Factors affecting the Aquatic Macroinvertebrate (EPT) Fauna at Nam Nao National Park, Thailand

by

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Mandatory Declaration

This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution and that, to the best of the candidate's knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

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ABSTRACT

Little is known about the invertebrate communities, which inhabit the freshwater streams of northeastern Thailand. This study has investigated the macroinvertebrate assemblages, which live in several forest streams in the popular Nam Nao National Park located in the headwaters of several important northeastern rivers.

The distribution and relative abundance of EPT taxa (orders Ephemeroptera, Plecoptera and Trichoptera) was investigated in relation to this environmental variability. The main purpose was to document the natural variation in these communities as a baseline against which to recognize detrimental impacts which may arise from increasing visitor pressure on the National Park.

This was approached via three research questions: Do taxa occupy certain substrates preferentially at different times of the year? Does taxa richness differ in various parts of the streams (pools, riffles and runs)? and what is the nature of the small scale variation in close proximity to a pre-existing tourist facility?

The streams, located in a monsoonal climate, were found to be highly variable in terms of monthly flows, substrates and other physico-environmental factors. The invertebrate fauna was sampled by Surber sampling, and was found to be very rich. It was dominated by mayflies and caddisflies, but had a low diversity of stoneflies. Responses to environmental factors differed at order, family and genus level. Some taxa were relatively insensitive to natural changes, others were sensitive at some times and at some sites, whereas others displayed clear preferences for certain habitat factors all year.

Communities were recognized by TWINSPAN analysis and ordination methods.

The project was successful in recognizing certain taxa, which were indicators for various environments at certain times of the year. A useful baseline dataset has been achieved which can be used in future as a benchmark for pristine water conditions in the National Park.

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1. INTRODUCTION

Increasing demands are being made on the freshwater resources of tropical Asia as regional economies expand and human populations increase. In northeast Thailand a strongly seasonal climate results in water shortage at certain times of the year and demand for irrigation is in competition with environmental flows.
Understanding of stream ecology in tropical Asia will be a critical tool in effective decision making in resource management in the future. However present knowledge is very limited, although studies on river and stream systems are slowly accumulating (Rundle *et al.* 1993, Suren 1994, Dudgeon 1995, Inmuong 1997, Mustow 1997).

The larvae of insects living in freshwater are usually very sensitive to pollution and other man-made impacts (Abel, 1989). These animals, which make up most of the benthic macroinvertebrate community, have therefore been widely used to assess land-water related environment impacts (Hellawel, 1978, 1986; Bargos et al., 1990; Inmuong, 1997). The distribution and relative abundance of macroinvertebrates has been found to be an effective tool in quantifying both stream degradation and restoration (Richards and Minshall, 1992; Richards and Host, 1993; Inmuong, 1997). However, the utility of this biomonitoring approach has, until recently, largely been demonstrated in the temperate zones of North America and Europe, with more recent extension to Australia and New Zealand. The benthos of streams and rivers in tropical regions have been much less studied than in temperate regions, so it is quite uncertain to what extent generalizations from research in the temperate zone can apply to fresh water habitats in the tropics (Dudgeon, 1988). Consequently, much research into benthic macroinvertebrate communities and their association with environmental degradation in tropical Asia is required (Chaiyarach, 1980 and Dudgeon, 1994 cited in Inmuong, 1997).

1.1 RESEARCH QUESTIONS

The key questions in this investigation relate to the small scale distribution of the macroinvertebrate community within a northeast Thailand tropical stream system in order to generate foundation knowledge useful in biomonotoring. A key issue is to what extent there is small scale variation among the fauna in space and time which is due to natural variation in the environment. Once this has been determined, it will be easier to recognize responses in the fauna due to pollution and other impacts against the background of a highly variable system.
The current state of taxonomic understanding of this fauna is very uneven. Consequently, only EPT taxa (i.e. Ephemeroptera, Plecoptera and Trichoptera) are considered in his study because they are relatively well known at family and genus level, and keys are available. EPT taxa have been used successfully to recognize ecological impairment by Plafkin *et al.* (1989) and are recommended more generally by Resh (1995).

The specific questions addressed in this thesis are as follows:

1. Do EPT taxa colonize different substrate types preferentially in space and time? The relevance of this question is that rapid sampling methods (as used in surveys) may need to target a cross section of substrata rather than be completely random across the streambed, in order to achieve a representative sample. Alternatively, it may be revealed that a particular substrate is especially rich in sensitive taxa, which could be targeted as indicators. Many studies from the temperate zone have investigated the small scale distribution of stream fauna and shown that environmental variables such as current velocity, substratum particle size and food sources are typically important (Wright *et al.* 1984).

