquatic macroinvetebrate species.

There are many instances found in correspond to such a habitat specification criterion. These are, for examples, two obvious mayflies groups, Heptageniidae and Leptophlebiidae, discovered them dwelling only in a good environmental places, which including clean waters, cool temperature and rock substrates. Certain trichopteran groups favor to inhabit at such above specific habitat are Psychomyiidae, Goeridae, Leptoceridae, Odontoceridae, Hydroptilidae, and Calamoceratidae. Some dipteran groups discovered which limiting to dwell at such refuge are Rhagionidae and Tipulidae. Coleopteran groups corresponded to such habitat are Gyrinidae, Elmidae and Hydrophilidae. Perlidae is the only one stonefly family discovered in this catchment, its living is also restricted to the upper part of the catchment. Gomphidae is the only odonatan taxa which often found living at highlands. The megalopteran Sialidae is, the only family discovered, existing at the uppermost upstream lands. Unlike others, the hemipteran families are all wide spread throughout the Pong basin.

The more epidemic trichopteran taxa are Hydropsychidae, Philopotamidae, Polycentropodidae and Ecnomidae. These taxa groups are very often found inhabiting in lowland deeper waters. If the waters become clean, some mayflies groups are also widespread throughout the catchment both shallow and deeper stretches, these are Potamanthidae, Caenidae and Ephemeridae. Most abundant dipteran taxa throughout the catchment are Chironomidae and Ceratopogonidae. Odonatan Lebellulidae and Macromiidae groups are found almost everywhere. The Corbiculidae bivalves and viviparidae are also abundant elsewhere.

The more specific taxa dwellers at pollution sites are of mainly dipteran groups, i.e. Chironomidae, Ceratopogonidae, Chaoboridae, and Oligochaete. Some sites with heavy organic pollution, the only living taxa group explored is only of Chironomidae family.

As this study recovers animal samples from river sediments, all of the animals discovered are limited to organisms that living only on river beds. The high requirement oxygen taxa would not expectedly to be found in the deeper water samples with less amount of dissolved oxygen prevailed. The generalization associating with benthic taxa assemblages above is then primarily involved in the findings of what taxa depositing at the river bottom sediments. Such these delineation about benthic larvae groups have never been published elsewhere in Thailand. Thus, the preliminary findings by this study will contribute the significant knowledge of biology of the Thai native macroinvertebrate fauna, which will be available for later references or more specific studies.

Dilemma of cross comparisons between benthic taxa assemblages versus sites?

Species richness is generally recognized as a primary "metrics" that used to characterize the degrees of biological quality of any environment of concern. To compare the species richness across all of the sites without regarding taxa-habitat (site) preferential interaction, therefore this is less relevance. Recent research recommended to the one, who is inevitably going to use this type of "metrics", have to modify that data through some sorts of what is now called "multimetrics" (Lenat and Barbour 1994). This is in fact the late development to date associating with "metrics approached" as its main idea is to combine all of the results from several metrics by forming into wholly one reliable biological result.

However, it is claimed that such "multimetrics" approach is not always valid as being applied to all several habitats throughout the catchment (Norris 1995). Only the habitats with similar physical environments may be largely appropriate to use this type of "multimetrics" analysis, which such alike habitats are recently called "ecoregion".

In summary, all of the metrics being used now, the multimetrics recently supershade the conventional species richness measure and other similar indices. Nevertheless, to use this multimetrics with biological data, there will be a certain limitation by only applying it restricted to each ecoregion and that any comparisons can thereafter be made through similar habitats in that ecoregion.

At this stage, the number of species found by this study is then contributing only to listing the findings of species (or genera) which inhabiting in the Pong catchment region, rather than making a cross comparisons of among the sites in the catchment. Nevertheless, as this study encounters the time constraint on report due submission, such exercises associated with multimetrics would then be now not succeeded. The high stacks of data collected by this examination will thus be later analyzed by the multimetrics approach in the following years. The multimetric is indeed very much interesting, and it seems to be readiness to further handle by this study when the time span allowed. As this year all of quantitative data set have been timely already systematically stored, additionally most of the times of the first year investigation are for field samplings and specimens identifications.

Descriptions of average number of species assemblages of all sites versus times would be principally sufficient at this stage. The minimal average number of species occurs in April (Table 1), while the maximum is in February. The bi-month taxa recorded by this study indeed implies some facts associating with life cycle of aquatic macroinvetebrate fauna of the region. According to bimonthly sampling, large numbers of macroinvertebrate larvae are discovered in December and February (the cooler months), while the least numbers found in April (the hottest month). When disregarding environmental impacts to the numbers of taxa, this is generally indicating that most of the aquatic macroinvertebrates at this summer time go on to adult stage.

Cross comparisons by using species numbers, which only being preliminarily analyzed, show some certain facts about differentiation between the similar sub-regional sites. The number of species deposited at the upper Pong and Cheon rivers' sites are not different. This would considerably indicate a common environment that underlying between them, as most of them are locating at upstream highlands. However, the more insightful investigations about species assemblage at each site through time is still needed by this study.

The density of individuals (organisms) is another data set that would be expected to show a certain trends which relating to the organism-site variations. Interestingly, the average density of individuals is rising up at higher level in cooler months (December and February) whereas the hottest month (April) it becomes decreasing (Table 1). This phenomena is indeed corresponding to what is occurring with the species numbers. However, the density of organism values reveals very varying of each month data set.

(2) Habitat disturbance

Some facts revealed by this study are principally about the consequences of habitat disturbances. When considering the benthic species depositing at a site through time, it implies a set of causes that make the habitat not suitable for benthic animal dwelling. The disappearance and reoccurrence regimes may be the case for discussions here. The study results show two main sources of impacts emerged to water dwelling animals, i.e. physical and chemical factors.

Of the upper catchment sites the physical factor is prone to be the major impetus which disturbing the habitat at a site. This is leading to the disappearance of some benthic species which unable to resist that changes, for examples, heavy discharge, high turbidity caused by surface run-offs etc. Thus, all of the fragile larvae are wiped out by the river flow. In contrast, once when the river waters return to normal state, these larvae are then reappearing. This can be obviously seen from most of the sites of the upper Pong catchment.

Another important note about physical effect is that between the sites which lying at the same altitude, some sites have different taxa compositions. Certain examples can be drawn from the study is about the differences between the lower Cheon and the upper Pong sites. The two grouped sites have different physical environments, for examples, water depth, discharge, riparian vegetation and substrates, these factors are mainly thus determining the occurrence of certain benthic species.

Some lower sites of the catchment are also showing such above paradox, i.e. P08, P09 and P11. The three sites here are not only affected by physical source but also from organochemical origin. The first two sites locating at main stream channel, very often that once when the water quality changed due to organic pollution discharged from upstream, certain taxa assemblages become rapidly declining, and finally all disappearing. Whenever the water quality is relatively improved, that taxa begin to increase in numbers. In this aspect, the chemical factor has a much more impact to animals than the physicals.

The site P11 is of the Pra Kuea river locating nearby the city but a little further upstream before the Pra Kuea reaching the city center. This site is susceptible to organic pollution source from communities. The realm of occurrence of certain species associated with pollution is resemble to the sites P08 and P09.

At this stage, according to the two cases mentioned, it can be concluded that as their physical environment at a certain time of the year are quite static, the water pollution point source is then being the cause of species disappearance.

Effects of organic pollution is very apparent when considering a relationship between the sites P12 and P13 and their benthic animal dwellers. These sites locate at almost the center of the city and their physical characteristics are quite constant throughout the year, except at sometimes during raining periods. When excluding the rainy months, all of the remaining times the benthic animal (organism) variation is only limited to the number of chironomid larvae. These sites in fact show a clear gross organic pollution due on the numbers of benthic animal, and where only chironomid taxa is found. Thus, the least number of chironomid organism found can be related to the organic pollution intensity. On the other hand, once when, for example, the BOD reduces in level the numbers of the midge larvae increase.

Another obvious chemical impact is of the Chi river sites, for example, C01. This site during summer months becomes blackish as a result of saline intrusion from underlying rocks. No substantial impact from other chemical sources occurred to this site Chaoboridae is the only major taxa can dwell in this site in summer months, at when the water bodies become less diluted.

To this end, it can be summarized that the existence of benthic animal is determined by two main factors, i.e. habitat specification and habitat disturbance. The dwelling of a species at a site when without any external impacts both by physical and chemical sources is mainly depending on its habitat preference. The regime of present and absent at a time of the species in a certain site is based on its habitat disturbance. These two approaches can be used to further examine in many several aspects associating with this animal groups.

For examples, the first may be useful for any detailed studies about biology of a certain taxa which being based on what is initially found by this study. The findings of such a species where it only inhabits in a certain site, the site with particular prevailing environment. Species and habitat conservation at that site may be another topic to continue.

The second may pose many hypotheses relating to the theme of present and absent of a species at a site. For examples, it might be profitable to see that to what specific level of BOD that will allow such a species to survive at a site in the natural situation. A certain correlation between that two ends may be found and that lending the results to adjust the ambient BOD standard which can be actually applied to the real situation in Thailand, rather than using overseas standard as presently practiced.

6.2 Faunal diversity and grouping of the sites demonstrated by multivariate analyses

Discussions about the effectiveness of using multivariate methods in quantifying environmental data in Thailand are difficult. Knowledge associating with several multivariate data analysis procedures are very poor, and also their software are not readily accessible from most developing countries. Training to use several multivariate procedures is viewed to be very necessary for the Thai academicians in the future. Training schools towards this type of analysis are largely available in advance western universities.

Prior to elucidating the data results analyzed by the classification method, the TWINSPAN and the ordination, the SSH, by this study, it is worthy to have a short discussions about the uses of both types of data analyses to date.

Multivariate methods have been very much more well known and widely applied since Wright *et al.* (1984) they first explore of using the TWINSPAN analysis incorporated with ordination method, the DECORANA, in classifying the streams in England based upon macroinvertebrate fauna. Later, there are many several shortcoming publications of using these techniques to examine the distribution of benthic fauna and their relationship to physicochemical factors (for examples, Furse *et al.* 1984, Ormerod and Edwards 1987, Rundle and Hidrew 1990, Fledman and Connor 1992, Gower 1994 and Reynoldson *et al.* 1995).

The TWINSPAN is proved to be robust in analyzing species/samples data metrix and finally generating the site groupings based on their faunal composition. In other words, the sampling sites are classified into groups via their animal attributes. Norris (1995), like most other investigators, insisted that the multivariate method is far superior to other types of analysis techniques. As ecological data is multidimensional in nature, this approach is very appropriate to be used in analyzing biological data.

The polythetic divisive type, the TWINSPAN, is rarely use in Thailand, then referencing and discussion cannot be apparently made here. Indeed, few papers appeared of using TWINSPAN analysis, for examples, which recently appears in Rajchapakdee (1992) who was doing her masters research at Chiang Mai University, all of her multivariate data analysis handling aided by the British academicians. This research limits the study areas only within some small forest streams in Doi Suthep, Chiang Mai. Extensive investigation across the catchment, like this study, has never yet been done. Thus, this research is then being the first attempt in Thailand of using this type of analysis for a basin-wide study.

The ordination methods themselves are also proved to be a very useful tool in revealing a certain position of a site in the space plot. Several ordination methods available to date, but have to be extremely caution when use. Some methods of this type of analyses, including TWINSPAN, are applied appearing in Thailand as masters research, but rather genuinely understanding about the theories behind them is very limited. Thus, any conclusions due made may be less valid.

Of among ordination methods Minchin (1987) pointed out from the several tests that some popular ordination methods lack data analysis robustness, particularly DCA (e.g., DECORANA and CANOCO) procedures. It is indeed the problems of linearity (linear? or non-linear? or semi-linear?) responses of biological data. To use any of particular ordination procedures, i.e. Factor Analysis (FA), Principal Component Analysis (PCA), Principal Coordinates Analysis (PCoA), DEtrended CORrespondence ANAlysis (DECORANA), with biological (community) data have to be extremely careful.

Later, Belbin (1995) found that the best fit ordination analysis procedure to biological data is of the semilinearity type, and thus leading to the creation and the use of Semi-Strong Hybrid Multidimensional Scaling (SSH in this term) in stead of those procedures mentioned. Most recently Norris (1995) reviews and reaffirms the appropriateness of SSH which agreeable to that of Minchin (1987). Thus, the ordination results, by using those former ordination procedures, recently presented by some investigators in Thailand would produce some distortions of the samples/sites in the space biplots. Any interpretations of the former Thai researchers' results aided by lending some former ordination methods are rather not entirely valid.

The classification type-the TWINSPAN, on the other hand, is still effective in classifying community data to date. However, the use of this procedure is also needed very much critical consideration. As the TWINSPAN applied the Chi-squared distance to generate the results which emphasizing the rare species by disregarding the total abundance of a species. Predetermination design about the data input into the TWINSPAN program then have to be initially carefully made. If not, the outputs as the grouped of sites/samples and species are to be not effectively valid. The bivariate family data (present and absent) by this study is then free from that limitation, and that expected to contribute a critical logical results.

Discussions made here about the TWINSPAN and SSH results analyzed by this study will be falling into three main aspects, firstly grouping of the sites based on these two methods will be disputed, secondly key macroinvertebrate species assemblages at each grouped sites are briefly discussed, and lastly, any relationships between the grouped sites and environmental variables are necessarily fundamentally concluded.

6.3 Clusters of the sites

(1) Reference sites

As can be seen from Figs. 4 to 8, there have been a considerable shifting of the sites between the TWINSPAN groups through bimonthly variation. Attractively, the sites H01, H03, P02, P03 and P04 have always been attached to the same end of the TWINSPAN dendrogram in every sampling occasion. These sites locate relatively at upstream highlands. The sites H01 and H03 are situated at higher altitude of about 600 M.S.L., whereas the sites P02, P03 and P04 are markedly at lower locations with altitude of about 200 M.S.L.

It appears that these sites can be classified as reference sites of the Pong catchment, the sites that with the relative pristine conditions can be later used for comparison by other sites of concern. The SSH biplots also show a well separation of these sites, may named "reference sites", in concordance with the TWINSPAN results. Thus, it is promising that these sites are well characterizing a certain environmental state in which through the year maintaining a condition attributable to aquatic macroinvertebrate dwelling.

Mayflies Heptageniidae, Leptophlebiidae and riffle beetle Elmidae are the common faunal taxa that can be found throughout the year at these reference sites. It is very much well known about the heptageniid and leptophlebiid taxa that they all require quiet pristine clean waters. The biological working party scores (BMWP), which arbitrarily grouping the taxa according to their tolerant values to environmental stress, assigned these two taxa, like most other sensitive taxa, at highest score (10) (Spellerberg 1991).

Elmidae is another taxa group which is often found in those reference sites. Many European researchers state that the elmid taxa is quite common everywhere in European continent, but this is rather much different as in Asian environment here. What is found by this study is agreed to Jäch and Kodada (1995) who recognize that the elmid riffle beetle can be used as indicators of water quality, and also featuring a condition of endangered habitats in this part of the world. They note that these taxa most frequently discover dwelling at fast flowing high saturated forest streams. The elmids thus like to dwell in the relatively clean water habitat. European score applied for the elmid, 5, which implying its moderate tolerant to pollution, is therefore not likely to be used with Asian tropical environment.

However, there may be some genera of Elmidae that may follow the European case as by this study some elmids are found inhabiting downstream. This might be the case of species specific. Biology of this taxa group in Thailand will still be needed as to fulfill a more understanding of this family. Another important observation likely to note here is that we very often find the elmids gradually recover when the water environment become improved, but they disappear rapidly once if the waters begin to degrade.

It is not always the case that the heptageniids can only be discovered at highland cool streams, but in some particular reaches of lowland river we still find them dwelling as when the water quality are considerably improved. To this end, the present of this taxa can also be used as another indicator species. However, it is true that most abundance of these taxa are at highland cool streams. Possible interesting hypothesis may pose here that whether the genera and species of heptageniids are the same in those lowland and highland habitats. Taxonomic studies about this species is thus further needed. Another point of concern may be that of what additional factors other than water quality which conditioning such a taxa to live.

(2) Temporal translocation of the sites

There have been certain ten sites that transferring from one to another of between two TWINSPAN sides by the first level split, these are C02, N03, N04, P06, P07, P08, P09, P10, P11 and P14. These moving about sites are needed more clarifications here.

In October, even most of the sites at lowlands are extensive affected by high river flows, there are still three sites that a certain numbers of families had been explored, C02, N04 and P10. The faunal groups that determine these sites shifting to be included in the better environmental quality sites of this month, groups A and B as in Fig. 4a, these are Elmidae, Caenidae and Ephemeridae. These faunal groups are common taxa that living in these grouped sites.

The more subtle split between the better environment grouped sites A and B is by using the absence of indicator families, Baetidae and Leptophlebiidae. Special attention would then place on the absence of Leptophlebiidae where this taxa has been never found at lowlands. Baetidae is however able to be discovered almost every site in the catchment. As stated earlier that the leptophlebiids are typed as good environment dwellers. The grouped site A is thus characterizing a much better environmental quality than any other grouped sites.

On the other end of the TWINSPAN result in October, Oligochaete and Ceratopogonidae are the taxa indicating the groups C and D. The sites P01, N01, N02, N03 and N05 of the upper catchment are placed in these groups which rather much impaired groups. The determining factors forcing translocating those sites which revealed by correlating environmental factors with TWINSPAN groups and SSH axes are physical factors, i.e. discharge, river morphology and turbidity. These sites at this time of the year are very much affected by physical disturbances and thus driving them to be grouped with most of the lowland impacted sites. Fig. 4d also confirms the effects of particular physical factors across these sites.

When considering all of the sites in terms of biodiversity, the grouped sites A have far greatest diverse numbers of faunal families, Fig. 4c, while the grouped sites D have the least. The maximum diversity site is H04 (Tad Mok) with 14 families while the minimal is 2 families of P01 (Na Noi). In fact, the waters at Tad Mok is temporarily available, it will be eventually dried up in February and April. However, the substratum of this site is bed rock and well protected by a dense riparian vegetation. While, the site P01 characterizes a fast turbulent flows during October as this site receives the waters flushing steeply from the Phu Kradueng National Park where the Pong river originated.

However, it can be concluded at this stage that the findings associating with biodiversity at a site by this study is in fact very essential as we can quantify the degrees of biodiversity of the lands (sites) across the catchment at a certain time of the year.

In December, one obvious site, P09, of the lowlands is included in the better environmental quality grouped sites. The site P09 is discovered a large numbers of faunal families deposited when at this time of the year the waters at this site restore to normal condition. Leptophlebiidae is still being an important faunal species indicating the first TWINSPAN splitted level. All of the lower sites of the Cheon river are well separated and grouped into the impacted grouped sites.

Besides the physical factors, e.g. discharge, which conditioning the faunal assemblage at a site, in this month the other prime conditioners are DO and nutrients. All of those lower Cheon sites have been greatly affected by nutrient intensity, Fig. 5d. Even the DO vector in Fig. 5d does not show a clear association about the influence of DO (as a limitation of the selected axes to be plotted), but the DO is very highly significantly related to axis1. This means that in this month the DO values have a great influence on discrimination of the site groupings.

The topmost faunal diversity is H03 which 26 families found, while the least is P13 with only 2 families. According to Fig. 5c, the much more degrees of biodiversity sites are the sites located at the bottom of the plot, i.e. the grouped sites A. It can easily notice that the site P01, formerly including in the impacted sites in October, then at this month, returns to normal state by having 8 faunal families discovered. Moreover, the most striking fact is about its faunal family contents between the two months, October versus December, thus only two families occurred in October, Chironomidae and Ceratopogonidae, but in December found eight families. Further, the site P01 with eight families discovered, four outstanding sensitive families also appear, these are Heptageniidae, Phryganeidae, Leptophlebiidae and Perlidae, and thus resulting in the site P01 characterizing good environmental quality, and with higher faunal diversity in this month.

The site P13 which belongs to group C (the highest level BOD and lowest DO group-Table 3) has only two families dwelling, Chironomidae and Oligochaete. These two families are very much well known from overseas that they imply an occurrence of water pollution, and the result explored here is also agreed to that-the pollution indicator species.

In this instance, it can be summarized that the high DO level (Table 3) is being the first enhanced factor that leading to the high aquatic benthic animal diversity, as clearly seen at site H03. The second is physical factor, e.g. discharge, velocity and depth, which very much revealed affecting faunal community variation. But when those physical factors decrease their intensity, the water becomes calm and once again it is able to mediate more faunal groups assemblages, as apparently shown in the case of site P01.

In February, the lower sites of the Cheon river (N01 to N05) are still being included in the impacted sites of the TWINSPAN groups, Fig. 6a. Two of the lower sites, P06 and P08, are translocated to be included in the less impacted upstream sites. There are two obvious components that made these two sites encompassed in group B, the first is the number of faunal families increased and the second is the indicator families. Both of them have more numbers of families, similarly ten families. Potamantidae is one of the most sensitive forms which found at site P08.

The most diverse faunal families are of P02 and H03, both have the same numbers as 20 families. In this instance, the site P02 may be used as the reference site for comparison with any sites with the same plain (200 M.S.L.), while the site H03 is used to distinguish faunal diversity of among the higher altitude sites (600 M.S.L).

However, as the fact that even the above two sites have greater family numbers but when considering the sensitive families occupying at a site of the same altitude, the site P03 is discovered more number of sensitive families dwelling than P02. For examples, the site P03 is explored dwelling by Perlidae and Leptophlebiidae whereas none of these taxa found at P02. This case is also the same when comparing between the sites H01 and H03.

A certain fact which revealed by the results of TWINSPAN groupings from all bimonthly investigation that these sites (P02, P03, H01 and H03) are always binding together. Therefore, we wish to recommend here that it would be more appropriate to assign such that grouped sites firstly to be reference sites rather than using only a single site. Further, such reference grouped sites can then be divided into sub-groups with different altitudes and other physical environments. This second divisive groups of each is then to be compared by any sites of interest, the test sites which having similar environmental attributes to that sub-group sites. All of the reference sites firstly constructed are derived from the classification by the TWINSPAN procedure and further reconfirmed by the ordination SSH method.

The site P13 in February is virtually polluted. Both BOD and nutrients are at highest values in this month. There is only one faunal family dwelling in this site, i.e. the pollution indicator Chironomidae. Consequently, the site P13 is far well excluded locating beyond any other groups by the SSH biplot, Fig. 6b. The faunal diversity positions obviously reveal, Fig. 6c, lining towards groups A, B and D. Most of the faunal families are extended to groups A and B. Such this instance, the sites in groups A and B can be assigned as reference sites. These is indeed a well mixture of highland and lowland sites which can be determined for later comparison with other sites at this time of the year.

In the hottest month, April, the number of faunal family begins to reduce in most sites. Interestingly, the site H01 is now becoming the site having the maximum number of taxa, 16 families. Most of the remaining sites are affected by several environmental factors as shown by their high correlation to the SSH axes. Abundant faunal families of the lowland sites are markedly decreased.

The grouped sites A illustrate the maximum diversity of faunal family as clearly indicated by their positions in Fig. 7c. The sites P01 to P03 of the upper catchment are tied to this grouped sites. At this time of the year, the site P04 of lowland area of the upper catchment is included in this grouped sites. At the site N01, the environment is well improved and subsequently made the site having more number of families, thus binding it to this group.

The site H03 which is used to have the most diverse faunal families, it now becomes the site which well separated from the faunal topmost grouped sites. However, it is still countable to be included in the less impacted sites when compared to the other sites, Fig. 7a. As the sites H03 and H01 line on the same altitude, but each of them has far unequal amount of forest covers, the site H01 has more than ninety percent forest cover while the site H03 has less than ten percent, this consequently leads to different degrees of capacity in nourishing forest-water related animals.

Additional example is of the site H02, which is on the same plain as H01 and H03. In April, this site is now becoming stagnant with less amount of waters available. On one side of the stream bank the lands have been extensively cleared for corn fields and thus varnishing almost all of the trees, during summer this site becomes stagnant. The site has comparatively the least faunal family numbers discovered when sampling, i.e. only two families.

According to the above evidences, it can be concluded that the degrees of forest abundance can play a major role in supporting aquatic animal communities. This is exactly right as in our tropical environment, and it is becoming obviously critical situation particularly during summer month.

To this end, however, we currently still do not know the fact of detailed life cycles of our native aquatic macroinvertebrates. What we found by this study now it is just merely being the beginning step of exploring the variations of structure and abundance of our native aquatic macroinvertebrates through time and space. There are yet to be several thousand topics needed to be further investigated, e.g. biology of each faunal groups, detailed sensitivity of each species to environmental changes and so many on.

In June, the early rainy month, larger amount of waters become available at the driest site, H04, and it becomes wet with much waters available. Macroinvertebrate fauna increase in numbers in a certain sites, particularly the sites where locating at uppermost catchment, i.e. H03 and H04. These two sites have 10 and 0 (no waters available) family numbers in April, in June contradictorily they have 18 and 21 families respectively. The site H04 now becomes restoration with rather healthy ecosystems after it had gone through an abrupt harsh environment for almost four months. In this month, the site H04 occupies the highest family number when compared to any other sites. Four sensitive families, Heptageniidae, Elmidae, Molannidae and Leptophlebiidae, are discovered abundantly at this site.

The number of faunal family is also increasing at site H03, 18 families. The sensitive Potamantidae which once appeared in April also being discovered in June. The sites H03, H04 and P14 are bound to be the only one grouped sites in this month that characterizing the most diverse faunal family assemblages. Fig. 8c clearly illustrates the highest diverse families extending to the grouped sites D.

Two main extremely polluted sites in June are H02 and P13, and clearly being separated from the remaining sites, Fig. 8b. Faunal diversity at these two sites are comparatively at lowest numbers, Fig. 8c. H02 receives a considerable first storm effect which subsequently wiping out all of depositing animals. While in the lowland areas, the sites are just about to be affected by this event. Their waters are not yet receiving much disturbance by storms like the uppermost sites where the water dilution very much prevailed. Thus the site P13 yet, for example, reveals a severe degree of water pollution impact, its BOD level rising up to 12.80 mg/L. There is only Chaoboridae faunal family discovered inhabiting at this site.

The site P14 (Ta Hin) of the lowlands in June is included in the most diverse faunal family sites H03 and H04. Of among faunal families inhabiting in this site, the sensitive form Elmidae is also discovered. The site P08 is also bound to group E which is also relatively less impacted. The TWINSPAN groups D and E in this month are less impacted and indicating much abundant faunal families inhabiting, Fig. 8c. These less polluted sites clearly have been minimal impacted from discharge, width and depth, Fig. 8d. The DO value is the highest influential factor that conditioning the positions of the sites in the SSH plot, Fig. 8b. These three sites, H03, H04 and P14 in Fig. 8b are clearly shown such high DO levels which relating to axis1.

It appears that, in June, both the TWINSPAN and SSH are highly sensitive which being capable of differentiating the sites, particularly the extreme sites, such as H02 and P13, which characterizing severe water pollution occurred and also the least faunal families dwelling.

6.4 Overall synopsis

Indeed, even this study intends to reveal a certain results that have been discovered only limited to the first year of investigation. But, the authors in fact found that very much critical efforts have been spent on this research prior to attaining the overall research objectives set forth so far. Several points that have been raised on the way through this report so far, and that may need thousands of studies to be furnish in order to achieve well understanding about our native macroinvertebrate fauna. This is as a result of the lack of critical research done associating with these faunal groups in Thailand for decades.

However, important findings according to this study can be shortly summarized as followings.

(1) Macroinvertebrate taxa distribution across the catchment are very much diverse. The environmental factors that determining them assemblages at a site are both from physical and chemical sources. These two main determinants are originated from both human and natural induces.

(2) The occurrence of benthic fauna are being conditioned by two main intrinsic modes, namely, habitat specification and habitat disturbance. The former implies the favor of a macroinvertebrate species likely to dwell at a certain site at which that site has a unique environment appropriated to such a species. While the latter reveals the consequence of habitat modification that made the habitat not suitable for macroinvertebrate species assemblages.

(3) Taxa abundance and community composition are both well clearly related to environmental changes both by time and space. Disturbances from both human and natural sources can be characterized by macroinvertebrate taxa variations.

(4) The less impacted sites reveal having the more degree diversity of macroinvertebrate taxa than that of the impacted sites.

(5) Macroinvertebrate community at a catchment wide scale can be successfully classified and ordinated to form different groups of sites by multivariate analyses methods, thus enabling us to spatially and temporally compare among all of the investigating sites.

(6) The analyses by multivariate methods can lead to a construction of any reference sites, which later these sites can be used for comparison with any sites of concern. The group of reference sites is more encouraged than only assigning to a single site.

(7) Most indicator species published internationally which being able to indicate water pollution, this findings also discover most of the results agreed to those publications. However, there are still some taxa being noticeably placed in doubt as raised by this study. This is mainly from our native taxa are of tropical environment in which to some extent they characterize some forms of differentiation from those in temperate zone. For example, European researchers found their *Simulium* sp. everywhere across the landscapes, but our native *Simulium* sp. is only limited to the upstream coollands.

(8) The degrees of environmental quality factors at a site, even only a result from one year of research, it is clear that, such degrees can be assessed by using macroinvetebrate fauna variation results. This will lead to a critical issue in nature conservation and restoration at a particular sites or certain landscapes.

(9) The "biodiversity" certainly as agreed to international approach can be assessed by this animal group. To include macroinvertebrate approach in "biodiversity" quantifying methods is the most appropriate way as claimed by many international investigators. The findings by this study is also agreed to that statement as these taxa are water-forestry related animals in nature. The more pristine areas the more macroinvertebrate taxa will be, this is what we actually ascertain.

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Appendix 1

Macroinvertebrate fauna of the Pong catchment in October, 1995

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
C01	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	2	0	0
C01	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	1	0	0
C01	Trichoptera	Hydropsychidae	Macrostemum similior	0	0	0	0	1	0
C01	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	1	0	0
C01	Trichoptera	Polycentropodidae	Polycentropus sp.	0	0	1	0	0	0
C01	Diptera	Chironomidae	Chironominae	2	0	3	2	1	11
C01	Diptera	Chironomidae	Tanypodinae	1	0	1	6	1	4
C02	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	0	0	1
C02	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	0	1	0
C02	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	1
C02	Diptera	Chironomidae	Chironominae	6	0	5	1	4	4
C02	Diptera	Chironomidae	Tanypodinae	2	3	0	9	3	3
C02	Diptera	Chaoboridae	Chaoborus sp.	0	1	0	0	0	0
C02	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	2	0	0	1	0
C03	Ephemeroptera	Ephemeridae	Litobrancha sp.	1	0	0	0	1	2
C03	Trichoptera	Polycentropodidae	Polycentropus sp.	0	0	0	0	2	0
C03	Diptera	Chironomidae	Chironominae	5	7	1	20	1	1
C03	Diptera	Chironomidae	Tanypodinae	0	0	0	0	1	3
C03	Diptera	Ceratopogonidae	Bezzia sp.	5	0	0	0	0	0
C03	Diptera	Chaoboridae	Chaoborus sp.	0	1	31	0	7	1
C03	Oligochaeta	Oligochaeta	Oligochaeta	27	2	0	9	7	0
H01	Trichoptera	Hydropsychidae	Hydropsyche sp.	0	1	0	0	0	0
H01	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	0	1	0	0
H01	Ephemeroptera	Baetidae	Baetis sp.2	0	0	0	1	0	0
H01	Ephemeroptera	Caenidae	Caenis sp.1	1	2	0	0	0	1
H01	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	0	0	1
H01	Plecoptera	Perlidae	Neoperla sp.	0	0	1	0	0	0
H01	Odonata	Gomphidae	Erpetogomphus sp.	0	0	0	1	0	1
H01	Diptera	Chironomidae	Chironominae	0	0	0	0	2	2
H01	Diptera	Tipulidae	Hexatoma sp.	0	1	1	1	0	1
H02	Ephemeroptera	Baetidae	Baetis sp.2	0	0	1	0	0	0
H02	Ephemeroptera	Leptophlebiidae	Habrophlebiodes sp.	0	2	1	0	0	0
H02	Hemiptera	Gerridae	Metrobates sp.	0	0	0	0	1	0
H02	Coleoptera	Hydrophilidae	Hydrochus sp.	0	1	0	0	0	0
H02	Diptera	Chironomidae	Chironominae	14	11	17	15	3	6
H02	Diptera	Chironomidae	Tanypodinae	2	1	1	2	0	1
H02	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	1	0	0	0
H03	Trichoptera	Odontoceridae	Namamyia sp.	1	0	0	0	0	0
H03	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	1	0	0	0	0	0
H03	Ephemeroptera	Polymitarcyidae	Campsurus sp.	0	1	2	0	0	0
H03	Ephemeroptera	Caenidae	Caenis sp.1	0	0	1	1	2	2
H03	Ephemeroptera	Leptophlebiidae	Habrophlebiodes sp.	2	0	1	1	3	3
H03	Ephemeroptera	Baetidae	Baetis sp.2	0	0	0	1	0	0
H03	Coleoptera	Elmidae	Hexacylloepus sp.	1	0	0	0	0	0
H03	Coleoptera	Dytiscidae	Cybister sp.	0	0	0	0	1	1
H03	Megaloptera	Sialidae	Sialis sp.	1	1	1	0	0	0
H03	Odonata	Gomphidae	Dromogomphus sp.	1	0	0	0	0	0
H03	Odonata	Gomphidae	Hagenius sp.	0	0	1	0	0	0
H03	Diptera	Tabanidae	Tabanidae	0	0	1	0	0	0
H03	Diptera	Chironomidae	Chironominae	0	0	1	0	2	2
H03	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	0	1	0	0
H04	Ephemeroptera	Ephemeridae	Ephemera sp.	11	1	1	5	0	5
H04	Ephemeroptera	Caenidae	Caenis sp.1	0	1	0	1	0	0
H04	Ephemeroptera	Leptophlebiidae	Habrophlebiodes sp.	0	1	4	1	0	1
H04	Ephemeroptera	Baetidae	Baetis sp.2	3	0	0	0	0	1

Macroinvertebrate fauna of the Pong catchment in October, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
H04	Ephemeroptera	Baetidae	Baetis sp.3	1	0	0	0	1	0
H04	Trichoptera	Odontoceridae	Namamyia sp.	0	0	0	2	0	0
H04	Coleoptera	Elmidae	Hexacylloepus sp.	0	0	0	0	0	1
H04	Coleoptera	Psephenidae	Eubrianax sp.	0	0	0	1	0	0
H04	Coleoptera	Hydrophilidae	Hydrophilidae	0	1	0	0	0	0
H04	Odonata	Gomphidae	Erpetogomphus sp.	0	1	0	0	0	0
H04	Odonata	Libellulidae	Libellulidae	0	0	1	0	0	0
H04	Odonata	Platycnemididae	Platycnemididae	1	0	0	0	0	0
H04	Lepidoptera	Pyralidae	Petrophila sp.	0	0	0	0	1	0
H04	Diptera	Chironomidae	Chironominae	3	1	0	1	0	1
H04	Diptera	Chironomidae	Tanypodinae	0	1	0	0	0	0
H04	Mesogastropoda	Viviparidae	Mekongia sp.	0	0	0	1	0	0
N01	Coleoptera	Elmidae	Stenelmis sp.	1	0	0	0	0	0
N01	Coleoptera	Curculionidae	Stenopelmus sp	0	0	0	0	1	0
N01	Diptera	Chironomidae	Chironominae	0	1	0	1	0	0
N01	Diptera	Chironomidae	Tanypodinae	1	0	0	0	2	0
N01	Veneroida	Corbiculidae	Corbicula blandina	1	0	0	0	1	0
N01	Mesogastropoda	Viviparidae	Melanoides tuberculata	1	0	0	0	0	0
N01	Oligochaeta	Oligochaeta	Oligochaeta	10	17	12	8	8	13
N02	Diptera	Chironomidae	Chironominae	1	1	0	0	8	1
N02	Diptera	Chironomidae	Tanypodinae	0	1	2	0	0	11
N02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	1	0	0
N02	Diptera	Tipulidae	Hexatoma sp.	0	1	0	0	0	0
N02	Mesogastropoda	Viviparidae	Melanoides tuberculata	0	0	0	1	0	0
N02	Veneroida	Corbiculidae	Corbicula blandina	0	0	0	0	1	0
N02	Oligochaeta	Oligochaeta	Oligochaeta	11	3	5	18	9	0
N03	Trichoptera	Hydropsychidae	Macrostemum similior	0	0	1	0	0	0
N03	Trichoptera	Polycentropodidae	Polycentropus sp.	2	0	0	0	0	0
N03	Ephemeroptera	Leptophlebiidae	Leptophlebia sp.	0	0	1	1	0	0
N03	Mesogastropoda	Viviparidae	Filopaludina martensi martensi	0	0	1	1	0	0
N03	Odonata	Gomphidae	Aphylla sp.	2	0	0	0	1	1
N03	Odonata	Gomphidae	Dromogomphus sp.	0	0	1	0	0	0
N03	Diptera	Chironomidae	Chironominae	2	2	4	0	1	0
N03	Diptera	Chironomidae	Tanypodinae	0	4	8	4	1	0
N03	Diptera	Athericidae	Athericidae	0	0	0	1	0	0
N03	Mesogastropoda	Viviparidae	Filopaludina martensi martensi	0	0	1	0	0	0
N03	Oligochaeta	Oligochaeta	Oligochaeta	1	0	0	0	0	0
N04	Trichoptera	Polycentropodidae	Polycentropus sp.	1	0	0	1	0	2
N04	Ephemeroptera	Ephemeridae	Lirobranchia sp.	4	21	18	3	12	11
N04	Ephemeroptera	Caenidae	Caenis sp.1	30	1	3	0	0	1
N04	Coleoptera	Elmidae	Hexacylloepus sp.	0	1	2	1	1	0
N04	Odonata	Gomphidae	Aphylla sp.	0	0	0	1	0	0
N04	Diptera	Chironomidae	Chironominae	14	2	1	4	1	2
N04	Diptera	Chironomidae	Tanypodinae	0	2	0	1	0	0
N04	Diptera	Athericidae	Athericidae	0	0	0	1	0	0
N05	Trichoptera	Hydropsychidae	Cheumatopsyche malayoensis	0	0	1	0	0	0
N05	Ephemeroptera	Ephemeridae	Lirobranchia sp.	1	0	0	0	0	0
N03	Ephemeroptera	Baetidae	Baetis sp.1	0	0	1	0	0	0
N05	Coleoptera	Ptilodactylidae	Ptilodactylidae	0	0	0	0	1	0
N05	Diptera	Chironomidae	Chironominae	1	0	0	0	1	0
N05	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	2	0
P01	Diptera	Chironomidae	Chironominae	0	1	0	0	0	0
P01	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	0
P02	Trichoptera	Hydropsychidae	Macrostemum similior	0	1	0	0	0	1

Macroinvertebrate fauna of the Pong catchment in October, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P02	Trichoptera	Hydropsychidae	Cheumatopsyche sp.	0	0	0	1	0	0
P02	Ephemeroptera	Caenidae	Caenis sp.1	0	0	1	0	0	0
P02	Diptera	Chironomidae	Chironominae	4	0	0	0	0	0
P02	Diptera	Tipulidae	Hexatoma sp.	0	0	0	0	0	1
P02	Odonata	Gomphidae	Aphylla sp.	0	0	0	0	1	1
P02	Odonata	Macromiidae	Macromia sp.	0	0	2	0	1	1
P03	Trichoptera	Hydropsychidae	Macrostemum similior	0	0	0	0	2	0
P03	Trichoptera	Hydropsychidae	Cheumatopsyche sp.	0	2	0	0	5	0
P03	Trichoptera	Polycentropodidae	Polycentropus sp.	0	0	0	0	1	0
P03	Diptera	Chironomidae	Chironominae	3	0	0	1	2	0
P03	Diptera	Chironomidae	Tanypodinae	0	0	0	0	0	1
P03	Diptera	Tipulidae	Hexatoma sp.	1	1	0	0	1	2
P03	Odonata	Macromiidae	Macromia sp.	0	0	0	1	0	0
P03	Odonata	Gomphidae	Erpetogomphus sp.	1	1	3	1	0	1
P03	Odonata	Gomphidae	Progomphus sp.	0	0	1	0	0	0
P03	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	1	0	0	2
P04	Trichoptera	Hydropsychidae	Ceratopsyche sp.	0	0	0	0	1	0
P04	Trichoptera	Hydropsychidae	Leptonema sp.	0	1	0	1	0	1
P04	Ephemeroptera	Leptophlebiidae	Leptophlebia sp.	1	0	0	1	0	0
P04	Ephemeroptera	Siphlonuridae	Ameletus sp.	0	0	0	0	1	0
P04	Plecoptera	Perlidae	Neoperla sp.	0	0	0	0	1	0
P04	Coleoptera	Elmidae	Stenelmis sp.	1	0	0	0	0	0
P04	Diptera	Chironomidae	Chironominae	1	0	1	0	0	0
P04	Diptera	Simuliidae	Simulium sp.	0	0	0	1	0	0
P04	Diptera	Tipulidae	Hexatoma sp.	0	0	0	1	0	0
P04	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	1	0	6	0	1
P05	Odonata	Gomphidae	Erpetogomphus sp.	1	0	0	0	0	0
P05	Coleoptera	Elmidae	Heterelmis/Hexacylloepus sp.	0	1	0	0	0	0
P05	Diptera	Chironomidae	Chironominae	0	0	0	0	0	1
P06	Trichoptera	Ecnomidae	Ecnomus sp.	5	1	0	2	1	1
P06	Trichoptera	Hydropsychidae	Macrostemum similior	23	0	0	0	0	0
P06	Trichoptera	Polycentropodidae	Polycentropus sp.	4	0	0	0	0	0
P06	Ephemeroptera	Polymitarcyidae	Campsurus sp.	3	8	0	2	0	3
P06	Odonata	Cordulegastridae	Cordulegaster sp.	0	0	0	0	0	1
P06	Hemiptera	Naucoridae	Pelocoris sp.	0	0	1	0	0	0
P06	Hemiptera	Belostomatidae	Abedus sp.	0	0	1	0	0	0
P06	Diptera	Chironomidae	Chironominae	76	123	177	142	40	104
P06	Diptera	Chironomidae	Tanypodinae	2	0	1	0	0	0
P06	Diptera	Chaoboridae	Chaoborus sp.	1	0	0	0	1	0
P07	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	2	0	0
P07	Trichoptera	Hydropsychidae	Macrostemum similior	2	0	0	0	0	0
P07	Trichoptera	Polycentropodidae	Polycentropus sp.	4	3	0	0	0	0
P07	Diptera	Chironomidae	Chironominae	4	4	6	2	3	6
P07	Diptera	Chironomidae	Tanypodinae	3	0	1	0	0	1
P07	Diptera	Chaoboridae	Chaoborus sp.	3	4	3	1	4	2
P07	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	1	0
P07	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	1	6
P08	Trichoptera	Ecnomidae	Ecnomus sp.	4	0	0	0	1	0
P08	Trichoptera	Hydropsychidae	Macrostemum similior	1	0	0	0	0	1
P08	Trichoptera	Polycentropodidae	Polycentropus sp.	1	1	1	0	2	0
P08	Odonata	Gomphidae	Hagenius sp.	1	0	0	0	0	0
P08	Odonata	Gomphidae	Aphylla sp.	0	0	0	0	0	2
P08	Odonata	Libellulidae	Orthemis sp.	0	0	1	0	0	1
P08	Odonata	Platycnemididae	Platycnemididae	0	0	0	0	0	1
P08	Coleoptera	Chrysomelidae	Donacia sp.	0	1	0	0	0	0

Macroinvertebrate fauna of the Pong catchment in October, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P08	Hemiptera	Naucoridae	Pelocoris sp.	0	0	0	0	0	2
P08	Hemiptera	Belostomatidae	Abedus sp.	0	0	0	0	0	1
P08	Diptera	Chironomidae	Chironominae	10	10	6	9	12	2
P08	Diptera	Chironomidae	Tanypodinae	0	8	7	3	0	3
P08	Diptera	Ceratopogonidae	Bezzia sp.	0	1	2	0	0	0
P08	Decapoda	Palaemonidae	Macrobrachium lanchesteri	1	0	0	5	0	0
P09	Trichoptera	Polycentropodidae	Polycentropus sp.	5	4	1	3	1	7
P09	Odonata	Gomphidae	Aphylla sp.	0	0	0	1	0	0
P09	Odonata	Gomphidae	Hagenius sp.	0	1	0	0	0	0
P09	Diptera	Chironomidae	Chironominae	11	17	0	1	7	0
P09	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	3	0	0
P09	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	0	1	1	1
P10	Trichoptera	Polycentropodidae	Polycentropus sp.	0	4	0	0	0	0
P10	Trichoptera	Ecnomidae	Ecnomus sp.	2	1	0	0	0	0
P10	Ephemeroptera	Ephemeridae	Litobrancha sp.	8	4	0	0	0	0
P10	Ephemeroptera	Caenidae	Caenis sp.1	1	0	0	0	0	0
P10	Coleoptera	Elmidae	Hexacylloepus sp.	1	0	0	0	0	0
P10	Diptera	Chironomidae	Chironominae	6	0	1	1	3	3
P10	Diptera	Chironomidae	Tanypodinae	0	0	0	0	19	0
P10	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	1	1	1	0
P10	Gastropoda	Thiaridae	Melanoides tuberculata	0	0	0	0	0	1
P11	Ephemeroptera	Polymitarcyidae	Campsurus sp.	1	0	0	0	0	0
P11	Diptera	Chironomidae	Chironominae	11	7	5	3	3	8
P11	Diptera	Chironomidae	Tanypodinae	1	0	0	7	0	0
P11	Oligochaeta	Oligochaeta	Oligochaeta	0	3	0	1	3	0
P12	Diptera	Chironomidae	Chironominae	4	12	2	3	2	4
P12	Diptera	Chironomidae	Tanypodinae	2	2	1	4	2	4
P12	Diptera	Ceratopogonidae	Bezzia sp	1	0	0	0	0	0
P12	Diptera	Chaoboridae	Chaoborus sp.	0	0	0	0	0	1
P12	Oligochaeta	Oligochaeta	Oligochaeta	2	0	0	0	0	0
P13	Diptera	Chironomidae	Chironominae	0	1	0	0	0	0
P13	Oligochaeta	Oligochaeta	Oligochaeta	0	1	0	0	0	0
P14	Ephemeroptera	Ephemeridae	Litobrancha sp.	10	0	3	10	7	3
P14	Ephemeroptera	Caenidae	Caenis sp.2	0	0	0	0	1	0
P14	Diptera	Chironomidae	Chironominae	1	0	0	0	0	0
P14	Diptera	Chironomidae	Tanypodinae	1	0	0	0	0	1
P14	Oligochaeta	Oligochaeta	Oligochaeta	0	1	0	0	0	0
P15	Trichoptera	Ecnomidae	Ecnomus sp.	2	0	0	0	0	0
P15	Trichoptera	Polycentropodidae	Polycentropus sp.	0	0	0	0	0	1
P15	Trichoptera	Hydropsychidae	Macrostemum similior	15	0	0	0	0	0
P15	Ephemeroptera	Ephemeridae	Litobrancha sp.	1	0	0	0	0	1
P15	Diptera	Chironomidae	Chironominae	3	4	4	13	5	1
P15	Diptera	Chironomidae	Tanypodinae	3	0	2	0	0	0
P15	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	1	0	0
P15	Oligochaeta	Oligochaeta	Oligochaeta	0	0	1	0	0	0
P15	Veneroida	Corbiculidae	Corbicula blandiana	0	0	0	1	0	0

Macroinvertebrate fauna of the Pong catchment in December, 1995

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
C01	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	1	1
C01	Diptera	Chironomidae	Chironominae	5	2	0	4	2	3
C01	Diptera	Chironomidae	Tanypodinae	0	1	0	0	0	0
C01	Diptera	Chaoboridae	Chaoborus sp.	0	0	0	1	0	0
C01	Oligochaeta	Oligochaeta	Oligochaeta	0	1	5	0	1	2
C02	Ephemeroptera	Ephemeridae	Lisobrancha sp.	0	0	0	0	1	0
C02	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	1
C02	Diptera	Chironomidae	Chironominae	2	6	9	1	3	4
C02	Diptera	Chironomidae	Tanypodinae	0	2	4	0	0	2
C02	Diptera	Chaoboridae	Chaoborus sp.	1	0	0	0	0	2
C02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	1	0
C03	Diptera	Chironomidae	Chironominae	0	0	1	5	2	4
C03	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	0
H01	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	0
H01	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	0	2	0
H01	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	0	0	0	0
H01	Ephemeroptera	Leptophlebiidae	Habrophlebiodes sp.	2	0	0	0	0	0
H01	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	0	0	0	0
H01	Ephemeroptera	Caenidae	Caenis sp.1	1	0	1	0	3	0
H01	Ephemeroptera	Ephemeridae	Ephemera sp.	0	0	0	0	0	0
H01	Ephemeroptera	Baetidae	Baetis sp.2	7	0	3	1	3	2
H01	Ephemeroptera	Siphlonuridae	Siphlonuridae	1	0	0	0	0	0
H01	Diptera	Chironomidae	Chironominae	0	0	0	0	0	5
H01	Diptera	Chironomidae	Tanypodinae	0	0	59	21	27	5
H01	Diptera	Tipulidae	Limnophila sp.	0	0	0	4	3	4
H01	Odonata	Gomphidae	Erpetogomphus sp.	0	0	2	2	2	1
H01	Odonata	Gomphidae	Labrogomphus sp.	1	0	0	0	0	0
H01	Trichoptera	Hydropsychidae	Macrostemum similior	4	0	2	0	0	0
H01	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	165	0	216	11	63	12
H01	Trichoptera	Hydropsychidae	Amphipsyche meridiana	11	0	4	0	0	0
H01	Trichoptera	Hydropsychidae	Synaptopsyche klakahana	107	0	0	0	0	0
H01	Trichoptera	Hydroptilidae	Hydroptila sp.	1	0	0	0	0	0
H01	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	0	0	0	0
H01	Diptera	Chironomidae	Chironominae	154	0	0	0	0	0
H01	Diptera	Rhagionidae	Rhagionidae	1	0	0	0	0	0
H01	Diptera	Tipulidae	Tipulidae	3	0	0	0	0	0
H02	Trichoptera	Philopotamidae	Chimarra sp.	1	1	0	0	1	0
H02	Trichoptera	Phryganeidae	Oligostomis sp.	1	0	0	0	0	1
H02	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	1	1	0	4
H02	Ephemeroptera	Baetidae	Baetis sp.1	0	0	1	1	0	4
H02	Diptera	Chironomidae	Chironominae	0	1	0	1	1	0
H02	Diptera	Chironomidae	Tanypodinae	0	0	1	1	1	0
H02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	1	0
H02	Megaloptera	Sialidae	Sialis sp.	1	2	0	1	0	0
H02	Coleoptera	Dytiscidae	Hyphydrus sp.	2	0	0	0	0	0
H02	Odonata	Macromiidae	Macromia sp.	1	2	0	1	1	0
H02	Decapoda	Palaemonidae	Macrobrachium lanchesteri	2	0	0	0	0	0
H03	Trichoptera	Calamoceratidae	Anisocentropus sp.	2	1	9	24	0	10
H03	Trichoptera	Hydroptilidae	Oxyethira sp.	2	1	2	0	0	0
H03	Trichoptera	Philopotamidae	Chimarra sp.	1	0	2	0	0	0
H03	Trichoptera	Polycentropodidae	Pholocentropus sp.	1	0	0	0	1	0
H03	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	0	0	1	1
H03	Trichoptera	Goeridae	Goera sp.	0	0	0	0	0	1
H03	Ephemeroptera	Heptageniidae	Heptagenia sp.	2	0	2	0	0	0
H03	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	7	0	0	1

Macroinvertebrate fauna of the Pong catchment in December, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
H03	Ephemeroptera	Caenidae	Caenis sp.1	13	3	4	0	2	2
H03	Ephemeroptera	Ephemeridae	Litobrancha sp.	2	5	6	3	0	4
H03	Ephemeroptera	Ephemeridae	Ephemera sp.	13	5	4	3	2	4
H03	Ephemeroptera	Baetidae	Baetis sp.1	2	1	0	0	1	4
H03	Megaloptera	Sialidae	Sialis sp.	2	1	2	1	2	0
H03	Coleoptera	Psephenidae	Eubrianax sp.	6	1	6	0	4	0
H03	Coleoptera	Hydrophilidae	Berosus sp.	0	1	0	0	0	1
H03	Diptera	Chironomidae	Chironominae	61	3	28	4	2	7
H03	Diptera	Chironomidae	Tanypodinae	62	4	3	3	2	2
H03	Diptera	Rhagionidae	Atherix sp.	1	5	3	3	0	1
H03	Diptera	Culicidae	Mimomyia sp.	0	1	0	0	1	1
H03	Diptera	Ceratopogonidae	Bezzia sp.	1	1	0	1	0	1
H03	Diptera	Tipulidae	Limnophila sp.	0	1	0	1	0	1
H03	Odonata	Coenagrionidae	Argiocnemis sp.	2	1	2	1	2	0
H03	Odonata	Macromiidae	Macromia sp.	1	1	0	0	2	2
H03	Odonata	Gomphidae	Erpetogomphus sp.	1	1	2	1	2	2
H03	Odonata	Gomphidae	Sinogomphus sp.	2	1	2	1	1	0
H03	Odonata	Libellulidae	Diplacodes sp.	1	1	4	0	3	2
H03	Hemiptera	Corixidae	Tenagobia sp.	0	2	1	0	0	1
H03	Hemiptera	Gerridae	Rhyacobates sp.	0	2	1	0	1	0
H03	Oligochaeta	Oligochaeta	Oligochaeta	0	1	4	24	3	10
H04	Trichoptera	Ecnomidae	Ecnomus sp.	1	2	0	0	0	1
H04	Ephemeroptera	Heptageniidae	Heptagenia sp.	32	1	27	1	4	2
H04	Ephemeroptera	Ephemeridae	Ephemera sp.	2	13	27	1	1	6
H04	Ephemeroptera	Caenidae	Caenis sp.1	1	2	1	1	1	0
H04	Ephemeroptera	Baetidae	Baetis sp.2	0	0	0	0	1	1
H04	Odonata	Gomphidae	Progomphus sp.	1	1	1	0	0	0
H04	Odonata	Macromiidae	Macromia sp.	0	1	0	0	0	2
H04	Diptera	Chironomidae	Chironominae	8	3	3	16	4	5
H04	Diptera	Chironomidae	Tanypodinae	2	1	4	17	1	3
H04	Diptera	Rhagionidae	Atherix sp.	0	1	5	0	1	1
H04	Hemiptera	Gerridae	Rhyacobates sp.	0	1	1	0	0	0
H04	Hemiptera	Corixidae	Tenagobia sp.	0	1	0	1	4	2
H04	Oligochaeta	Oligochaeta	Oligochaeta	1	2	0	0	0	2
N01	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	1	0	0
N01	Plecoptera	Perlidae	Phanoperla sp.	0	0	0	1	0	0
N01	Plecoptera	Perlidae	Neoperla sp.	42	3	9	1	0	22
N01	Ephemeroptera	Ephemeridae	Ephemera sp.	0	1	2	0	0	0
N01	Ephemeroptera	Caenidae	Caenis sp.1	1	0	2	1	0	0
N01	Diptera	Chironomidae	Chironominae	6	5	8	12	14	5
N01	Diptera	Chironomidae	Tanypodinae	6	2	7	4	2	2
N01	Diptera	Ceratopogonidae	Bezzia sp.	1	2	8	1	2	2
N01	Oligochaeta	Oligochaeta	Oligochaeta	42	3	9	20	0	22
N01	Plecoptera	Perlidae	Neoperla sp.	42	3	9	1	0	22
N02	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	3	3	1	0	2
N02	Coleoptera	Psephenidae	Eubrianax sp.	0	0	0	1	0	1
N02	Diptera	Chironomidae	Chironominae	0	1	0	2	0	1
N02	Diptera	Chironomidae	Tanypodinae	0	0	0	1	0	0
N02	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	1	0	0
N02	Oligochaeta	Oligochaeta	Oligochaeta	0	3	3	1	0	2
N03	Coleoptera	Elmidae	Stenelmis sp.	1	0	0	1	0	0
N03	Decapoda	Palaemonidae	Macrobrachium lanchesteri	1	0	0	0	0	0
N03	Diptera	Chironomidae	Chironominae	1	2	1	1	1	0
N03	Diptera	Chironomidae	Tanypodinae	1	1	1	1	1	0
N03	Diptera	Ceratopogonidae	Bezzia sp.	1	1	1	2	1	0

Macroinvertebrate fauna of the Pong catchment in December, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
N03	Ephemeroptera	Baetidae	Baetis sp.2	1	1	1	2	1	0
N03	Trichoptera	Polycentropodidae	Neureclipsis sp.	1	0	1	0	0	0
N03	Trichoptera	Leptoceridae	Leptocerus sp.	1	0	0	0	2	1
N03	Trichoptera	Polycentropodidae	Phylocentropus sp.	1	0	0	0	2	1
N04	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	3	0	3	0	6
N04	Trichoptera	Polycentropodidae	Neureclipsis sp.	0	0	0	0	1	6
N04	Trichoptera	Ecnomidae	Ecnomus sp.	0	3	0	3	0	1
N04	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	1	1	1	0
N04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	2	1	1	1	0
N04	Coleoptera	Elmidae	Stenelmis sp.	1	3	1	0	1	0
N04	Coleoptera	Psephenidae	Eubrianax sp.	0	4	1	0	1	0
N04	Diptera	Chironomidae	Chironominae	2	4	0	6	3	2
N04	Diptera	Chironomidae	Tanypodinae	2	1	1	6	3	2
N04	Diptera	Ceratopogonidae	Bezzia sp.	0	1	1	0	7	0
N04	Ologochaeta	Oligochaeta	Oligochaeta	0	2	0	0	1	0
N05	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	2	0	0
N05	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	0	0	0	0
N05	Trichoptera	Polycentropodidae	Polycentropus sp.	2	0	1	0	3	0
N05	Odonata	Macromiidae	Macromia sp.	0	0	1	0	0	0
N05	Diptera	Chironomidae	Chironominae	3	0	0	0	0	0
N05	Diptera	Chironomidae	Tanypodinae	5	0	0	2	0	0
N05	Diptera	Ceratopogonidae	Bezzia sp.	3	0	0	1	0	0
P01	Ephemeroptera	Heptageniidae	Heptagenia sp.	2	0	0	0	0	0
P01	Ephemeroptera	Caenidae	Caenis sp.1	3	0	0	0	1	0
P01	Trichoptera	Phryganeidae	Ptilostomis sp.	0	0	1	0	0	0
P01	Diptera	Chironomidae	Chironominae	6	9	8	15	12	1
P01	Diptera	Tipulidae	Pedicia sp.	0	0	3	1	0	0
P01	Plecoptera	Perlidae	Phanoperla sp.	1	0	0	0	0	0
P01	Coleoptera	Psephenidae	Eubrianax sp.	1	0	0	0	0	0
P01	Coleoptera	Elmidae	Stenelmis sp.	0	0	1	0	0	0
P01	Odonata	Gomphidae	Erpetogomphus sp.	1	0	0	1	2	2
P01	Odonata	Gomphidae	Macromia sp.	0	1	0	0	0	0
P01	Decapoda	Palaemonidae	Macrobrachium lanchesteri	1	0	0	0	0	12
P02	Ephemeroptera	Caenidae	Caenis sp.1	0	33	233	1	29	4
P02	Ephemeroptera	Baetidae	Baetis sp.1	0	2	1	1	2	2
P02	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	1	0	0	0
P02	Trichoptera	Hydropsychidae	Macrostemum similior	97	41	1	77	23	3
P02	Trichoptera	Hydropsychidae	Cheumatopsyche sp.	500	351	6	532	61	12
P02	Trichoptera	Hydropsychidae	Macronema sp.	18	24	2	44	5	2
P02	Trichoptera	Hydroptilidae	Ochrotrichia sp.	1	2	1	0	2	1
P02	Trichoptera	Goeridae	Goera sp.	0	0	2	0	0	0
P02	Plecoptera	Perlidae	Phanoperla sp.	0	0	0	1	0	0
P02	Coleoptera	Elmidae	Stenelmis sp.	0	5	19	20	4	1
P02	Odonata	Gomphidae	Erpetogomphus sp.	0	2	3	0	1	1
P02	Odonata	Macromiidae	Macromia sp.	0	0	1	0	0	0
P02	Odonata	Protoneuridae	Protoneura sp.	0	1	0	0	0	0
P02	Diptera	Chironomidae	Chironominae	0	5	10	24	4	13
P02	Diptera	Chironomidae	Tanypodinae	0	6	9	7	3	2
P02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	1	0
P02	Diptera	Simuliidae	Simulium sp.	0	0	0	1	0	0
P02	Diptera	Tipulidae	Pedicia sp.	0	0	0	0	0	2
P02	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	0	0	1	0
P02	Bivalvia	Corbiculidae	Corbicula blandiana	0	0	0	0	105	3
P03	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	1	0	0	0
P03	Ephemeroptera	Ephemeridae	Litobrancha sp.	2	1	0	0	0	1

Macroinvertebrate fauna of the Pong catchment in Decemberber, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P03	Trichoptera	Goeridae	Goera sp.	0	1	0	0	0	0
P03	Trichoptera	Polycentropodidae	Polycentropus sp.	2	2	1	2	2	3
P03	Hemiptera	Gerridae	Rhyacobates sp.	1	0	0	0	0	0
P03	Coleoptera	Psephenidae	Eubrianax sp.	0	0	0	0	0	1
P03	Diptera	Chironomidae	Chironominae	0	1	1	0	0	2
P03	Diptera	Chironomidae	Tanypodinae	0	1	0	0	0	0
P03	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	0
P03	Diptera	Tipulidae	Limnophila sp.	0	3	0	1	0	3
P03	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	0	0	0	1
P04	Ephemeroptera	Heptageniidae	Heptagenia sp.	5	3	0	1	0	4
P04	Ephemeroptera	Caenidae	Caenis sp.1	0	6	4	3	4	4
P04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	4	5	2	7	1	2
P04	Ephemeroptera	Leptophlebiidae	Cheumatopsyche sp.	0	6	3	0	0	0
P04	Trichoptera	Hydroptilidae	Ochrotrichia sp.	1	3	1	0	1	0
P04	Trichoptera	Hydropsychidae	Macronema sp.	0	0	1	0	0	0
P04	Coleoptera	Psephenidae	Eubrianax sp.	1	0	0	0	0	0
P04	Coleoptera	Elmidae	Stenelmis sp.	1	0	8	1	2	1
P04	Plecoptera	Perlidae	Phanoperla sp.	1	2	0	1	0	3
P04	Diptera	Chironomidae	Tanypodinae	0	3	1	2	0	0
P04	Diptera	Chironomidae	Chironominae	0	0	3	1	0	0
P04	Diptera	Tipulidae	Limnophila sp.	0	0	3	0	1	0
P04	Odonata	Macromiidae	Macromia sp.	0	0	0	1	0	0
P04	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	0	1	1	2
P04	Veneroida	Corbiculidae	Corbicula blandiana	3	0	0	1	1	3
P05	Ephemeroptera	Ephemeridae	Liobranchia sp.	0	0	0	3	0	0
P05	Ephemeroptera	Caenidae	Caenis sp.2	0	0	0	2	0	0
P05	Odonata	Gomphidae	Erpetogomphus sp.	0	0	0	0	1	0
P05	Coleoptera	Elmidae	Stenelmis sp.	0	0	2	0	0	0
P05	Diptera	Chironomidae	Chironominae	3	0	2	0	2	0
P05	Diptera	Chironomidae	Tanypodinae	0	0	1	0	0	0
P05	Diptera	Chaoboridae	Chaoborus sp.	3	3	4	0	1	3
P05	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	0
P05	Oligochaeta	Oligochaeta	Oligochaeta	0	0	3	0	0	0
P06	Ephemeroptera	Polymitarcyidae	Campsurus sp.	0	6	2	1	0	0
P06	Trichoptera	Ecnomidae	Ecnomus sp.	0	2	1	0	0	0
P06	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	0	0	1
P06	Odonata	Macromiidae	Macromia sp.	0	0	0	0	0	1
P06	Diptera	Chironomidae	Chironominae	28	52	49	46	29	45
P06	Diptera	Chironomidae	Tanypodinae	9	8	1	3	7	11
P06	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	0	4
P06	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	1	0
P07	Trichoptera	Polycentropodidae	Phylocentropus sp.	3	2	0	1	2	2
P07	Diptera	Chironomidae	Chironominae	4	3	1	6	2	6
P07	Diptera	Chironomidae	Tanypodinae	4	2	0	2	8	0
P07	Diptera	Ceratopogonidae	Bezzia sp.	1	0	0	0	0	0
P07	Diptera	Chaoboridae	Chaoborus sp.	2	26	1	1	8	12
P07	Oligochaeta	Oligochaeta	Oligochaeta	0	3	1	5	0	0
P08	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	1	0	0	0
P08	Ephemeroptera	Caenidae	Caenis sp.2	2	1	0	0	0	8
P08	Trichoptera	Ecnomidae	Ecnomus sp.	1	1	0	0	0	0
P08	Diptera	Chironomidae	Chironominae	2	54	21	1	16	6
P08	Diptera	Chironomidae	Tanypodinae	3	0	0	5	1	2
P08	Diptera	Chaoboridae	Chaoborus sp.	2	0	4	1	0	1
P08	Oligochaeta	Oligochaeta	Oligochaeta	3	0	0	0	0	0
P08	Bivalvia	Corbiculidae	Corbicula blandiana	1	0	0	0	17	3

Macroinvertebrate fauna of the Pong catchment in December, 1995 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P09	Ephemeroptera	Caenidae	Caenis sp.2	10	0	3	0	0	0
P09	Ephemeroptera	Baetidae	Baetis sp.1	0	2	1	0	0	0
P09	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	3	0	0	0
P09	Coeloptera	Elmidae	Stenelmis sp.	0	1	7	0	1	0
P09	Odonata	Macromiidae	Macromia sp.	1	0	0	0	0	0
P09	Odonata	Gomphidae	Aphylla sp.	0	0	1	0	0	1
P09	Odonata	Gomphidae	Erpetogomphus sp.	0	0	1	0	0	1
P09	Odonata	Chlorolestidae	Megalestes sp.	0	1	0	0	0	1
P09	Diptera	Chironomidae	Chironominae	5	9	5	2	37	10
P09	Diptera	Chironomidae	Tanypodinae	4	3	0	0	1	1
P09	Diptera	Ceratopogonidae	Bezzia sp.	3	1	0	0	1	0
P09	Oligochaeta	Oligochaeta	Oligochaeta	0	0	2	0	0	0
P09	Bivalvia	Corbiculidae	Corbicula blandiana	0	0	4	0	0	0
P10	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	1	2	5	0	0
P10	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	0	1	0
P10	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	1	0	0
P10	Diptera	Chironomidae	Chironominae	7	0	0	3	9	22
P10	Diptera	Chironomidae	Tanypodinae	0	0	0	0	1	3
P10	Diptera	Chaoboridae	Chaoborus sp.	0	0	1	0	0	0
P10	Diptera	Ceratopogonidae	Bezzia sp.	2	0	0	0	1	0
P11	Ephemeroptera	Polymitarcyidae	Campsurus sp.	0	1	0	0	0	0
P11	Diptera	Chironomidae	Chironominae	20	7	8	3	11	2
P11	Diptera	Chironomidae	Tanypodinae	0	0	1	0	0	0
P11	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	2	3	6
P12	Diptera	Chironomidae	Tanypodinae	0	0	2	0	0	0
P12	Diptera	Chaoboridae	Chaoborus sp.	0	0	1	0	0	0
P12	Diptera	Tipulidae	Limnophila sp.	1	0	0	0	0	0
P12	Oligochaeta	Oligochaeta	Oligochaeta	20	0	0	0	10	2
P13	Diptera	Chironomidae	Chironominae	1	0	1	5	4	0
P13	Oligochaeta	Oligochaeta	Oligochaeta	1	0	1	0	0	0
P14	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	2	1	0	2	0
P14	Ephemeroptera	Caenidae	Caenis sp.2	0	0	1	0	0	0
P14	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	2	0	0
P14	Diptera	Chironomidae	Chironominae	7	1	1	1	2	6
P14	Diptera	Chironomidae	Tanypodinae	0	2	3	0	1	0
P14	Diptera	Chaoboridae	Chaoborus sp.	0	5	1	3	0	0
P14	Diptera	Ceratopogonidae	Bezzia sp.	2	2	1	0	2	1
P15	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	3	0	0
P15	Trichoptera	Philopotamidae	Chimarra sp.	1	0	0	1	0	0
P15	Diptera	Chironomidae	Chironominae	0	0	0	2	0	0
P15	Diptera	Chironomidae	Tanypodinae	0	0	0	7	0	0
P15	Diptera	Chaoboridae	Chaoborus sp.	1	5	1	0	1	0

Macroinvertebrate fauna of the Pong catchment in February, 1996

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
C01	Diptera	Chironomidae	Chironominae	6	1	1	1	1	6
C01	Diptera	Chironomidae	Tanypodinae	1	0	0	8	1	4
C01	Diptera	Chaoboridae	Chaoborus sp.	0	0	1	0	0	0
C01	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	1	3	0
C01	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	1
C02	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	1	1	0
C02	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	0	1	0
C02	Diptera	Chironomidae	Chironominae	4	7	2	0	1	1
C02	Diptera	Chironomidae	Tanypodinae	0	0	1	0	3	0
C02	Diptera	Chaoboridae	Chaoborus sp.	0	0	3	3	0	0
C02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	0	1
C02	Oligochaeta	Oligochaeta	Oligochaeta	2	0	0	0	0	0
C03	Diptera	Chironomidae	Chironominae	0	2	0	3	12	11
C03	Diptera	Chaoboridae	Chaoborus sp.	0	0	0	0	0	3
C03	Diptera	Ceratopogonidae	Bezzia sp.	11	2	0	0	1	0
C03	Coleoptera	Elmidae	Cleptelmis sp.	0	1	0	0	0	0
C03	Veneroida	Corbiculidae	Corbicula blandiana	0	0	1	1	0	0
H01	Coleoptera	Hydrophilidae	Hydrophilidae	0	0	0	0	3	1
H01	Coleoptera	Gyrinidae	Dineutus sp.	0	0	0	0	0	0
H01	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	3	1	0
H01	Coleoptera	Elmidae	Phanocerus sp.	0	0	0	0	0	0
H01	Decapoda	Palaemonidae	Macrobrachium lanchesteri	1	2	0	1	0	0
H01	Diptera	Chironomidae	Chironominae	0	0	0	0	0	0
H01	Diptera	Chironomidae	Tanypodinae	7	8	0	5	3	0
H01	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	0
H01	Diptera	Rhagionidae	Atherix sp.	1	0	0	4	0	1
H01	Diptera	Tipulidae	Limnophila sp.	2	0	0	0	0	0
H01	Ephemeroptera	Potamanthidae	Potamanthus sp.	1	4	22	24	19	17
H01	Ephemeroptera	Ephemeridae	Ephemera sp.	2	0	0	0	0	0
H01	Ephemeroptera	Baetidae	Baetis sp.1	2	2	0	0	0	8
H01	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	0	0	0
H01	Ephemeroptera	Leptophlebiidae	Cooroterpes sp.	1	1	0	1	0	0
H01	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	1	0	0	2
H01	Odonata	Gomphidae	Labrogomphus sp.	0	1	1	12	4	0
H01	Plecoptera	Perlidae	Phanoperla sp.	0	0	0	0	0	0
H01	Trichoptera	Polycentropodidae	Polycentropus sp.	1	0	4	9	20	0
H01	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	2	0	0	0	5
H01	Trichoptera	Polycentropodidae	Neureclipsis sp.	1	0	0	0	0	0
H01	Trichoptera	Philopotamidae	Chimarra sp.	0	1	3	1	0	0
H01	Trichoptera	Calamoceratidae	Anisocentropus sp.	0	0	0	0	1	0
H01	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	1	1	9	17	0	0
H01	Trichoptera	Hydropsychidae	Macrostemum similar	0	0	0	0	18	0
H01	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	2	2	0	0
H02	Coleoptera	Elmidae	Stenelmis sp.	0	1	1	0	0	0
H02	Diptera	Chironomidae	Chironominae	0	0	2	0	0	0
H02	Ephemeroptera	Baetidae	Baetis sp.1	0	0	2	0	1	1
H02	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	0	0	1	0
H02	Megaloptera	Sialidae	Sialis sp.	0	0	2	0	0	3
H02	Odonata	Gomphidae	Sinogomphus sp.	1	1	0	0	7	0
H03	Coleoptera	Psephenidae	Eubrianax sp.	0	0	0	0	0	1

Macroinvertebrate fauna of the Pong catchment in February, 1996 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
H03	Coleoptera	Elmidae	Stenelmis sp.	1	0	0	0	2	0
H03	Diptera	Chironomidae	Chironominae	167	2	13	1	51	6
H03	Diptera	Chironomidae	Tanypodinae	18	6	21	0	0	0
H03	Diptera	Ceratopogonidae	Bezzia sp.	0	0	2	17	3	1
H03	Diptera	Rhagionidae	Atherix sp.	4	1	0	0	0	0
H03	Diptera	Tipulidae	Limnophila sp.	0	0	1	0	0	0
H03	Diptera	Culicidae	Mimomyia sp.	0	1	0	0	0	0
H03	Ephemeroptera	Baetidae	Baetis sp.1	0	0	1	0	7	0
H03	Ephemeroptera	Caenidae	Caenis sp.1	0	1	0	0	9	0
H03	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	32	2	0	0
H03	Hemiptera	Corixidae	Sigara sp.	0	0	0	0	2	0
H03	Hemiptera	Corixidae	Tenagobia sp.	1	1	0	0	0	0
H03	Megaloptera	Sialidae	Sialis sp.	0	1	1	0	0	2
H03	Odonata	Libellulidae	Diplacodes sp.	0	0	10	1	1	0
H03	Odonata	Coenagrionidae	Argiocnemis sp.	8	7	0	0	1	3
H03	Odonata	Aeshnidae	Aeschnophlebia sp.	0	0	1	0	1	0
H03	Odonata	Gomphidae	Sinogomphus sp.	0	0	0	0	0	0
H03	Odonata	Gomphidae	Erpetogomphus sp.	0	0	0	1	2	0
H03	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	0
H03	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	10	4	1	0
H03	Trichoptera	Leptoceridae	Triaenodes sp.	2	0	0	0	0	0
H03	Trichoptera	Calamoceratidae	Anisocentropus sp.	0	0	0	0	1	0
H03	Trichoptera	Polycentropodidae	Polycentropus sp.	1	4	0	0	0	0
N01	Coleoptera	Elmidae	Stenelmis sp.	4	0	1	1	0	0
N01	Diptera	Chironomidae	Chironominae	1	3	5	0	0	1
N01	Diptera	Chironomidae	Tanypodinae	11	0	0	3	0	0
N01	Diptera	Tipulidae	Limnophila sp.	0	14	8	0	1	13
N01	Ephemeroptera	Ephemeridae	Litobrancha sp.	1	1	0	1	0	0
N01	Oligochaeta	Oligochaeta	Oligochaeta	62	0	0	23	0	21
N01	Veneroida	Corbiculidae	Corbicula blandina	1	42	10	3	65	1
N02	Diptera	Chironomidae	Chironominae	0	0	0	0	0	6
N02	Diptera	Chironomidae	Tanypodinae	3	4	0	4	0	1
N02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	2	0
N02	Ephemeroptera	Ephemeridae	Litobrancha sp.	1	0	0	0	0	1
N02	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	1	0	0	0	2	0
N03	Coleoptera	Psephenidae	Eubrianax sp.	2	0	0	0	0	0
N03	Coleoptera	Elmidae	Stenelmis sp.	1	0	0	0	0	0
N03	Diptera	Chironomidae	Chironominae	2	0	0	0	0	0
N03	Ephemeroptera	Caenidae	Caenis sp.1	1	0	1	0	0	0
N03	Trichoptera	Polycentropodidae	Polycentropus sp.	0	0	1	0	1	0
N03	Trichoptera	Polycentropodidae	Nureclipsis sp.	1	0	0	0	0	0
N04	Coleoptera	Gyrinidae	Dineutus sp.	0	0	1	0	0	0
N04	Coleoptera	Psephenidae	Eubrianax sp.	0	0	1	0	2	0
N04	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	0
N04	Decapoda	Palaemonidae	Macrobrachium lanchesteri	3	2	1	0	1	2
N04	Diptera	Chironomidae	Chironominae	1	3	0	0	7	10
N04	Diptera	Chironomidae	Tanypodinae	1	0	1	0	0	0
N04	Diptera	Ceratopogonidae	Bezzia sp.	1	0	0	0	3	2
N04	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	0	0	0
N04	Ephemeroptera	Caenidae	Caenis sp.1	11	3	0	0	1	0

Macroinvertebrate fauna of the Pong catchment in February, 1996 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
N04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	5	0	3	6
N04	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	4	0	0
N04	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	1	0	1	13
N05	Coleoptera	Psephenidae	Eubrianax sp.	1	1	0	1	0	0
N05	Diptera	Chironomidae	Chironominae	0	0	1	0	2	2
N05	Diptera	Chironomidae	Tanypodinae	0	0	0	0	0	10
N05	Diptera	Chaoboridae	Chaoborus sp.	0	0	0	0	1	0
N05	Diptera	Ceratopogonidae	Bezzia sp.	11	7	7	4	0	1
N05	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	0	2	1
N05	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	5
N05	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	5	0	12	0
N05	Trichoptera	Polycentropodidae	Neureclipsis sp.	0	2	0	3	0	3
P01	Ephemeroptera	Caenidae	Caenis sp.1	0	0	2	5	2	0
P01	Ephemeroptera	Ephemeridae	Ephemera sp.	0	0	0	1	0	0
P01	Ephemeroptera	Baetidae	Baetis sp.2	0	0	0	2	1	4
P01	Trichoptera	Calamoceratidae	Anisocentropus sp.	0	0	1	1	0	0
P01	Trichoptera	Hydropsychidae	Cheumatopsyche malayniensis	3	0	3	0	0	0
P01	Trichoptera	Psychomyiidae	Tinodes sp.	0	1	0	0	0	0
P01	Trichoptera	Polycentropodidae	Cyrnellus sp.	0	1	1	0	0	0
P01	Odonata	Gomphidae	Erpetogomphus sp.	3	2	3	16	0	3
P01	Odonata	Libellulidae	Acisoma sp.	0	0	1	0	0	0
P01	Odonata	Libellulidae	Diplacodes sp.	0	0	0	0	0	1
P01	Coleoptera	Elmidae	Cleptelmis sp.	1	3	0	0	0	0
P01	Hemiptera	Aphelocheiridae	Aphelocheirus sp.	0	0	0	0	0	0
P01	Diptera	Chironomidae	Chironominae	2	1	1	13	14	7
P01	Diptera	Chironomidae	Tanypodinae	1	1	0	0	4	0
P01	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	2	7
P01	Diptera	Tipulidae	Limnophila sp.	4	8	5	1	1	0
P01	Veneroida	Corbiculidae	Corbicula blandiana	4	1	0	0	0	1
P02	Ephemeroptera	Caenidae	Caenis sp.1	0	3	0	1	1	0
P02	Ephemeroptera	Baetidae	Baetis sp.2	10	5	0	42	5	11
P02	Trichoptera	Hydropsychidae	Cheumatopsyche malayniensis	0	0	0	4	0	32
P02	Trichoptera	Hydropsychidae	Macrostemum similar	0	0	0	2	0	10
P02	Trichoptera	Hydroptilidae	Ochrotrichia sp.	0	1	0	11	1	5
P02	Odonata	Gomphidae	Erpetogomphus sp	2	0	0	2	0	1
P02	Odonata	Gomphidae	Sieboldius sp.	0	0	0	0	0	1
P02	Odonata	Libellulidae	Diplacodes sp.	0	9	0	0	3	0
P02	Odonata	Protoneuridae	Prodasineura sp.	0	0	0	0	1	0
P02	Odonata	Coenagrionidae	Argiocnemis sp.	0	1	0	0	0	0
P02	Coleoptera	Elmidae	Cleptelmis sp.	0	0	7	11	0	15
P02	Coleoptera	Elmidae	Stenelmis sp.	0	4	0	1	13	0
P02	Coleoptera	Hydrophilidae	Berosus sp.	0	0	0	0	1	0
P02	Coleoptera	Gyrinidae	Dineutus sp.	0	4	7	7	0	0
P02	Coleoptera	Psephenidae	Eubrianax sp.	0	0	0	1	0	0
P02	Hemiptera	Gerridae	Rheumatogonus sp.	28	0	0	0	0	0
P02	Hemiptera	Corixidae	Tenagobia sp.	0	4	0	0	0	0
P02	Diptera	Chironomidae	Chironominae	12	84	39	42	22	38
P02	Diptera	Chironomidae	Tanypodinae	0	19	0	17	20	9
P02	Diptera	Ceratopogonidae	Bezzia sp.	0	30	1	0	10	1

Macroinvertebrate fauna of the Pong catchment in February, 1996 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P02	Diptera	Tipulidae	Limnophila sp.	0	0	0	0	0	1
P02	Veneroida	Corbiculidae	Corbicula blandiana	60	13	34	53	18	8
P02	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	1	0	0	0	0
P02	Oligochaeta	Oligochaeta	Oligochaeta	0	2	34	0	3	7
P03	Ephemeroptera	Caenidae	Caenis sp.1	1	0	0	5	0	0
P03	Ephemeroptera	Caenidae	Centroptilum sp.	0	0	0	11	0	0
P03	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	9	0	0	0	0	0
P03	Ephemeroptera	Ephemeridae	Ephemera sp.	0	3	0	2	0	0
P03	Trichoptera	Hydropsychidae	Cheumatopsyche maliysiensis	265	0	96	1	64	55
P03	Trichoptera	Hydropsychidae	Macrostemum similior	16	0	0	0	3	0
P03	Trichoptera	Leptoceridae	Triaenodes sp.	0	0	1	4	0	0
P03	Trichoptera	Hydroptilidae	Ochrotrichia sp.	0	0	0	4	0	0
P03	Plecoptera	Perlidae	Phanoperla sp.	1	0	1	0	0	1
P03	Odonata	Gomphidae	Erpetogomphus sp.	7	4	7	1	5	4
P03	Odonata	Gomphidae	Labrogomphus sp.	0	4	0	0	0	0
P03	Odonata	Libellulidae	Diplacodes sp.	0	1	0	0	0	0
P03	Odonata	Protoneuridae	Prodasineura sp.	0	1	0	0	0	0
P03	Coleoptera	Elmidae	Cleptelmis sp.	55	0	7	8	27	0
P03	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	9
P03	Coleoptera	Psephenidae	Eubrianax sp.	1	0	0	0	0	0
P03	Coleoptera	Dytiscidae	Eretes sp.	1	0	0	0	0	0
P03	Coleoptera	Dytiscidae	Dytiscus sp.	0	0	0	0	0	1
P03	Diptera	Chironomidae	Chironominae	0	7	0	8	0	0
P03	Diptera	Chironomidae	Tanypodinae	1	2	0	11	4	0
P03	Diptera	Ceratopogonidae	Bezzia sp.	0	7	0	0	0	0
P03	Diptera	Tipulidae	Limnophila sp.	37	0	3	13	34	3
P03	Diptera	Culicidae	Mimomyia sp.	0	1	0	0	0	0
P03	Veneroida	Corbiculidae	Corbicula blandiana	1	0	7	4	6	6
P03	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	0	1	0	0
P04	Ephemeroptera	Caenidae	Caenis sp.1	15	33	0	4	1	2
P04	Ephemeroptera	Baetidae	Baetis sp.1	0	1	0	0	2	1
P04	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	0	0	0	1
P04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	1	0	17	0	7	21
P04	Trichoptera	Ecnomidae	Ecnomus sp.	0	2	3	1	2	1
P04	Odonata	Libellulidae	Diplacodes sp.	0	1	1	0	0	0
P04	Hemiptera	Corixidae	Palmacorixa sp.	3	0	0	0	0	0
P04	Hemiptera	Gerridae	Limnogonus sp.	0	0	0	2	0	0
P04	Diptera	Chironomidae	Chironominae	39	18	9	8	0	18
P04	Diptera	Chironomidae	Tanypodinae	119	8	7	5	0	8
P04	Diptera	Ceratopogonidae	Bezzia sp.	1	1	0	0	0	0
P04	Diptera	Tipulidae	Limnophila sp.	1	0	0	0	0	0
P04	Veneroida	Corbiculidae	Corbicula blandiana	0	3	0	0	0	1
P04	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	7	0	0	3
P04	Oligochaeta	Oligochaeta	Oligochaeta	2	0	0	0	0	0
P05	Ephemeroptera	Ephemeridae	Liobrancha sp	0	0	0	0	0	1
P05	Diptera	Chironomidae	Chironominae	1	0	0	1	7	0
P05	Diptera	Chironomidae	Tanypodinae	0	0	2	0	0	0
P05	Diptera	Chaoboridae	Chaoborus sp.	24	121	17	19	0	18
P05	Veneroida	Corbiculidae	Corbicula blandiana	0	0	0	1	0	0
P05	Oligochaeta	Oligochaeta	Oligochaeta	3	0	0	0	0	0

Macroinvertebrate fauna of the Pong catchment in February, 1996 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P06	Ephemeroptera	Caenidae	Caenis sp.2	0	1	14	0	4	7
P06	Ephemeroptera	Potamanthidae	Potamanthus sp.	0	1	9	0	0	6
P06	Trichoptera	Ecnomidae	Ecnomus sp.	0	3	2	0	1	0
P06	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	5	0	0
P06	Odonata	Gomphidae	Hagenius sp.	0	0	3	0	1	2
P06	Odonata	Macromiidae	Epophthalmia sp.	0	0	0	0	1	0
P06	Odonata	Libellulidae	Diplacodes sp.	0	0	0	0	0	2
P06	Diptera	Chironomidae	Chironominae	5	55	67	42	74	11
P06	Diptera	Chironomidae	Tanypodinae	7	9	6	6	10	18
P06	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	1	1	1
P06	Oligochaeta	Oligochaeta	Oligochaeta	0	0	2	0	0	0
P07	Ephemeroptera	Caenidae	Caenis sp.2	1	0	0	12	0	0
P07	Ephemeroptera	Potamanthidae	Potamanthus sp.	3	0	0	10	0	0
P07	Trichoptera	Polycentropodidae	Phylocentropus sp.	1	0	0	0	5	2
P07	Diptera	Chironomidae	Chironominae	42	7	8	27	3	4
P07	Diptera	Chironomidae	Tanypodinae	3	15	49	2	6	37
P07	Diptera	Ceratopogonidae	Bezzia sp.	1	0	0	2	1	0
P07	Diptera	Chaoboridae	Chaoborus sp.	0	0	0	0	0	1
P07	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	1	0	0
P08	Ephemeroptera	Caenidae	Caenis sp.2	0	1	0	0	2	20
P08	Ephemeroptera	Baetidae	Baetis sp.2	0	0	0	0	2	0
P08	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	1	0	1	0
P08	Trichoptera	Ecnomidae	Ecnomus sp.	0	1	0	0	0	0
P08	Odonata	Gomphidae	Sinogomphus sp.	0	1	0	0	0	0
P08	Odonata	Libellulidae	Diplacodes sp.	0	0	0	0	0	1
P08	Diptera	Chironomidae	Chironominae	6	30	22	5	33	19
P08	Diptera	Chironomidae	Tanypodinae	2	3	4	4	13	5
P08	Diptera	Ceratopogonidae	Bezzia sp.	0	9	3	1	1	0
P08	Veneroida	Corbiculidae	Corbicula blandiana	1	0	0	3	8	0
P08	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	1	0	5
P09	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	2	0	0
P09	Hemiptera	Corixidae	Micronecta sp.	0	1	0	0	0	0
P09	Diptera	Chironomidae	Chironominae	8	17	58	24	8	38
P09	Diptera	Chironomidae	Tanypodinae	0	5	0	1	3	3
P09	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	0	0	0
P09	Veneroida	Corbiculidae	Corbicula blandiana	1	0	0	0	0	0
P09	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	1	0	0	0	0
P10	Ephemeroptera	Caenidae	Caenis sp.2	0	0	0	0	1	0
P10	Diptera	Chironomidae	Chironominae	2	4	2	4	6	1
P10	Diptera	Chironomidae	Tanypodinae	1	1	0	1	1	0
P10	Diptera	Chaoboridae	Chaoborus sp.	1	0	0	0	0	0
P10	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	0	0	2
P11	Ephemeroptera	Caenidae	Caenis sp.2	6	12	0	0	0	0
P11	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	0	0	0	8
P11	Diptera	Chironomidae	Chironominae	36	30	7	3	7	14
P11	Diptera	Chironomidae	Tanypodinae	3	1	0	0	1	0
P11	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	1	1
P11	Oligochaeta	Oligochaeta	Oligochaeta	0	1	0	0	0	0
P12	Diptera	Chironomidae	Chironominae	21	21	1	4	81	26
P12	Diptera	Chironomidae	Tanypodinae	0	0	0	0	7	0

Macroinvertebrate fauna of the Pong catchment in February, 1996 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P12	Diptera	Ceratopogonidae	Bezzia sp.	0	3	0	0	0	0
P12	Veneroida	Corbiculidae	Corbicula blandiana	0	11	0	0	0	0
P12	Oligochaeta	Oligochaeta	Oligochaeta	1	1	0	0	0	0
P13	Diptera	Chironomidae	Chironominae	0	0	0	0	0	3
P13	Diptera	Chironomidae	Tanypodinae	1	0	1	0	0	0
P14	Ephemeroptera	Caenidae	Caenis sp.2	0	0	0	0	1	0
P14	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	1	0	5	2
P14	Diptera	Chironomidae	Chironominae	3	6	0	5	1	1
P14	Diptera	Chironomidae	Tanypodinae	0	0	3	0	1	1
P14	Diptera	Ceratopogonidae	Bezzia sp.	0	1	2	0	0	1
P14	Oligochaeta	Oligochaeta	Oligochaeta	3	0	0	0	0	0
P15	Diptera	Chironomidae	Chironominae	2	0	0	1	0	1
P15	Diptera	Chironomidae	Tanypodinae	0	0	0	1	0	0
P15	Diptera	Chaoboridae	Chaoborus sp.	0	1	3	0	1	2
P15	Oligochaeta	Oligochaeta	Oligochaeta	1	0	0	0	1	0

Macroinvertebrate fauna of the Pong catchment in April, 1996.

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
C01	Diptera	Chironomidae	Chironominae	0	0	1	0	0	0
C01	Diptera	Chironomidae	Tanypodinae	0	0	1	1	0	1
C01	Diptera	Chaoboridae	Chaoborus sp.	4	6	14	0	12	0
C02	Diptera	Chironomidae	Chironominae	0	0	0	1	0	6
C02	Diptera	Chironomidae	Tanypodinae	0	1	0	1	0	1
C02	Diptera	Chaoboridae	Chaoborus sp.	13	1	2	0	1	0
C02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	1	0	0
C03	Diptera	Chironomidae	Chironominae	1	0	9	0	6	0
C03	Diptera	Chaoboridae	Chaoborus sp.	0	0	1	0	0	0
C03	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	2	0	0
C03	Oligochaeta	Oligochaeta	Oligochaeta	0	0	1	0	0	0
H01	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	1	0
H01	Coleoptera	Elmidae	Cleptelmis sp.	2	1	1	2	0	0
H01	Diptera	Chironomidae	Chironominae	0	0	0	21	8	18
H01	Diptera	Chironomidae	Tanypodinae	6	11	34	0	1	1
H01	Diptera	Tipulidae	Limnophila sp.	0	0	5	2	1	5
H01	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	3	3	4	4	1	0
H01	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	2	4	1	2
H01	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	0	3	0
H01	Ephemeroptera	Ephemeridae	Ephemera sp.	0	0	1	3	0	1
H01	Hemiptera	Aphelocheiridae	Aphelocheirus sp.	1	0	0	0	2	0
H01	Odonata	Gomphidae	Erpetogomphus sp.	0	0	0	0	0	0
H01	Plecoptera	Perlidae	Phanoperla sp.	1	0	3	0	0	0
H01	Trichoptera	Goeridae	Goera sp.	0	0	1	0	1	0
H01	Trichoptera	Hydropsychidae	Amphipsyche meridiana	2	0	0	0	0	0
H01	Trichoptera	Stenopsychidae	Stenopsyche siamensis	0	0	1	3	0	0
H01	Trichoptera	Psychomyiidae	Tinodes sp.	1	0	0	0	7	0
H01	Trichoptera	Polycentropodidae	Polycentropus sp.	0	4	32	10	2	23
H01	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	0	0	0	0
H01	Trichoptera	Philopotamidae	Chimarra sp.	0	0	0	0	1	3
H02	Diptera	Chironomidae	Chironominae	22	0	0	0	0	0
H02	Ephemeroptera	Ephemeridae	Ephemera sp.	1	8	1	3	0	2
H03	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	0	0	0
H03	Coleoptera	Psephenidae	Eubrianax sp.	3	0	3	0	1	1
H03	Coleoptera	Dytiscidae	Deronectes sp.	0	1	1	0	0	0
H03	Diptera	Chironomidae	Chironominae	0	0	11	0	0	2
H03	Diptera	Chironomidae	Tanypodinae	13	1	1	1	0	0
H03	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	0	1
H03	Ephemeroptera	Caenidae	Caenis sp.1	0	0	2	1	0	0
H03	Ephemeroptera	Potamanthidae	Potamanthus sp.	1	0	0	0	1	0
H03	Ephemeroptera	Ephemeridae	Ephemera sp.	0	0	0	0	0	0
H03	Odonata	Libellulidae	Diplacodes sp.	0	0	1	0	1	0
H03	Odonata	Gomphidae	Sinogomphus sp.	0	0	2	0	0	0
H03	Oligochaeta	Oligochaeta	Oligochaeta	3	1	0	0	17	0
H03	Trichoptera	Polycentropodidae	Polycentropus sp.	1	0	1	1	1	24
N01	Coleoptera	Elmidae	Stenelmis sp.	9	0	4	0	7	5
N01	Diptera	Chironomidae	Chironominae	1	7	0	3	0	0
N01	Ephemeroptera	Caenidae	Caenis sp.1	2	3	0	0	0	0

Macroinvertebrate fauna of the Pong catchment in April 1996 (continue)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
N01	Odonata	Gomphidae	Erpetogomphus sp.	0	0	1	0	0	1
N01	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	1
N01	Veneroida	Corbiculidae	Corbicula blandina	1	1	1	1	1	36
N02	Diptera	Chironomidae	Chironominae	0	0	0	0	0	1
N02	Diptera	Chironomidae	Tanypodinae	2	4	1	1	3	0
N02	Diptera	Muscidae	Limnophora sp.	0	0	0	0	0	1
N02	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	0	1	0
N03	Coleoptera	Elmidae	Cleptelmis sp.	0	0	3	0	0	0
N03	Coleoptera	Elmidae	Stenelmis sp.	1	1	4	19	13	5
N03	Diptera	Chironomidae	Chironominae	0	0	0	8	0	0
N03	Diptera	Chironomidae	Tanypodinae	6	0	4	1	0	2
N03	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	1	0	0
N03	Ephemeroptera	Caenidae	Caenis sp.1	2	2	0	1	0	0
N03	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	0	0	3	0
N03	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	1	0	0
N03	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	1	3	9
N03	Trichoptera	Polycentropodidae	Polycentropus sp.	2	0	0	1	0	0
N03	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	1	0	0	0
N04	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	1	0	0
N04	Coleoptera	Elmidae	Stenelmis sp.	6	0	0	0	1	1
N04	Coleoptera	Psephenidae	Eubrianax sp.	1	0	0	1	0	0
N04	Diptera	Chironomidae	Chironominae	4	0	20	0	4	0
N04	Diptera	Chironomidae	Tanypodinae	4	1	5	0	0	1
N04	Diptera	Ceratopogonidae	Bezzia sp.	3	3	9	0	3	0
N04	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	1	0	1
N04	Trichoptera	Polycentropodidae	Polycentropus sp.	1	1	1	0	1	0
N05	Diptera	Chironomidae	Chironominae	2	0	0	0	1	0
N05	Diptera	Chironomidae	Tanypodinae	0	3	2	6	0	1
N05	Diptera	Chaoboridae	Chaoborus sp.	1	0	2	0	2	0
N05	Diptera	Ceratopogonidae	Bezzia sp.	0	3	0	0	0	1
N05	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	1	0	0	0
N05	Oligochaeta	Oligochaeta	Oligochaeta	0	1	0	0	0	0
P01	Ephemeroptera	Ephemeridae	Litobrancha sp.	1	0	0	0	0	0
P01	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	1	0	0	0	0
P01	Trichoptera	Sericostomatidae	Notidobia sp.	0	0	1	0	0	0
P01	Coleoptera	Elmidae	Cleptelmis sp.	0	2	0	0	0	0
P01	Odonata	Gomphidae	Stenogomphus sp.	0	0	0	1	0	0
P01	Diptera	Chironomidae	Chironominae	0	0	0	0	2	0
P01	Diptera	Tipulidae	Limnophila sp.	0	0	0	0	0	1
P01	Oligochaeta	Oligochaeta	Oligochaeta	0	1	0	0	0	0
P02	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	1	0	0	0	0
P02	Ephemeroptera	Caenidae	Caenis sp.1	0	5	0	0	0	1
P02	Coleoptera	Elmidae	Cleptelmis sp.	0	10	0	0	0	0
P02	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	1
P02	Odonata	Gomphidae	Erpetogomphus sp.	0	1	0	1	0	0
P02	Odonata	Gomphidae	Labrogomphus sp.	0	0	0	0	1	0
P02	Odonata	Libellulidae	Diplacodes sp.	0	0	0	1	0	0
P02	Diptera	Chironomidae	Chironominae	0	1	3	0	1	2
P02	Diptera	Chironomidae	Tanypodinae	0	0	2	0	0	0

Macroinvertebrate fauna of the Pong catchment in April 1996 (continue).

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P02	Diptera	Athericidae	Atrichops sp.	0	1	0	0	0	2
P02	Diptera	Simuliidae	Simulium sp.	0	0	1	0	0	0
P02	Veneroida	Corbiculidae	Corbicula blandiana	1	0	0	2	2	1
P02	Oligochaeta	Oligochaeta	Oligochaeta	49	48	11	5	16	24
P03	Trichoptera	Philopotamidae	Chimarra sp.	0	0	1	0	0	0
P03	Coleoptera	Elmidae	Cleptelmis sp.	7	0	4	0	0	2
P03	Coleoptera	Elmidae	Stenelmis sp.	0	0	1	1	0	0
P03	Odonata	Gomphidae	Erpetogomphus sp.	1	0	0	0	0	0
P03	Hemiptera	Nepidae	Ranatra sp.	1	0	0	0	0	0
P03	Diptera	Chironomidae	Chironominae	2	1	3	0	0	0
P03	Diptera	Athericidae	Atrichops sp.	1	0	0	0	0	0
P03	Diptera	Ceratopogonidae	Bezzia sp.	1	0	1	0	0	0
P03	Diptera	Tipulidae	Limnophila sp.	1	5	7	1	0	1
P03	Veneroida	Corbiculidae	Corbicula blandiana	4	5	8	14	20	5
P04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	15	5	4	4
P04	Ephemeroptera	Leptophlebiidae	Traverella sp.	0	1	0	0	0	0
P04	Ephemeroptera	Caenidae	Caenis sp.1	0	0	3	2	0	2
P04	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	1	1	0	0	2
P04	Trichoptera	Ecnomidae	Ecnomus sp.	10	1	2	0	2	1
P04	Trichoptera	Hydropsychidae	Macrostemum similior	0	1	0	0	0	0
P04	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	1	0
P04	Odonata	Gomphidae	Erpetogomphus sp.	0	0	0	0	0	1
P04	Hemiptera	Belostomatidae	Sphaerodema sp.	1	1	1	0	0	0
P04	Diptera	Chironomidae	Chironominae	1	0	1	0	0	0
P04	Veneroida	Corbiculidae	Corbicula blandiana	0	0	2	0	0	0
P05	Ephemeroptera	Caenidae	Caenis sp.2	0	1	0	0	0	0
P05	Coleoptera	Elmidae	Cleptelmis sp.	0	1	0	0	0	0
P05	Diptera	Chironomidae	Chironominae	0	3	2	9	0	1
P05	Diptera	Chironomidae	Tanypodinae	0	2	1	1	1	1
P05	Diptera	Chaoboridae	Chaoborus sp.	1	0	0	2	1	1
P06	Ephemeroptera	Potamanthidae	Potamanthus sp.	0	0	2	0	1	0
P06	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	3	0	0	0	1
P06	Diptera	Chironomidae	Chironominae	12	19	89	5	87	21
P06	Diptera	Chironomidae	Tanypodinae	2	1	0	8	2	2
P06	Diptera	Ceratopogonidae	Bezzia sp.	1	2	0	0	1	0
P07	Trichoptera	Polycentropodidae	Phylocentropus sp.	3	1	0	0	2	0
P07	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	0	1	0
P07	Hemiptera	Belostomatidae	Sphaerodema sp.	0	0	0	0	1	0
P07	Diptera	Chironomidae	Chironominae	4	6	1	0	4	1
P07	Diptera	Chironomidae	Tanypodinae	2	1	33	17	2	4
P07	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	0	0	0
P07	Oligochaeta	Oligochaeta	Oligochaeta	1	0	0	0	0	0
P08	Ephemeroptera	Baetidae	Baetis sp.2	1	0	0	1	0	0
P08	Ephemeroptera	Baetidae	Centroptilum sp.	0	0	0	0	1	0
P08	Trichoptera	Polycentropodidae	Phylocentropus sp.	1	0	0	2	0	0
P08	Trichoptera	Hydropsychidae	Amphipsyche meridiana	0	0	1	0	0	0
P08	Trichoptera	Leptoceridae	Triaenodes sp.	0	0	0	1	0	0
P08	Odonata	Gomphidae	Labiogomphus sp.	0	0	0	1	0	0

Macroinvertebrate fauna of the Pong catchment in April 1996 (continue).

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P08	Odonata	Libellulidae	Diplacodes sp.	1	0	0	0	0	0
P08	Diptera	Chironomidae	Chironominae	7	9	2	2	2	0
P08	Diptera	Chironomidae	Tanypodinae	8	4	4	1	2	0
P08	Diptera	Ceratopogonidae	Bezzia sp.	4	0	0	1	0	7
P08	Veneroida	Corbiculidae	Corbicula blandiana	2	2	0	0	0	0
P08	Oligochaeta	Oligochaeta	Oligochaeta	10	2	0	0	2	0
P09	Ephemeroptera	Baetidae	Centroptilum sp.	0	0	0	0	2	0
P09	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	0	1	0
P09	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	0	2	0
P09	Diptera	Chironomidae	Chironominae	15	6	6	12	12	9
P09	Diptera	Chironomidae	Tanypodinae	0	0	0	0	1	1
P09	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	8	0
P09	Veneroida	Corbiculidae	Corbicula blandiana	0	0	0	0	2	0
P10	Ephemeroptera	Ephemeridae	Litobrancha sp	6	2	0	0	0	2
P10	Ephemeroptera	Caenidae	Caenis sp.2	0	1	0	0	0	0
P10	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	1	0	0
P10	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	0	1	0
P10	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	1	0
P10	Diptera	Chironomidae	Chironominae	2	0	2	0	1	0
P10	Diptera	Chironomidae	Tanypodinae	1	0	1	0	0	0
P10	Diptera	Ceratopogonidae	Bezzia sp.	2	0	1	1	2	0
P10	Oligochaeta	Oligochaeta	Oligochaeta	6	0	1	0	0	0
P11	Ephemeroptera	Caenidae	Caenis sp.2	0	1	1	0	0	1
P11	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	0	0	1
P11	Odonata	Gomphidae	Sinogomphus sp.	1	0	0	0	0	0
P11	Diptera	Chironomidae	Chironominae	16	21	19	8	8	72
P11	Diptera	Chironomidae	Tanypodinae	7	2	0	1	0	6
P11	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	1	1	7
P11	Oligochaeta	Oligochaeta	Oligochaeta	8	0	0	2	0	0
P12	Diptera	Chironomidae	Chironominae	5	0	1	0	0	0
P12	Diptera	Chironomidae	Tanypodinae	1	0	0	0	0	0
P12	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	0
P12	Veneroida	Corbiculidae	Corbicula blandiana	0	0	0	5	0	1
P12	Oligochaeta	Oligochaeta	Oligochaeta	1	0	1	0	0	1
P13	Diptera	Chironomidae	Chironominae	0	1	0	0	0	0
P13	Diptera	Chaoboridae	Chaoborus sp.	0	1	1	0	0	0
P13	Veneroida	Corbiculidae	Corbicula blandiana	0	0	5	0	0	0
P14	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	1	0	0	0	0
P14	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	2	0	0	0	1
P14	Trichoptera	Ecnomidae	Ecnomus sp.	0	1	0	0	0	0
P14	Diptera	Chironomidae	Chironominae	5	8	4	1	3	0
P14	Diptera	Chironomidae	Tanypodinae	2	2	3	12	3	7
P14	Diptera	Ceratopogonidae	Bezzia sp.	0	1	1	0	0	0
P14	Veneroida	Corbiculidae	Corbicula blandiana	0	0	1	0	0	0
P14	Oligochaeta	Oligochaeta	Oligochaeta	3	0	0	0	0	0
P15	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	0	1
P15	Oligochaeta	Oligochaeta	Oligochaeta	1	0	8	0	0	2

Macroinvertebrate fauna of the Pong catchment in June, 1996.

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
C01	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	1	0	0	0
C01	Coleoptera	Elmidae	Cleptelmis sp	0	0	0	0	0	1
C01	Diptera	Chironomidae	Tanypodinae	0	2	0	1	0	0
C02	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	1	0	0	7
C02	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	0	0	1
C02	Diptera	Chironomidae	Chironominae	0	0	5	2	0	9
C02	Diptera	Chironomidae	Tanypodinae	0	1	3	0	2	1
C02	Diptera	Ceratopogonidae	Bezzia sp.	0	0	1	0	0	1
C02	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	1
C03	Trichoptera	Polycentropodidae	Phylocentropus sp.	4	2	0	0	1	0
C03	Diptera	Chironomidae	Chironominae	0	0	0	1	1	0
C03	Diptera	Chironomidae	Tanypodinae	3	0	0	0	0	0
C03	Oligochaeta	Oligochaeta	Oligochaeta	2	0	0	6	0	0
H01	Coleoptera	Psephenidae	Eubrianax sp.	2	0	1	0	1	1
H01	Diptera	Chironomidae	Chironominae	0	0	0	1	0	0
H01	Diptera	Chironomidae	Tanypodinae	1	0	3	0	0	0
H01	Diptera	Rhagionidae	Atherix sp.	1	0	0	0	0	0
H01	Diptera	Tipulidae	Limnophila sp.	0	0	0	0	1	1
H01	Ephemeroptera	Ephemeridae	Ephemera sp.	7	6	4	3	0	0
H01	Ephemeroptera	Caenidae	Caenis sp.1	0	0	1	0	1	1
H01	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	0	0	0	0
H01	Ephemeroptera	Leptophlebiidae	Thraulodes sp.	0	0	1	0	0	0
H01	Hemiptera	Belostomatidae	Sphaerodema sp.	4	3	0	0	0	1
H01	Coleoptera	Elmidae	Cleptelmis sp.	2	0	0	0	0	0
H01	Plecoptera	Perlidae	Phanoperla sp.	0	1	1	0	1	0
H01	Trichoptera	Polycentropodidae	Neureclipsis sp.	6	0	0	0	0	0
H01	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	1	0	0	1	0
H01	Trichoptera	Psychomyiidae	Tinodes sp.	0	0	2	2	0	0
H01	Trichoptera	Goeridae	Goera sp.	1	2	0	0	0	0
H01	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	0	0	2	2	1	0
H01	Trichoptera	Hydropsychidae	Hydropsyche sp.	13	3	2	0	0	0
H02	Megaloptera	Sialidae	Sialis sp.	1	2	2	1	0	1
H03	Coleoptera	Dytiscidae	Neptosternus sp.	1	0	0	0	1	0
H03	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	0
H03	Coleoptera	Psephenidae	Eubrianax sp.	0	0	0	0	1	0
H03	Coleoptera	Hydrophilidae	Enochrus sp.	0	0	0	0	0	1
H03	Decapoda	Palaemonidae	Macrobrachium lanchesteri	1	0	1	0	0	0
H03	Diptera	Athericidae	Atrichops sp.	1	0	0	0	0	0
H03	Diptera	Chironomidae	Chironominae	0	5	0	0	1	0
H03	Diptera	Chironomidae	Tanypodinae	1	3	0	0	0	0
H03	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	0	2	0
H03	Diptera	Tipulidae	Limnophila sp.	0	1	1	0	0	0
H03	Ephemeroptera	Ephemeridae	Ephemera sp.	0	0	0	0	0	0
H03	Ephemeroptera	Baetidae	Pseudocloeon sp.	1	5	0	1	1	0
H03	Ephemeroptera	Baetidae	Centroptilum sp.	0	0	1	0	0	0
H03	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	1	0	5
H03	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	0	0	1	0
H03	Ephemeroptera	Potamanthidae	Potamanthus sp.	0	0	0	0	3	1
H03	Hemiptera	Corixidae	Cenocorixa sp.	0	0	0	0	0	0
H03	Veneroida	Corbiculidae	Corbicula blandina	0	0	7	0	3	0
H03	Odonata	Macromiidae	Macromia sp.	3	0	0	0	1	3
H03	Odonata	Libellulidae	Diplacodes sp.	0	1	0	0	0	0
H03	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	1	0
H03	Trichoptera	Ecnomidae	Ecnomus sp.	0	1	0	1	0	0

Macroinvertebrate fauna of the Pong catchment in June, 1996 (continuous).

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
H03	Trichoptera	Leptoceridae	Triaenodes sp.	1	0	0	0	0	0
H04	Coleoptera	Elmidae	Cleptelmis sp.	0	1	1	0	2	1
H04	Coleoptera	Psephenidae	Eubrianax sp.	0	0	2	0	0	0
H04	Coleoptera	Gyrinidae	Dineutus sp.	1	0	0	1	4	4
H04	Decapoda	Palaemonidae	Macrobrachium lanchesteri	0	0	1	2	1	0
H04	Diptera	Chironomidae	Chironominae	6	0	0	5	0	0
H04	Diptera	Chironomidae	Tanypodinae	0	2	14	0	10	2
H04	Diptera	Simuliidae	Simulium sp.	6	0	0	8	0	1
H04	Ephemeroptera	Ephemeridae	Ephemera sp	27	11	0	0	10	0
H04	Ephemeroptera	Baetidae	Centroptilum sp.	1	0	0	7	1	2
H04	Ephemeroptera	Caenidae	Caenis sp.I	0	1	15	0	0	4
H04	Ephemeroptera	Heptageniidae	Heptagenia sp.	5	0	0	18	2	0
H04	Trichoptera	Leptoceridae	Triaenodes sp.	0	0	1	0	0	5
H04	Ephemeroptera	Leptophlebiidae	Paraleptophlebia sp.	0	0	0	1	0	0
H04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	3	0	1	0	0	0
H04	Ephemeroptera	Leptophlebiidae	Leptophlebia sp.	0	1	0	1	0	0
H04	Ephemeroptera	Leptophlebiidae	Thraulodes sp.	0	0	0	0	0	7
H04	Megaloptera	Corydalidae	Neochauliodes sp.	0	0	0	0	2	0
H04	Odonata	Aeshnidae	Oplonaeschna sp.	0	0	0	1	0	1
H04	Odonata	Libellulidae	Diplacodes sp.	0	0	0	0	0	0
H04	Odonata	Gomphidae	Erpetogomphus sp.	1	0	0	2	5	0
H04	Odonata	Platycnemididae	Copera marginipes	0	0	0	0	1	0
H04	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	9	0	0
H04	Trichoptera	Calamoceratidae	Anisocentropus sp.	0	1	0	0	3	2
H04	Trichoptera	Philopotamidae	Chimarra sp.	1	0	4	0	0	1
H04	Trichoptera	Hydropsychidae	Macrostemum similior	0	0	1	0	0	5
H04	Trichoptera	Hydropsychidae	Ceratopsyche sp.	0	0	9	0	0	2
H04	Trichoptera	Hydroptilidae	Hydroptila sp.	0	0	2	0	1	0
H04	Trichoptera	Hydroptilidae	Oxyethira sp.	0	0	0	0	0	3
H04	Trichoptera	Molannidae	Molanna sp.	0	0	1	0	0	0
N01	Diptera	Chironomidae	Chironominae	0	2	0	0	0	2
N01	Diptera	Chironomidae	Tanypodinae	0	0	0	0	0	1
N01	Diptera	Ceratopogonidae	Bezzia sp.	1	1	0	0	1	1
N01	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	15	0	0
N01	Veneroida	Corbiculidae	Corbicula blandina	21	4	18	0	11	17
N02	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	2	0	0
N02	Diptera	Chironomidae	Tanypodinae	0	1	2	0	0	0
N02	Diptera	Ceratopogonidae	Bezzia sp.	2	0	0	0	1	1
N02	Ephemeroptera	Caenidae	Caenis sp.I	0	1	0	0	0	0
N02	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	1
N03	Coleoptera	Elmidae	Cleptelmis sp.	0	3	1	0	1	0
N03	Diptera	Chironomidae	Tanypodinae	0	0	0	3	0	0
N03	Diptera	Athericidae	Atrichops sp.	0	1	0	0	3	0
N03	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	1	0	1	0	0
N03	Odonata	Gomphidae	Erpetogomphus sp.	0	1	0	0	0	0
N03	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	1	1
N03	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	1	0	0	0	0
N04	Coleoptera	Elmidae	Cleptelmis sp.	0	0	0	0	0	1
N04	Diptera	Chironomidae	Chironominae	2	10	0	0	5	1
N04	Diptera	Chironomidae	Tanypodinae	1	0	4	0	0	5
N04	Diptera	Ceratopogonidae	Bezzia sp.	1	0	1	4	2	1
N04	Ephemeroptera	Ephemeridae	Litobrancha sp.	4	16	1	0	0	0
N04	Ephemeroptera	Caenidae	Caenis sp.I	0	0	1	0	0	2
N04	Oligochaeta	Oligochaeta	Oligochaeta	1	5	1	0	0	0
N04	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	4	0	5	0
N04	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	1	0	3	0
N05	Diptera	Chironomidae	Chironominae	18	0	3	0	0	0

Macroinvertebrate fauna of the Pong catchment in June, 1996 (continuous).

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
N05	Diptera	Chironomidae	Tanypodinae	1	0	1	1	6	1
N05	Diptera	Ceratopogonidae	Bezzia sp.	2	0	1	1	1	1
N05	Ephemeroptera	Ephemeridae	Litobrancha sp.	32	0	0	16	0	0
N05	Ephemeroptera	Caenidae	Caenis sp.1	2	13	11	1	18	2
N05	Trichoptera	Ecnomidae	Ecnomus sp.	2	0	0	1	0	0
P01	Trichoptera	Hydropsychidae	Ceratopsyche sp.	1	0	0	0	1	2
P01	Coleoptera	Elmidae	Stenelmis sp.	0	1	0	0	1	0
P01	Diptera	Tipulidae	Limnophila sp.	0	1	0	0	0	3
P01	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	2
P02	Ephemeroptera	Baetidae	Centroptilum sp.	0	0	0	2	0	3
P02	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	0	2	0
P02	Trichoptera	Hydropsychidae	Ceratopsyche sp.	8	9	0	4	3	0
P02	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	0	0	0	0	0	44
P02	Odonata	Gomphidae	Erpetogomphus sp.	1	0	0	0	0	0
P02	Coleoptera	Elmidae	Cleptelmis sp.	2	1	0	1	1	2
P02	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	0	0	9
P02	Diptera	Chironomidae	Chironominae	0	0	5	0	0	2
P02	Diptera	Tipulidae	Limnophila sp.	2	1	0	0	0	1
P02	Veneroida	Corbiculidae	Corbicula blandiana	0	0	0	1	2	0
P02	Oligochaeta	Oligochaeta	Oligochaeta	4	3	0	0	0	0
P03	Ephemeroptera	Caenidae	Caenis sp.1	0	0	0	1	0	1
P03	Trichoptera	Leptoceridae	Triaenodes sp.	0	0	0	0	1	0
P03	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	0	1	1	27	66	1
P03	Coleoptera	Elmidae	Cleptelmis sp.	0	1	1	0	1	0
P03	Coleoptera	Elmidae	Stenelmis sp.	0	0	0	1	0	0
P03	Diptera	Tipulidae	Limnophila sp.	0	2	0	7	2	0
P03	Oligochaeta	Oligochaeta	Oligochaeta	0	0	1	0	0	0
P04	Ephemeroptera	Leptophlebiidae	Paraleptophlebia sp.	0	1	0	0	0	0
P04	Ephemeroptera	Leptophlebiidae	Choroterpes sp.	0	0	0	0	0	1
P04	Ephemeroptera	Leptophlebiidae	Traverella sp.	1	3	4	2	0	0
P04	Trichoptera	Hydropsychidae	Cheumatopsyche malaysiensis	11	19	3	1	6	4
P04	Trichoptera	Hydropsychidae	Amphipsyche meridiana	0	0	0	0	1	0
P04	Coleoptera	Elmidae	Cleptelmis sp.	1	2	0	1	0	0
P04	Coleoptera	Elmidae	Stenelmis sp.	0	0	2	2	2	2
P04	Coleoptera	Curculionidae	Stenopelmus sp.	0	0	0	0	1	0
P04	Coleoptera	Psephenidae	Eubrianax sp.	0	2	0	0	0	0
P04	Diptera	Tipulidae	Limnophila sp.	1	0	0	0	0	0
P04	Veneroida	Corbiculidae	Corbicula blandiana	2	0	0	0	0	0
P05	Ephemeroptera	Caenidae	Caenis sp.2	0	5	0	0	0	0
P05	Ephemeroptera	Ephemeridae	Litobrancha sp.	7	38	22	24	11	8
P05	Trichoptera	Ecnomidae	Ecnomus sp.	1	0	0	0	0	0
P05	Trichoptera	Polycentropodidae	Phylocentropus sp.	5	0	1	1	0	0
P05	Coleoptera	Elmidae	Cleptelmis sp.	0	1	0	2	1	0
P05	Diptera	Chironomidae	Chironominae	0	0	0	0	1	0
P05	Diptera	Chironomidae	Tanypodime	10	3	4	0	1	5
P05	Oligochaeta	Oligochaeta	Oligochaeta	2	0	0	0	0	0
P06	Ephemeroptera	Potamanthidae	Potamanthus sp.	0	0	0	1	0	1
P06	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	0	4	0	3
P06	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	0	1	0
P06	Odonata	Macromiidae	Macromia sp.	0	0	0	0	0	1
P06	Diptera	Chironomidae	Chironominae	7	34	26	363	136	420
P06	Diptera	Chironomidae	Tanypodinae	0	3	13	11	6	24
P06	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	1	0	0
P06	Diptera	Chaoboridae	Chaoborus sp.	1	1	5	1	10	0
P06	Oligochaeta	Oligochaeta	Oligochaeta	1	4	0	0	7	10

Macroinvertebrate fauna of the Pong catchment in June, 1996 (continuous).

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P07	Trichoptera	Polycentropodidae	Phylocentropus sp.	1	0	0	0	0	0
P07	Diptera	Chironomidae	Chironominae	0	0	0	0	1	1
P07	Diptera	Chironomidae	Tanypodinae	6	1	10	33	4	4
P07	Diptera	Ceratopogonidae	Bezzia sp.	1	1	1	0	2	1
P07	Diptera	Chaoboridae	Chaoborus sp.	1	0	0	1	0	2
P07	Oligochaeta	Oligochaeta	Oligochaeta	1	1	0	4	0	0
P08	Trichoptera	Ecnomidae	Ecnomus sp.	0	1	0	3	0	10
P08	Trichoptera	Hydropsychidae	Amphipsyche meridiana	5	0	0	3	1	1
P08	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	0	0	1	0	0
P08	Trichoptera	Curculionidae	Stenopelmus sp.	1	0	0	0	0	0
P08	Diptera	Chironomidae	Chironominae	3	13	6	3	5	26
P08	Diptera	Chironomidae	Tanypodinae	0	3	1	1	0	8
P08	Diptera	Tipulidae	Limnophila sp.	1	0	0	0	0	0
P08	Oligochaeta	Oligochaeta	Oligochaeta	3	0	1	0	2	0
P09	Ephemeroptera	Caenidae	Caenis sp.1	0	0	3	0	0	0
P09	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	0	1	0	0
P09	Ephemeroptera	Heptageniidae	Heptagenia sp.	0	0	0	0	0	1
P09	Trichoptera	Ecnomidae	Ecnomus sp.	0	1	1	0	0	0
P09	Trichoptera	Polycentropodidae	Phylocentropus sp.	0	1	4	1	0	0
P09	Trichoptera	Leptoceridae	Ceraclea sp.	0	2	2	0	0	0
P09	Coleoptera	Dytiscidae	Eretes sp.	0	2	0	0	0	0
P09	Odonata	Protoneuridae	Prodasineura sp.	0	0	0	0	0	2
P09	Hemiptera	Gerridae	Cylindrostethus sp.	0	1	4	3	3	0
P09	Hemiptera	Gerridae	Rhematogonius sp.	0	0	0	0	1	0
P09	Diptera	Chironomidae	Chironominae	1	5	23	2	0	2
P09	Diptera	Chironomidae	Tanypodinae	0	17	22	0	0	0
P09	Diptera	Ceratopogonidae	Bezzia sp.	0	0	2	2	0	0
P09	Diptera	Chaoboridae	Chaoborus sp.	0	0	1	0	0	0
P09	Oligochaeta	Oligochaeta	Oligochaeta	2	0	2	0	0	0
P10	Trichoptera	Polycentropodidae	Phylocentropus sp.	1	2	0	0	1	6
P10	Diptera	Chironomidae	Chironominae	28	3	0	5	0	1
P10	Diptera	Ceratopogonidae	Bezzia sp.	2	0	0	0	0	0
P10	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	0	1
P11	Ephemeroptera	Caenidae	Caenis sp.2	2	0	1	0	0	0
P11	Ephemeroptera	Potamanthidae	Potamanthus sp.	2	0	7	0	0	0
P11	Diptera	Chironomidae	Chironominae	20	6	0	40	0	0
P11	Diptera	Chironomidae	Tanypodinae	0	0	0	3	0	0
P11	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	1	0
P11	Oligochaeta	Oligochaeta	Oligochaeta	2	0	0	0	1	0
P12	Diptera	Chironomidae	Chironominae	0	0	0	0	128	67
P12	Diptera	Ceratopogonidae	Bezzia sp.	0	0	0	0	1	0
P12	Diptera	Chaoboridae	Chaoborus sp.	1	0	0	0	0	0
P12	Oligochaeta	Oligochaeta	Oligochaeta	2	0	3	0	2	2
P13	Diptera	Chaoboridae	Chaoborus sp.	0	1	0	0	0	0
P14	Ephemeroptera	Ephemeridae	Litobrancha sp.	4	0	0	3	1	7
P14	Ephemeroptera	Baetidae	Centroptilum sp.	0	0	2	0	0	0
P14	Trichoptera	Ecnomidae	Ecnomus sp.	0	0	2	0	0	0
P14	Trichoptera	Hydropsychidae	Amphipsyche meridiana	0	0	2	0	0	0
P14	Coleoptera	Elmidae	Cleptelmis sp.	1	0	0	0	1	0
P14	Diptera	Chironomidae	Chironominae	3	0	3	0	2	0
P14	Diptera	Chironomidae	Tanypodinae	0	0	1	0	3	0
P14	Diptera	Ceratopogonidae	Bezzia sp.	0	0	3	0	0	0
P15	Ephemeroptera	Ephemeridae	Litobrancha sp.	0	0	5	1	0	0
P15	Trichoptera	Polycentropodidae	Phylocentropus sp.	1	0	2	0	0	0
P15	Diptera	Chironomidae	Chironominae	13	10	0	2	0	0
P15	Diptera	Chironomidae	Tanypodinae	1	1	2	11	1	0

Macroinvertebrate fauna of the Pong catchment in June, 1996 (continuous)

Site Code	Order	Family	Species	Rep1	Rep2	Rep3	Rep4	Rep5	Rep6
P15	Diptera	Ceratopogonidae	Bezzia sp.	0	1	0	2	0	0
P15	Oligochaeta	Oligochaeta	Oligochaeta	0	0	0	0	1	3
P15	Oligochaeta	Oligochaeta	0	0	0	0	1	3	0.67

Appendix 2

Physicochemical variable in October, 1995.

Site code	Air t	Water t	Velo	Width	Depth	Discha	pH	Alka	Condu	TDS	Turbid	TSS	Or-P	N	DO	BOD
C01	30.00	29.60	0.40	74.00	9.10	223.60	8.00	56.00	261.00	180.00	26.00	37.80	0.02	0.20	3.90	0.60
C02	33.00	29.50	0.80	79.00	8.90	7.70	8.00	60.00	261.00	230.00	27.00	47.50	0.00	0.10	3.90	0.90
C03	31.00	29.20	0.80	82.00	9.00	302.10	8.00	60.00	263.00	160.00	18.00	29.30	0.07	0.10	3.50	1.20
H01	25.20	22.70	1.30	5.00	0.60	3.10	7.70	56.00	110.90	91.30	25.00	154.50	0.14	0.20	6.90	0.90
H02	24.00	24.60	0.30	7.00	0.70	1.30	7.20	44.00	75.30	64.40	26.00	134.50	0.04	0.10	6.40	1.10
H03	25.40	23.90	0.60	7.00	0.50	1.80	7.80	72.00	124.30	101.50	83.00	274.50	0.00	0.00	6.60	1.50
H04	27.00	27.50	0.60	3.00	0.10	0.20	8.30	116.00	225.00	177.60	6.80	68.00	0.02	0.20	7.20	1.20
N01	37.00	27.50	0.60	15.00	3.50	26.80	7.30	90.00	117.00	95.90	85.00	221.00	0.07	0.00	4.10	1.20
N02	30.00	25.60	0.40	27.00	2.00	17.90	8.20	76.00	158.20	127.10	65.00	175.00	0.02	0.10	4.40	1.90
N03	28.00	29.20	1.70	35.00	3.90	191.30	7.10	116.00	227.00	193.80	27.00	166.00	0.02	0.10	3.70	1.40
N04	28.00	29.30	0.90	31.00	5.40	123.70	8.00	120.00	235.00	185.20	34.00	164.00	0.02	0.10	6.60	1.30
N05	33.00	28.20	0.80	22.00	7.50	101.60	8.00	102.00	195.20	124.00	22.50	21.30	0.00	0.00	4.60	0.00
P01	28.40	24.90	1.30	17.00	1.10	20.80	8.50	104.00	171.00	156.00	46.00	37.00	0.00	0.10	7.50	1.20
P02	30.70	27.20	1.00	7.00	0.90	3.00	8.00	126.00	246.00	238.00	37.00	33.00	0.00	0.20	6.10	1.40
P03	31.30	25.60	0.80	18.00	0.50	6.50	8.10	162.00	195.30	188.00	53.00	38.00	0.00	0.10	6.10	1.90
P04	34.00	27.30	1.30	17.00	0.40	6.60	8.30	110.00	221.00	108.00	42.00	39.80	0.02	0.00	7.00	0.50
P05	32.00	27.40	0.10	28.00	4.60	8.60	8.40	108.00	217.00	156.00	35.00	28.50	0.80	0.00	6.40	0.50
P06	31.00	28.60	0.30	68.00	7.90	221.80	8.20	88.00	172.50	140.00	3.00	3.60	0.10	0.10	5.10	1.70
P07	27.00	28.90	0.60	71.00	9.60	328.80	8.20	84.00	193.10	154.00	3.30	4.40	0.04	0.10	4.40	1.20
P08	33.00	29.60	0.90	42.00	3.40	109.30	8.40	82.00	194.90	142.00	6.80	12.50	0.04	0.20	7.30	1.50
P09	33.00	29.00	0.80	51.00	3.70	203.50	8.00	84.00	184.50	148.00	39.00	58.30	0.07	0.40	6.30	1.10
P10	35.30	30.90	0.60	50.00	8.60	231.20	8.10	88.00	107.90	140.00	12.00	37.80	0.02	0.80	5.30	1.30
P11	33.50	29.50	0.10	15.00	2.00	1.90	7.60	80.00	196.30	160.00	12.00	10.50	0.02	0.05	2.70	1.10
P12	36.00	30.00	0.20	23.00	2.80	8.50	7.50	98.00	330.00	2.60	25.00	16.30	0.07	1.40	2.60	2.10
P13	30.00	31.60	0.10	78.00	4.00	28.50	8.10	92.00	330.00	236.00	28.00	36.50	0.14	1.20	2.10	4.60
P14	30.00	28.30	0.30	53.00	9.20	131.10	7.60	86.00	183.70	132.00	11.50	22.80	0.04	0.20	4.40	0.90
P15	30.00	29.70	0.10	65.00	7.30	21.90	7.80	88.00	214.00	162.00	20.00	29.80	0.10	0.50	2.80	2.10

Physicochemical variable in December, 1995

Site code	Air t	Water t	Velo	Width	Depth	Discha	pH	Alka	Condu	TDS	Turbid	TSS	Or-P	N	DO	BOD
C01	28.70	24.30	0.16	47.00	6.30	40.70	7.80	92.00	637.00	396.00	12.80	27.60	0.02	0.30	7.69	1.01
C02	28.50	23.00	0.32	48.00	3.40	44.50	7.90	104.00	629.00	366.00	15.16	30.00	0.24	0.30	7.85	0.78
C03	29.30	23.40	0.36	32.00	2.00	50.70	7.90	94.00	640.00	412.00	13.40	32.00	0.10	0.30	7.52	1.01
H01	17.00	13.90	0.89	1.90	0.20	0.30	8.10	88.00	210.00	144.00	10.20	4.00	0.02	0.03	8.30	2.30
H02	22.00	13.20	0.08	2.30	0.25	0.04	8.10	62.00	141.30	78.00	21.60	3.80	0.02	0.02	8.30	1.68
H03	20.00	14.90	0.16	5.20	0.25	0.20	8.00	144.00	302.00	170.00	7.70	3.20	0.04	0.02	7.80	1.77
H04	24.00	19.30	0.00	0.50	0.05	0.00	8.60	120.00	278.00	154.00	1.80	1.80	0.04	0.03	7.90	1.31
N01	23.50	20.80	0.16	15.00	3.40	0.20	8.30	248.00	498.00	278.00	2.50	2.00	0.00	0.01	7.00	1.31
N02	26.00	21.00	0.24	24.00	2.00	10.00	8.50	82.00	201.00	172.00	12.30	11.60	0.02	0.03	6.90	1.95
N03	26.00	21.40	0.24	36.00	1.70	12.80	8.20	152.00	313.00	132.00	31.30	5.20	0.02	0.50	7.46	3.92
N04	27.00	21.40	0.16	20.00	3.00	10.90	8.30	132.00	315.00	156.00	16.30	9.20	0.02	0.30	7.47	1.02
N05	29.00	23.60	0.08	24.00	2.30	4.10	8.40	160.00	337.00	168.00	16.30	13.60	0.02	0.20	7.61	2.41
P01	30.00	22.10	0.89	7.00	0.55	2.34	8.30	172.00	308.00	212.00	3.90	7.20	0.04	0.05	8.40	1.18
P02	30.00	22.50	1.21	11.00	0.13	1.32	8.20	260.00	553.00	354.00	6.40	3.20	0.14	0.03	7.23	4.53
P03	28.00	22.30	1.37	15.00	0.30	4.99	8.50	186.00	381.00	232.00	5.20	3.88	0.00	0.03	7.95	2.36
P04	30.00	20.80	0.83	25.00	0.13	2.55	8.30	208.00	414.00	210.00	13.30	8.40	0.02	0.10	8.11	1.37
P05	32.50	24.90	0.48	36.00	3.50	52.62	8.30	186.00	382.00	210.00	12.00	9.20	0.02	0.08	6.90	1.20
P06	23.20	23.90	0.16	32.00	6.30	45.08	8.30	88.00	182.70	92.00	5.30	9.20	0.02	0.06	7.28	1.01
P07	27.20	24.00	0.40	36.00	8.00	154.11	8.00	86.00	220.00	112.00	4.60	5.60	0.04	0.04	5.18	1.11
P08	33.00	25.60	0.43	47.00	0.62	10.90	8.80	90.00	218.00	130.00	2.50	1.50	0.02	0.30	7.28	0.95
P09	30.30	25.80	0.48	39.00	0.65	12.17	8.00	96.00	265.00	130.00	14.10	16.40	0.02	0.26	7.95	0.90
P10	30.00	25.10	0.16	36.00	4.40	92.00	8.00	92.00	305.00	148.00	13.70	18.40	0.02	0.07	7.58	2.13
P11	31.00	26.40	0.08	7.60	0.28	0.20	7.80	124.00	1795.00	1880.00	21.60	48.40	0.02	1.50	2.21	1.33
P12	25.00	24.70	0.08	19.00	1.03	1.40	7.20	178.00	855.00	480.00	38.30	97.20	1.20	0.70	0.86	18.10
P13	27.00	24.50	0.08	32.00	1.20	2.79	8.10	168.00	882.00	434.00	12.70	51.20	0.70	1.50	1.56	17.80
P14	29.40	24.70	0.16	38.00	4.00	20.70	8.00	96.00	311.00	166.00	11.20	58.80	0.00	0.05	7.21	2.61
P15	28.00	24.50	0.24	48.00	5.00	30.11	8.40	94.00	307.00	170.00	21.20	28.00	0.02	0.10	6.70	1.67

Physicochemical variable in February, 1996

Site code	Air t	Water t	Velo	Width	Depth	Discha	pH	Alka	Condu	TDS	Turbid	TSS	Or-P	N	DO	BOD
C01	29.00	27.47	0.37	46.00	4.70	71.84	8.50	104.00	951.33	633.67	10.34	8.00	0.02	0.01	7.17	0.97
C02	28.00	26.30	0.16	48.00	6.40	43.22	8.50	237.00	1251.67	833.83	6.80	9.20	0.02	0.01	7.62	1.06
C03	29.00	26.33	0.16	28.00	1.65	6.73	8.42	106.00	1262.33	841.33	16.60	8.00	0.02	0.01	7.17	0.57
H01	22.10	14.75	0.44	6.00	0.18	0.50	7.83	94.00	179.45	119.55	5.45	4.00	0.04	0.14	7.63	0.54
H02	25.40	14.07	0.00	5.00	0.35	0.00	7.33	70.00	125.52	83.80	4.99	3.30	0.02	0.13	1.85	1.10
H03	26.80	20.27	0.00	6.00	0.28	0.00	8.00	190.00	313.30	208.50	2.05	2.30	0.10	0.54	7.65	4.25
N01	26.70	21.70	0.08	22.00	1.71	2.70	8.07	318.00	541.83	360.50	2.25	2.40	0.07	0.24	9.88	1.30
N02	25.80	21.02	0.08	25.00	1.96	3.41	8.22	70.00	122.67	81.78	7.09	4.40	0.07	0.24	9.27	1.08
N03	29.00	22.93	0.31	28.00	1.06	8.36	7.97	74.00	138.10	92.08	37.10	22.40	0.07	0.76	9.53	1.17
N04	30.00	23.35	0.16	28.00	2.30	9.74	7.92	82.00	153.40	102.12	242.00	11.60	0.04	0.52	8.78	0.69
N05	25.50	23.24	0.16	32.00	2.82	12.87	8.02	114.00	212.40	141.50	11.40	8.00	0.02	0.04	6.56	1.14
P01	29.00	24.38	0.21	11.00	0.14	0.29	8.42	192.00	332.83	221.83	3.80	2.50	0.02	0.05	8.83	1.68
P02	27.00	25.47	0.15	8.00	0.12	0.12	7.83	212.00	394.33	262.67	6.20	3.30	0.02	0.04	8.45	1.06
P03	29.00	24.22	0.47	12.00	0.15	0.78	8.38	226.00	397.33	264.50	28.10	22.30	0.02	0.04	8.37	0.99
P04	28.00	24.98	0.08	26.00	0.23	0.43	8.47	196.00	363.00	243.83	3.72	2.50	0.02	0.04	8.85	1.33
P05	26.00	23.28	0.17	43.00	3.45	23.91	8.78	190.00	351.33	234.00	20.90	17.20	0.02	0.04	8.50	3.32
P06	30.00	24.30	0.33	69.00	8.90	188.33	8.32	88.00	168.47	112.28	3.40	3.80	0.02	0.03	7.32	1.13
P07	28.00	23.13	0.32	71.00	9.50	198.57	8.08	88.00	201.12	133.92	3.56	4.20	0.02	0.03	7.17	1.24
P08	23.30	22.62	0.40	47.00	1.30	19.63	7.97	110.00	177.62	118.28	2.07	2.50	0.02	0.04	7.70	0.41
P09	26.00	25.53	0.53	46.00	1.80	39.74	8.58	88.00	187.07	124.63	4.99	3.60	0.01	0.02	8.83	0.53
P10	28.80	24.85	0.16	33.00	4.80	36.75	8.17	92.00	210.50	140.33	37.40	41.20	0.01	0.01	8.18	1.02
P11	27.00	25.18	0.40	6.00	0.33	0.68	7.75	94.00	290.33	193.33	65.50	73.20	0.02	0.30	5.57	1.58
P12	33.80	22.78	0.08	32.00	1.40	5.12	7.75	120.00	476.00	317.33	46.40	26.80	0.10	0.07	4.30	6.81
P13	27.00	24.38	0.12	47.00	1.73	8.37	8.05	84.00	463.50	309.83	27.30	21.60	1.40	20.00	7.82	9.56
P14	27.00	25.05	0.13	67.00	3.50	27.20	8.37	94.00	219.33	145.90	26.70	21.20	0.02	0.06	8.33	1.34
P15	28.00	27.30	0.16	58.00	8.10	69.17	8.33	88.00	215.83	143.90	11.66	8.60	0.40	0.05	7.03	1.86

Physicochemical variable in April, 1996

Site code	Air t	Water t	Velo	Width	Depth	Discha	pH	Alka	Condu	TDS	Turbid	TSS	Or-P	N	DO	BOD
C01	37.00	34.27	0.08	61.00	3.33	14.40	8.33	94.00	1218.50	811.00	23.40	9.00	0.02	0.10	8.20	1.75
C02	27.00	31.13	0.08	60.00	2.63	10.80	8.13	90.00	1286.67	1286.67	10.10	8.33	0.02	0.07	7.40	1.70
C03	33.50	30.53	0.08	40.00	6.38	17.34	8.13	92.00	1690.33	1128.33	11.90	11.33	0.02	0.08	7.10	1.62
H01	32.00	24.03	0.19	5.00	0.34	0.27	7.63	86.00	178.40	118.92	6.50	3.00	0.06	0.05	7.32	0.73
H02	29.00	22.98	0.00	4.10	0.28	0.00	7.37	46.00	95.93	63.87	34.70	86.00	1.10	0.08	1.97	2.37
H03	23.00	24.62	0.36	7.00	0.37	0.79	7.73	74.00	145.87	97.08	19.80	51.50	0.80	0.20	5.22	1.86
N01	26.00	27.90	0.11	13.00	1.07	1.70	7.83	154.00	308.17	205.17	15.30	68.50	0.40	0.50	5.52	1.37
N02	28.00	26.18	0.15	20.00	1.42	3.76	8.07	88.00	167.27	111.53	12.00	31.00	0.40	0.30	6.97	1.23
N03	29.00	27.98	0.21	20.00	1.88	6.93	7.83	90.00	187.72	124.98	61.30	74.50	0.50	0.30	6.07	1.16
N04	24.80	27.43	0.21	23.00	2.82	13.97	7.77	76.00	162.33	108.33	59.00	69.50	0.70	0.60	6.37	1.64
N05	27.00	28.32	0.16	17.00	4.02	9.71	7.90	82.00	181.93	120.60	240.00	136.00	0.60	0.80	6.38	1.10
P01	34.00	30.18	0.71	9.50	0.28	1.66	8.00	82.00	167.47	112.22	127.60	138.50	0.20	0.40	6.82	1.37
P02	28.00	29.47	0.28	3.20	0.17	0.13	7.73	138.00	272.67	181.72	23.00	68.50	0.50	5.50	4.47	1.89
P03	29.00	28.52	0.63	5.20	0.38	1.07	7.98	114.00	249.17	160.05	164.00	298.50	0.10	1.10	6.43	1.53
P04	26.20	27.20	0.86	18.00	0.48	3.98	7.98	90.00	181.75	121.17	387.00	319.00	0.50	1.10	6.68	1.21
P05	25.00	28.95	0.19	41.00	3.37	23.73	7.75	76.00	176.27	117.47	249.00	136.00	0.40	4.50	4.92	1.32
P06	22.00	24.97	0.16	63.00	6.07	52.61	7.88	82.00	171.10	113.90	4.84	3.00	0.02	0.10	3.88	1.33
P07	23.00	26.07	0.20	65.00	6.11	69.09	8.00	84.00	196.00	130.43	3.45	3.00	0.02	0.10	3.05	1.90
P08	27.00	27.68	0.27	41.00	0.70	6.69	8.43	82.00	193.77	129.18	2.35	2.00	0.04	1.40	8.37	1.04
P09	31.00	28.87	0.68	35.00	0.36	7.53	7.98	82.00	204.83	136.62	24.20	21.00	0.90	0.30	7.02	0.80
P10	39.00	33.13	0.20	54.00	3.20	30.07	8.00	82.00	198.83	132.55	25.50	21.00	0.04	0.30	7.35	1.39
P11	27.00	27.00	0.21	39.00	2.67	18.53	7.82	100.00	241.50	152.70	18.05	10.50	0.02	0.40	7.23	1.89
P12	38.00	31.10	0.33	23.00	1.28	3.40	7.53	134.00	520.00	352.67	34.60	26.50	0.10	0.50	2.70	0.67
P13	27.50	28.03	0.11	38.00	1.84	6.88	7.67	112.00	439.83	292.83	16.65	15.50	0.80	0.80	5.57	4.30
P14	30.00	29.83	0.21	48.00	2.67	23.76	7.82	76.00	229.83	152.70	40.20	23.50	0.04	0.50	7.23	2.28
P15	37.50	32.67	0.13	63.00	6.80	49.69	7.88	80.00	250.00	166.77	16.20	10.67	0.10	0.20	7.05	1.44

Physicochemical variable in June, 1996

Water t	Velo	Width	Depth	Discha	pH	Alka	Condu	TDS	Turbid	TSS	Or-P	N	DO	BOD
33.10	0.15	32.00	4.02	18.88	8.40	62.00	288.83	192.17	430.00	218.00	0.04	0.30	5.80	0.52
31.43	0.16	31.00	3.97	19.67	7.97	64.00	321.50	214.50	400.00	153.00	0.04	0.40	5.95	1.02
31.33	0.32	21.00	1.79	12.03	8.05	82.00	353.17	235.33	395.00	165.50	0.04	0.40	6.50	0.89
23.50	0.43	5.60	0.14	0.34	8.25	72.00	141.78	94.38	21.00	9.00	0.00	0.10	6.91	0.69
24.00	0.28	4.30	0.21	0.25	8.20	36.00	62.43	41.60	62.00	31.50	0.00	0.10	6.51	1.25
24.30	0.37	6.65	0.35	0.86	7.25	90.00	141.63	93.83	41.00	17.00	0.04	0.20	6.80	0.96
28.15	0.33	3.20	0.10	0.10	7.73	92.00	187.78	125.15	7.50	3.50	0.02	0.30	7.33	0.57
28.68	1.34	14.60	0.61	11.98	8.13	106.00	224.33	150.02	125.00	253.00	0.00	0.10	6.88	1.30
28.13	0.40	19.00	2.19	16.61	8.07	92.00	181.18	120.75	80.00	93.00	0.00	0.20	7.40	0.75
28.35	0.37	27.00	2.07	20.85	8.02	92.00	187.42	124.90	72.00	89.00	0.00	0.20	7.50	1.35
28.93	0.29	24.00	3.20	22.55	8.25	108.00	229.17	152.60	53.00	63.00	0.00	0.20	7.03	2.50
29.08	0.24	24.00	2.75	15.82	8.20	96.00	194.43	129.60	81.00	73.00	0.04	0.30	6.52	1.12
29.68	1.04	12.00	0.38	4.68	7.43	56.00	120.20	80.20	200.00	228.50	0.02	0.30	7.20	0.96
30.00	0.52	5.00	0.22	0.56	7.72	202.00	333.00	221.30	56.00	23.50	0.02	0.70	5.63	0.94
28.25	0.75	12.00	0.76	4.86	7.87	86.00	158.88	105.80	100.00	212.50	0.00	0.30	4.63	3.31
29.20	0.44	22.00	0.35	3.42	8.18	98.00	174.40	115.92	350.00	303.00	0.14	0.40	6.78	1.92
29.58	0.13	32.00	2.29	9.77	8.10	74.00	146.15	97.27	128.00	274.50	0.02	1.70	5.08	2.26
29.30	0.31	3.70	0.82	1.43	8.50	102.00	232.40	137.30	15.00	13.00	0.02	0.30	6.30	1.22
28.40	0.18	29.00	0.69	3.60	8.60	126.00	287.40	193.90	23.50	32.00	0.30	0.70	3.20	10.50
29.10	0.12	58.00	1.20	8.35	8.60	130.00	311.20	222.13	24.00	38.50	0.40	1.10	2.80	12.80
29.58	0.39	39.00	3.01	69.26	8.08	94.00	172.03	115.02	27.00	23.50	0.04	0.70	6.72	1.55
31.18	0.43	40.00	4.74	82.36	8.10	78.00	191.56	126.44	33.00	22.50	0.02	0.80	6.88	1.84
28.00	0.24	53.00	4.20	46.48	8.30	90.00	178.90	122.60	27.50	30.00	0.02	0.20	6.10	1.41
30.00	0.28	68.00	7.10	117.61	8.30	92.00	172.70	116.80	8.50	8.50	0.00	0.10	3.80	1.52
29.00	0.27	69.00	7.70	124.80	8.30	98.00	174.10	118.20	7.80	6.50	0.00	0.20	5.30	1.68
28.00	0.19	49.00	2.40	19.44	8.20	102.00	169.40	102.70	6.50	8.00	0.02	0.50	5.80	1.70
28.20	0.16	42.00	3.10	29.82	8.50	86.00	172.00	115.20	15.00	12.50	0.00	0.60	5.70	1.84

The performance of biotic scores and indices in assessing water pollution: a case study in the Pong catchment of north-east Thailand.

Abstract

Estimates of family diversity were made at the scale of the catchment, three regions along the catchment (upper, mid and lower) and at individual sites. Both methods yielded similar estimates of whole catchment family diversity (31-34 families). However this differed at the scale of the regions within catchments for streambed grab samples (4.1-12.3 families) but not edgewater samples (7.3-8.1 families), and at the scale of the sites within the regions.
Families were unevenly sampled by the 2 methods at each site. Gerridae, Baetidae, Corixidae and Protoneuridae dominated the edge samples, while streambed grab samples were rich in Chironomidae, Hydropsychidae and Corbiculidae.
These results suggest that scale is an important consideration when determining an appropriate sampling protocol.
Among indices and scores tested measures of species richness, family richness, and EPT richness best-reflected water quality. Shannon-Wiener index most significantly correlated to water pollution. BMWP/ASPT system was significantly correlated to organic water pollution.

Introduction

The assessment of water quality using benthic macroinvertebrate data is currently applied via two main approaches; firstly, by applying various indices and score systems, and secondly, by employing multivariate analyses of community structure. The index and score systems (sometimes called "metrics", particularly in North America) are more popularly used among water authorities in continental Europe and North America (Johnson *et al.* 1993).

The index systems were first developed and derived from the classical German method-the Saprobien system invented by Kolkwitz and Marsson in 1909 (Metcalfe 1989). Water quality according to this system is classified into polysaprobic, alpha- and beta-mesosaprobic and oligosaprobic zones in which each water body, respectively, ranges from highly polluted to saturated oxygen with very diverse fauna. The indicator taxa used in the Saprobien system are mainly bacteria, algae, protozoan, rotifers and some benthic macroinvertebrates.

Later, the Trent Biotic Index (TBI) was created by Woodiwiss in 1964 for monitoring water quality in the United Kingdom (Johnson *et al.* 1993). This index is mainly derived from the Saprobien system, but it focuses on using benthic macroinvertebrates as indicator taxa. Modified versions of these two systems are now in use at regional and local levels throughout Europe.

However, the above index systems have a number of limitations. Firstly, they are effective only in local geographical areas, and secondly, taxa identification usually requires expert personnel. As an alternative to the index system, the score system was later developed. The first era of the score system is marked by the development of Chandler's Biotic Score (CBS) system in Scotland (Chandler 1970), followed by

Chutter (1972) who proposed the use of a scoring system (The Chutter Score) for assessing water quality in South Africa. These two scoring methods were the first systems which exclusively used benthic macroinvertebrates for assessing water quality.

Still, with the above two score methods, the indicator taxa inevitably require species level identification, and this only apply to the species which existed in a certain locality. Their later use are still in question, for example, the CBS tested and found by Able (1989) that it was effective in detecting organic water pollution, while Pinder and Farr (1987) determined it to be insensitive. Research biologists focused more on the necessity of high taxonomic resolution for more precise inferential information in assessing water pollution. Water quality managers, in contrast, require rather rapid biological methods (like the chemical) which are time-efficient and cost-effective.

To meet the above gap, the Biological Monitoring Working Party system (BMWP) was then invented. This score system uses benthic macroinvertebrate taxa identified at family level (Armitage *et al.* 1983). Each macroinvertebrate family is assigned the score according to its relative tolerance value (the score ranges 0-10). Later, the BMWP score was discovered to vary less with season and sampling methods if divided by the taxa (family) numbers, and become the Average Score per Taxon (ASPT). The BMWP was found to be more sensitive in detecting organic pollution, but less sensitive in unpolluted waters (Bargos *et al.* 1990).

The BMWP is still in use in the United Kingdom and has influenced the shortcoming of the score systems. The Hilsenhoff's Family-Level Biotic Index is widely used in North America (Hilsenhoff 1988). In Australia, the SIGNAL (Stream Invertebrate Grade Number-Average Level) was proposed by Chessman (1995). The first method uses only arthropod taxa while the second takes into account all macroinvertebrate groups. Both methods are designed for rapid bioassessment of water quality. The latter was recently tested, and was found to be quite promising (Growns *et al.* 1995). However, these two scoring methods require more tests conducted in other "rivers" apart from "shallow streams" in mountainous areas, for example, the deeper rivers in tropical climates. Consequently, these score systems will be tested in this study.

Unlike the score system which was primarily based on pollution tolerant values, the indices system (sometimes called community structure indices) emphasises on the variation of a species in a community sample. Washington (1984) reviewed eighteen indices most commonly used (e.g., Shannon's, Magalef's, Simpson's, Menhinick's etc.) and he found that each index has limited uses, and all indices require extensively tests with respect to, for example, seasonal regime, sampling methods, sample size, duration of sampling and taxonomic level. Among those indices, even the most recommended index-the Shannon-Wiener Index (UNEP, WHO, UNESCO and WMO, 1992) for Washington (1984) to be less relevant noted use in water quality assessment. Surprisingly, indeed, current publications about the performance of these indices in evaluating water quality are rare.

In addition to the above score and indices systems, the multimetric (multiple indices) was now recently proposed for use in the United States (see more details in Resh *et al.* 1995 and Barbour *et al.* 1995 and references therein). This new approach was influenced by the rapid bioassessment method created by Plafkin *et al.* (1989). The multimetric approach was developed as to rectify the former individual metrics which many claimed to have limitations in use (e.g., as in Norris and George 1993). In fact, the multimetric approach to date is the combination of the former indices traditionally used. Its aim is to reduce the weakness or increase the strength of individual indices by combining them together. It is also claimed that multiple indices can contribute more meaningful and effective ecological information for water resource planning (Barbour *et al.* 1995).

To date, the most commonly used multimetrics are richness measures, including total species richness and Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa abundance (see details in Barbour *et al.* 1995). In addition to the EPT, individual metrics for Ephemeroptera, Trichoptera or Diptera abundance was also been adopted (DeShon 1995). All these are based on the conventional notion that degradation of water quality will also reduce the number of benthic species, particularly sensitive taxa (Spellerberg 1992, Resh 1995 *et al.* 1995). As benthic larval assemblages are sedentary in nature, changes in their community structure or population or species levels may well reflect water quality alteration (Rosenberg and Resh 1993, Norris and Norris 1995).

However, there has been very limited use made of benthic macroinvertebrate score and index systems in assessing water quality in Southeast Asia. These countries are under rapid economic growth and suffer much from water pollution. Consequently, development of aquatic pollution monitoring methods is urgently required in this region (Dudgeon *et al.* 1994). Recently, Resh (1995) proposed certain macroinvertebrate taxa metrics (mostly mixed with multiple indices) which might be used for monitoring water quality in newly industrialised countries.

Aims of study

We explore the performance of some current score and index systems and wish to test some of them with the Pong catchment water condition, northeast Thailand. These scores and indices are compared between two different sampling methods, the qualitative and quantitative samples. The main aim here is to test whether the qualitative will be reliably effective when compared to the results derived from the conventional quantitative sampling. The data from two sampling types will also be evaluated via multimetrics, scores and indices systems.

Study site description

The Pong catchment is located on the northeastern plateau of Thailand (Fig.1) between 16°00'-17°15' N and 101°15'-103°15' E. It has an area of 15,190 km^2 and ranges in altitude from 88 to 300 meters above sea level. The Pong system consists of two main tributaries, the Pong and the Cheon. These two rivers receive waters flowing mostly from headwater streams located in the Phetchaboon mountain range. Three large dams that supply water for cultivated lands, industrial zones and communities within the catchment regulate the main channel of the Pong.

Twenty-one sampling stations were established across the Pong floodplain. Site P01-P08 is in the upper Floodplain above Ubolratana dam, while sites P09-P21 are located in the lower catchment area. The land of upper catchment part (P01-P08) is mainly modified for agriculture. The middle catchment part, P09-P13 are located along the Pong river reaches below Ubolratana dam. There is the largest pulp-paper mill factory in Southeast Asia located close to the riverbank and discharges its sewage into the Pong River between site P09 and P10. Sites P14-P18 are located in the lowest part of the catchment. The river receive discharge mainly from city sewage, particulary the river reach from sites P15 onwards. The final sampling site on the Pong river is P18 located above the confluence of the Pong and Chi rivers, approximately 5 km above the Mahasarakam weir. Site P19 to P21 are on the Chi River, which are located in the lowermost part of the catchment region. These sites are affected by substratum rock salt intrusion that becomes severe during summer.

Materials and methods

Qualitative versus quantitative sampling

Qualitative samples were collected from edge waters of twenty one sampling stations in February 1996 using a pond net (0.25x0.25 m with 500 μm mesh). The method was standardised by using fifteen-minute sampling on each riverbank at a site. Six quantitative samples were randomly taken from the riverbed at each site. Sampling benthic fauna at upstream reaches used a Surber sampler (0.30 m x 0.30 m with 500 μ m mesh aperture), while sampling in deeper waters downstream necessitated use of an Ekman Grab. Specimens were identified to the lowest taxonomic level possible, censused and preserved in 70% ethanol. These two data sets will be tested through application of multimetrics, scores and diversity indices.

Major water quality parameters were sampled at the same time as the macroinvertebrate sampling. These were water electrical conductivity (EC), total suspension solid (Total SS), phosphate (PO_4), nitrate (NO_3), dissolved oxygen (DO) and biochemical oxygen demand (BOD-5day). The methods used to sample and analyze all water quality variables followed the standard methods described in GEMS/WATER (UNEP, WHO, UNESCO and WMO (1992) and APHA (1992).

The score system

Three score systems are utilised: the BMWP/ASPT (Armitage *et al.* 1983), SIGNAL (Chessman 1995), and Hilsenhoff Biotic Index (Hilsenhoff 1988). Within the first two systems, each invertebrate family is assigned the score created by both methods, and all scores are summed and later divided by the number of families in a sample. The last score system used by this study here is modified slightly from the original Hilsenhoff's which used only 100 organisms caught as the divider while in this study we used the total number of insect individual caught instead.

The diversity indices system

The diversity indices system applied here selects some most commonly used indices in water quality assessment. These are Simpson's, Margalef's, Shannon's and Hurlbert's PIE. All are shown as follows:

(a) Simpson's Index = $\sum n_i (n_i-1)/n (n_i-1)$

(b) Margalef's index = $S-1/\log_e n$

(c) Shannon Wiener index = $-\sum (n_i/n \log_e n_i/n)$

(d) Hurlbert's PIE = $(n/n-1)\{(1-\sum (n_i/n)^2\}$

Where S=the number of species in a sample
n=the number of individuals in a sample
n_i=the number of individuals of a species *i* in a sample

Testing the score and indices systems

At each site the six replicates from quantitative sampling were aggregated as one sample. Similarly, the specimens collected qualitatively from both riverbanks were also combined as one sample. These two data sets will be analysed by various fundamental indices: the richness measures (the so-called multimetrics), these are number of individuals, species richness, family richness and EPT taxa richness. Secondly, the score and indices systems were used. All these results will be compared between quantitative and qualitative sampling.

The score and indices results from both sampling methods were correlated to major water quality variables using Pearson-product moment. This was done as to use the water quality variables as the reference frame of comparison between score and indices systems produced from the two sampling methods. All data were transformed to log (x+1) when necessary to improve normality prior to statistical analyses.

Results

Multimetric approach

Benthic animal abundance

The specimens collected by the two methods were different in total number(t_{20}=6.00, P<0.001) and taxonomic identity. The six replicates taken by the Ekman grab had a combined total of 4215 specimens while the edge sampling yielded 1208 specimens. The grab samples were composed mainly of Diptera (58.5%), Trichoptera (15.8%) and Ephemeroptera (9.3%), whereas the edge samples were dominated by Hemiptera (43.2%), Ephemeroptera (19.4%) and Odonata (16.2%).

Taxa richness

Although the cumulative number of taxa recorded by edge sampling (n=60) was similar to the streambed grab sampling (n=53, t_{20}=2.05, P=0.054), the composition differed greatly. The edge samples mainly consisted of Hemiptera and Odonata whereas grab samples yielded a high relative abundance of Trichoptera, Ephemeroptera and Odonata (Table 1).

The mean number of taxa from edge samples did not differ over the 3 broad regions in the catchment profile (upper mean taxa richness ± SD: 12.3±2.3, middle 10.6±3.0 and lower 10.7±3.5 respectively, $F_{2,18}$=0.810, P<0.46). In contrast, the benthic taxa richness recovered by grab sampling differed over the catchment landscape ($F_{2,18}$=7.96, P<0.003), Fig.2a. The upper catchment had greater richness (13.5±7.2), than the middle and lower catchment 7.4±2.6 and 4.1±1.5 taxa respectively.

Overall at the whole catchment scale, family richness estimates from edge-water and streambed samples were very similar (31 and 34 families respectively).

Benthic families taken by the grab method varied between catchment regions ($F_{2,18}$= 8.237, P=0.003). Streambed samples from the upper region contained more families (12.3±5.9) than those from sites in the middle (7.4±2.6) and lower catchment (4.1± 1.6). The edge-water samples, on the other hand, did not reveal any significant difference in family diversity over the catchment profile. The upper, middle and lower catchment sites had 8.1±2.3, 7.6±2.9, 7.3±3.4 families respectively ($F_{2,18}$=0.183, P=0.83).
The obvious difference between the results derived from two sampling methods is taxa richness. Families with the greatest number of individuals taken by edge sampling were Gerridae (21% of all specimens), Baetidae (17%), Corixidae (16%) and Protoneuridae (13%) while grab sampling yielded large numbers of Chironomidae (47%), Hydropsychidae (13%) and Corbiculidae (6%). More specimens were present in edge-water samples from middle and downstream sites than upstream, whereas the streambed grab samples yielded most individuals in upstream sites. The fundamental metrics, species and family richness of the two different sampling methods are quite different from each other.

Correlation between taxa richness and water quality variables

There was no significant correlation between species richness from edge-water samples and major water quality parameters. The species richness from quantitative data revealed significant negative relation with PO_4, NO_3 and positive with DO (Table 2). The most polluted site was P16. Its average BOD rose to 9.3 mg/L, nutrient levels were also high with NO_3 2.0 mg/L and P 1.4 mg/L. Only 5 Chironomid larvae were found from six-replicate riverbed samples, while eight species of macroinvertebrates were in from edge-water. There were the mayfly Baetis sp., the water bug *Ctenipocoris* sp., *Mesovelia* sp., *Micronecta* sp. *Halobates* sp., damselflies *Ischnura* sp. and *Pseudagion* sp. And the freshwater shrimp *Macrobrachium lanchesteri*. The DO level in site P16 was considerably high, averaging 7.8 mg/L, and resulted from the photosynthesis of unicellular algae *Microcystis*. In this aspect, the high DO level did not always necessarily correspond to benthic taxa abundance or diversity. Four water quality parameters were related to the number of families recovered by quantitative samples, but there was no significant correlation found from qualitative data (Table 3).

Ephemeroptera, Plecoptera and Trichoptera (EPT) index

Twenty three species of EPT were recorded from streambed samples, whereas only 9 species were recovered. The qualitative data had 6 EPT families, while a total of 15 families were recover from riverbed samples (Table 4). Only two major water quality parameters, BOD and DO, showed a significant relationship to EPT taxa richness in streambeds samples (r=0.77, P=0.001 and r=0.23, P=0.108 respectively). There was no significant correlation between EPT taxa richness of both sampling methods and other major water quality pollution parameters, such as conductivity, nitrate, phosphate and total suspension solid. Percent EPT composition (% EPT individuals/Total abundance), relates to major water quality parameters. Percent EPT taxa composition from quantitative samples shows association with BOD (r=0.49, P=0.012), conductivity (r=0.53,P=0.007) and PO4 (r=0.45,P=0.021), but not with TSS and NO_3. There was no significant correlation between percent EPT taxa from qualitive samples and any water quality parameters. EPT family richness from quantitative samples was also positive correlated to DO (r=0.42,P=0.028), and negatively related to BOD (r=-0.39,P=0.042). There was no correlation between quantitative EPT richness and TSS, NO_3 and PO_4. The EPT family richness from qualitative data did not significantly relate to any water quality parameters.

The scoring systems

All biotic scores from quantitative samples tended to agree with trends in water pollution, they showed different correlation values with pollution parameters (Table 5). Only BMWP/ASPT and SIGNAL scores were significantly negatively related to organic pollute (BOD). BMWP/ASPT showed positive correlation to DO. Hilsenhoff's score showed high association with NO3 and PO4 levels. All three score systems were well related to PO_4 levels. All of three scores failed to detect inorganic pollutants (EC and TSS). The scores from qualitative data did not obviously relate to spatial water quality variation (Table 5).

Discussion

The qualitative and quantitative methods made very different results. The results are clearly suggested that the qualitative method cannot replace the conventional quantitative method in the Pong catchment. The use of a pond net to collect macroinvertebrates fauna was shown to be effective and recommended elsewhere (Furse *et al.* 1981, De Pauw and Vanhooren 1983, Wright et al. 1988, Hellawell 1986, Lenat 1988, Abel 1989). This sampling method can be an integral component of rapid bioassessment (Resh and Jackson 1993, Resh 1995). However, the results from this study show very different species composition from the two different sampling methods. So, for reliable results, the quantitative sampling method is recommend in the Pong.

Richness measures

Conventional indices using taxa richness measures were effective, but in this study, such measure have to be derived from quantitative data. Almost all-major water pollution variables were correlated these quantitative richness indices. The much polluted the water are, the less number of benthic taxa richness found. When relating macroinvertebrate family richness to water quality parameters, the results were similar to that when using the species richness. So, it is clearly to conclude that family level identification to quantify water pollution in the Pong catchment is satisfactory.

EPT indices

The EPT index that is widely used in North America also revealed significant differences between sampling methods and habitat characteristics. The EPT collected from edge-water samples had fewer sensitive taxa. Most were Baetid mayfly which generally known as a widespread taxon with a wide toleration range to water pollution (Hellawell 1986). In contrast, the EPT species richness data from streambed was strongly negatively correlated to BOD, which is the critical water quality problem currently, encountered in this region. Thus, the EPT taxa richness from qualitative samples did not reflect any variation in water pollution variables, while the EPT richness from riverbed samples did, and can possible save cost and time by not having to include other taxa groups. The study found that the EPT taxa richness also relates to DO level. So, the EPT contributed another advantage as it reflected the healthy aquatic ecosystems. However, high DO content does not always indicate clean waters, because it can result from algal bloom which occurs frequently in the lower reaches of the Pong. The correlation of EPT family richness and percent EPT abundance/Total abundance to water quality in this study are considerably inferior to the EPT species richness measure.

Biotic score systems

All three score systems examined by this study performed similarly in relation to water pollution. Thus, all three scoring methods are well correlated to organic water pollution. Only macroinvertebrate families taken from the riverbed contributed meaningful results in relation to water quality. Data from edge-water showed no significant correlation to any water quality parameters. The BMWP/ASPT score was relatively related to DO, BOD and PO_4. BOD and PO_4 are critical water quality pollutants in this catchment, particularly where the river receives a high quantity of sewage discharges, resulting in very low BMWP/ASPT scores for these river stretches. The BMWP/ASPT is sensitive to organic pollution; this results is broadly the same as reported elsewhere (Murphy 1978, Bargos *et al.* 1990, Rossaro and Pietrangelo 1993). Another advantage of BMWP/ASPT score is that most families listed in BMWP are also found in Thailand. Even the BMWP/ASPT contains benthic macroinvertebrate families'scores base on their tolerance values test in Great Britain, but to some extent this can practically be applied to the tropical Pong river. Anyway, this study found that the low score families listed in BMWP which mean High tolerant also inhabited in very polluted area in this region, while the high-score taxa (less tolerant) were found mostly in minimally impacted sites. Resh and Jackson (1993) recommended that this score might need modification for use in different geographical areas. The study suggests that only slight adjustment may be required to apply this BMWP score system for assessing water quality in the Pong catchment. The SIGNAL score system only significantly related to two variables, BOD and PO_4, and less reliable in detecting the most significant water quality variable DO. Hilsenhoff's had poor performance in detecting organic pollution because it had no significant correlation to BOD. However, this score system has high sensitivity to nutrient levels (NO_3 and PO_4). This system failed to discriminate between impact and less impact sites in the Pong catchment, while both BMWP/ASPT and SIGNAL did.

Diversity indices

Only the data from riverbed showed significant correlation to water quality variables. The Shannon Wiener index showed significant correlates to DO and BOD. Simpson's and Hurlbert's PIE indices both showed significant correlation only with DO. Margalef's indices, on the other hand, did not reveal significant association with any water parameters. So, the Shannon Wiener index performed well in relation to changes in water quality. The H' value was correlated with BMWP (r=0.67). The H' needs species level identification while the BMWP score system requires family level. In this aspect, the BMWP is more advantage than the H' when one wants to monitor water pollution rapidly.

In summary, the assessment of water quality in the Pong catchment by mean of benthic macroinvertebrate data summarised indices and scores are quite promising. The data from quantitative sampling method was reliable in respond to water quality changes. Richness measures, both at species and family level, were superior to other indices and scores in assessing water quality changes. EPT richness measures are also valid in a similar way to taxa richness. The BMWP/ASPT score system was more reliable in detecting organic pollution while other scoring methods performed poorly. Of the four diversity indices tested, the Shannon-Wiener index (H') was more sensitive to water quality variation than the others.

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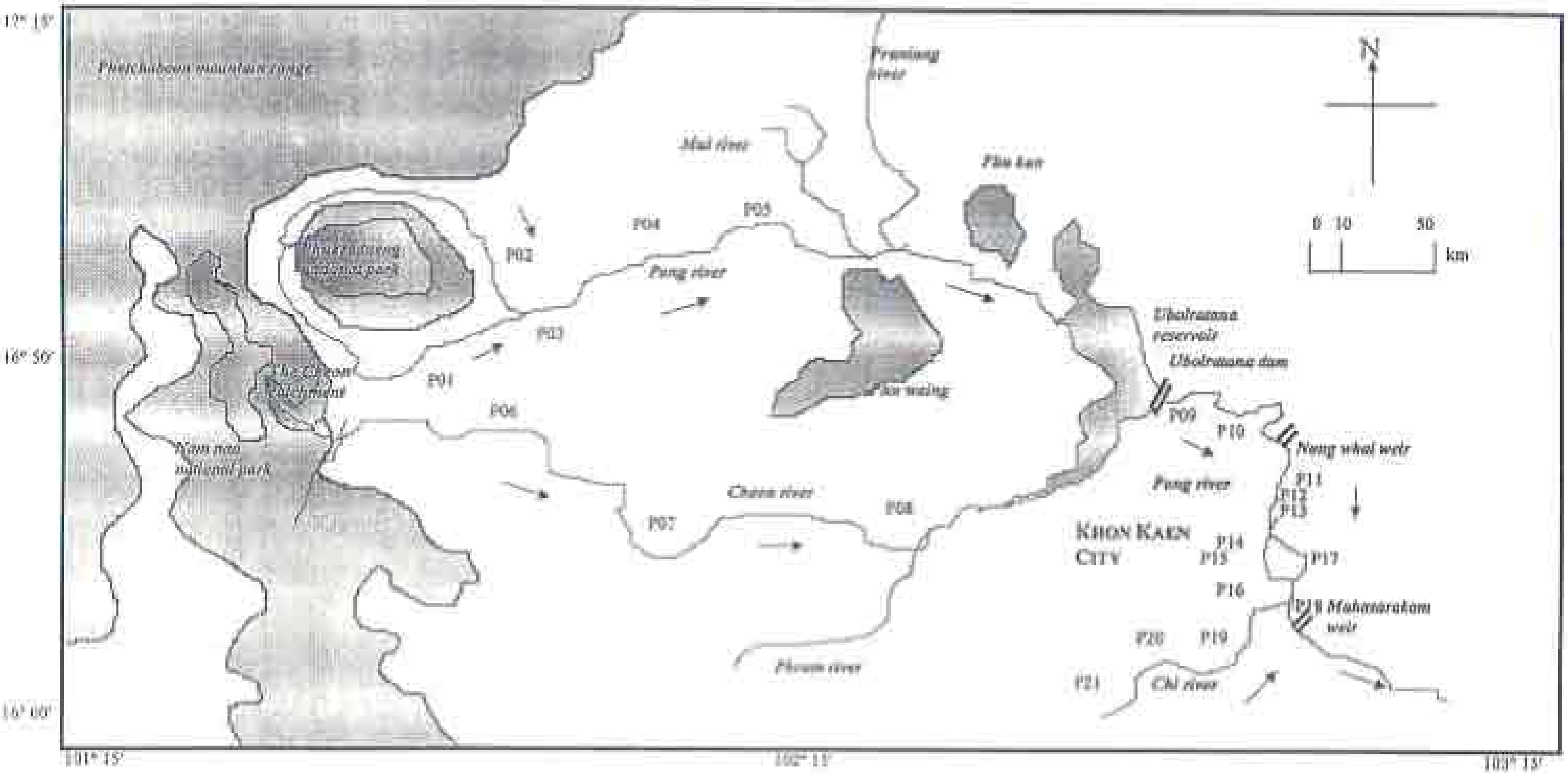

Fig. 1 Sampling sites of the Pong catchment northeast Thailand (Phu means mountain, P01-P08=Upper zone; P09-P21=Lower zone)

Table 1 Species composition between quantitative and qualitative sampling methods

Taxa	Quantitative		Qualitative	
	No. of species	percent	No. of species	percent
Coleoptera	7	13	6	10
Decapoda	1	2	1	2
Diptera	5	9	2	3
Ephemeroptera	10	19	7	12
Hemiptera	5	9	24	40
Odonata	10	19	15	25
Oligochaeta	1	2	0	0
Lepidoptera	0	0	1	2
Plecoptera	1	2	0	0
Trichoptera	12	23	2	3
Veneroida	1	2	2	3
Total	53	100	60	100

Table 2 Correlations between species richness from edge-water and streambed samples and major water quality variables (* indicate significant correlation)

Major water quality variables	Quantitative		Qualitative	
	r	p value	r	p value
EC (micro S/cm)	-0.1782	0.22	-0.2418	0.145
NO_3 (mg/L)	-0.5357*	0.006*	0.0312	0.447
PO_4 (mg/L)	-0.6615*	0.001*	-0.024	0.459
TSS (mg/L)	-0.3173	0.081	-0.0122	0.479
DO (mg/L)	0.4312*	0.011*	-0.1961	0.197
Log BOD (mg/L)	-0.5396*	0.006*	.0.639	0.392

Table 3 Correlations between number of family from edge-water and streambed samples and major water quality variables (* indicate significant correlation)

Major water quality variables	Quantitative		Qualitative	
	r	p value	r	p value
EC (micro S/cm)	-0.1706	0.230	-0.2202	0.169
NO_3 (mg/L)	-0.5710*	0.003*	0.0522	0.411
PO_4 (mg/L)	-0.6807*	0.001*	0.0164	0.472
TSS (mg/L)	-0.3305	0.072	0.0681	0.385
DO (mg/L)	0.4102*	0.022*	-0.1825	0.107
Log BOD (mg/L)	-0.5525	0.005*	0.0463	0.421

Table 4 Comparative percent composition of EPT individuals between quantitative and qualitative samples

Order	Family	Quantitative	Qualitative
Ephemeroptera	Baetidae	9.2	84.8
	Caenidae	16.7	5.5
	Ephemeridae	1.6	0
	Heptageniidae	0.1	0.1
	Leptophlebiidae	6.5	3.4
	Potamantidae	2.7	0
Plecoptera	Perlidae	0.3	0
Trichoptera	Calamoceratidae	0.2	0
	Ecnomidae	3	0
	Hydropsychidae	52.3	0.4
	Hydroptilidae	2.1	0
	Leptoceridae	0.5	1.3
	Polycentropodidae	3.1	0
	Psychomyiidae	0.1	0

Table 5 Pearson-product moment correlations ® between biotic scores and indices and major water quality variables when using (a) quantitative data and (b) qualitative data (* indicate significant correlation)

(a)

Water quality variables	BMWP's	SIGNAL's	Hilsenhoff's	H'	Hurlbert's PIE	Margalef's	Simpson's
Log EC	-0.3068	-0.0493	-0.0742	0.1659	-0.0828	-0.1038	0.0828
	P=.088	P=.416	P=.375	P=.236	P=.361	P=.327	P=.361
NO_3	-0.227	-0.3576	0.732*	0.0936	0.1259	0.0126	-0.1259
	P=.161	P=.056	P= .0001	P=.343	P= .293	P=.478	P= .293
PO_4	-0.4312*	-0.5787*	0.6308*	0.2593	0.0012	-0.0009	-0.0012
	P= .025	P= .003	P= .001	P=.123	P=.498	P=.498	P=.498
Log TSS	-0.3463	-0.3315	0.3387	0.364	-0.2856	-0.2436	0.2856
	P=.062	P=.071	P=.067	P=.052	P=.105	P=.144	P=.105
DO	0.5574*	0.2777	0.2255	0.4496	0.4209*	-0.202	-0.4209*
	P=.004	P=.111	P= .163	P=.020	P=.029	P=.190	P=.029
Log BOD	-0.4238*	-0.5226*	0.3501	-0.3846*	-0.2768	0.0712	0.2768
	P=.028	P=.008	P=.060	P=.043	P=.112	P=.380	P=.112

(b)

Water quality variables	BMWP's	SIGNAL's	Hilsenhoff's	H'	Hurlbert's PIE	Margalef's	Simpson's
Log EC	-0.1602	0.1359	0.4051	0.0693	0.1446	-0.1828	-0.1446
	P=.488	P=.557	P=.068	P=.765	P=.532	P=.428	P=.532
NO_3	0.235	0.2871	0.1021	0.2483	0.2956	-0.0206	-0.2956
	P=.305	P=.207	P=.660	P=.278	P=.193	P=.929	P=.193
PO_4	0.0095	0.351	0.1373	0.2253	0.2724	-0.0422	-0.2724
	P=.967	P=.119	P=.553	P=.326	P=.232	P=.856	P=.232
LOG TSS	0.0167	-0.1028	-0.2563	0.1476	0.3224	-0.2183	-0.3224
	P=.943	P=.657	P=.262	P=.523	P=.154	P=.342	P=.154
DO	0.3960	0.1086	-0.1173	-0.2745	-0.2243	-0.237	0.2243
	P=.075	P=.639	P=.613	P=.228	P=.328	P=.301	P=.328
Log BOD	-0.0238	0.1918	0.1528	0.3741	0.3949	0.07	-0.3949
	P=.918	P=.405	P=.508	P=.095	P=.076	P=.763	P=.076

Effect of Headwater Catchment Degradation on Water Quality and Benthic Macroinvertebrate Community in Northeast Thailand

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Abstract

Six replicates of benthic macroinvertebrates and stream water were sampling bimonthly for macroinvertebrate fauna composition and water physicochemistry analysis from six sampling sites along the Cheon headwater catchment in northeast Thailand from October 1995 to August 1996. The aims of this study were to examine the catchment water physicochemical quality variation as well as its aquatic benthic macroinvertebrate community and other related aquatic terrestrial environment factors. It was found that degradation of the Cheon headwater was evident by water physicochemical parameters and benthic macroinvertebrates. The water quality in the forest land sites was less degraded than at bared sites. The apparent degradation of water quality in this catchment was caused by clearing for agriculture. The streams covered by forests were less affect by surface runoff, resulting in high DO and low BOD level. The DO, BOD and SS levels resulting from land clearing have influential effects on macroinvertebrates. The macroinvertebrate analysis more accurately reflected these impacts in the streams than the water physicochemistry. The species richness and abundance in the disturbed sites were less diverse than in the pristine sites. The degree of fauna composition in disturbed areas varied according to the extent of land clearing. Among the benthic macroinvertebrate fauna, trichopteran was the most distinctive taxon which was more abundant in very pristine site than the other sites. The net-spinning caddis larvae and riffle beetle *Cleptelmis* sp. clearly showed significance of good forest cover condition and high DO level. While sensitive Heptageniid and Ephemerid mayflies nymphs were found only strictly in microhabitats with high DO level but not strongly related to forest cover or land clearing. Oligochaete, dipteran and mollusc were abundance at impact sites, as they were pollution indicator taxa. Classification and ordination methods identify clear environmental impact influenced by both natural and human causes.

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Introduction

The two main sources of human influence on the most Asian stream and river ecosystems are land modification for crop cultivation and river regulation and control (Dudgeon 1992, 1994b). Tangtam and Aimpan (1995) reported that the Cheon headwater catchment area has a forest-land loss rate as high as 2.1 percent per year and has suffered severely from extensive top soil loss, as high as 18 ton/ha/year. Such excessive runoffs from this catchment are mainly from the absence of vegetation cover since 70% of the land has been cleared for corn and sugar cane cultivation. They also stated that the primary key to relief from such vast sediment flowing into the streams was to restore and manage the riparian vegtation that lined the riparian zone. The Cheon headwater catchment used to be a very important rainfall catchment which perpetually supplied waters to northeast Thailand, but it is no longer contributing waters to the lower flood plain. The Thai government has now initiated a rehabilitation program for the Cheon. However there remains a large number of studies required, generally regarding aquatic environment information (Tangtam and Aimpan 1995). Impacts due to this land modification on floral and faunal communities are still not known. Macroinvertebrate fauna , both at community and species levels, is one of several well-known criteria used to assess land-water related environmental impact (Hellawell 1978, Wright *et al.* 1984, Abel 1989, Plafkin *et al.* 1989, Friedrich, Chapman and Beim 1992, Lenat and Barbour 1994, Barton 1996 and Magati 1996). In the case of catchment studies, distribution of macroinvertebrate fauna is found to be an effective tool in quantifying either stream degradation or restoration (Richards and Minshall 1992, Richards and Host 1993). Most studies of macroinvertebrate communities associated with environmental degradation have been conducted in the temperature zone, but very few in Asia. According to Chaiyarach (1980) and Dudgeon (1994), aquatic environment studies in tropical Asia are inevitably needed in order to contribute to better water resources management. The major objective of this research is to establish baseline data and to study environmental variation of a tropical catchment headwater, the Cheon catchment. Particular emphases are (i) examining the catchment water physicochemical quality variation (ii) corresponding of water physicochemistry to aquatic benthic macroinvertebrates community change (iii) to explore wheather its variation can reflect adverse effects from environmental degradation.

Description of the Cheon catchment

The Cheon catchment is located on the northeastern plateau of Thailand, 570 km northeast of Bangkok and has an area of 727 kilometers. It lies between 16°30'-16°54'N, 101°30'-101°55' E, and its altitude ranges from 280-780 m.s.l. The landscape of the Cheon is mostly hilly valleys and its landform is classified as a slope complex, with slops ranging from 6-27%. Most of the catchment terrain is modified for growing seasonal crops, especially mixed horticultural crops on land slopes which are mostly cleared. The rainfall regime of the catchment differs, with the upper flood plain having a seven-month rainy period from late April to October, while the lower has a wet season of six-month duration from May to October. Its average annual rainfall is about one third higher at 1378 mm whereas the lower flood plain receives 1034 mm. The annual average temperature of the catchment is slightly lower than the lower plain, reaching a maximum in April and May average 29.2 °C, while the coolest month average 20.7 °C in December.

In March, the evaporation rate of the catchment is at its highest, and humidity is at its lowest. It appears as a very dry and harsh landscape. During this time of the year, the bush fires and forest burning by local inhabitant occur frequently. March to early April is the time when the local people are most likely to clear the land for planting crops.

The annual climatic regime of the catchment, in general features a pattern of wet and dry periods. Geophysical structure of the Cheon catchment is mainly sedimentary rock which mostly consists of sandstone, shale and siltstone substrata. The surface soils with an average maximum depth of 0.5 m, are mixed with sandy and clayey loam and belong to the great group-red yellow podsolic soil. With intensive crops growing in this catchment during past decades, the lands then largely became less fertile, and thus extensive fertilisers are applied.

High levels of suspended solids diffused from the croplands were observed during pre-surveys by this study. They caused the catchment streams and rivers to appear very turbid, especially during the rainy season. The streams run particularly across a landscape where there is less forest cover, and both coarse and fine solids diffusion dramatically affected their waters.

Although large areas of the catchment land have been modified for massive crop planting, there still remains remnant vegetation within the catchment. Most vegetation patches are standing trees and shrubs which line the river banks. These patchy trees are thus expected to have a substantial role in supporting the aquatic ecosystem function within this catchment. Also, these riparian strips act as barriers for preventing excessive surface runoff from the croplands flowing into the catchment streams.

It can be observed that wherever streams of this catchment have thick strips of buffer vegetation, the water appears to be relatively clear and less turbid, particularly during the storm season. Such riparian vegetation corridors are mostly of mixed vegetation communities, mainly deciduous and dry evergreen trees. The locals seem inclined to preserve these vegetation strips, especially those in the upper catchment. However, at the lower catchment, the locals continue to use the riparian zone for growing crop up to the stream edge.

The only remaining large area of forest is located in the northwest of the Cheon basin (Fig. 1). The vegetation community here is mainly dry evergreen forest and covers approximately 15% of the total catchmant area. This is where the first sampling station was established, and it is intended to be a reference site for comparison with other sampling sites. The forest community of this site is relatively pristine and well protected by the Nam Nao National Park.

Study site description

The sites were established at pristine, moderate and severely disturbed locations, as well as lower in stream reaches. There were six sampling sites in total. The reference site (A) was situated in a protected area of dense forest, located 30 km from Nam Nao District. This site, in particular, was to be compared with other human disturbed sites (B to F in Fig. 1). Site B was about 10 km northeast of site A, but was considerably affected by nearby lands which were heavily modified for cornfields. Site B had a minute riparian strip approximately 1-2 m width. These two sampling sites were located in the second order streams which are tributaries of the Cheon river. Both sites C and D were located in the northeast part of the catchment, and were second order streams. The lands around site C were mostly cleared for cornfields and only some buffer vegetation strips were left along the riparian zone. Site D was located in the stream that runs across a Bhuddist monastery area. The vegetation in this site is relatively protected, and has a dense buffer strip covering the streamside. Site E was located in the southeastern sectors of the catchment, and is characteristic of the lowland Cheon water course. Here the river channel morphology become wider and deeper, particularly during rainy months. A patch of standing vegetation also existed, located sparsely along the river bank. The water current sometimes appeared to be slow and stagnant, particularly during summer. The surrounding lands of this site were cleared for massive sugar cane plantation.

The last sampling site F was located immediately above the Pong lower flood plain. This river stretch was similar to site E, but the adjacent lands were used mainly for residential and agricultural purposes.

Local communities inhabited the riverbanks at site F where they also grew a large variety of vegetables.

Materials and Methods

Sampling was conducted bimonthly at the six sampling sites, from October 1995 to August 1996. Six replicates were applied to sample benthic animals at each sampling site. A uniform stretch of river waterway at each sampling site approximately 100 m in length was marked, and six replicates were sampled randomly within it. Water physicochemistry data were concurrently collected on the same date of benthic fauna sampling.

Sampling water physicochemistry used the van Don bottle at the mid depth of water column where each of the faunal sampling unit were located. The integrated water sample technique was applied by mixing those six water samples in order to represent the water physicochemistry quality at a site. Preservation and analysis of water samples followed the standard methods described in APHA (1992).

Water current and discharge were measured in the field. The water flow-rate and discharge were measured applying the conventional hydrological methods as described in WMO (1980) and discharge values were calculated. All field practices for sampling water physicochemistry followed the guideline methods described in the GEMS/WATER operational guide by UNEP, WHO, UNESCO and WMO (1992). Detailed habitat condition at a site of each visit was also recorded.

Seventeen water physicochemical variables were examined in the field and laboratory. The variables measured in the field were water velocity, stream depth and width, discharge, water temperature, electrical conductivity (EC), dissolved solids (TDS), dissolved oxygen (DO) and pH. Those water physicochemical variables analysed in the laboratory were alkalinity, turbidity, suspended solids (SS), orthophosphate (PO_4), reactive dissolved nitrate-nitrogen (NO_3), biochemical oxygen demand (BOD), chloride (Cl) and sulfate (SO_4).

In this study the *SS* level was used to indirectly quantify the magnitude of surface runoffs, and also the sediments input into streams from surrounding lands. The SS was expected to cause microhabitat alteration detrimental for macroinvertebrate colonisation.

Turbidity was selected to measure the visual properties or transparency of water. The turbidity level was expected to condition the degree of light penetration within a water column. Further, the magnitude of turbidity level would determine the extent of photosynthesis available for benthic faunal community as allochonous food sources.

The TDS and EC were used as rough indicators of mineral salt content in waters, when direct measurement of each dissolved ion could not be made.

Benthic fauna was quantitatively sampled following the general methods recommended by Hellawell (1986). Sampling benthic fauna at shallow upstream sites used a surber sampler (0.30x0.30 m with 500 µm mesh aperture). An Ekman grab (0.15x0.15 m) was used to sample benthic animals in deeper waters at downstream sites.

Benthic samples taken in the field were first collected into polyethylene plastic bags and preserved with 90% ethyl alcohol. The benthic samples were then brought to the laboratory where they were washed and sieved using a series of standard sieves in which the last layer retained was at 500 µm mesh screen.

The animal samples were then hand-sorted on white trays using forceps. All specimens were identified to the lowest possible taxonomic level using available keys. The specimens were further enumerated and lastly preserved with 70% ethyl alcohol. All of the specimens were labelled and contained in vials.

Data analysis

Description

Taxa richness, faunal density, number of organisms, percentage of faunal composition all used descriptive statistics. Faunal variation between time and space employed univariate analysis. Univariate analysis was also applied to the water quality data set. All descriptive and univariate analyses employed the SPSS package (SPSS 1994). All of the data were tested for normal distribution. Log transformation was used whenever necessary as to improve normality. The fauna and environmental data sets were further analysed by multivariate analysis techniques. The software used was PATN (Belbin 1995).

Classification

The sampling sites based on water physicochemical data were clustered by the hierarchical agglomerative clustering UPGMA (Unweighted Pair Group arithMetic Averaging, Sneath and Sokal 1973).

As water physicochemical variables had different scale of measurement, prior to using UPGMA clustering method, they were first standardised by mean/standard deviation. The water physicochemistry data were clustered based on Euclidean distance association metric.

The fauna data were classified using TWINSPAN (Two-way Indicator Species Analysis). Concordance between TWINSPAN classification site groupings and site ordination patterns was also explored. Discriminant function analysis (DFA) was used to find combinations of predetermined significant environmental variables which best predicts the TWINSPAN site groups (Wright 1995). This significance level set for all analyses was 0.05 confidence interval, unless otherwise specified.

Ordination

The faunal data set was ordinated by HMDS (semi-strong Hybrid MultiDimensional Scaling, Belbin 1995), using the Bray-Curtis association metric. Associations between faunal ordination axes and environmental variables were examined using Pearson product-moment correlation. Correlation between ordination axes and macroinvertebrate taxa were sought using the pricipal axis correlation method (PCC option in PATN) to test which taxa significantly correlated to the ordination axes.

Results

Water physicochemistry

Stream discharges within the Cheon catchment varied significantly by site ($F_{2,38}$=8.63, p <0.001). The second order streams had lower water discharges than the fourth and fifth order stream sites. The mean monthly discharge of the catchment reached a maximum in October, the last rainy month, with an average of 8.52 cu.m/sec. The minimum discharge was in a cooler and dry month in February with its lowest level, 1.32 cu.m/sec. The water discharge level of the catchment sites were also significantly positively correlated to suspended solids (r=0.58, p=0.002), turbidity (r=0.49, p=0.003) and velocity level (r=0.44, p=0.009).

Water velocity, suspended solids and turbidity levels of the catchment streams reflected the temporal and spatial discharge pattern. The average maximum *SS* level, in particular, occurred in October is 171.2 mg/L and the minimum level in February, 3.0 mg/L. The highest *SS* level was mainly resulting from a high amount of surface discharge flux along the catchment waterways. At this time the water became very turbid and many floating plant fragments floated along the river channels, particularly at lower stream reaches. The upstream sites had an average *SS* level lower than the downstream sites, which average were 57.3 mg/L and 74.6 mg/L, respectively. Water velocity varied considerably through seasonal regime, maximum velocity in rainy season was 1.4 m/sec while minimum velocity is in dry season. The water became almost stagnant in some stream reaches. The *SS* and turbidity levels were well related, but they reached their peak in different times. The *SS* showed the peak value in October, averaging 171.3 mg/L, while the turbidity reached the maximum level in August with a mean of 74.5 NTU.

Air temperature varied markedly between sites. The upper site had significantly lower average temperature than the lower sites, which ranged from 24.4-25.5 °C and 27.5-27.6 °C respectively (t_4=5.96, $p<0.01$). Average air temperature of all sampling sites reached a maximum in April, 27.6 °C, while dropping to a minimum in December, 22.4 °C.

The average water temperature significantly differed between sites. The first two upper stream site (A and B) with relatively high percent forest cover had markedly lower water temperature than other sites, which averaged 20.3 °C and 24.2 °C, respectively. The water temperature levels also varied between dry and wet seasons ($F_{1,35}=61.34$, $p<0.001$).

The water temperature rose to its highest level 25.1 °C in April and then decreased to a minimum 17.2 °C in December. The stream sites located in areas with denser forest cover (A and B) had lower water temperature than the more exposed sites.

The nutrient levels of the catchment waters varied significantly by sites and months. Th PO_4 levels ranged from non-detectable levels to a maximum of 1.10 mg/L, with the mean 0.11 mg/L. The NO_3 levels ranged from non-detectable value to the highest level 0.54 mg/L, with the mean 0.15 mg/L. The NO_3 levels varied significantly between months ($F_{5,18}=3.14$, $p<0.05$). The NO_3 in waters were relatively higher in February and April, when they averaged 0.25 and 0.23 mg/L respectively. The lowest level of NO_3 measured 0.02 mg/L was in the minimal discharge month of December. The annual average NO_3 level of the Cheon was 0.15 mg/L.

The PO_4 levels of the Cheon varied significantly between months ($F_{5,28}$=15.21, p<0.001), but not by sites ($F_{5,28}$=0.33, p>0.05). The average PO_4 level of all sampling sites was 0.11 mg/L. In wet season, the average dissolved PO_4 level was higher, 0.14 mg/L while during dry period was 0.04 mg/L. Like NO_3, the PO_4 increased to its peak level in April, the first rainy month, averaging 0.56 mg/L.

The highest average TDS level, 170.84 mg/L, was in February and decreased to an average of 106.96 mg/L in June and October. The site A and B had distinctively lower TDS value than other sampling sites. TDS level varied significantly between month ($F_{5,28}$=3.62, p<0.01). The EC values of all the sampling sites ranged from 62.4 to 541.5 µS/cm, with a mean of 207.3 µS/cm. The EC levels in December and February were relatively higher than in other months. Sites A and B had distinctively lower TDS and EC than other sampling sites. The alkalinity values as $CaCO_3$ in all sampling sites fluctuated similar to TDS and EC levels, and ranged from 36.0 to 318.0 mg/L. The average alkalinity level of the catchment water was 100.6 mg/L. Alkalinity levels did not vary between months ($F_{5,28}$=1.[illegible], p>0.05), but they were spatially different ($F_{5,28}$=9.16, p<0.01). Site A, B and F had lower alkalinity levels which were 75.3, 52.0 and 85.0 mg/L, respectively. Sites C, D and E, in contrast, had relatively higher alkalinity values, which were 109.7, 110.0 and 174.7 mg/L respectively.

The pH levels was insignificant between sites ($F_{5,28}$=0.79, p<0.05) and months ($F_{5,28}$=2.31, p <0.05). The pH levels of all sites ranged from 6.2 to 8.8, with a mean of 7.8. The SO_4 levels ranged from 0.5 to 22.1 mg/L, with the mean level 10.3 mg/L. The SO_4 level did not significantly differ between sites ($F_{5,28}$=1.31, p>0.05), but it distinctively varied by months ($F_{5,28}$=6.34, p<0.01). The SO_4 level was higher in wet months than in dry season. Similar to SO_4 value, the Cl. level was relatively low, which range from 3.5 to 15.9 mg/L. The Cl level varied significantly between sites ($F_{5,28}$=7.56, p<0.01), but not by months ($F_{5,28}$=1.33, p>0.05). The highest Cl level occurred in December. The DO level varied significantly between months ($F_{5,28}$=3.51, p<0.05). The lowest level, averaging 4.9 mg/L was in April and the averaging highest level was 7.8 mg/L in December. The DO values were negatively correlated with SS (r= -0.72, p=0.001) and TDS (r= -0.77, p=0.001). The BOD level of the catchment water varied significantly between seasons ($F_{1,32}$=4.35, p<0.05). In the dry season the mean BOD level was 1.7 mg/L, while in the rainy period it was 1.2 mg/L.

Site clustering by water physicochemistry data

Figure 2 shows the dendrogram of sites clustered by UPGMA based on seasonal water physicochemical data. Most of the sampling sites are clearly separated into two main clusters, and largely following seasonal regime (dry and rain). Water samples taken from both dry and wet seasons in site D are still attached to the same cluster, inferring that water quality in site D did not change in either season.

Other sites, apart from site D, are well separated in agreement with samples taken by seasonal regime. The strongest influential physicochemical variables which discriminant the grouped sites were turbidity, SS, PO_4 (Kruskal-Wallis =8.562, df=2, p=0.0138) and SO_4 (Kruskal-Wallis =7.208, df=2, p=0.0272). During the rainy period, these significant variables were higher in levels when compared to the dry season. Site A, the less disturbed site, in particular, is comparatively well segregated from other sites in both seasons.

Benthic macroinvertebrate community and their species variability

Benthic macroinvertebrates representing a total of 13 orders, 57 families, 99 species were discovered. Chironomidae and Oligochaeta, however, were counted as a single taxon each. The most diverse benthic macroinvertebrates are the caddisflies with a total of 23 species, and accounting for 24 % of the total number of benthic species discovered. Mayflies constitute the second largest group, with 17 species. Among insect larval species, the rarest species are lepidopteran and plecopteran taxa with 1 and 2 species each. Dipteran taxa have the highest abundance with its density of 211.15 specimen/m^2. The next most dominant larval taxa are caddisflies and mayflies, with average densities of 178.3 and 118.9 specimen/m^2, respectively. The control site A has the highest benthic animal density with 214.8 specimen/m^2. Site B to D have 81.7, 128.9 and 17.6 specimen/m^2. The downstream sites, E and F, have relatively minimal individual density, which are 7.2 and 17.2 specimen/m^2, respectively.

The benthic density and species richness varied between months. Both benthic species richness and densities increased in the dry-cool months, particularly in December and February. During April, the first rainy month, benthic species richness and density declined gradually until the end of the monsoon season in October. The highest individual density occurred in December, 217.5 organism/m^2, and lowest in October 52.5 organism/m^2. The species richness also followed the density pattern, and was highest in December 13.2 species and lowest in August 8.7 species.

Reference site A, located in a healthy forest, has notably the largest density of trichopterans, 319.16 specimens/m^2, while sites B to C have lower caddis individual density. Gastropod, bivalve and Oligochaeta taxa were absent from site A during the one-year sampling. Oligochaeta, in particular, is abundant in site C, 180.6 specimens/m^2, eventhough this site was located in the same plain as site A. Taxa richness of sites A to F are 41, 19, 57, 48, 16 and 14 taxa, respectively. Taxa richness and density declines downstream. Comparing between upstream (A to D) and downstream (E to F), the upper sites have benthic 96 species with a mean individual density of 128.9 specimen/m^2, while lower sites have 21 specimens and 17.2 individual/m^2.

The less disturbed site A, has the highest macroinvertebrate fauna density, and the maximum number of caddisfly species. The most common in site A were the trichopterans: *Cheumatopsyche malaysiensis*, with 1851.8 organism/m^2, *Synaptopsyche klakahana*, with 1188.8 individual/m^2, and the ephemeropteran *Potamanthus* sp. with 966.7 specimen/m^2. Site B located next to site A, has a total of 19 benthic species identified. Most abundant species were dipteran Chironomidae, the odonatan *Sinogomphus* sp. and the mayfly *Ephemera* sp. with densities of 240.0, 166.7, and 166.7 organism/m^2, respectively. In site C, the most dominant species are the mayflies *Choroterpes* sp., *Ephemera* sp. and the caddisfly *Polycentropus* sp. with densities of 283.3, 233.3 and 183.3 organism/m^2, respectively. Site D, the intermittent stream, is dominated by mayflies *Ephemera* sp., *Heptagenia* sp. and Chironomidae with 438.9, 355.6 and 375.0 individual/m^2, respectively. The two lowland sites, E and F, are dominated by dipterans, Oligochaeta and bivalves. The individual densities of Oligochaeta and bivalve *Corbicula brandiana* which dominate site E are 142.6 and 131.7 organism/m^2. The dominant species of site F are Chironomidae and Oligochaeta, which have the same density of 38.9 organism/m^2.

Multivariate analyses of benthic community data

The result of TWINSPAN classification using faunal density data is shown in Figure 3. Eight sample groupings are split at the third level of TWINSPAN division. The samples collected from site E and F are separated at the first division. However, one of the upstream samples, B6, is included in this group. The indicator species contributing to the split on the positive side is Oligochaeta, while on the negative side is mayfly *Caenis* sp1.

On the negative side: at level 2, all upstream samples are split into four groups, group 1 to 4. Indicator species at level 2 is ephemeropteran *Habrophlebiodes* sp. At level 3, indicator species are the elmid beetle *Cleptelmis* sp., Oligocheata, the ceratopogonid dipteran *Bezzia* sp. and the megalopteran *Sialis* sp.

On the positive side: at level 2, indicator species are the dipteran *Bezzia* sp., bivalve *Corbicula brandiana*, Oligochaeta and elmid coleopteran *Stenelmis* sp. At level 3, the indicator taxa are trichopteran *Phylocentropus* sp. and coleopteran *Stenelmis* sp.

Sample collected from downstream sites are clearly separated into one major group at level 1 (group 5 to 8), eventhough these samples were collected in different months. The indicators species produced from the TWINSPAN agree with the samples/sites finding. The profundal ceratopogonid *Bezzia* sp., nematode Oligochaeta and bivalve *Corbicula brandiana* all prefer to inhibit downstream sites.

The occurrence of the biting midge *Bezzia* sp. was related to water pollution. *Bezzia* was often found in upstream site C. For example, in April, the first monsoon month, site c had the greatest *Bezzia* sp. density 255.6 organism/m^2 which was the highest density of this species in all sites. At this time, site C also had high average BOD, EC and TDS level, which were 4.5 mg/L, 313.5S/cm and 208.5 mg/L, respectively.

Like *Bezzia* sp., Oligochaeta is an indicator taxon that can identify polluted water samples, particularly the fine separation of samples between group 3 and 4. The contrast between samples taken from sites C and A is apparent: site C had high average Oligochaeta density, 466.7 organism/m^2 while there was no Oligochaeta in site A.

The megalopteran *Sialis* sp. is a significant indicator species that discriminates between samples within group 4. This species was found in two sites, B and C. Site C had a maximum abundance of *Sialis* in December of 133.3 organism/m^2.

Water quality variables differed markedly between TWINSPAN groups, particularly BOD, SS and turbidity ($F_{7,28}$=3.439, $p<0.05$, $F_{7,28}$=7.187, $p<0.05$, $F_{7,28}$=3.218, $p<0.05$ respectively). TWINSPAN group 3 and 4 had relatively cleaner water quality. Also, both groups had more species richness than the other groups. The finer difference between sample groups 3 and 4 was indicated by the presence of riffle bettle *Cleptelmis* sp. in group 3. Waters in group 3 had comparatively low BOD, SS and turbidity levels, which were 1.1 mg/L, 19.2 mg/L and 17.1 NTU, respectively.

Of all TWINSPAN groups, sample groups 1 to 4 had cleaner water quality and higher species richness than group 5 to 8. Water discharge and SS were identified by DFA to be the most significant variables. The DFA can predict and separate the TWINSPAN groups 1 to 4 clearly, with 100 percent success (Fig. 4). The water quality variables of sample group 3 indicated less impacted than group 4, and the difference between these groups was also reflected in the benthic fauna.

TWINSPAN group 3 was mostly comprised of sensitive species less tolerant to environmental stress, including those listed in Hellawell (1986) and Lenat (1993). These are the trichopterans:*Goera* sp., *Hydroptila* sp., *Tinodes* sp., *Molanna* sp., *Anisocentropus* sp., *Chimarra* sp., *Oxyethira* sp. and *Trianodes* sp.; the coleopterans: *Cleptelmis* sp. and *Dineutus* sp.; the ephemeropterans: *Thraulodes* sp., *Ephemera* sp., *Paraleptophlebia* sp. and *Heptagenia* sp. and the dipteran *Simulium* sp.

TWINSPAN group 4 had the highest species richness (Table 1) it had less abundant sensitive species than group 3. Sensitive species of group 4 are the trichopterans: *Chimarra* sp., *Trianodes* sp. and *Ecnomus* sp.; the ephemerans: *Choroterpes* sp. and *Potamanthus* sp.; and the coleopteran *Stenelmis* sp.

Ordination results

The sample ordination results generally resemble those produced by the TWINSPAN. The samples from less impacted sites are ordered at the positive end of ordination axis 1 (Fig. 5a). This group of samples corresponds with TWINSPAN group 3. The samples from impacted sites (B, E and F) are distinctly separated from the rest in the ordination space.

The ordination result can also idenify the sample with more diverse species. Sample A3, in particular, located at the highest positive value on axis 1, had the highest species richness (21 species) suggesting that axis 1 may be a richness vector.

Figure 5b shows the species vectors that highly correlate with the ordination space, as derived from the Monte Carlo test. There are strong agreements between TWINSPAN indicator species (Fig. 3) and HMDS species vectors (Fig. 4). The two most important indicator species produced by TWINSPAN, *Caenis* sp1 and Oligochaeta, are also clearly identified as influential by the HMDS.

Caenis sp1 is the indicator species of the first TWINSPAN division and is identified by the HMDS to have a high correlation with the ordination space (r=0.72). The *Caenis* sp1 vector points towards sites/samples A, C and D, at the middle of the plot. *Caenis* sp1 was a common species that occurred in upstream sites. Oligocheata also highly corelates with the ordinatin space (r=0.81), and its vector points to downstream samples/sites.

The elmid *Cleptelmis* sp. vector increases in the direction of samples of site A and D, where this species was abundant. It was evident that the riffle bettle *Cleptelmis sp.* was abundant only in clear and clean waters, as in TWINSPAN group 3. Thus, the *Cleptelmis* sp. vector identified by HMDS is also confirmed by the indicator species produced by TWINSPAN.

Otherr species which highly correlate with the odination space are the mayfly *Ephemera* sp. and the alderfly *Sialis* sp. *Ephemera* sp. was abundant in site A and D, while *Sialis* sp. was often found in site B. All these species vectors point to their corresponding sampling samples/sites in the ordination space. *Sialis* sp. was often found in site B. All these species vectors point to their corresponding samples/sites in the ordination space. *Sialis sp.* is also the indicator species which TWINSPAN used to split the sample groups 3 and 4. *Ephemera* sp., on the otherhand, is not identified as influential by the TWINSPAN. Pearson product-moment correlation test showed that altitude (r=0.78, $p<0.001$), land use category (r=0.71, $p<0.001$), buffer strip width (r=-0.67, $p<0.001$), stream depth (r=-0.71, $p<0.001$), stream width (r=-0.65, $p<0.001$) and water physicochemistry: water discharge (F=-0.68, $p<0.001$), turbidity (r=-0.40, $p<0.01$), SS (r=-0.69, $p<0.001$) and water temperature (r=-0.44, $p<0.01$) are all significantly correlated to axis 1. Buffer strip (r=0.45, $p<0.01$) and TDS (r=-0.37, $p<0.05$) are correlated to axis 2.

Discussion ans conclusion

Enviromental impact: water quality variation

The variation of water quality in the Cheon headwater catchment generally followed the monsoonal cycle. Like many tropical Asian streams during the rainy season, there were large amounts of sediment diffused from the adjacent land surface into streams (Dudgeon 1995). The high-low flow regime dramatically altered the stream conditions and benthic faunal habitats, reflected in quite a marked contrast of water quality between wet and dry seasons. In reference site A which located in the protected forest area of Nam Nao National Park, the water quality did not significantly vary, whereas the sites in bare lands critically suffered from land runoffs.

The impact of land use was clear when comparing between sites A to D which were all located at the same altitude and belong to the same stream order. The water quality in the forest land site was less impacted than at exposed sites. SS was the most significant water impurity in this catchment. The sites with thick vegetation strips had relatively lower SS levels than the sites with less riparian zone.

The ambient and water temperature were also influenced by the magnitude of the surrounding forest. The air and water temperatures at well vegetated riparian sites were lower than at the bare sites.

The most serious dissolved nutrient problem of the Cheon was due to PO_4, which fluctuated between seasons. It was very high in the wet season (0.14 mg/L), and minimal in the dry season (0.04 mg/L). The NO_3, however, did not vary by seasonal regime, its levels were 0.16 mg/L and 0.13 mg/L in wet and dy seasons, respectively. In this instance, the results suggested that the NO_3 could be transformed into other forms under the nitrogen cycle. The seasonal rainfall in April was a major cause off diffused nutrient bound sediment from agricultural lands entering into the stream.

Average TDS, EC Chloride and SO_4 level of the Cheon water was relatively low and did not indicate much impact. The levels of pH and alkalinity were relatively high but the values still fall within acceptable range of natural waters. The alkalinity sourse of the Cheon was mainly bicarbonate ion.

Largely, the water samples collected from the Cheon had DO and BOD level that met the national standard value of 6.0 and 1.5 mg/L, respectively (Ministry of Science, Technology and Environment-MSTE 1992). But when considering DO and BOD values between stream sites, these two variables had shown clear water quality impacts. The waters in impacted sites had relatively lower DO content and higher BOD than the less disturbed sites.

The fluctuation of DO values between sites was closely correlated with two combined factors; seasonal regime and SS. During heavy rainfall, the stream sites located in the cleared lands were much impacted from surface runoffs, thus yielding very high SS levels. The diffused sediment further caused the DO depletion within the water column. Like Do values, the BOD of the Cheon water varied between sites. The impacted sites from land clearing had high BOD levels. Diffused sediment from the land surface is the major cause of high BOD within the water column.

The result from UPGMA identified that SS and PO_4 were the two most significant water quality impurities of the Cheon waters. Both values were derived from diffused sediment, and more intensive agriculture, particularly in the stream sites located in cleared lands. The magnitude of water quality impact in the Cheon was greatest during the first rainy month, April.

Regarding water physicochemistry condition, it can be summarised that the Cheon headwater streams showed appearent water quality impacts from land use. The streams located in the bare lands received much impact from diffused solids, which led to high BOD and low DO levels. The waters in stream situated in forestland were less impacted from surface runoffs, resulting in high DO and low BOD. These two water quality parameters are in fact, important determinants which influence aquatic animal life. The benthic macroinvertebrates are animals which are sensitive to water quality changes. The DO, BOD and SS levels resulting from land clearing, have influential effects on macroinvertebrates.

Environmental impact: the presence of indicator species

The remarkedable appearant between the control and impact sites is that the reference site has a large number of species different from the disturbed sites. Disturbed sites with different degrees of impact also had different species composition.

Both sensitive and tolerant species were restricted to different sites and times. Among the macroinvertebrate fauna, Trichopters was the most distinctive taxon which was more abundant in site A: *Amphipsyche meridiana*, *Cheumatopsyche malaysiensis*, *Tinodes* sp., *Stenopsyche siamensis*, *Hydropsyche* sp., *Neureclipsis* sp. and *Synaptopsyche klukahana*. Most of these species were found during December, the post-flooding period with a rather cool climate. These caddisfly species built their fixed retreat on cobbles. The waters in site A during December were very clean with a high DO level of 8.3 mg/L and a moderate current speed of 0.9 m/sec. In this instance, it suggested that the presence of these caddisfly species was associated with seasonal regime, DO and forest cover.

Some caddis species in site A showed a periodic occurrence following seasonal regime. *A. meridiana* was the first species which appeared only after the post-flooding period. The emergence of *A. meridiana* was also reported in recovery streams after floods in Indonesia (Boon 1984). Similarly the hydropsychid *C. malaysiensis* and *Hydropsyche* sp. were also found in site A after the rainy season. These three filter-feeder caddis built their fixed retreat on submerge cobbles in site A. This site had relatively clean water. These caddis species were classed as mildly to moderately tolerant species by Roux et al. (1992). *A. meridiana* and *C. malaysiensis* inhabited in Yakruea and Phromlaeng stream of Nam Nao National Park, 40 km from the Cheon, with also relatively clean water (Sangpradub and Naknan 1997). It suggested that the presence of these species was still related to mild perturbation.

Another distinctive caddisfly in site A was the polycentropid *Neureclipsis* sp. This net-spinning caddis is also sensitive to organic pollution (Hellawell 1986). Tinodes sp. and *S. siamensis* were found only in site A. Both caddis species preferred to inhabit in cool, shaded stream with high DO level in site A. These two species were rare in this catchment, but the first species was abundant in pristine streams in Phukadueng National Park, 50 km from the Cheon (Inmuong 1997). Both caddis species were found in Yakruea and Phromlaeng stream of Nam Nao National Park. *S. siamensis* seemed to be resticted to Phromlaeng stream (Sangpradub and Naknan 1997).

Although almost no studies to date associate any single caddisfly species with environmental factors in the Asian tropics, the restriction of these net-spinner species to site A may indicate pristine water conditions. Further, the existence of these caddisflies clearly showed the significance of forest cover to the streams and adjacent lands. Consequently, studies into the influence of land clearing on stream waters might use the presence of net-spinner caddisflies as a biological indicator.

Mayflies also showed remarkedably different distributions between sites. *Potamanthus* sp. was particularly abundant in site A. The BMWP score (Hellawell 1986) assigned a score of 10 (highly sensitive) to all *Potamanthidae* and Lenat (1993) classed *Potamanthus* sp. as a sensitive species to water pollution. This species was very common sprawling on the stream bottom in site A, but rarely found in other sites. *Heptagenia* sp. and *Ephemera* sp. which were found in various sampling occasions in site A to D. These species were found only in streams where the waters had a high DO level. These two mayfly taxa are widespread and recognised elsewhere assensitive species which require highly dissolved oxygen (Hilsenhoff 1988).

Unlike caddisflies, the distribution of these two mayflies was not strongly related to forest cover or land clearing, but rather reflected the dispersion of microhabitats with high DO levels within the streams. This suggests that, within a modified stream reach, there may be still certain microhabitats that could be occupied by these high oxygen-requiring larvae.

Only elmid beetle species, Clepteimis sp. was related to the degree of impact between sites. This beetle family was classed as moderate tolerant species in Great Britain. But Jach and Kidada (1995) noted that most elmids in Asia could be used to indicate good water quality. This is reinforced by this study since the riffle beetle *Clepteimis* was more abundant in high oxygenated waters both in riffle and run areas in site A. It was mostly limited to site A, and like net-spinnig caddis, is a member of the indicator fauna of high DO and good forest cover condition.

Stoneflies are another taxon commonly used to incicate good water quality (Baumann 1979, Harper 1994). Plecopteran were very rare in this catchment, and only two species of Perlidae were found. *Neoperla sp.* is widespread (Sivec 1984) while *Phanoperla* sp. is abundant in tropical Asia (Harper 1994). Perlidae has been claimed to be a family sensitive to pollution (Hilsenhoff 1988, Stewart 1992). These stonefly species were found in both less impact site A and impacted downstream site E. So, it was less reliable to be as indicator species for water pollution in this catchment. Uchida (1990) and Harper (1994) reported that Asian perlidae occupied both highland and lowland streams and were well adapted to environmental changes.

In contrast to the sensitive species approch, the presence of tolerant species at a site was found to be another valuable indicator capable of differentiating degrees of impact. This study confirmed the status of Oligochaeta, Ceratopogonidae and Chironomidae as pollution indicator taxa, as all three groups were abundant at impacted stations.

Environmental impact: the implication of macroinvertebrate density

Quantifying freshwater catchment impacts using the presence of indicator species was quite a promising approch as discussed above. The density data, in addition, allowed more rigorous analysis in the cool month of December, while the impacted sites had the greatest individual density in the first rainy month of April. The less impacted sites were dominated by caddisfly and mayfly species, while the impacted sites were dominated by dipterans, Oligochaeta and molluscs.

Macroinvertebrate individual density fluctuated markedly following the seasonal climate, largely due to the flooding regime. Within a site, the variation of individual density through time showed a clear relationship with physical water properties, especially discharge, SS and turbidity. Between sites, differences in individual densities were associated with land use and the nature of the riparian buffer strip. The dominant cause that dramatically reduced the individual density was land clearing which led to the elevated water discharge and high SS and turbidity within water column. Finally, the habitat was altered and became unsuitable for macroinvertebrate colonisation as previously found by Dudgeon (1994). Generally, the total individual density data from multiple habitat sampling can reflect the magnitude of impacts on sites. More precisely, a high individual density of certain taxa, particularly caddisfly and mayfly, can indicate more pristine water at a site, whereas high individual densities of Chironomidae, Ceratopogonidae and Oligochaeta, on the other hand, signify more degraded stream sites.

Classification and ordination results

The indicator species produced by the TWINSPAN classification also confirmed the outcomes when using individual density data as discussed above. Both pollution tolerant and sensitive species indicated by the TWINSPAN showed a clear relationship with the magnitude of special and temporal impacts at a site.

Indicator species from the TWINSPAN provide invaluable information as these species strongly relate to the environmental impacts between samples/sites. For example, Figure 3 illustrates the classification results from all samples combined from all months and sites, and it is very difficult to separate samples within groups 3 and 4 if using species richness and individual density data.

The existence of indicator species, for example, *Bezzia* sp., led to the discrimination between samples groups 3 and 4. The presence of the key stone species, *Bezzia* sp., signifies the environmental impact occurring in samples/sites, as in the case of site C which has *Bezzia* sp. abundantly present in February when the water were severely polluted with maximum levels of BOD, EC and TDS.

The impact of discharge and SS from overland flow on species composition in each TWINSPAN group is also obvious. For instance, samples of group 3, in particular, had relatively less polluted waters and had high sensitive species richness, such as trichopterans:*Goera* sp., *Hydroptila* sp., *Tinodes* sp., *Molanna* sp., *Anisocentropus* sp., *Chimarra* sp., *Oxyethira* sp., *Triaenodes* sp., the coleopterans: *Cleptelmis* sp., *Dineutus* sp.; the ephemeropterans: *Thraulodes* sp., *Ephemera* sp., *Paraleptophlebia* sp., *Heptagenia* sp., and the dipteran: *Simulium* sp.

The most useful results produced by TWINSPAN are the indicator species since these provide ecologically meaningful data regarding environmental stress. Both "sensitive" or "pollution" indicator species can be obtained indirectly from the TWINSPAN output while tolerant scores for all species from ecotoxicological test are not yet available.

TWINSPAN effectively classified the less impacted and impacted samples/sites. The ordination results also conformed to the TWINSPAN output. Identifying those samples/sites which were impacted, as well as the indicator species produced by the two methods. This similarity in output suggests these data sets may be used interchangeably in multivariate analyses.

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Figure 2 Dendrogram from hierarchical agglomerative clustering of all sites seasonally sampling sites based on physicochemical variables

Figure 1 Location of sampling sites a-E in the Cheon headwater catchment, with local names in parentheses (redrawn from Tangtam and Aimpan 1995)

Figure 3 Classification of Cheon catchment samples by TWINSPAN. Groupings are retained at the 3rd level of division, including indicator species.

(letters represent site codes, numbers stand for sampling months, 1=October 1995, 2=December 1995, 3=February 1996, 4=April 21996, 5=June 1996 and 6=August 1996)

Figure 4 A biplot between discriminant function 1 and 2, the legend groups corresponding to the TWINSPAN groups in Figure 3.

(Functions 1 and 2 are significant when tested by Wilks' lambda, $p<0.001$, $p<0.05$, respectively)

Figure 5 Biplots between axes 1 and 2 of (a) samples ordination by HMDS (stress 0.1623) and (b) significant species vectors which strongly correlate to ordination space.

(Figure 5a, letters represent site codes, numbers stand for sampling months, 1=October 1995, 2=December 1995, 3=February 1996, 4=April 1996, 5=June 1996 and 6=August 1996.

Figure 5b, Atherix=*Atherix* sp., Caenis1=*Caenis* sp1, Chironom=Chironomidae, Chorotер=*Chorotерpes* sp., Cleptelm=*Cleptelmis* sp., Euonomus=*Eusomus* sp., Erpetogom=*Erpetogomphus* sp., Ephemera=*Ephemera* sp., Oligocha=Oligochaeta and Sialis=*Sialis* sp.

Table 1 Number of species per TWINSPAN group

Taxa	TWINSPAN group							
	1	2	3	4	5	6	7	8
Insect taxa								
Coleoptera	0	5	5	10	0	3	1	2
Diptera	0	3	6	6	2	3	2	3
Ephemeroptera	0	7	10	10	2	3	2	0
Hemiptera	0	1	3	4	4	0	0	0
Lepidoptera	0	1	0	0	0	0	0	0
Megaloptera	1	1	1	1	0	0	0	0
Odonata	0	6	3	9	0	1	0	0
Plecoptera	0	0	2	0	2	0	0	0
Trichoptera	0	7	18	14	1	0	0	0
Non-insect taxa								
Mesogastropoda	0	1	0	0	0	0	0	1
Oligochaeta	0	0	0	1	1	1	1	1
Veneroida	0	0	0	1	0	1	1	1
Taxa richness	**1**	**33**	**49**	**57**	**9**	**12**	**8**	**8**
Average density (organisms/m^2)	**77.7**	**224.1**	**104.2**	**123.8**	**68.3**	**10.2**	**89.1**	**45.5**

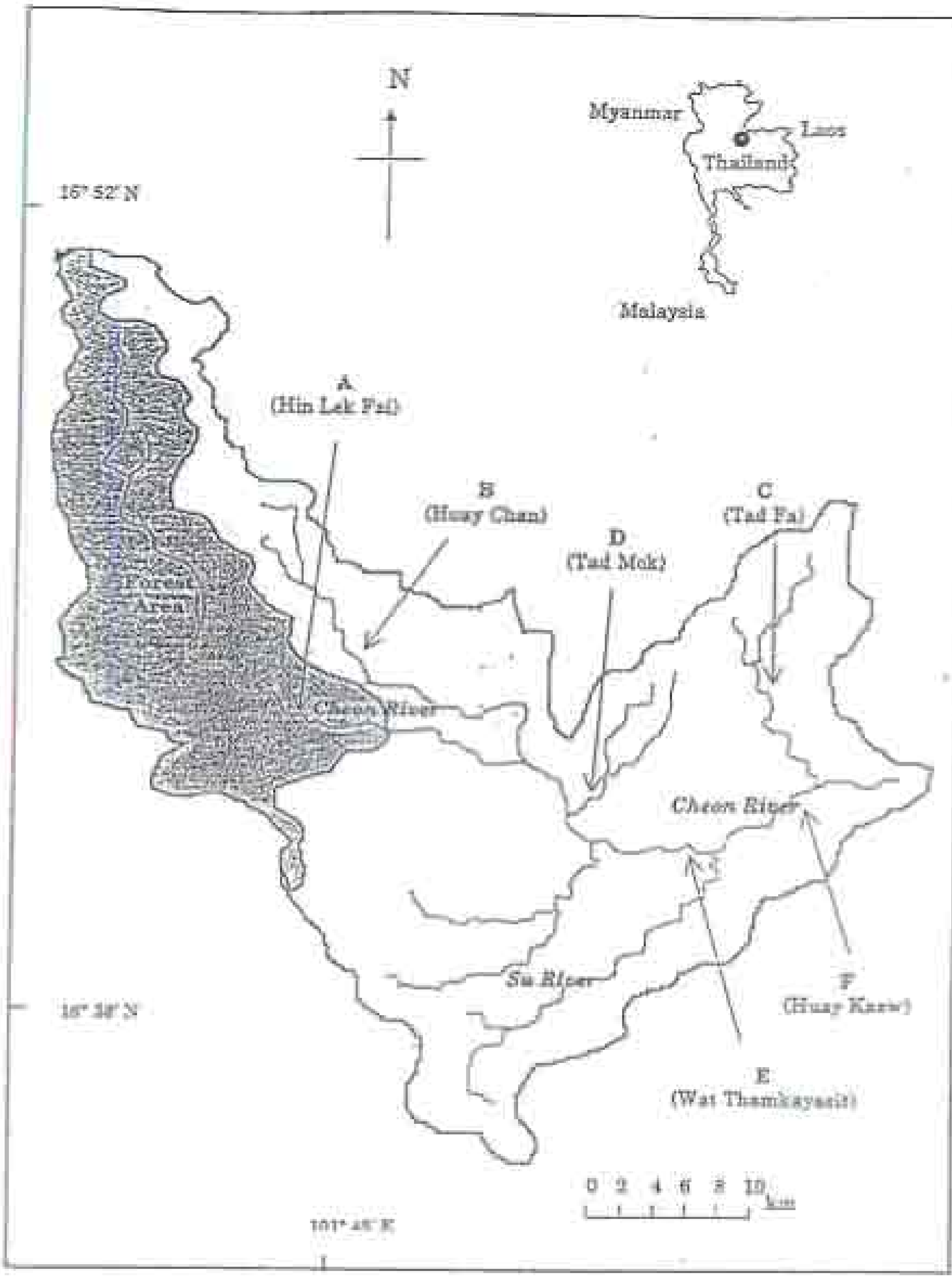


Figure 1 Location of sampling sites a-E in the Cheon headwater catchment, with local names in parentheses (redrawn from Tangtam and Aimpan 1995)

(a)

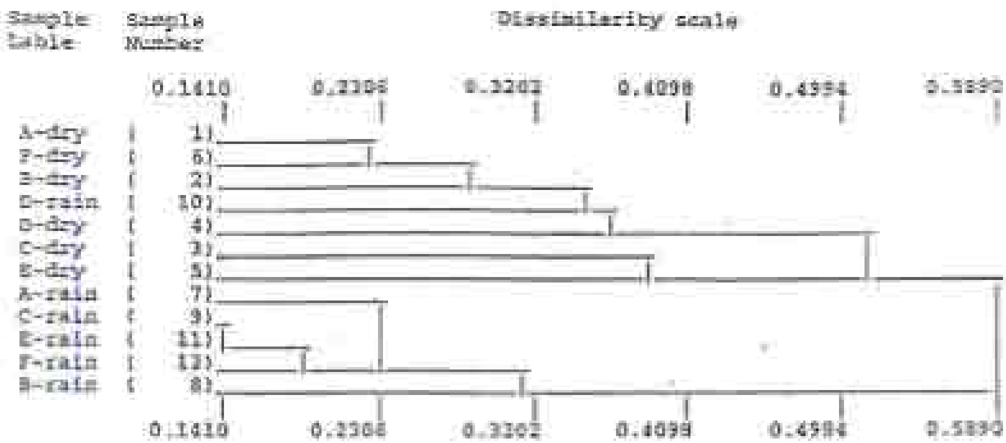
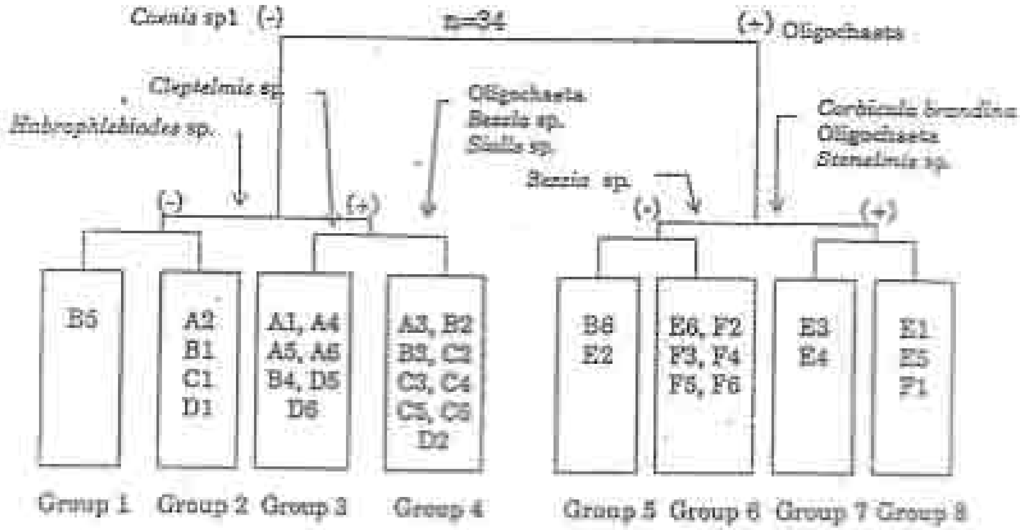


Figure 2 Dendrogram from hierarchical agglomerative clustering of all sites seasonally sampling sites based on physicochemical variables



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(letters represent site codes, numbers stand for sampling months, 1=October 1995, 2=December 1995, 3=February 1996, 4=April 21996, 5=June 1996 and 6=August 1996)

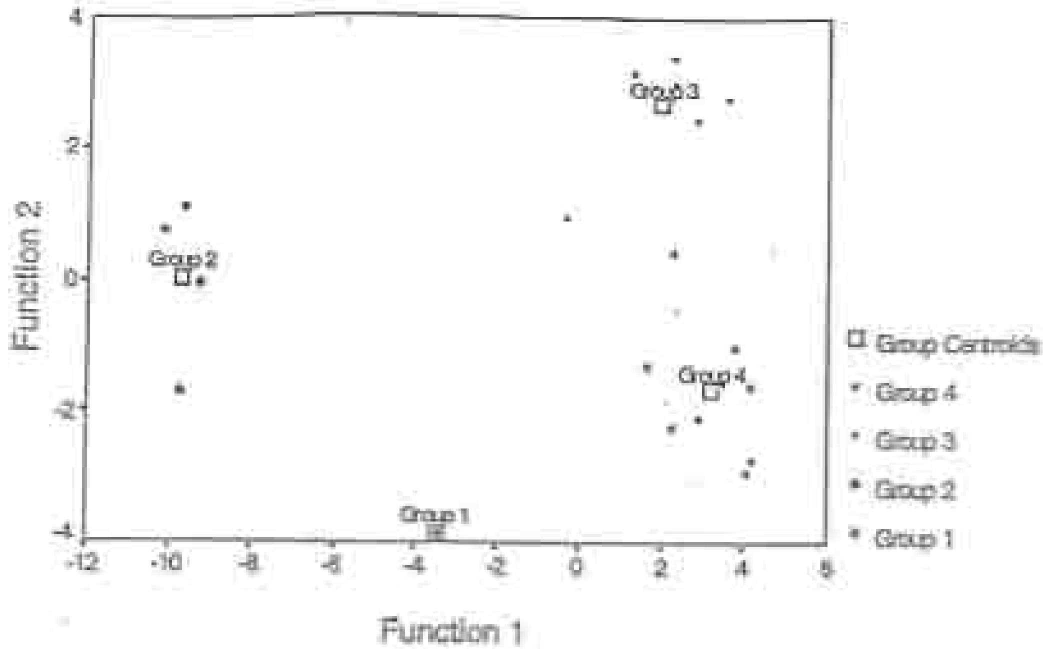
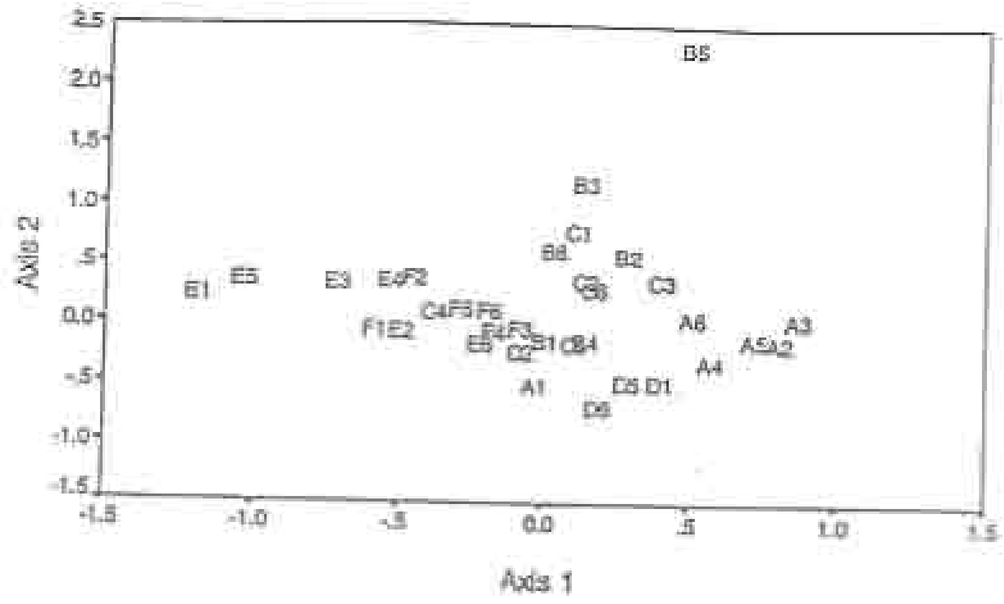


Figure 4. A biplot between discriminant function 1 and 2, the legend groups corresponding to the TWINSPAN groups in Figure 3.

(Functions 1 and 2 are significant when tested by Wilks' lambda, $p<0.001$, $p<0.05$, respectively)

(a)



(b)

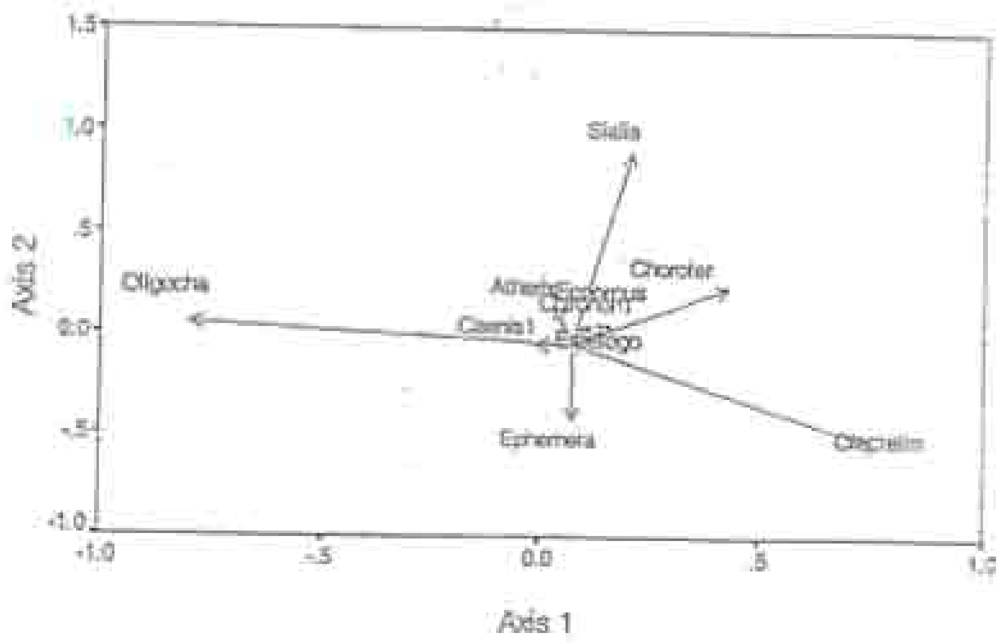


Figure 5 Biplots between axes 1 and 2 of (a) samples ordination by HMDS (stress 0.1623) and (b) significant species vectors which strongly correlate to ordination space.

(Figure 5a: letters represent site codes, numbers stand for sampling months, 1=October 1995, 2=December 1995, 3=February 1996, 4=April 1996, 5=June 1996 and 6=August 1996.

Figure 5b: Atherix=*Atherix* sp., Caenis1=*Caenis* sp1, Chironom=Chironomidae, Choroter=*Chorotarpes* sp., Cheptelm=*Cheptelmis* sp., Ecnomus=*Ecnomus* sp., Erpetogom=*Erpetogomphus* sp., Ephemera=*Ephemera* sp., Oligocha=Oligochaeta and Sialis=*Sialis* sp.

Distribution of Caddisfly Larvae in relation to Environmental Changes in the Pong Catchment of Northeast Thailand

Abstract

Caddisfly larvae were quantitatively sampled bimonthly from twenty-one stations across the Pong catchment for two years (1996-1997). Caddis taxon richness was highest in the upper part of the catchment but markedly decreased downstream. The distribution pattern of caddisflies in the Pong highlighted some species-landscape phenomena. Certain taxa were limited to upstream waters, notably *Anisocentropus*, *Goera*, *Leptocerus*, *Pseudoneureclipsis*, *Oxyethira* and *Tinodes*. The most widespread caddisflies were *Polycentropus* and *Dipseudopsis*. The density of caddis larvae was closely correlated with water temperature, water velocity, altitude and alkalinity. The overall results suggested they could be another indicative of water pollution impacts in the catchment caused by humans and which became especially apparent during the long dry season.

Introduction

Knowledge about stream and river ecosystems in Southeast Asia is still in its infancy and, in particular, there has been few publications addressing spatiotemporal variation of the benthic fauna in riverbeds (Dudgeon 1995). Distribution patterns of aquatic macroinvertebrates through time and space can contribute information useful in assessing water resource degradation (Resh *et al.* 1995), but have been rarely applied in Asia, particularly Thailand, due to the poor state of knowledge (Sangpradub *et al.* 1997).

Caddisflies are a key aquatic group in Asia and an important costituent of the EPT (Ephemeroptera, Plecoptera and Trichoptera) metric, known to be related to changes in water physicochemistry (Lenat and Barbour 1994, Resh, Norris and Barbour 1995), at least in the temperate zone. In tropical Asian inland waters, caddisfly distribution patterns and their association with environmental factors require much more research (Dudgeon *et al.* 1994) before their utility can be demonstrated.

The aims of this study were threefold. Firstly, to investigate the spatiotemporal distribution of the caddis larvae assemblage in the Pong catchment rivers of northeast Thailand. Secondly, to analyze and quantify changes in the major environmental variables, mainly water physicochemical parameters, in the Pong. Lastly, to explore correlations between caddis larvae abundance in terms of density and taxon richness, and environmental variables.

Physical geography of the Pong catchment

The Pong catchment is located on the northeastern plateau of Thailand (Fig.1) between 16°00'-17°15' N and 101°15'-103°15' E. It has an area of 15,190 km^2 and ranges in altitude from 88 to 300 metres above sealevel. The Pong system consists of two main tributaries, the Pong and the Cheon. These two rivers receive waters flowing mostly from headwater streams located in the Phetchaboon mountain range. The main channel of the Pong is regulated by three large dams which supply water for cultivated lands, industrial zones and communities within the catchment.

The climate within the catchment is characterized by a marked contrast in seasonal rainfall, with the wet season (May-October) having a mean monthly rainfall of 266.9 mm, while the dry season (November-April) has a mean monthly rainfall of 2.7 mm.

Sampling regime

We established twenty-one sampling sites (P01-P21) which represented a range of less disturbed and impacted areas (Fig. 2). Caddis larvae were quantitatively sampled bimonthly over two years (1996-1997). Six samples (replicates) were randomly takenfrom the streambed at each site. Sampling benthic fauna at upstream reaches used a Surber sampler (0.30 m x 0.30 m with 500 μm mesh aperture), while sampling in deeper waters downstream necessitated use of an Ekman Grab.

Major water quality variables were sampled at the same time as the caddis sampling. These were water velocity, channel depth and width, discharge, temperature, pH, alkalinity, electrical conductivity, total dissolved solids, total suspended solids (TSS), turbidity, phosphate (PO_4), nitrate (NO_3), dissolved oxygen (DO), biochemical oxygen demand (BOD-5day), chloride (Cl), and sulfate (SO_4). The methods used to sample and analyze all water quality variables followed the standard methods described in GEMS/WATER (UNEP, WHO, UNESCO and WMO (1992) and APHA (1992).

Benthic samples were sorted by hand on white trays using forceps. All caddis specimens were identified using available keys to the lowest possible taxonomic level, mostly to genus. The identified specimens were counted and preserved in 70% ethyl alcohol. All of the specimens are archived in the Department of Biology, Khon Kaen University, Thailand.

Data analysis

Multivariate methods were used to simplify and visualise the relationships between sampling sites based on their caddis fauna.

We used caddis larval density as the raw data input for multivariate analyses, however log transformation (log x+1) was applied to the raw data, if necessary, to improve normality. The PATN software package for detecting pattern in ecological data (Belbin 1995) was used for most of the analysis.

Ordination of the sampling sites employed Semi-Strong Hybrid Multi Dimensional Scaling (HMDS) via the Bray-Curtis association measure (Marchant 1990, Clarke

1993). All sampling sites were then classified using the Unweighted Pair Group arithMetic Averaging (UPGMA) method (Sneath and Sokal 1973, Gauch 1982) to identify the degree of similarity/dissimilarity between sampling sites which were arranged into proximal groups. These groups were further clarified via the GDEF option in PATN. The ordination and classification were both applied for faunal analysis so as to confirm or cross check the result of each method.

Significant correlations between UPGMA grouped sites and environmental variables were examined using Discriminant Function Analysis (DFA) (Green 1993, Norris and Georges 1993) via the Discriminant option in SPSS (1994).

The Principal Axis Correlation (PCC option in PATN) and Monte Carlo Randomisation with n=100 (MCAO option in PATN) was used to test which caddisfly genera were significantly correlated with the ordination space. A significance level of 95% was applied throughout this unless otherwise specified

Results

Water quality variation within the Pong floodplain

Bimonthly examination of water physicochemistry in the Pong showed that some variables varied significantly during the year, most notably discharge, flow rate, TSS, turbidity, BOD and DO.

The Pong waters had different mean discharge, flow rate, TSS and turbidity between catchment zones. The sites located in the upper zone (P01-P08) had the lowest mean discharge (20.4 cu.m/sec) while the stations in the middle (P09-P13) and lowermost part of the catchment (P14-P21) had discharges which increased substantially (101.8 and 74.6 cu.m/sec, respectively). As expected, the mean discharges also varied markedly between seasons. In dry season, the mean discharge was minimal in the Pong main stream (24.6 cu.m/sec), but increased threefold during the wet season (97.0 cu.m/sec).

The importance of siltation on the Pong waters was apparent in the TSS and turbidity levels. Generally, the mean TSS of the upper sites was higher than the middle and lower stations (138.8, 12.9 and 42.3 mg/L, respectively). Similarly, mean turbidity was higher in the upper sites than in the middle and lower sites (95.9, 10.6 and 61.1 NTU, respectively). The Pong waters were very turbid during the wet season (79.7 NTU) but relatively clear in dry season (43.5 NTU).

In general, the upstream waters were less affected by organic pollution than the downstream sites. There were remarkable impacts from organic pollution in some stretches, particularly where the river flows through the city. The mean BOD level at site 16, for example, was very high at 15.2 mg/L (Fig.3). The mean BOD of the Pong waters varied significantly between seasons, and was relatively higher (4.3 mg/L) in the dry season than in the rainy months (2.6 mg/L).

Dissolved oxygen in the Pong waters differed spatially, with upstream sites having higher mean DO levels than sites located in the middle and lower catchment (7.0, 6.6 and 5.2 mg/L, respectively).

Spatiotemporal variation of caddis larvae

Caddis larvae abundance

Caddis taxon richness peaked in February when 17 genera were detected. The most diverse caddis larvae present in this month belonged to the families Hydropsychidae, Hydroptilidae and Leptoceridae. The net-spinning hydropsychid genera included *Cheumatopsyche*, *Hydropsyche*, *Leptonema* and *Macrostemum*. The fragile case-caddis hydroptilid larvae were only abundant in upstream waters and included the genera *Hydroptila*, *Orthrotrichia* and *Oxyethira*. Leptoceridae larvae were rare in the Pong catchment generally and *Leptocerus* and *Triaenodes* were both found only in February in upstream waters. Psychomyiidae was another family seldom found in this catchment and only a single individual of *Tinodes* was discovered in site P01 in February 1996.

The most widespread caddis larvae in the Pong were *Ecnomus*, *Polycentropus* and *Dipseudopsis*. These were frequently found in rather deeper waters, but were absent in very organically polluted waters, such as at sites P15 and P16.

Caddis larvae density

The mean caddis larval density peaked in December (150.7 larvae/m^2). The taxa found in highest densities during this month were *Cheumatopsyche* (2707.4 larvae/m^2) and *Macrostemum* (209.9 larvae/m^2). The former taxon was restricted to upstream sites (P01 to P03), while the latter was rather widespread. *Macrostemum*, in particular, increased in numbers markedly after the catchment waters recovered from severe flooding.

Multivariate analysis

Multidimensional scaling adequately separated the sampling sites in the ordination space (Fig.4). The less organically polluted sites which supported a more diverse caddisfly fauna were clustered separately from the impacted sites. The less impacted sites can be subdivided into three minor groups; P01, P02 to P04, and P06 and P08. Caddis taxon richness was highest in site P01 (12 genera), followed by sites P02 to P04 (9 genera) and sites P06&P08 (8 genera). The remaining sites with relatively impacted waters had much lower richness.

All caddis taxa which correlated significantly to the arrangement of the sites in the ordination space are shown in Fig.4. Dominant caddis larvae limited to upstream waters, including *Anisocentropus*, *Goera*, *Leptocerus*, *Neureclipsis*, *Oxyethira* and *Tinodes* appear in the lower part of Fig.4. The free-living caddis larva *Polycentropus* was mostly indicative of lowland sites (top left in Fig.4).

Significant correlations between sites grouped by UPGMA classification (based on caddis larval density data) and environmental variables are shown in Table 1. The most influential environmental variables which significantly related to the UPGMA groups were water temperature, water velocity, altitude and alkalinity.

Conclusion and discussion

Seasonal flooding, a cyclical environmental event, was the key factor influencing the occurrence of caddisfly larvae in the flowing waters of the Pong catchment. During mid-rainy period very limited numbers of caddis larvae were recovered from the benthic samples. Of these, the most abundant taxa were *Polycentropus* and *Dipseudopsis*, suggesting that these two genera are tolerant to very high flow conditions. During the wet season, the density of caddis larvae did not differ significantly between stations in the upper and lower catchment zones. Elsewhere in Asia, assemblages of caddis larvae are also known to be much affected by heavy tropical spates particularly during the monsoonal months (Dudgeon 1995).

During the dry season, all the sampling sites were less impacted by natural events, but were much affected by human disturbance. Both taxon richness and density of larvae varied substantially between sites, according to the prevailing environmental impacts. The least organically polluted sites had the highest caddis taxon richness and larval density. The relatively polluted sites, in contrast, had low taxon richness and minimal larval density. The effect of organic pollution upon caddis larval abundance in the temperate zone is well documented (Hellawell 1986, Lenat 1993, Barbour *et al.* 1995, Wright *et al.* 1995). However, similar evidence is so far very scarce from tropical regions. This study contributes a new data set from this region which supports the possibility of using caddis larvae for assessing water pollution. The results further suggest that these measures would be most effective if used to assess organic pollution in the drier months.

The ordination and classification results showed the caddis communities at the sampling sites also relate to percent forest cover and riparian vegetation. Forest cover and riparian strips could both contribute to the richness of caddis taxa, and also affect water quality. The upstream sites with the most forest cover and thickest buffer supported the more diverse caddis taxa. Barling and Moore (1994) also noted a significant influence of forest and buffer strips upon benthic fauna assemblages and water quality. Within the Pong catchment, those sites with more forest cover, low water temperature, high DO, but low BOD, were the most prefered habitats for caddisflies.

Indicator taxa can be deduced from the correlation analysis. At lowland sites in both shallow and deeper water, the dominant caddis larva was the free-living form *Polycentropus*, which was also found to reappear soon after the stream begins to recover from severe spates and organic pollution. In contrast, the indicator taxa in upstream waters were more diverse, including many hydroptilid and hydropsychid taxa.

Some caddisflies responded to an improvement in water quality following severe pollution by urban sewage. Downstream of the city at site P18 for example, as the DO level increased and BOD reduced, the first caddis larvae to reappear were the free-living forms *Ecnomus*, *Dipseudopsis*, and *Polycentropus*, and the net-spinning *Macrostemum*. Also, the caddis taxon richness spatially fluctuated in concert with BOD and DO levels (Fig.3). Thus, it was clear that these two water quality variables had a marked effect on the distribution of caddis larvae in the Pong catchment.

As this study conducted sampling mostly in cleared parts of the catchment, further investigations in pristine forest streams in the Pong region are still needed. Detailed taxonomic studies of caddisflies, especially larvae and their ecology, are still essential needs in Thailand. Even this study showed levels of organic pollution was associated with differences in caddis larvae abundance, but more long-term studies should be encouraged to establish the causes.

Acknowledgments

We would like to thank the Thailand Research Fund (TRF) and Khon Kaen University which kindly funded this research. We thank many friends and colleagues from the Department of Biology, Khon Kaen University, Thailand, for their encouragement and support during the study. We are also very grateful to the staff of the Environmental Health Center Region 6, Department of Health, Thailand, for help in collecting specimens in the field.

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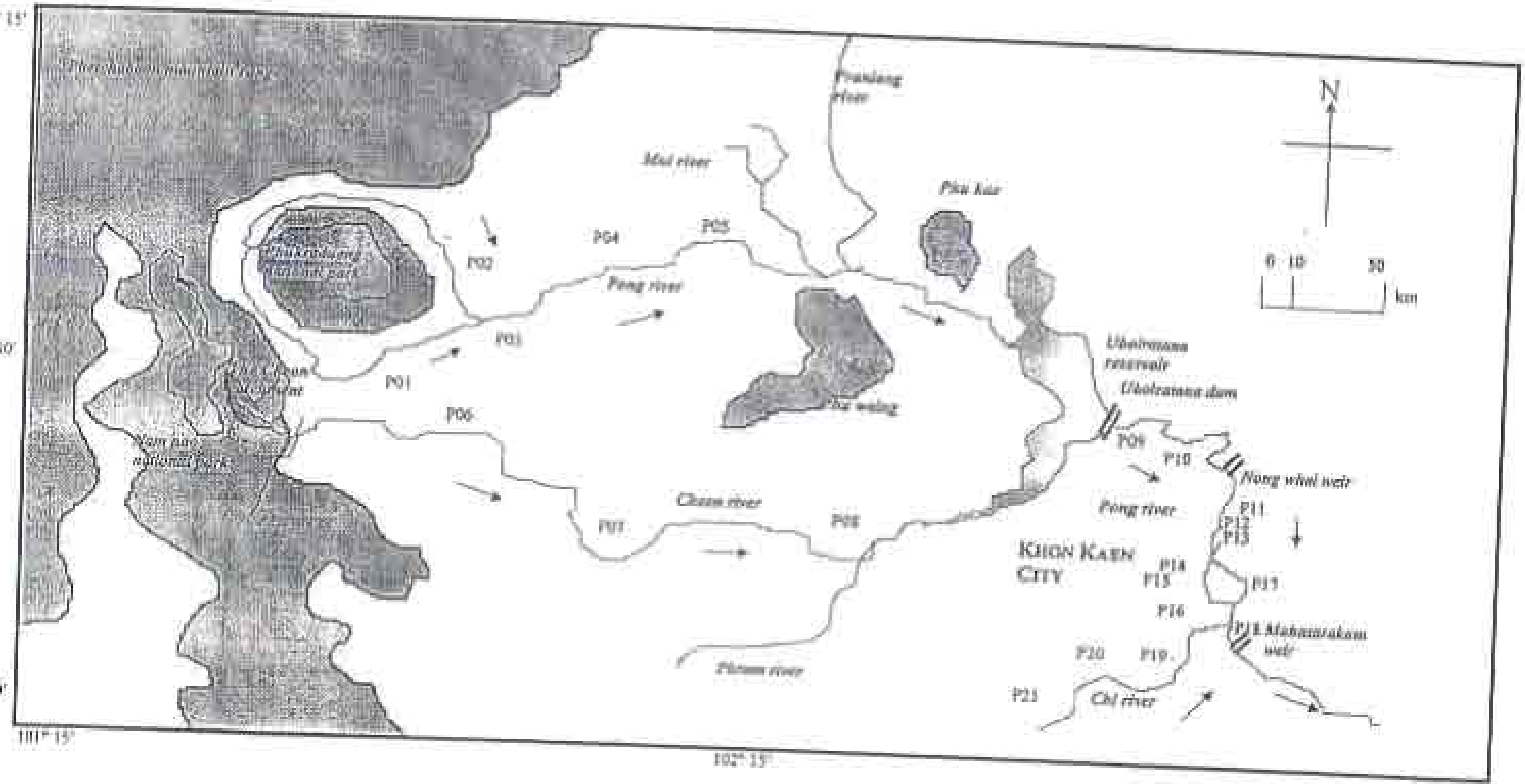


Fig. 1 Sampling sites of the Pong catchment northeast Thailand (Phu means mountain, P01-P08=Upper zone; P09-P21=Lower zone)

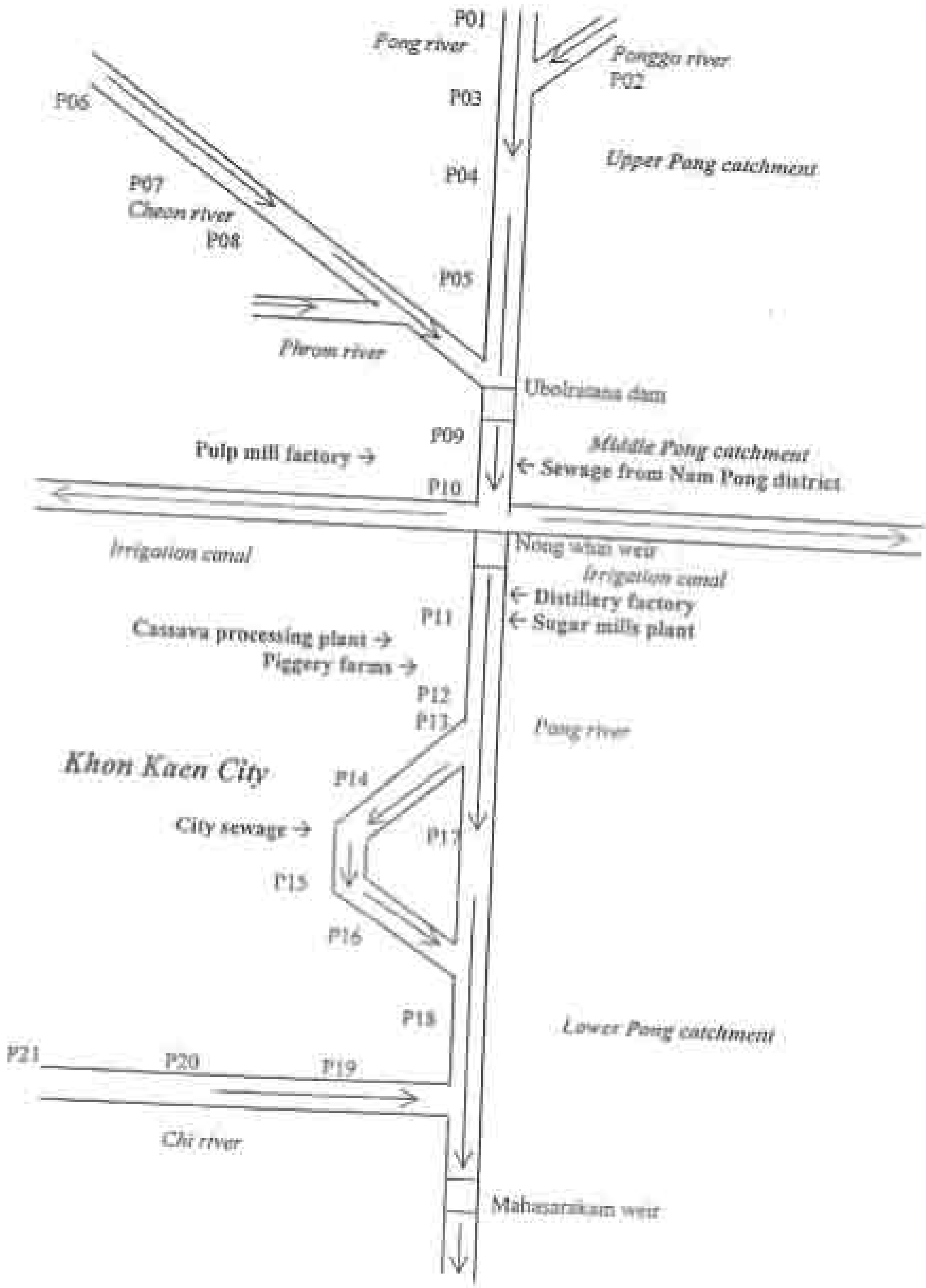


Fig. 2 Diagrammatic summary of the sampling sites and major point-source discharges in the Pong catchment

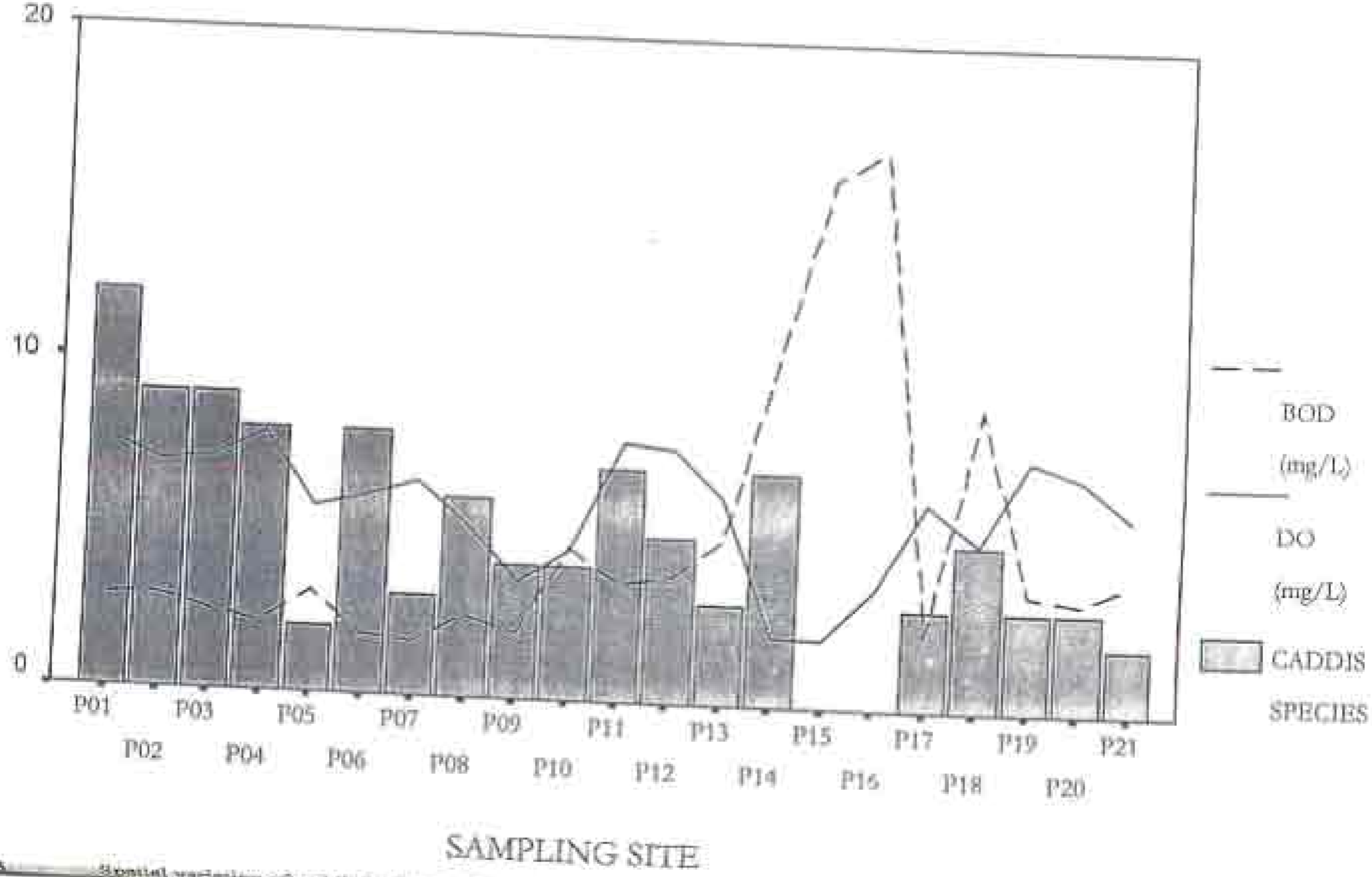


Fig. 3 Spatial variation of caddisfly taxon richness in relation to BOD and DO levels

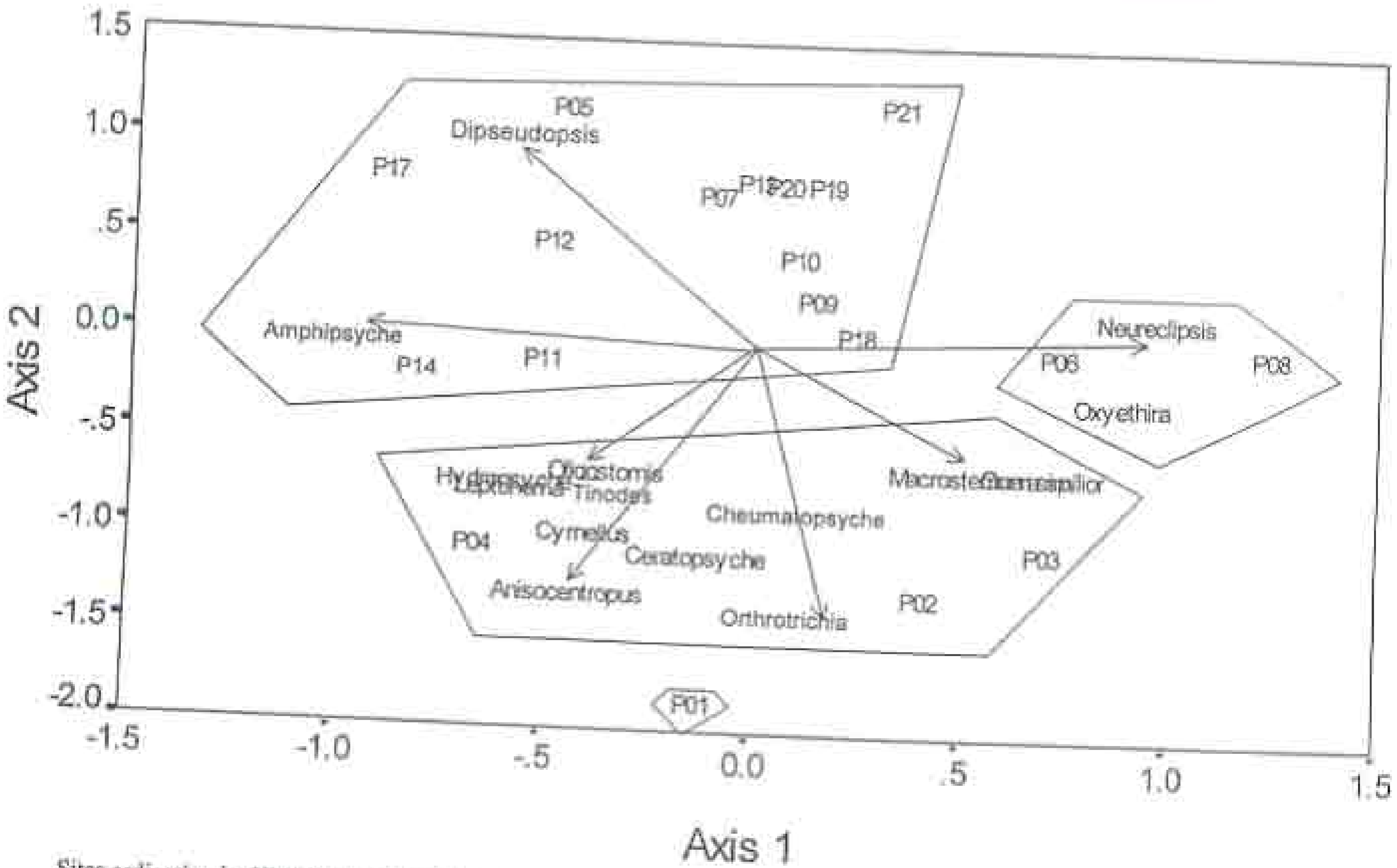


Fig. 4 Sites ordination by HMDS (stress 0.1650) using caddisfly density data, some taxon vectors significantly correlated to the ordination space were shown, and polygons indicated sites grouping by UPMGA

ดัชนีชีวภาพสำหรับการจัดจำแนกคุณภาพน้ำทางชีววิทยา ด้วยสัตว์ไม่มีกระดูกสันหลังหน้าดินในลุ่มน้ำพอง

Biotic Index for Biological Classification of Water Quality Using Benthic Macroinvertebrate in the Pong Catchment

บทคัดย่อ

ดัชนีชีวภาพสำหรับจัดจำแนกคุณภาพน้ำทางชีวภาพในลุ่มน้ำพองได้ถูกกำหนดขึ้นจากการให้คะแนนแก่สัตว์ตามความทนทานต่อมลภาวะสารอินทรีย์ และการพิจารณาสัดส่วนของกลุ่มสัตว์ในโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดินตามการกระจายในบริเวณที่มีการปนเปื้อนของสารอินทรีย์ระดับที่แตกต่างกันในแม่น้ำพอง

คำนำ

ผลการเปรียบเทียบวิธีการเก็บตัวอย่างสัตว์ไม่มีกระดูกสันหลังหน้าดินด้วยวิธีเชิงปริมาณ (quantitative) และวิธีเชิงคุณภาพ (qualitative) และการทดสอบระบบค่าคะแนนระบบต่างๆที่นิยมใช้อยู่ในประเทศต่างๆ พบว่าเฉพาะวิธีการเก็บตัวอย่างเชิงปริมาณเท่านั้นที่ให้ผลลัพธ์น่าเชื่อถือสำหรับการทดสอบระบบค่าคะแนนนั้นผลการศึกษาแสดงให้เห็นว่าค่าคะแนนระบบ BMWP (Biological Monitoring Working Party) ของสหราชอาณาจักรเท่านั้นที่มีแนวโน้มว่าอาจสามารถนำมาใช้กับข้อมูลของสัตว์ในลุ่มน้ำพองได้ (Sangpradub *et al.* 1997) และจากผลการศึกษาในปีแรก (พ.ศ. 2538-2539) พบว่าโครงสร้างชุมชนของสัตว์ไม่มีกระดูกสันหลังหน้าดินมีความสัมพันธ์กับการเปลี่ยนแปลงคุณภาพสิ่งแวดล้อมในลุ่มน้ำพอง (Sangpradub *et al.* 1996) การศึกษาครั้งนี้มีวัตถุประสงค์ที่จะพัฒนาดัชนีชีวภาพสำหรับจัดจำแนกคุณภาพน้ำในลุ่มน้ำพองโดยวิธี (1) ใช้ระบบค่าคะแนน และ (2) ดูโครงสร้างชุมชนสัตว์

วิธีการศึกษา

1. ระบบค่าคะแนน

จากค่าคะแนน BMWP (Armitage *et al.*, 1983) ทดสอบค่าคะแนนระบบ BMWP/ASPT กับข้อมูลสัตว์ในลำน้ำพองเดือนกุมภาพันธ์ 2539 ที่เก็บด้วยวิธีเชิงปริมาณเปรียบเทียบกับการจัดกลุ่มสถานีด้วยข้อมูลคุณภาพน้ำซึ่งสามารถจัดแบ่งได้ 3 กลุ่มสถานี และจำนวนวงศ์ของสัตว์ (แสด

richness) ในเดือนเดียวกัน (*Sangpradub et al., 1996*) เพื่อ (1) ดูความสอดคล้องของผลการวิเคราะห์ข้อมูลด้วยวิธีการที่แตกต่างกัน (2) ดูความเหมาะสมของค่าคะแนนของระบบ BMWP/ASPT กับสัตว์แต่ละวงศ์ในลำน้ำพอง และพิจารณาระดับดัชนีของค่าคะแนนนี้เพื่อนำมาใช้ในการจัดจำแนกคุณภาพน้ำทางชีววิทยา

2. การพิจารณาโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดิน

จากผลการศึกษาที่พบว่าโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดินเปลี่ยนแปลงเมื่อมีการเปลี่ยนแปลงคุณภาพสิ่งแวดล้อมของแหล่งน้ำ (*Sangpradub et al.,* 1996) ได้แบ่งกลุ่มสัตว์ไม่มีกระดูกสันหลังหน้าดินออกเป็น 5 กลุ่มใหญ่ ตามผลการศึกษาโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดิน คือ

กลุ่มที่1 ประกอบด้วยสัตว์ที่พบมากในบริเวณลำธารต้นน้ำที่ไม่ถูกรบกวน ได้แก่ ตัวอ่อนแมลงสโตนฟลาย (Plecoptera) ตัวอ่อนแมลงชีปะขาววงศ์ Heptageniidae และ Tricorythidae ตัวอ่อนของแมลงหนอนปลอกน้ำที่มีปลอก (cased caddis) ทุกวงศ์ ยกเว้นวงศ์ Leptoceridae ตัวอ่อนแมลงช้างปีกใสวงศ์ Corydalidae

กลุ่มที่2 ประกอบด้วยสัตว์ที่พบมากในบริเวณลำธารต้นน้ำที่ถูกรบกวน ได้แก่ ตัวอ่อนของแมลงชีปะขาววงศ์ Leptophlebiidae ตัวอ่อนของแมลงหนอนปลอกน้ำที่ไม่มีปลอก (caseless caddis) ทุกวงศ์ ยกเว้นวงศ์ Ecnomidae และวงศ์ Dipseudopsidae และตัวอ่อนแมลงช้างปีกใสวงศ์ Sialidae ด้วงวงศ์ Gyrinidae เหรียญน้ำ (Psephenidae) ตัวอ่อนแมลงปอในวงศ์ Cordulegastridae Gomphidae และ Micromiidae ตัวอ่อนริ้นดำ (Simuliidae) และตัวอ่อนแมลงวันแมงมุม (Tipulidae)

กลุ่มที่3 ประกอบด้วยสัตว์ที่พบมากในบริเวณที่มีการปนเปื้อนของสารอินทรีย์ ได้แก่ตัวอ่อนของแมลงชีปะขาววงศ์ Baetidae ตัวอ่อนของแมลงหนอนปลอกน้ำวงศ์ Leptoceridae และ Hydropsychidae ด้วงน้ำไหล (Elmidae) ตัวอ่อนแมลงปอวงศ์ Libellulidae กุ้ง (Palaemonidae) และหอยขม (Viviparidae)

กลุ่มที่4 ประกอบด้วยสัตว์ที่พบมากในบริเวณที่มีการปนเปื้อนของสารอินทรีย์ค่อนข้างมาก ได้แก่ ตัวอ่อนแมลงชีปะขาววงศ์ Caenidae ตัวอ่อนของแมลงหนอนปลอกน้ำวงศ์ Ecnomidae และ Dipseudopsidae

กลุ่มที่5 ประกอบด้วยสัตว์ที่พบมากในบริเวณที่มีการปนเปื้อนของสารอินทรีย์สูงมากและ/หรือมีค่าการนำไฟฟ้าสูงอันเนื่องมาจากการละลายของหินเกลือในธรรมชาติ ได้แก่ หนอนแดง (Chironomidae) ตัวอ่อนริ้นน้ำกร่อย (Chaoboridae) ตัวอ่อนริ้นเข็ม (Ceratopogonidae) และไส้เดือนน้ำจืด (Oligochaeta)

สัดส่วนของสัตว์แต่ละกลุ่มในชุมชนหนึ่งๆ สามารถจัดจำแนกคุณภาพแหล่งน้ำได้ ดังแสดงในตารางที่ 3

ผลการศึกษา

1. ระบบค่าคะแนน

เมื่อนำค่าคะแนนระบบ BMWP/ASPT มาทดสอบกับข้อมูลสัตว์ในลำน้ำพองเดือนกุมภาพันธ์ 2539 เปรียบเทียบกับการจัดจำแนกกลุ่มสถานีด้วยข้อมูลคุณภาพน้ำ ซึ่งสามารถจัดแบ่งได้ 3 กลุ่มสถานี และจำนวนวงศ์ของสัตว์ (taxa richness) ในเดือนเดียวกัน เพื่อดูความสอดคล้องของผลการวิเคราะห์ ด้วยวิธีการที่แตกต่างกัน (ตารางที่ 1) พบว่าการจัดจำแนกกลุ่มสถานีด้วยข้อมูลคุณภาพน้ำส่วนมากสอดคล้องกับการจัดจำแนกสถานีด้วย BMWP/ASPT เมื่อพิจารณาการจัดจำแนกสถานีด้วยระบบ BMWP/ASPT เปรียบเทียบกับจำนวนวงศ์ของสัตว์ (taxa richness) ซึ่งเป็นวิธีหนึ่งที่นิยมใช้ในการเปรียบเทียบความหลากหลายของสิ่งมีชีวิต โดยจัดจำแนกจำนวนวงศ์ของสัตว์เป็น 3 กลุ่ม คือ กลุ่มที่1 มีจำนวน 1-5 วงศ์ กลุ่มที่ 2 มีจำนวน 6-10 วงศ์ และกลุ่มที่ 3 มีจำนวน 11-20 วงศ์ พบว่าการจัดจำแนกสถานีไม่สอดคล้องนักคือ มี 5 สถานีที่ไม่เข้าตามกลุ่ม แสดงว่าค่าคะแนนของสัตว์บางวงศ์ที่ปรากฏใน BMWP/ASPT ไม่เหมาะกับสัตว์ที่พบในลุ่มน้ำพอง คือสัตว์บางวงศ์มีค่าคะแนนสูงเกินไปและสัตว์บางวงศ์มีค่าคะแนนต่ำเกินไปเมื่อเปรียบเทียบกับการกระจายตัวของสัตว์ในสถานีต่างๆ

ดังนั้นจึงได้ทำการกำหนดค่าคะแนนใหม่แก่สัตว์ไม่มีกระดูกสันหลังหน้าดิน โดยนำข้อมูลสัตว์ไม่มีกระดูกสันหลังหน้าดินที่เก็บตัวอย่างด้วยวิธีเชิงปริมาณระหว่างปีพ.ศ. 2538-2539 ได้นำมากำหนดค่าคะแนนตั้งแต่ 1-10 ให้แก่สัตว์แต่ละวงศ์ตามการกระจายในแต่ละสถานีของลำน้ำพอง โดยมีหลักเกณฑ์ว่า สัตว์ที่มีการกระจายได้ในทุกสถานีแสดงว่าเป็นสัตว์ที่สามารถทนได้ในน้ำทุกคุณภาพ สัตว์เหล่านี้จะได้ค่าคะแนนต่ำ เช่น ไส้เดือนน้ำจืด (Oligochaeta) และหนอนแดง (Chironomidae) มีการกระจายอยู่ทุกสถานี ควรได้คะแนนต่ำสุด เมื่อพิจารณาร่วมกับคุณภาพทางเคมีฟิสิกส์ของน้ำพบว่าในน้ำที่มีคุณภาพเลวกว่าจะมีไส้เดือนน้ำจืดจำนวนมากกว่าหนอนแดง แสดงว่าไส้เดือนน้ำจืดมีความทนทานมากกว่าหนอนแดง จึงกำหนดค่าคะแนน 1 และ 2 ให้แก่ไส้เดือนน้ำจืดและหนอนแดงตามลำดับ ซึ่งหมายความว่าไส้เดือนน้ำจืดเป็นสัตว์ที่มีความทนทานมากที่สุดรองลงมาคือหนอนแดง ใช้หลักเกณฑ์เดียวกันนี้ในการพิจารณาให้ค่าคะแนนสัตว์วงศ์อื่นๆ จนครบ

ตารางที่ 1 การเปรียบเทียบการจัดจำแนกกลุ่มสถานีตามคุณภาพน้ำ ระบบคะแนน BMWP/ASPT และจำนวนวงศ์

คุณภาพเคมีของน้ำ	สถานี	BMWP/ASPT	สถานี	จำนวนวงศ์	สถานี
กลุ่ม 3	เลิงเปือย	1.5	เลิงเปือย	1	บึงเนียม
กลุ่ม 3	บึงเนียม	2	บึงเนียม	3	หนองแสง
กลุ่ม 3	โคกกลาง	3.33	โคกกลาง	4	หนองหิน
กลุ่ม 2	หนองหิน	3.67	หนองแสง	4	เลิงเปือย
กลุ่ม 2	หนองแสง	4.33	หนองนาคำ	5	หนองนาคำ
กลุ่ม 2	หนองแต้	4.5	บึงแก	5	หนองจิก
กลุ่ม 2	พระคือ	4.5	หนองหิน	5	โคกกลาง
กลุ่ม 2	บึงแก	4.88	กุดน้ำใส	5	พระคือ
กลุ่ม 2	โนนขามแป	5	โนนขามแป	6	บึงแก
กลุ่ม 2	กุดน้ำใส	5	พระคือ	7	โนนขามแป
กลุ่ม 1	ห้วยสายหนัง	5.22	ท่าเดื่อ	8	หนองไผ่
กลุ่ม 1	หนองไผ่	5.28	ศรีฐาน	9	ท่าเดื่อ
กลุ่ม 1	หนองนาคำ	5.33	หนองไผ่	10	หนองแต้
กลุ่ม 1	หนองจิก	5.6	หนองจิก	10	กุดน้ำใส
กลุ่ม 1	ศรีฐาน	5.64	ห้วยสายหนัง	14	นาน้อย
กลุ่ม 1	พานเค้า	6	นาน้อย	14	ห้วยสายหนัง
กลุ่ม 1	นาน้อย	6.14	หนองแต้	19	พานเค้า
กลุ่ม 1	ท่าเดื่อ	6.56	พานเค้า	20	ศรีฐาน

ตารางที่ 2 เปรียบเทียบคะแนนของระบบ BMWP กับคะแนนน้ำพอง

	คะแนน BMWP	คะแนนน้ำพอง
ด้วง Coleoptera		
Chrysomelidae	5	-
Clambidae	5	-
Curculionidae	5	5
Dryopidae	5	-
Dytiscidae	5	5
Elmidae	5	6
Gyrinidae	5	7
Haliplidae	5	-
Helodidae	5	-
Hydrophilidae	5	5
Hygrobiidae	5	-
Noteridae	6	-
Psephenidae	-	7
ตัวอ่อนแมลงสองปีก Diptera		
Athericidae	-	7
Ceratopogonidae	-	3
Chaoboridae	-	3
Chironomidae	2	2
Simuliidae	5	8
Tipulidae	5	7
ตัวอ่อนแมลงชีปะขาว Ephemeroptera		
Baetidae	4	5
Caenidae	7	4
Ephemerellidae	10	-
Ephemeridae	10	6
Heptageniidae	10	10
Leptophlebiidae	10	10
Potamanthidae	10	5
Siphlonuridae	10	8

ตารางที่ 2 เปรียบเทียบคะแนนของระบบ BMWP กับคะแนนน้ำพอง (ต่อ)

	คะแนน BMWP	คะแนนน้ำพอง
ด้วง Coleoptera		
ตัวอ่อนมวน Hemiptera		
Belostomatidae	-	5
Corixidae	5	5
Gerridae	5	5
Hydrometridae	5	-
Mesoveliidae	5	-
Naucoridae	5	5
Nepidae	5	5
notonectidae	5	-
Pleidae	5	-
ตัวอ่อนแมลงช้างปีกใส Megaloptera		
Corydalidae	-	10
Sialidae	4	7
ตัวอ่อนผีเสื้อน้ำ Pyralidae		
Pyralidae	-	3
ตัวอ่อนแมลงปอ Odonata		
Aeshnidae	8	-
Astacidae	8	-
Coenagrionidae	6	2
Cordulegastridae	8	7
Corduliidae	8	-
Gomphidae	8	8
Lestidae	8	8
Libellulidae	-	6
Libellulidae	8	6
Macromiidae	-	8
Platycnemididae	6	6

ตารางที่ 2 เปรียบเทียบคะแนนของระบบ BMWP กับคะแนนน้ำพอง (ต่อ)

	คะแนน BMWP	คะแนนน้ำพอง
ตัวอ่อนสโตนฟลาย Plecoptera		
Capniidae	10	-
Chloroperlidae	10	-
Leuctridae	10	-
Nemouridae	7	10
Perlidae	10	10
Perlodidae	10	10
Planariidae	5	-
ตัวอ่อนแมลงหนอนปลอกน้ำ Trichoptera		
Brachycentridae	10	10
Calamoceratidae	-	9
Dipseudopsidae	-	4
Ecnomidae	-	4
Goeridae	10	10
Helicopsychidae	-	10
Hydropsychidae	5	6
Hydroptilidae	6	8
Lepidostomatidae	10	10
Leptoceridae	10	7
Limnephilidae	10	-
Molannidae	10	10
Odontoceridae	10	10
Philopotamidae	8	10
Polycentropodidae	7	4
Psychomyiidae	8	10
Sericostomatidae	10	-
Unionidae	6	-
กุ้ง Palaemonidae	-	6
ไส้เดือนน้ำจืด Oligochaeta	1	1
ปลิง Hirudinae	3.4	-

ตารางที่ 2 เปรียบเทียบคะแนนของระบบ BMWP กับคะแนนน้ำพอง (ต่อ)

	คะแนน BMWP	คะแนนน้ำพอง
ไอโซปอด Isopod		
Asellidae	3	-
Gammaridae	6	-
หอยฝาเดียว Gastropoda		
Ancylidae	6	-
Lymnaeidae	3	3
Physidae	3	-
Planorbidae	3	2
Viviparidae	6	5

สัตว์ที่มีความทนทานมากต่อการเปลี่ยนแปลงของสิ่งแวดล้อมจะมีคะแนนต่ำและสัตว์ที่มีความทนทานน้อยกว่าจะมีคะแนนที่สูงขึ้นตามลำดับ เรียกค่าคะแนนนี้ว่า ค่าคะแนนน้ำพอง ดังแสดงในตารางที่2 ลำดับขั้นต่อมาคือการหา **ดัชนีน้ำพอง (Pong Biotic Index)** ซึ่งเป็นการแปลงค่าคะแนนที่ได้ในแต่ละสถานีให้เป็นตัวเลขที่ง่ายแก่การเข้าใจ คือมีค่าอยู่ในช่วง 1-10 โดยการผลรวมของคะแนนที่ได้ในแต่ละสถานีด้วยผลรวมเฉพาะจำนวนวงศ์ที่มีคะแนน

ดัชนีน้ำพอง = ผลรวมของคะแนนหารด้วยจำนวนวงศ์เฉพาะที่มีค่าคะแนน

ทดสอบดัชนีน้ำพองกับสัตว์ในลำธารของอุทยานแห่งชาติภูกระดึง อุทยานแห่งชาติน้ำหนาว อุทยานแห่งชาติภูพาน และสถานีต่างๆในลุ่มน้ำพอง เพื่อดูความเป็นไปได้ของการใช้ดัชนีนี้ในการจัดจำแนกแหล่งน้ำอื่นๆนอกเหนือจากลำน้ำพอง ได้ผลดังตารางที่ 3

จากดัชนีน้ำพองสามารถแบ่งช่วงดัชนีเพื่อจัดจำแนกคุณภาพน้ำทางชีววิทยาได้ดังนี้คือ

ช่วงดัชนี	คุณภาพน้ำ
6.5-10	ดีมาก
5.6-6.4	ดี
4.6-5.5	ค่อนข้างดี
3.6-4.5	พอใช้
2.6-3.5	สกปรก
1.0-2.5	สกปรกมาก

ตารางที่ 3 ผลการทดสอบดัชนีน้ำพองที่สถานีต่างๆในลุ่มน้ำพอง เมื่อเดือนกุมภาพันธ์ 2539

สถานี	ดัชนีน้ำพอง
นาน้อย	5.79
ศรีฐาน	5.04
ผานกเค้า	6.17
ห้วยสายหนัง	5.2
หนองนาคำ	3.0
หนองจิก	4.33
ท่าเดื่อ	4.93
หนองไผ่	3.89
หนองแต้	4.45
โนนขามแป	3.14
กุดน้ำใสน้อย	4.3
บึงแก	4.63
หนองหิน	3.0
โคกกลาง	2.8
เชิงเปือย	2.0
บึงเนียม	2.0
พระคือ	3.2
หนองหิน	3.0

จากผลตารางที่ 3 ลำน้ำพองช่วงต้นตั้งแต่บริเวณบ้านนาน้อยจนถึงก่อนเข้าเขื่อนอุบลรัตน์ ส่วนมากถูกจัดจำแนกว่ามีคุณภาพน้ำค่อนข้างดีจนถึงดี ลำน้ำพองตั้งแต่ใต้เขื่อนอุบลรัตน์ไปจนถึงฝายหนองหวาย (หนองแต้-กุดน้ำใส) ถูกจัดจำแนกว่าสกปรกจนถึงมีคุณภาพพอใช้ และลำน้ำพองบริเวณหลังฝายหนองหวายจนถึงฝายมหาสารคาม (บึงแก-หนองหิน) ถูกจัดจำแนกว่ามีคุณภาพไม่ดี คือสกปรกถึงสกปรกมาก เมื่อทดสอบดัชนีน้ำพองกับสัตว์ที่พบในลำธารอุทยานแห่งชาติ 3 แห่งได้ผลดังตารางที่ 4 ลำธารของอุทยานแห่งชาติภูกระดึงมีดัชนีน้ำพองสูงกว่าของอุทยานแห่งชาติน้ำหนาว ลำธารในอุทยานแห่งชาติภูกระดึงถูกจัดจำแนกว่ามีคุณภาพดีมาก ลำธารของอุทยานแห่งชาติ

น้ำหนาวมีคุณภาพค่อนข้างดีจนถึงดี ในขณะที่คุณภาพแหล่งน้ำของลำธารในอุทยานแห่งชาติภูพานอยู่ในเกณฑ์ดี

ตารางที่ 4 ผลการทดสอบดัชนีน้ำพองในลำธารอุทยานแห่งชาติภูกระดึง อุทยานแห่งชาติน้ำหนาว และอุทยานแห่งชาติภูพาน เครื่องหมายวงเล็บแสดงเดือนที่เก็บตัวอย่างสัตว์

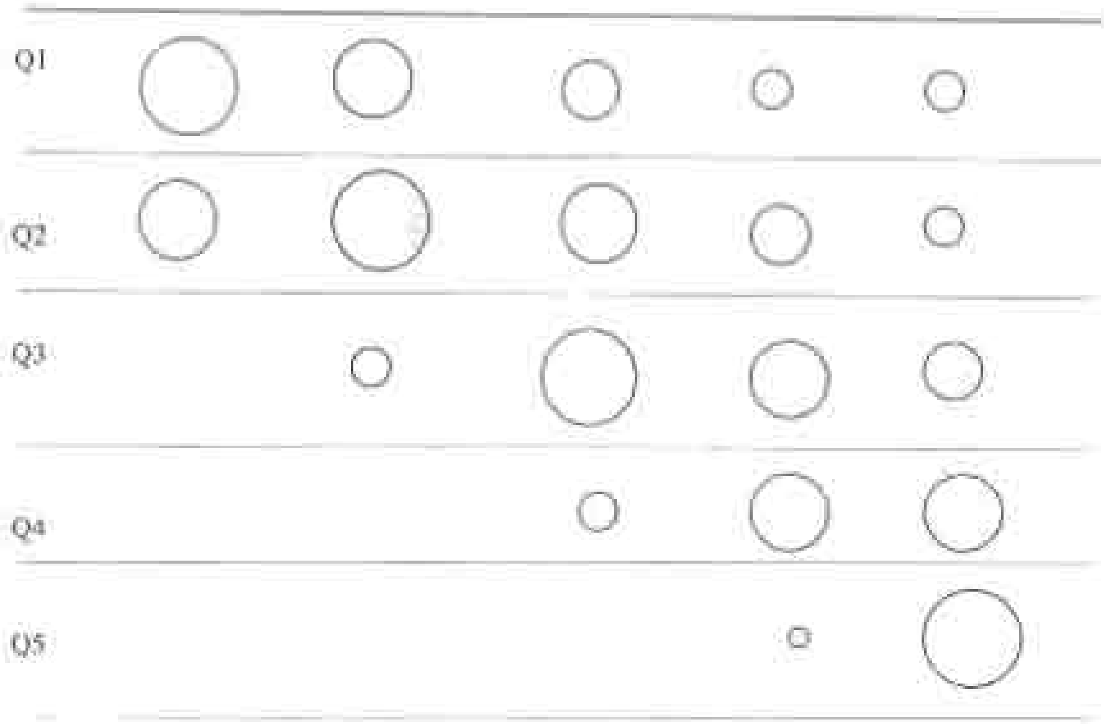
สถานี	ดัชนีน้ำพอง
อุทยานแห่งชาติภูกระดึง (กุมภาพันธ์ 2539)	
วังกวาง	8.3
ถ้ำใหญ่	7.9
เพิ่ญพบใหม่	7.2
โผนพบ	8
ผาน้ำผ่า	8.3
พอง	8.3
ถ้ำสอ	8.1
ขุนพอง	8.3
อุทยานแห่งชาติน้ำหนาว (พฤศจิกายน 2538)	
ห้วยหญ้าเครือ	5.29
ห้วยพรมแล้ง	5.83
อุทยานแห่งชาติภูพาน (กุมภาพันธ์-สิงหาคม 2540)	
ห้วยมะแงว	6.33
ห้วยแก้งมดแดง	6.0

2. การพิจารณาโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดิน

จากการแบ่งกลุ่มสัตว์ไม่มีกระดูกสันหลังหน้าดินตามข้อมูลการปรากฏในสถานีต่างๆของลุ่มน้ำพองออกเป็น 5 กลุ่ม โดยดูความสัมพันธ์กับปัจจัยคุณภาพทางเคมีฟิสิกส์ของน้ำ สัดส่วนของจำนวนสัตว์แต่ละกลุ่มจัดจำแนกคุณภาพของแหล่งน้ำได้เป็น 5 ระดับ เรียกว่า “ดัชนี Q” โดยเรียงลำดับ Q1 ไปจนถึง Q5 ตามการการจัดจำแนกว่าคุณภาพของน้ำทางชีววิทยาดีมากไปจนถึงไม่ดีมาก ดังแสดงในตารางที่ 5

ตารางที่ 5 แสดงส่วนประกอบสัดส่วนของสัตว์แต่ละกลุ่มกับดัชนี Q

ดัชนี Q กลุ่ม1	กลุ่ม2	กลุ่ม3	กลุ่ม4	กลุ่ม5
all Plecopteran	caseless caddis	Baetidae e	Caenidae	Chironomidae
all cased caddis	(ext Ecnomidae	Ephemeridae	Dipseudopsidae	Oligochaete
(ext Leptoceridae)	Hydropsychidae	Leptoceridae	Ecnomidae	
Heptageniidae	Dipseudopsidae	Hydropsychidae	Coenagrionidae	
Corydalidae	Leptophlebiidae	Elmidae	Chaoboridae	
	Sialidae	Libellulidae	Ceratopogonidae	
	Gyrinidae	Palaemonidae		
	Psephenidae	Polycentropodidae		
	Micronmiidae	Viviparidae		
	Cordulegastridae			
	Gomphidae			
	Micromidae			
	Simuliidae			
	Tipulidae			



เมื่อแทนจำนวนสัตว์ด้วยเครื่องหมายวงกลม

○ = น้อยมาก ○ = น้อย ○ = ปานกลาง ○ = ค่อนข้างมาก ○ = มาก

หมายเหตุ ext =ยกเว้น และสัตว์ในกลุ่ม 5 อาจมีจำนวนตัวมากหรือน้อยกว่าสัดส่วนที่ระบุไว้

จากดัชนีQ สามารถแบ่งช่วงดัชนีเพื่อจัดจำแนกคุณภาพน้ำทางชีววิทยาได้ดังนี้คือ

ดัชนี Q	คุณภาพน้ำ
Q1	ดีมาก
Q2	ดี
Q3	พอใช้
Q4	สกปรก
Q5	สกปรกมาก

เปรียบเทียบการจัดจำแนกคุณภาพน้ำในลำน้ำบางสายด้วยดัชนีน้ำพอง และดัชนี Q ได้ผลดังตารางที่ 6

ตารางที่ 6 การเปรียบเทียบการจัดจำแนกคุณภาพน้ำทางชีววิทยาในลุ่มน้ำพอง อุทยานแห่งชาติน้ำหนาวและอุทยานแห่งชาติภูกระดึง ด้วยดัชนีน้ำพองและดัชนี Q

สถานี	ดัชนีน้ำพอง	ดัชนี Q	ผลการจัดจำแนก(ดัชนีน้ำพอง, ดัชนี Q)
เลิงเปือย	2	Q5	สกปรกมาก
บึงเนียม	2	Q5	สกปรกมาก
โคกกลาง	2.8	Q4	สกปรก
หนองนาคำ	3	Q4	สกปรก
หนองหิน	3	Q4	สกปรก
หนองแสง	3	Q4	สกปรก
พระคือ	3.2	Q4	สกปรก
โนนขามแป	3.4	Q4	สกปรก
หนองไผ่	3.89	Q3	พอใช้
กุดน้ำใส	4.3	Q3	พอใช้
หนองจิก	4.33	Q3	พอใช้
หนองแต้	4.45	Q3	พอใช้
บึงแก	4.63	Q3	พอใช้
ท่าเดื่อ	4.93	Q2-Q3	ค่อนข้างดี, พอใช้-ดี
ศรีฐาน	5.04	Q2	ค่อนข้างดี, ดี
ห้วยสายหนัง	5.2	Q2	ค่อนข้างดี, ดี
นาน้อย	5.79	Q2	ดี
ผานกเค้า	6.17	Q2	ดี

ตารางที่ 6 การเปรียบเทียบการจัดจำแนกคุณภาพน้ำทางชีววิทยาในลุ่มน้ำพอง อุทยานแห่งชาติน้ำหนาวและอุทยานแห่งชาติภูกระดึง ด้วยดัชนีน้ำพองและดัชนี Q (ต่อ)

สถานี	ดัชนีน้ำพอง	ดัชนี Q	ผลการจัดจำแนก(ดัชนีน้ำพอง, ดัชนีQ)
ห้วยหญ้าเครือ	5.29	Q2	ค่อนข้างดี, ดี
ห้วยพรมแล้ง	5.83	Q2	ดี
วังกวาง	6.68	Q1	ดีมาก
ถ้ำใหญ่	6.74	Q1	ดีมาก
เพ็ญพบใหม่	6.76	Q1	ดีมาก
น้ำซอ	6.77	Q2-Q1	ดีมาก, ดี-ดีมาก
โนนพบ	7	Q1	ดีมาก
ผาน้ำผ่า	7	Q2-Q1	ดีมาก, ดี-ดีมาก
พะยอง	7.09	Q2-Q1	ดีมาก, ดี-ดีมาก
ขุนพอง	7.21	Q1	ดีมาก

การเปรียบเทียบดัชนีทั้งสองแบบได้ผลในการจัดจำแนกเหมือนกันเมื่อจำแนกว่าคุณภาพแหล่งน้ำนั้นพอใช้ถึงสกปรกมาก สำหรับในลุ่มน้ำพอง สถานีท่าเตื่อ ศรีฐาน และห้วยสายหนัง ดัชนีน้ำพองจัดจำแนกว่าคุณภาพน้ำทั้งสามแหล่งนี้ค่อนข้างดี ในขณะที่ดัชนี Q จัดจำแนกสถานีท่าเตื่อว่าคุณภาพพอใช้ถึงดี ส่วนสถานีศรีฐานและห้วยสายหนังถูกจัดจำแนกว่าน้ำนั้นคุณภาพดี ทั้งนี้เพราะดัชนีน้ำพองจัดจำแนกเป็น 6 ระดับ ส่วนดัชนี Q จัดจำแนกเป็น 5 ระดับคือไม่มีระดับค่อนข้างดี ผลที่ได้นี้แสดงว่าสถานีท่าเตื่อถูกจัดจำแนกไว้ในกลุ่มสถานีที่มีคุณภาพด้อยกว่าอีกสองสถานีเล็กน้อย ห้วยพรมแล้งถูกจัดจำแนกว่ามีคุณภาพดีกว่าห้วยหญ้าเครือ และคุณภาพน้ำของอุทยานแห่งชาติภูกระดึงถูกจำแนกอยู่ในเกณฑ์ดี-ดีมากและดีมาก จากผลการเปรียบเทียบการทดสอบการจัดจำแนกด้วยดัชนีทั้งสองนี้ดัชนี Q สามารถจัดจำแนกได้ละเอียดกว่าเล็กน้อย

จากการทดสอบความสัมพันธ์ระหว่างดัชนีน้ำพอง และดัชนี Q กับปัจจัยคุณภาพทางเคมีฟิสิกส์ของน้ำพบว่า เฉพาะค่า DO และ BOD เท่านั้นที่มีความสัมพันธ์อย่างมีนัยสำคัญกับดัชนีทั้งสองนี้ (ดัชนีน้ำพอง: ค่า DO r=0.729 P=0.001, ค่า BOD r=-0.492 P=0.038 และดัชนี Q: ค่า DO r=0.716 P=0.001, ค่า BOD r=-0.716 P=0.054) ซึ่งแสดงว่าดัชนีทั้งสองมีความไวต่อมลภาวะสารอินทรีย์ นอกจากนี้สหสัมพันธ์แสดงว่าดัชนีน้ำพองและดัชนี Q มีความสัมพันธ์กันมากถึงร้อยละ 96 (r=0.966, P=0.000)

วิจารณ์ผลการศึกษา

ค่าคะแนนระบบ BMWP/ASPT และค่าคะแนนน้ำพอง

การที่พบว่าค่าคะแนนของระบบ BMWP ไม่เหมาะสมกับข้อมูลของสัตว์ในลำน้ำพองนัก เนื่องจากสัตว์บางวงศ์ที่มีในระบบค่าคะแนนนั้นไม่พบในลำน้ำพองในขณะที่สัตว์บางวงศ์ที่พบว่ามีความสำคัญในลำน้ำพองไม่ปรากฏในระบบ BMWP และค่าคะแนนของสัตว์บางวงศ์สูงหรือต่ำเกินกว่าความเป็นจริงของสัตว์ที่พบกระจายอยู่ในลำน้ำพอง ทั้งนี้เพราะระบบ BMWP มีต้นกำเนิดจากสหราชอาณาจักรซึ่งมีความแตกต่างด้านภูมิประเทศและภูมิอากาศจากประเทศไทยซึ่งมีความแตกต่างด้านสิ่งมีชีวิตด้วย (Covich, 1988) ค่าคะแนนระบบ BMWP กับค่าคะแนนน้ำพองแตกต่างกันดังนี้คือ

กลุ่มด้วง (Coleoptera) ด้วงน้ำไหล (Elminthidae หรือ Elmidae) และด้วงสี่ตา (Gyrinidae) ซึ่งมีคะแนนใน ระบบ BMWP เท่ากับ 5 จากข้อมูลในลำน้ำพองได้ให้มีค่าเท่ากับ 6 และ 7 คะแนนตามลำดับ และได้เพิ่มวงศ์ Psephenidae ซึ่งไม่มีใน BMWP แต่พบมากในบริเวณน้ำพองตอนบนให้มีคะแนนเท่ากับ 7

กลุ่มแมลงสองปีก (Diptera) ใน BMWP มีแมลงสองปีก 3 ชนิดคือ หนอนแดง (Chironomidae) ตัวอ่อนริ้นดำ (Simuliidae) และตัวอ่อนแมลงวันแมงมุม (Tipulidae) มีคะแนน 2, 5 และ 5 ตามลำดับ ยกเว้นหนอนแดงแล้ว อีก 2 วงศ์ไม่สอดคล้องกับข้อมูลของไทยนัก คือ ในแหล่งน้ำภาคตะวันออกเฉียงเหนือตัวอ่อนริ้นดำมักพบบริเวณลำน้ำตอนบนที่สะอาดจนถึงค่อนข้างดี เช่นเดียวกับตัวอ่อนแมลงวันแมงมุม จึงได้ให้คะแนนเป็น 8 และ 7 ตามลำดับ และตัวอ่อนของแมลงสองปีกที่พบกระจายมากในแหล่งน้ำจืดของไทยคือ ตัวอ่อนริ้นน้ำกร่อย (Chaoboridae) และตัวอ่อนริ้นเข็ม (Ceratopogonidae) สัตว์ทั้งสองวงศ์นี้พบกระจายอยู่ในแหล่งน้ำทุกแห่งและตัวอ่อนริ้นน้ำกร่อยพบว่ามีความสัมพันธ์เชิงบวกกับค่าการนำไฟฟ้าของน้ำ สัตว์ทั้งสองวงศ์นี้ได้ค่าคะแนนจากการศึกษาครั้งนี้เท่ากับ 3 เนื่องจากแม้ว่าจะพบในทุกสถานีเช่นเดียวกับหนอนแดงแต่ในสถานีที่คุณภาพทางเคมีฟิสิกส์ของน้ำไม่ดีตัวอ่อนทั้งสองนี้มีจำนวนตัวน้อยกว่าหนอนแดง นอกจากนี้ตัวอ่อนของหนอนหางแฉก(Athericidae) ซึ่งไม่มีใน BMWP แต่มีมากในลำธารตอนบนของไทยได้ให้เท่ากับ 7 คะแนน

กลุ่มแมลงชีปะขาว (Ephemeroptera) ส่วนมากมีความสอดคล้องกับ BMWP ยกเว้น ตัวอ่อนแมลงชีปะขาวกระโปรง (Caenidae) ตัวอ่อนชีปะขาวเข็ม (Baetidae) และตัวอ่อนชีปะขาวหนวดสั้น (Siphlonuridae) ตัวอ่อนแมลงชีปะขาวกระโปรงและตัวอ่อนชีปะขาวเข็มมีการกระจายที่กว้างมากสามารถพบได้ในลำน้ำพองเกือบทุกสถานี ในบริเวณที่น้ำสกปรกตัวอ่อนของแมลงชีปะขาวทั้ง 2 วงศ์นี้จะเกาะอยู่ตามพืชน้ำ ในขณะที่ BMWP ให้คะแนนแก่ตัวอ่อนแมลงชีปะขาวกระโปรง เป็น 7 คะแนน ซึ่งแสดงว่าเป็นสัตว์ที่ทนทานค่อนข้างน้อย แต่ในลำน้ำพองพบว่าสามารถ

พบในน้ำที่มีคุณภาพทางเคมีฟิสิกส์ไม่ดีนักจึงให้คะแนนเป็น 3 และให้คะแนนตัวอ่อนแมลงชีปะขาวเข็มเป็น 4 เนื่องจากพบกระจายในน้ำที่มีคุณภาพทางเคมีฟิสิกส์ดีกว่า ชีปะขาววงศ์ Baetidae นี้มีรายงานว่าทั่วไปว่าทนทานต่อมลภาวะทางน้ำได้มาก (Hellawell 1986) ส่วนตัวอ่อนแมลงชีปะขาวหนวดสั้นซึ่งในสหราชอาณาจักรระบุว่าเป็นแมลงที่มีความทนทานน้อยมากจึงให้คะแนนเป็น 10 สำหรับในลำน้ำพองพบตัวอ่อนของชีปะขาววงศ์นี้ในบริเวณที่น้ำมีการปนเปื้อนจากอินทรีย์สารไม่มากนัก จึงให้เป็น 8 คะแนน

กลุ่มมวน (Hemiptera) ในระดับวงศ์สอดคล้องกับค่าคะแนนของ BMWP คือให้มีค่าเท่ากับ 5 คะแนน เพราะมวนแทบทุกวงศ์มีการกระจายกว้าง มวนเป็นกลุ่มสัตว์ที่อาศัยอยู่บริเวณผิวน้ำและบางชนิดอาศัยอยู่ในน้ำตามบริเวณริมน้ำใกล้ชายฝั่ง ดังนั้นจึงพบมากในการเก็บตัวอย่างด้วยสวิง (วิธีเชิงคุณภาพ) เช่นเดียวกับตัวอ่อนแมลงปอ แต่พบน้อยหรือไม่พบเลยในตะกอนที่ได้จากการเก็บตัวอย่างเชิงปริมาณในบริเวณที่น้ำลึก

กลุ่มแมลงปอ (Odonata) ตัวอ่อนแมลงปอ Coenagridae มีความทนทานค่อนข้างมาก กระจายอยู่แทบทุกแหล่งน้ำจึงให้คะแนนเป็น 2 ต่างจากในสหราชอาณาจักรที่พบว่าตัวอ่อนแมลงปอวงศ์นี้มีความทนทานปานกลาง ตัวอ่อนแมลงปอบ้าน (Libellulidae) และวงศ์ Platycnemididae กระจายอยู่บางแหล่งน้ำให้คะแนนเป็น 6 ส่วนตัวอ่อนแมลงปอวงศ์อื่นๆมีการกระจายแคบกว่าได้ให้คะแนนอยู่ในช่วง 7-8 คะแนน

ตัวอ่อนสโตนฟลาย (Stonefly) ซึ่งเป็นกลุ่มที่มักมีรายงานว่ามีความทนทานน้อยมากต่อการเปลี่ยนแปลงของสิ่งแวดล้อม แมลงกันต้านนี้พบว่ามีจำนวนน้อยมากในแหล่งน้ำภาคตะวันออกเฉียงเหนือ โดยมักพบในลำธารบริเวณต้นน้ำซึ่งมีอุณหภูมิต่ำและมีพื้นที่อาศัยเป็นก้อนหินเท่านั้น ตัวอ่อนแมลงวงศ์นี้พบในบริเวณลำน้ำพองตอนบนคือจากบ้านนาน้อยจนถึงบ้านห้วยสายหนังเท่านั้น แมลงวงศ์นี้มักพบในลำธารต้นน้ำตามเขตอุทยานแห่งชาติซึ่งเป็นแหล่งน้ำที่ไม่ถูกรบกวนหรือถูกรบกวนน้อยจึงให้คะแนนเท่ากับ 10

ตัวอ่อนแมลงหนอนปลอกน้ำ (Trichoptera) เป็นองค์ประกอบสัตว์ไม่มีกระดูกสันหลังหน้าดินที่สำคัญกลุ่มหนึ่งในแหล่งน้ำจืดเพราะมีสมาชิกหลากหลายมากและมีเป็นจำนวนมากเช่นกัน ตัวอ่อนแมลงหนอนปลอกน้ำที่พบว่าแตกต่างจากของสหราชอาณาจักรมากคือ วงศ์แมลงหนอนปลอกน้ำเข็ม (Leptoceridae) ที่มีความทนทานน้อยมากในสหราชอาณาจักรคือมีคะแนนเท่ากับ 10 แต่สามารถอาศัยอยู่ในแหล่งน้ำที่มีการปนเปื้อนจากสารอินทรีย์ของลุ่มน้ำพองได้ในการศึกษาครั้งนี้ได้ให้คะแนนเป็น 7 ตัวอ่อนแมลงหนอนปลอกน้ำรังดิน (Polycentropodidae) ก็มีการกระจายค่อนข้างกว้างสามารถอาศัยในบริเวณที่น้ำมีการปนเปื้อนค่อนข้างมากได้ และตัวอ่อนของแมลงหนอนปลอกน้ำซึ่งไม่มีในรายชื่อของ BMWP/ASPT แต่มีความสำคัญในลำน้ำพองมาก 2 วงศ์ คือ แมลงหนอนปลอกน้ำขาสั้น (Ecnomidae) และแมลงหนอนปลอกน้ำขาใบพาย (Dipseudopsidae) ตัวอ่อนของแมลงหนอนปลอกน้ำทั้งสองวงศ์นี้พบว่ามีการกระจายกว้างมากอาศัยอยู่ได้ในบริเวณที่น้ำมีการ

ปนเปื้อนมาก แต่ไม่พบในบริเวณที่มีการปนเปื้อนอย่างมากๆซึ่งมีเฉพาะหนอนแดงและไส้เดือนน้ำจืดอาศัยอยู่เท่านั้น ตัวอ่อนแมลงหนอนปลอกน้ำทั้งสามวงศ์นี้ได้ให้คะแนนเท่ากับ 4 คะแนน

สำหรับสัตว์ไม่มีกระดูกสันหลังเหล่านี้พบว่ากลุ่มที่มีความทนทานน้อยต่อการเปลี่ยนแปลงคุณภาพสิ่งแวดล้อมในลุ่มน้ำพองคือ ตัวอ่อนของแมลงชีปะขาว ตัวอ่อนแมลงสโตนฟลายและตัวอ่อนแมลงหนอนปลอกน้ำ หรือที่เรียกย่อๆว่าแมลงกลุ่ม EPT หรือกลุ่ม ET เมื่อตัดตัวอ่อนแมลงสโตนฟลายออกเพราะมีจำนวนค่อนข้างน้อย (Sangpradub *et al.* 1996, 1997) ข้อสังเกตนี้ได้รับการยืนยันอีกครั้งเมื่อเกิดเหตุการณ์น้ำพองเน่าปลาตายเมื่อวันที่ 5 ธันวาคม 2540 จากผลการตรวจสัตว์ไม่มีกระดูกสันหลังหน้าดินจากตะกอนในลำน้ำพองวันที่ 8 ธันวาคม 2540 พบว่าในตะกอนก่อนบริเวณที่เกิดการปนเปื้อน ตัวอ่อนแมลงชีปะขาวกระโปรง (*Caenis* sp.) ตัวอ่อนชีปะขาวกรามโค้ง (*Povilla* sp.) ตัวอ่อนหนอนปลอกน้ำเข็ม (*Leptocerus* sp.) ตัวอ่อนหนอนปลอกน้ำขาสั้น (Ecnomidae) และตัวอ่อนหนอนปลอกน้ำขาใบพาย (*Dipseudopsis* sp.) ร่วมกับสัตว์ชนิดอื่นๆ แต่หลังบริเวณที่เกิดการปนเปื้อนไม่ปรากฏตัวอ่อนของแมลงชีปะขาวและตัวอ่อนแมลงหนอนปลอกน้ำเลยในขณะที่พบว่าไส้เดือนน้ำจืด ตัวอ่อนแมลงสองปีก และกุ้งฝอยยังคงอาศัยอยู่ได้ในแหล่งน้ำบางบริเวณ (กรมอนามัย กระทรวงสาธารณสุข 2541) ทั้งๆที่ตัวอ่อนของแมลงชีปะขาวและตัวอ่อนของแมลงหนอนปลอกน้ำดังกล่าวนี้เคยพบอยู่ในลำน้ำนี้ตลอดปี (Sangpradub *et al.* 1996) และการสำรวจเดือนกรกฎาคม พ.ศ. 2541 พบว่าตัวอ่อนของแมลงกลุ่มดังกล่าวนี้กลับมาอาศัยในที่เดิมอีกและคุณภาพน้ำบริเวณนั้นดีขึ้น นอกจากนี้การศึกษาผลของการเลี้ยงปลาในกระชังต่อโครงสร้างชุมชนสัตว์ไม่มีกระดูกสันหลังหน้าดิน ผลเบื้องต้นพบว่าขณะที่มีการเลี้ยงปลาไม่ปรากฏตัวอ่อนแมลงชีปะขาวและตัวอ่อนหนอนปลอกน้ำอาศัยอยู่ในตะกอนบริเวณกระชังปลาเลย ในขณะที่บริเวณนอกกระชังปลามีสัตว์เหล่านี้อาศัยอยู่ได้ และเมื่อมีการเลิกเลี้ยงปลาพบว่าตัวอ่อนแมลงหนอนปลอกน้ำขาใบพาย *Dipseudopsis* sp. เข้ามาอาศัยอยู่ได้ (บุญเสถียร บุญสูง การติดต่อส่วนตัว) เหตุการณ์ทั้งสองกรณีนี้ช่วยยืนยันได้ว่าตัวอ่อนแมลงชีปะขาวและตัวอ่อนแมลงหนอนปลอกน้ำมีความทนทานน้อยต่อการเปลี่ยนแปลงของสิ่งแวดล้อมในแหล่งน้ำ และสามารถนำสัตว์ไม่มีกระดูกสันหลังหน้าดินมาใช้ร่วมในการประเมินหรือติดตามคุณภาพแหล่งน้ำจืดได้ นอกจากนี้มีข้อสังเกตว่า ตัวอ่อนของแมลงหนอนปลอกน้ำขาใบพาย *Dipseudopsis* sp. และตัวอ่อนแมลงหนอนปลอกน้ำขาสั้น *Ecnomus* sp. มีแนวโน้มที่จะเป็นตัวบ่งชี้ประจำถิ่น (Local Bioindicator) ของลุ่มน้ำพองเนื่องจากเป็นสัตว์กลุ่มแรกที่มาปรากฏตัวอีกเมื่อสภาพแวดล้อมเริ่มฟื้นตัวภายหลังจากที่หายไปเมื่อสภาพแวดล้อมเลวลง ซึ่งจะสามารถกล่าวได้อย่างแน่นอนหลังจากการวิจัยเรื่องผลของการเลี้ยงปลาในกระชังต่อโครงสร้างสัตว์ไม่มีกระดูกสันหลังหน้าดินของนายบุญเสถียร บุญสูง นักศึกษาชั้นปีที่ 4 ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยขอนแก่นเสร็จสิ้นลง

เมื่อพิจารณาการจัดจำแนกคุณภาพสิ่งแวดล้อมของแหล่งน้ำด้วยดัชนีน้ำพอง จะพบว่าสำหรับบริเวณที่มีคุณภาพดีมากมีค่าดัชนีค่อนข้างต่ำ คือตั้งแต่ 6.5 ขึ้นไป ทั้งนี้เนื่องจากค่าคะแนน

น้ำพองได้มาจากการพิจารณาสัตว์ระดับวงศ์ ซึ่งในระดับวงศ์นี้เป็นช่วงที่กว้างเนื่องจากสัตว์วงศ์เดียวกันบางชนิดจะมีความทนทานต่ำมาก ส่วนบางชนิดจะมีความทนทานมากกว่า เช่น ตัวอ่อนแมลงหนอนปลอกน้ำขาสั้น วงศ์ Ecnomidae มีการกระจายตั้งแต่ในแหล่งน้ำที่มีความสะอาดมากๆ เช่นในลำธารอุทยานแห่งชาติภูกระดึงไปจนถึงแหล่งน้ำบริเวณที่มีการปนเปื้อนมากในลำน้ำพอง ตัวอ่อนแมลงหนอนปลอกน้ำขาใบพาย วงศ์ Dipseudopsidae ตัวอ่อนแมลงชีปะขาวเข็ม (Baetidae) และตัวอ่อนแมลงชีปะขาวกระโปรง (Caenidae) ทั้งสามวงศ์นี้มีการกระจายกว้างเช่นเดียวกัน สัตว์ทั้งสี่วงศ์นี้จะมีค่าคะแนนที่ต่ำคืออยู่ในช่วง 3-4 คะแนน นอกเหนือจากตัวอย่างที่ได้กล่าวแล้วยังมีตัวอ่อนแมลงหลายวงศ์ที่มีการกระจายกว้างเช่นเดียวกันจึงทำให้ค่าคะแนนรวมค่อนข้างต่ำ เพราะถึงแม้จะเป็นแหล่งน้ำในเขตต้นน้ำลำธารก็จะใช้ค่าคะแนนเดียวกันสำหรับสัตว์วงศ์เดียวกัน แม้ว่าดัชนีน้ำพองจะมีค่าค่อนข้างต่ำเมื่อจัดจำแนกแหล่งน้ำที่มีคุณภาพสิ่งแวดล้อมดีก็ตาม พบว่าดัชนีนี้สามารถจัดจำแนกคุณภาพน้ำในช่วงลำน้ำพองส่วนล่างซึ่งมีมลภาวะได้ โดยสามารถแยกบริเวณที่มีการปนเปื้อนของสารอินทรีย์สูงมาก บริเวณที่มีการปนเปื้อนของสารอินทรีย์มาก และบริเวณมีการปนเปื้อนของสารอินทรีย์ไม่มากนักออกจากกันได้ คือในแหล่งน้ำบริเวณที่สกปรกมากหรือมีการปนเปื้อนอย่างมากสัตว์ที่พบจะเป็นไส้เดือนน้ำจืด หนอนแดง ตัวอ่อนริ้นน้ำกร่อย และตัวอ่อนริ้นเข็ม ซึ่งมีคะแนนอยู่ในช่วง 1-3 คะแนน ค่าดัชนีจะอยู่ในช่วง 1-2.5 ในขณะที่บริเวณที่มีการปนเปื้อนน้อยกว่าจะพบสัตว์ที่กล่าวมาแล้วร่วมกับตัวอ่อนแมลงชีปะขาวกระโปรง (Caenidae) ชีปะขาวเข็ม (Baetidae) แมลงหนอนปลอกน้ำขาสั้น (Ecnomidae) และแมลงหนอนปลอกน้ำขาใบพาย (Dipseudopsidae) เป็นต้น สัตว์เหล่านี้มีคะแนนอยู่ในช่วง 4-5 คะแนน ทำให้ดัชนีมีค่าสูงขึ้นมาเล็กน้อยจึงสามารถจัดจำแนกอยู่คนละกลุ่มได้

ดัชนี Q ได้มาจากการแบ่งกลุ่มสัตว์ที่พบกระจายในลำน้ำพองโดยอาศัยหลักการคล้ายคลึงกับการกำหนดค่าคะแนนน้ำพอง การจัดจำแนกแหล่งน้ำบริเวณสถานีต่างๆของลำน้ำพองด้วยดัชนีทั้งสองให้ผลที่ใกล้เคียงกัน ดัชนีน้ำพองกับดัชนี Q มีความสัมพันธ์กันสูงมากถึงร้อยละ 96.6 ทั้งดัชนีน้ำพองและดัชนี Q ต่างมีความสัมพันธ์อย่างมีนัยสำคัญกับปริมาณออกซิเจนละลาย (DO) และค่า BOD โดยมีความสัมพันธ์กับค่า DO มากกว่า คือประมาณ ร้อยละ 70 ทั้งดัชนีน้ำพองและดัชนี Q ต่างให้ผลเหมือนระบบ BMWP/ASPT ที่มีรายงานในหลายประเทศว่าไวต่อมลภาวะสารอินทรีย์ (Murphy 1978, Bargos *et al.* 1990, Rossaro และ Pietrangelo 1993) ถึงแม้ว่าผลการจัดจำแนกคุณภาพน้ำทางชีวภาพด้วยดัชนีทั้งสองให้ผลที่ใกล้เคียงกันก็ตาม แต่ดัชนี Q สามารถจัดจำแนกในช่วงระหว่างคุณภาพระดับหนึ่งกับอีกระดับหนึ่งได้ ซึ่งทำให้สามารถจำแนกย่อยขึ้น เช่นในลำธารของอุทยานแห่งชาติภูกระดึงเมื่อจัดจำแนกด้วยดัชนีน้ำพองจะอยู่ในระดับที่มีคุณภาพน้ำดี แต่เมื่อจัดจำแนกด้วยดัชนี Q บางลำธารถูกจัดจำแนกเป็นระดับ Q2-Q1 ในขณะที่ลำธารส่วนมากได้รับการจำแนกเป็นระดับ Q1 ที่แสดงว่ามีคุณภาพน้ำดี การที่บางลำธารถูกจัดจำแนกในระดับ Q2-Q1 นั้นเนื่องจากเมื่อเทียบสัดส่วนของสัตว์กลุ่มที่มีความทนทานได้น้อยมากกับกลุ่มสัตว์ที่มีความทนทาน

น้อยแล้ว ลำธารดังกล่าวนี้มีกลุ่มสัตว์ที่มีความทนทานน้อยจำนวนมากกว่ากลุ่มสัตว์ที่มีความทนทานน้อยมาก จึงควรอยู่ในระดับ Q2 และจากการที่ยังคงมีกลุ่มสัตว์ที่มีความทนทานน้อยมากเป็นจำนวนค่อนข้างมาก คือเกือบเป็นระดับ Q1 จึงได้จัดจำแนกให้อยู่ระหว่าง Q1 และ Q2 แต่ลำธารบางสายที่กลุ่มสัตว์ที่มีความทนทานน้อยมากมีจำนวนมากกว่ากลุ่มสัตว์ที่ความทนทานน้อยจะจัดจำแนกเป็น Q1 ในขณะที่การใช้ดัชนีน้ำพองนั้นถือหลักการการให้คะแนนแก่วงศ์สัตว์ที่พบโดยไม่คำนึงว่าสัตว์วงศ์นั้นจะมีจำนวนเท่าไร ดังนั้นในลำธารทั้งสองกรณีที่กล่าวแล้วนี้เมื่อใช้ดัชนีน้ำพองจะจัดจำแนกอยู่ในระดับเดียวกันคือ คุณภาพน้ำดีมาก

เมื่อเปรียบเทียบข้อดีและข้อด้อยของดัชนีน้ำพองกับดัชนี Q พบว่าทั้งสองดัชนีนี้ต้องการความรู้อนุกรมวิธานระดับวงศ์และใช้สัตว์เฉพาะวงศ์ที่พบบ่อย ข้อดีของดัชนีน้ำพองคือ มีค่าเป็นตัวเลขซึ่งสามารถแปลผลเข้าใจได้ง่าย ส่วนดัชนี Q นั้นในบางครั้งสัดส่วนของสัตว์แต่ละกลุ่มไม่เป็นไปตามที่ได้กำหนดไว้ ต้องอาศัยการพิจารณาตัดสินใจว่าควรอยู่ในระดับใด และสัตว์กลุ่มที่ 5 ซึ่งเป็นกลุ่มที่มีทนทานมากที่สุดนั้นในบางครั้งจะมีจำนวนตัวมากกว่าสัตว์กลุ่มอื่นๆ ในการพิจารณาสัดส่วนของสัตว์กลุ่มต่างๆจึงอาจตัดสัดส่วนของสัตว์กลุ่มนี้ออกไปได้ซึ่งจะทำให้การพิจารณาง่ายขึ้น ส่วนข้อดีของดัชนี Q คือ สามารถจัดจำแนกได้ย่อยกว่าในกรณีที่มีส่วนประกอบของสัตว์คล้ายคลึงกันเพราะจะนำจำนวนตัวเข้ามาพิจารณาด้วย

ดัชนีน้ำพองและดัชนี Q สามารถใช้จัดจำแนกแหล่งน้ำในลำน้ำพองได้ หากจะนำใช้ในลำน้ำสายอื่นๆของประเทศไทยยังต้องการการทดสอบและวิจัยอีกมากเพราะสัตว์ในลำน้ำอื่นๆแม้จะเป็นสัตว์ในวงศ์เดียวกันก็จะมีชนิดที่แตกต่างออกไปบ้างซึ่งต้องมีการปรับค่าคะแนนหรือจัดกลุ่มสัตว์ให้เหมาะสมกับสัตว์ที่พบในลำน้ำสายนั้นๆ ซึ่งในต่างประเทศจะมีการวิจัยพร้อมเพรียงกันในแหล่งน้ำทั่วประเทศเพื่อนำองค์ความรู้ที่เป็นความจริงของประเทศนั้นๆไปปรับจนกระทั่งสามารถใช้ระบบเดียวกันทั่วประเทศได้

ทั้งดัชนีน้ำพองและดัชนี Q ต่างได้มาจากตัวอย่างสัตว์ที่เก็บตัวอย่างด้วยวิธีเชิงปริมาณคือการเก็บด้วยอุปกรณ์จำพวก Surber sampler และ Ekman grab ซึ่งค่อนข้างยุ่งยากในบริเวณที่มีระดับน้ำลึกเพราะต้องอาศัยเรือเป็นพาหนะ จึงไม่สะดวกนักเมื่อเทียบกับวิธีการเก็บตัวอย่างเชิงคุณภาพคือการใช้สวิง ซึ่งสวิงนี้สามารถเก็บตัวอย่างสัตว์ที่อาศัยอยู่บริเวณผิวน้ำและบริเวณใกล้ฝั่งได้ สัตว์ที่ได้จากการเก็บตัวอย่างวิธีนี้ส่วนมากจะเป็นตัวอ่อนแมลงปอและมวน ซึ่งจากการวิเคราะห์เบื้องต้นพบว่าความรู้ระดับวงศ์ยังไม่พอเพียงเนื่องจากในมวนและตัวอ่อนแมลงปอแต่ละวงศ์มีการกระจายที่กว้างมากคือพบได้ในแหล่งน้ำทั่วไปแต่จากการสังเกตพบว่าในแต่ละแหล่งน้ำมีมวนและตัวอ่อนแมลงปอต่างชนิดกัน คาดว่าจะสามารถนำมาใช้ในการจัดจำแนกคุณภาพแหล่งน้ำได้เช่นกันซึ่งต้องอาศัยผลการวิจัย และจากการศึกษาแหล่งที่อยู่อาศัยย่อยของมวนในอุทยานแห่งชาติน้ำหนาวพบว่ามวนแต่ละชนิดมีการกระจายในแหล่งที่อยู่แตกต่างกัน (ศิริพร แจ่มสง 2540) ดังนั้นการที่จะนำมวน

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ความหลากหลายของตัวเต็มวัยแมลงชีปะขาว แมลงสโตนฟลาย และแมลงหนอนปลอกน้ำในลุ่มน้ำพอง

Diversity of Ephemeropteran Plecopteran and Trichopteran adults in the Pong Catchment

บทคัดย่อ

ตัวเต็มวัยของแมลงชีปะขาว แมลงสโตนฟลายและแมลงชีปะขาว ในลุ่มน้ำพองถูกเก็บโดยการใช้กับดักแสงไฟหลอดอุลตราไวโอเลต ในเดือนมีนาคมและเมษายน พ.ศ. 2541 พบตัวเต็มวัยของแมลงชีปะขาว 6 วงศ์ 16 ชนิด แมลงหนอนปลอกน้ำ 8 วงศ์ 28 ชนิด ส่วนแมลงสโตนฟลายพบ 1 ชนิด การตรวจเอกลักษณ์ส่วนมากได้ถึงระดับวงศ์ สกุล

คำนำ

สัตว์ไม่มีกระดูกสันหลังหน้าดินที่พบในตะกอนท้องน้ำของลุ่มน้ำพองส่วนมากเป็นตัวอ่อนแมลงน้ำกว่าร้อยละ 90 เนื่องจากยังไม่มีรูปวิธานสำหรับตัวอ่อนของตัวอ่อนแมลงน้ำสำหรับประเทศไทยทำให้การตรวจเอกลักษณ์ตัวอ่อนเป็นไปค่อนข้างลำบาก ส่วนมากสามารถทำได้ถึงระดับวงศ์ ซึ่งผลการศึกษาในลุ่มน้ำพองพบว่า ระดับวงศ์นี้สามารถแสดงความสัมพันธ์กับคุณภาพของแหล่งน้ำอย่างมาก อย่างไรก็ตามตัวอ่อนของแมลงบางชนิดมีการกระจายที่กว้างมาก หากสามารถระบุสกุลหรือชนิดได้จะสามารถพิจารณาความเกี่ยวเนื่องกับคุณภาพของแหล่งน้ำได้แน่นอนกว่าระดับวงศ์ เนื่องจากขณะนี้ยังไม่สามารถระบุชนิดจากระยะตัวอ่อนได้ จึงต้องมีการศึกษาตัวเต็มวัยของแมลงเหล่านี้เพื่อให้ทราบว่ามีกี่ชนิด แต่ละชนิดกระจายอยู่บริเวณใดบ้าง และเพื่อใช้หาความสัมพันธ์ระหว่างตัวเต็มวัยกับตัวอ่อนซึ่งจะทำให้สามารถระบุชนิดของตัวอ่อนได้ในที่สุด

วัตถุประสงค์

เพื่อหาความหลากหลายของตัวเต็มวัยแมลงน้ำ 3 อันดับ คือ แมลงชีปะขาว (Ephemeroptera) แมลงสโตนฟลาย (Plecoptera) และแมลงหนอนปลอกน้ำ (Trichoptera) ในบริเวณลุ่มน้ำพอง

อุปกรณ์และวิธีการศึกษา

ตัวเต็มวัยของแมลงน้ำ ณ สถานีต่างๆ ของลุ่มน้ำพองถูกเก็บในเดือนมีนาคมและเมษายน 2541 ซึ่งเป็นช่วงฤดูกาลที่มีรายงานว่ามีแมลงน้ำตัวเต็มวัยมากในประเทศไทย (Chantaramongkol และคณะ 1998) และประเทศฮ่องกง (Dudgeon 1988, 1989a, 1989b) โดยการใช้กับดักแสงไฟหลอดอัลตราไวโอเลตในแต่ละสถานีเป็นระยะเวลา 12 ชั่วโมง ตั้งแต่ เวลา 18.00 – 06.00 นาฬิกา ตัวอย่างที่ได้นำมาเลือกเฉพาะตัวเต็มวัยของแมลงชีปะขาว แมลงสโตนฟลายและแมลงหนอนปลอกน้ำ ดองตัวอย่างแมลงที่ได้ด้วยเอทิลแอลกอฮอล์ความเข้มข้นร้อยละ 70 หลังจากนั้นนำมาตรวจเอกลักษณ์ภายใต้กล้องจุลทรรศน์สเตอริโอถึงระดับอนุกรมวิธานต่ำสุดเท่าที่ทำได้

ผลการศึกษา

จากตัวอย่างทั้งหมดพบตัวเต็มวัยของแมลงสโตนฟลายเพียง 1 ตัวเป็นตัวเมียและไม่สมบูรณ์จึงไม่สามารถตรวจเอกลักษณ์ได้ ตัวเต็มวัยของแมลงชีปะขาวและแมลงหนอนปลอกน้ำพบรวมทั้งสิ้น 14 วงศ์ 44 ชนิด รายละเอียดดังนี้คือ

แมลงชีปะขาว (อันดับ Ephemeroptera) พบทั้งสิ้น 6 วงศ์ 16 ชนิด

1. วงศ์ Baetidae พบ 4 ชนิด

   Acentrella sp.

   Cloeon sp.

   Procloeon sp. และ ไม่สามารถระบุสกุลได้อีก 1 ชนิด

2. วงศ์ Caenidae พบ 2 ชนิด คือ

   Caenis sp.1 และ *Caenis* sp.2

3. วงศ์ Ephemeridae พบ 2 ชนิด คือ

   Hexagenia sp. และ *Ephemera* sp.

4. วงศ์ Heptageniidae พบ 1 ชนิด ไม่สามารถระบุสกุลได้

5. วงศ์ Leptophlebiidae พบ 4 ชนิด คือ

   Choroterpes sp.1

   Choroterpes sp.2

   Thraulodes sp.1

   Thraulodes sp.2

6. วงศ์ Polymitarcyidae พบ 3 ชนิดคือ

Povilla sp.

Tortopus sp. และไม่สามารถระบุสกุลได้ 1 ชนิด

แมลงหนอนปลอกน้ำ (อันดับ Trichoptera) พบ 8 วงศ์ 28 ชนิด

1. วงศ์ Helicopsychidae พบ 1 ชนิดคือ

Helicopsyche sp.

2. วงศ์ Hydroptilidae พบ 4 ชนิดคือ

Hydroptila sp.1

Orthotrichia sp.1

Orthotrichia sp.1 และไม่สามารถระบุสกุลได้ 1 ชนิด

3. วงศ์ Hydropsychidae พบ 6 ชนิดคือ

Cheumatopsyche charites

Hydropsyche sp.

Macrostemum sp.

Oestropsyche sp.

Polymorphanisus nigricornis

Synaptopsyche

4. วงศ์ Leptoceridae พบ 12 ชนิดคือ

Leptocerus sp.1

Leptocerus sp.2

Leptocerus sp.3

Leptocerus sp.4

Leptocerus sp.5

Oecetis sp.1

Oecetis sp.2

Oecetis sp.3

Oecetis sp.4

Oecetis sp.5

Mystacides sp.

Setodes sp.

5. วงศ์ Limnephilidae พบ 1 ชนิดคือ

   Leptophylax sp.

6. วงศ์ Polycentropodidae พบ 1 ชนิด ไม่สามารถระบุสกุลได้
7. วงศ์ Psychomyiidae พบ 2 ชนิด

   Tinodes sp. และไม่สามารถระบุสกุลได้ 1 ชนิด

8. วงศ์ Uenoidae พบ 1 ชนิด ไม่สามารถระบุสกุลได้

วิจารณ์ผลการศึกษา

จำนวนวงศ์และชนิดของตัวเต็มวัยแมลงชีปะขาว แมลงสโตนฟลายและแมลงหนอนปลอกน้ำที่ได้ไม่แตกต่างจากตัวอ่อน แมลงชีปะขาวพบตัวเต็มวัย 6 วงศ์ 16 ชนิด ตัวอ่อนพบ 6 วงศ์ 19 ชนิด แมลงสโตนฟลายพบตัวเต็มวัย 1 ชนิด ตัวอ่อนพบ 1 วงศ์ 2 ชนิด และแมลงหนอนปลอกน้ำพบตัวเต็มวัย 8 วงศ์ 28 ชนิดส่วนตัวอ่อนพบ 13 วงศ์ 26 ชนิด (Sangpradub และคณะ 1996) แต่ส่วนประกอบของแมลงแต่ละวงศ์แตกต่างกัน เช่น แมลงหนอนปลอกน้ำวงศ์ Leptoceridae พบตัวอ่อน 3 สกุล 3 ชนิด ตัวเต็มวัยพบ 4 สกุล 12 ชนิดเป็นต้น ปัจจุบันยังไม่ทราบวงชีวิตของแมลงเหล่านี้ในประเทศไทยว่ามีช่วงเดือนใดที่จะเป็นตัวเต็มวัย แต่ส่วนมากจะพบมากในช่วงฤดูร้อน (Chantaramongkol และคณะ 1998) ตัวเต็มวัยของแมลงชีปะขาวที่พบส่วนมากเป็นระยะ subimmago และเป็นตัวเมียทำให้ไม่สามารถระบุชนิดได้แน่ชัด เช่นเดียวกันกับแมลงหนอนปลอกน้ำพบตัวเมียมากกว่าตัวผู้เช่นกัน จากการนำตัวอ่อนระยะสุดท้ายของแมลงชีปะขาวและแมลงหนอนปลอกน้ำมาเลี้ยงในห้องปฏิบัติการเพื่อให้ออกคราบเป็นตัวเต็มวัย ซึ่งจะทำให้สามารถระบุชนิดและหาความเกี่ยวเนื่องระหว่างตัวอ่อนและตัวเต็มวัยได้ ไม่ประสบความสำเร็จเนื่องจากตัวอ่อนไม่สามารถมีชีวิตอยู่ได้ในห้องปฏิบัติการ แมลงชีปะขาวตัวอ่อนและตัวเต็มวัยพบเป็นวงศ์เดียวกัน ส่วนแมลงหนอนปลอกน้ำพบว่ามี 2 วงศ์ที่ไม่เคยพบตัวอ่อนคือ วงศ์ Limnephilidae และวงศ์ Uenoidae ซึ่งเป็นไปได้ว่าอาจเป็นตัวเต็มวัยในแหล่งน้ำนิ่งใกล้บริเวณนั้นที่บินมาหาแสงไฟที่เปิดล่อ แมลงหนอนปลอกน้ำวงศ์ Leptoceridae พบมากถึง 12 ชนิด แมลงหนอนปลอกน้ำวงศ์นี้มีการกระจายค่อนข้างกว้าง ดังนั้นถ้าสามารถแยกสกุลหรือชนิดได้ว่าอาศัยอยู่ในสิ่งแวดล้อมเช่นไร จะทำให้สามารถทำนายคุณภาพของแหล่งน้ำได้จากสัตว์ที่พบ ตัวอ่อนแมลงหนอนปลอกน้ำ 2 วงศ์ที่พบว่ามีความสำคัญค่อนข้างมากในลำน้ำพองบริเวณที่มีการปนเปื้อนของสารอินทรีย์มากคือ วงศ์ Ecnomidae และวงศ์ Dipseudopsidae การเก็บตัวเต็มวัยครั้งนี้ไม่พบ ทั้งนี้อาจเนื่องจากระยะเวลาที่เก็บตัวอย่างไม่ตรงกับเวลาเป็นตัวเต็มวัยของแมลงทั้งสองนี้ การศึกษาครั้งนี้ยังไม่สมบูรณ์ ต้องมีการศึกษาวิจัยต่อไปอีก ซึ่งใช้เวลาเพราะจะเป็นการสะสมองค์ความรู้อย่างช้า ๆ จนกระทั่งสามารถนำมาใช้ประโยชน์ได้ในเวลาต่อไป

กิตติกรรมประกาศ

คณะผู้วิจัยขอขอบคุณสำนักงานกองทุนการวิจัย และมหาวิทยาลัยขอนแก่นที่สนับสนุนทุนการวิจัย

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รูปวิธานเบื้องต้นระดับอันดับของตัวอ่อนแมลงน้ำและระดับวงศ์ของตัวอ่อนแมลงน้ำบางกลุ่มในประเทศไทย

Preliminary Keys to Order and to Family of Selected Order of Immature Aquatic Insects of Thailand

บทคัดย่อ

รูปวิธานเบื้องต้นระดับอันดับของตัวอ่อนแมลงน้ำ รูปวิธานเบื้องต้นระดับวงศ์ของตัวอ่อนแมลงชีปะขาว แมลงสโตนฟลาย และแมลงหนอนปลอกน้ำของประเทศไทย สร้างจากลักษณะสัณฐานวิทยาของตัวอ่อนแมลงน้ำที่พบในประเทศไทย รูปภาพประกอบในรูปวิธานวาดจากตัวอย่างจริงโดยอาศัยกล้องจุลทรรศน์สำหรับวาดภาพ

บทนำ

ตัวอ่อนของแมลงน้ำมีความสัมพันธ์กับคุณภาพน้ำมาก แต่ยังไม่มีการนำตัวอ่อนแมลงน้ำมาใช้ประโยชน์ทางด้านการเฝ้าระวังคุณภาพน้ำและคุณภาพสิ่งแวดล้อมในประเทศไทยอย่างเป็นทางการ ทั้งนี้เพราะขาดความรู้ด้านอนุกรมวิธาน จากผลการวิจัย เรื่องความสัมพันธ์ระหว่างสัตว์ไม่มีกระดูกสันหลังหน้าดินกับปัจจัยคุณภาพสิ่งแวดล้อมในลุ่มน้ำพอง พบความจริงว่านอกเหนือจากสัตว์ไม่มีกระดูกสันหลังกลุ่มไส้เดือนน้ำจืดแล้วตัวอ่อนแมลงน้ำมีความสัมพันธ์กับคุณภาพน้ำเป็นอย่างมาก ดังนั้นหากมีการสร้างรูปวิธานของตัวอ่อนแมลงน้ำสำหรับผู้ไม่มีความรู้ด้านกีฏวิทยา ก็จะทำให้สามารถนำความรู้ด้านตัวอ่อนของแมลงน้ำมาใช้ประโยชน์ด้านต่างๆ ได้

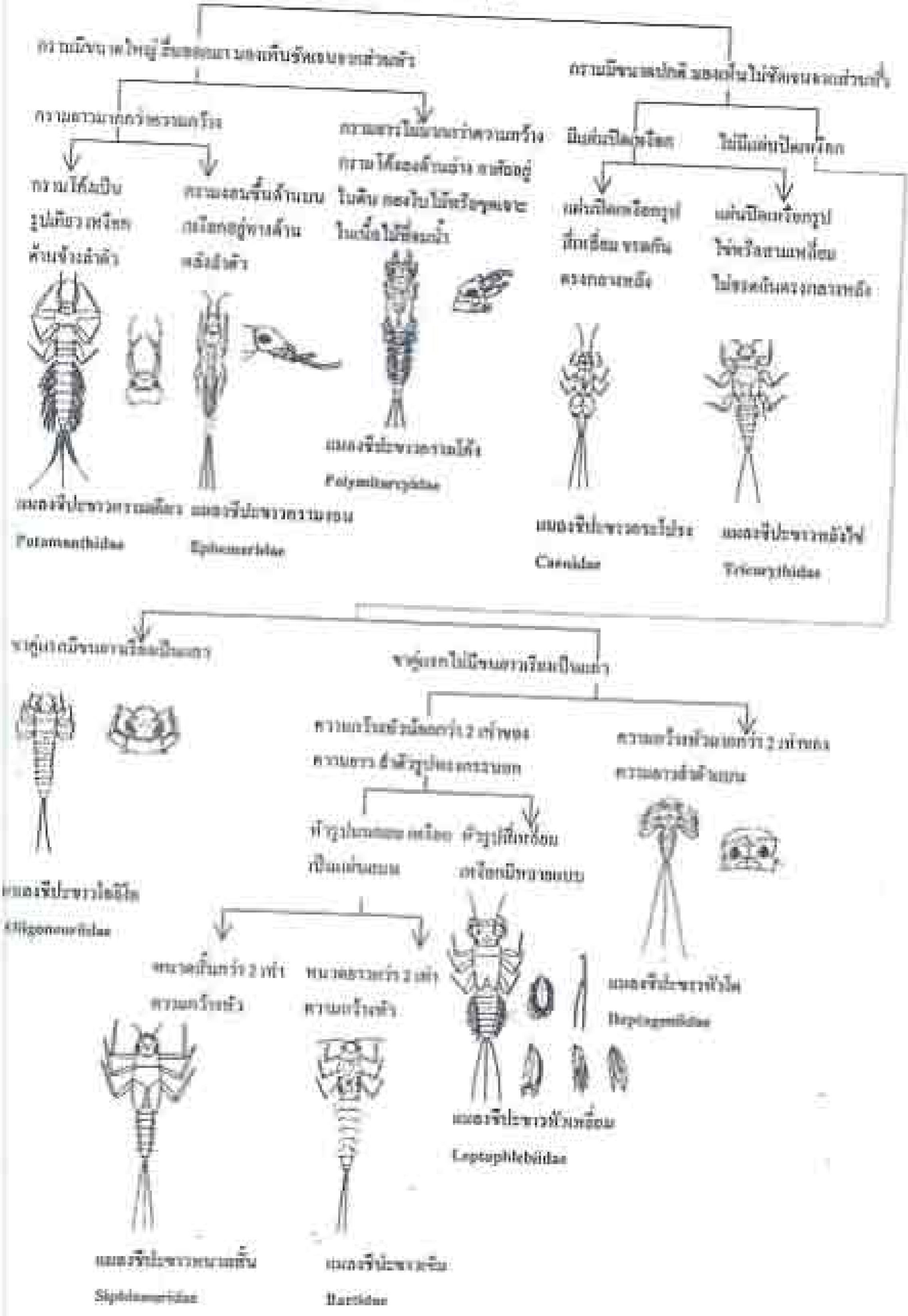
อุปกรณ์และวิธีการศึกษา

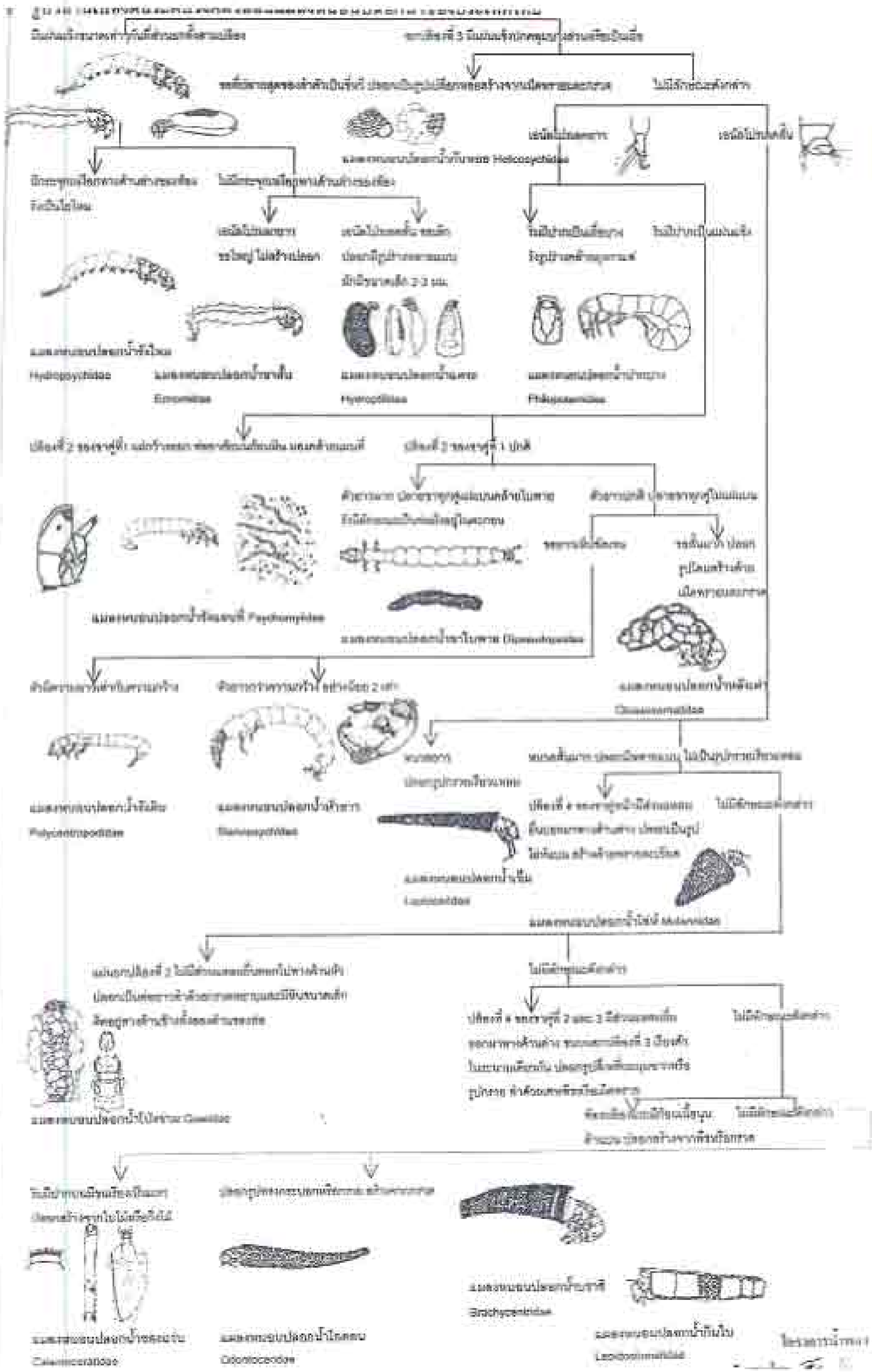
ตัวอย่างของตัวอ่อนแมลงน้ำจากการเก็บตัวอย่างในลุ่มน้ำพอง จากลำธารในอุทยานแห่งชาติน้ำหนาว อุทยานแห่งชาติภูกระดึง และอุทยานแห่งชาติภูพาน ในระดับอันดับถูกนำมาเปรียบเทียบลักษณะสัณฐานวิทยา เพื่อสร้างรูปวิธานเบื้องต้นระดับอันดับ รูปภาพประกอบรูปวิธานวาดภายใต้กล้องจุลทรรศน์สเตอริโอโดยใช้ท่อวาดภาพ (camera lucida)

สร้างรูปวิธานเบื้องต้นระดับวงศ์ของตัวอ่อนแมลงชีปะขาว แมลงสโตนฟลาย และแมลงหนอนปลอกน้ำ จากตัวอย่างตัวอ่อนแมลงอันดับดังกล่าวที่เก็บจากลำธารต่างๆดังกล่าวข้างต้น โดยใช้หลักการเช่นเดียวกับการสร้างรูปวิธานระดับอันดับ

รูปวิธานเบื้องต้นอันดับของตัวอ่อนแมลงน้ำในประเทศไทย

รูปวิธานเบื้องต้นวงศ์ตัวอ่อนแมลงชีปะขาวของประเทศไทย





Helicopsychidae
Hydropsychidae
Ecnomidae
Hydroptilidae
Philopotamidae
Psychomyiidae
Dipseudopsidae
Glossosomatidae
Polycentropodidae
Stenopsychidae
Leptoceridae
Molannidae
Goeridae
Calamoceratidae
Odontoceridae
Brachycentridae
Lepidostomatidae

รูปวิธานเบื้องต้นระดับวงศ์ของตัวอ่อนแมลงสโตนฟลายของประเทศไทย

มีเหงือกเฉพาะที่ฐานของขา

แมลงสโตนฟลายเสือ

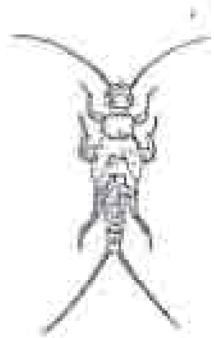
Perlidae

ไม่มีเหงือกที่ฐานของขา

- ปีกขนานกับลำตัว ไม่มีเหงือกที่คอ

  ?

- ปีกกางออกจากลำตัว อาจมีเหงือกที่คอ



แมลงสโตนฟลายนักกล้าม

Nemouridae

รูปวิธานนี้ยังไม่สมบูรณ์มาก เนื่องจากมีตัวอย่างของตัวอ่อนน้อย