2. Does EPT taxa richness differ in relation to parts of the stream system, i.e. pool, riffle and run? Independent of the substrate, different stream sections may possibly be favored by

some taxa. Given the large seasonal variation in rainfall and hence streamflows, it is important to understand the relationship between the fauna and seasonality.

3. Is there any difference in the fauna upstream and downstream of a small tourist facility? A pre-existing small restaurant situated on a small stream discharges liquid waste to the water and may have a previously unmeasured effect on the biota. Is the natural variation in the stream fauna likely to make judgements on the effect of the facility impossible to determine?

2. MATERIALS AND METHODS

2.1 THE STUDY AREA

Nam Nao National Park is one of 138 national parks in Thailand, and constitutes part of the remaining thirty four per cent of forest cover left in the country (OEPP, 2001). It was established as a National Reservation Forest Area in 1954 and was later constituted as a National Park in 1972. The name Nam Nao means 'cool water' and was adopted because the park is a watershed and its cool mountain streams feed the Pa Sak and Shi rivers which are the main water resources which support the populations in the central plateau and northeast plain of Thailand respectively.

The park is very pristine and diverse in both flora and fauna and is largely covered with very dense forest producing fine views. The park has a wide range of landscapes, which vary with altitude, and these support 7 different forest types ranging from temperate coniferous forest at high altitude to tropical evergreen forest lower in the park. The most distinctive feature of this park is the magnificent coniferous forest. Many wild animals live within this forest, including wild cattle, elephant, deer, wild dog, tiger, rabbit, jungle fowl, pheasant and many other birds. There are many beautiful waterfalls and caves such as Huai Pla-Lad Cave or Morakot Cave, Pha-Hong Cave, Nam Nao Cave, Huai Sai Waterfall, Sai-Thong Waterfall, Pran Nok Waterfall etc.

The climate in this park is cool, almost European in nature, with positively chilly mornings and evenings in December and January (Nestle Group, 1993).

2.2 LOCATION AND PHYSIOGRAPHY

Nam Nao National Park is situated between 16° 30′N and 16° 57′N latitude and between 101° 23′ E and 101° 45′ E longitude, with an estimated area of 966 km^2 (Figure 2.1 and 2.2). It is in the rolling hills of the Petchabun and Chaiyaphum range. The terrain varies between 650 and 1,200 meters above sea level. The highest peak of this park is at Phu Pha Chit, about 1,271 meters asl.

Figure 2.1 Map of Thailand and Nam Nao National Park location

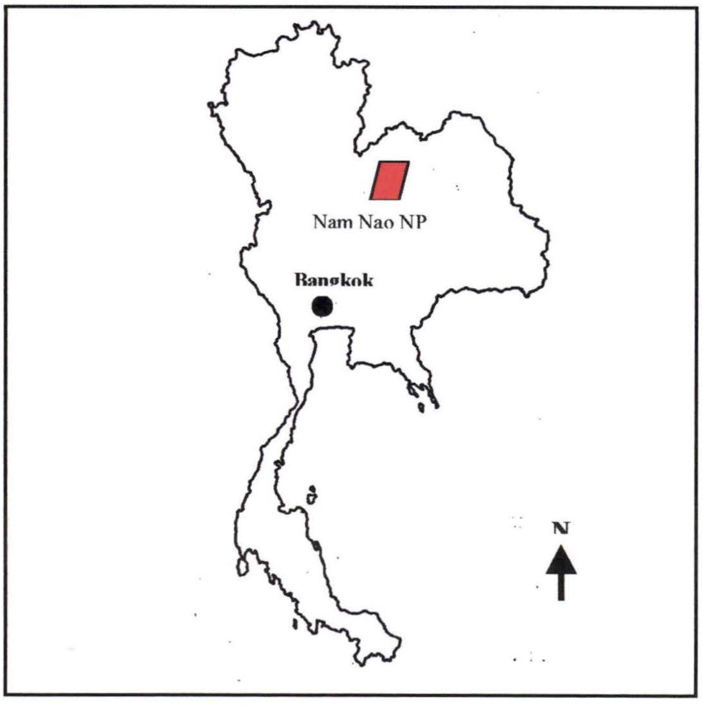
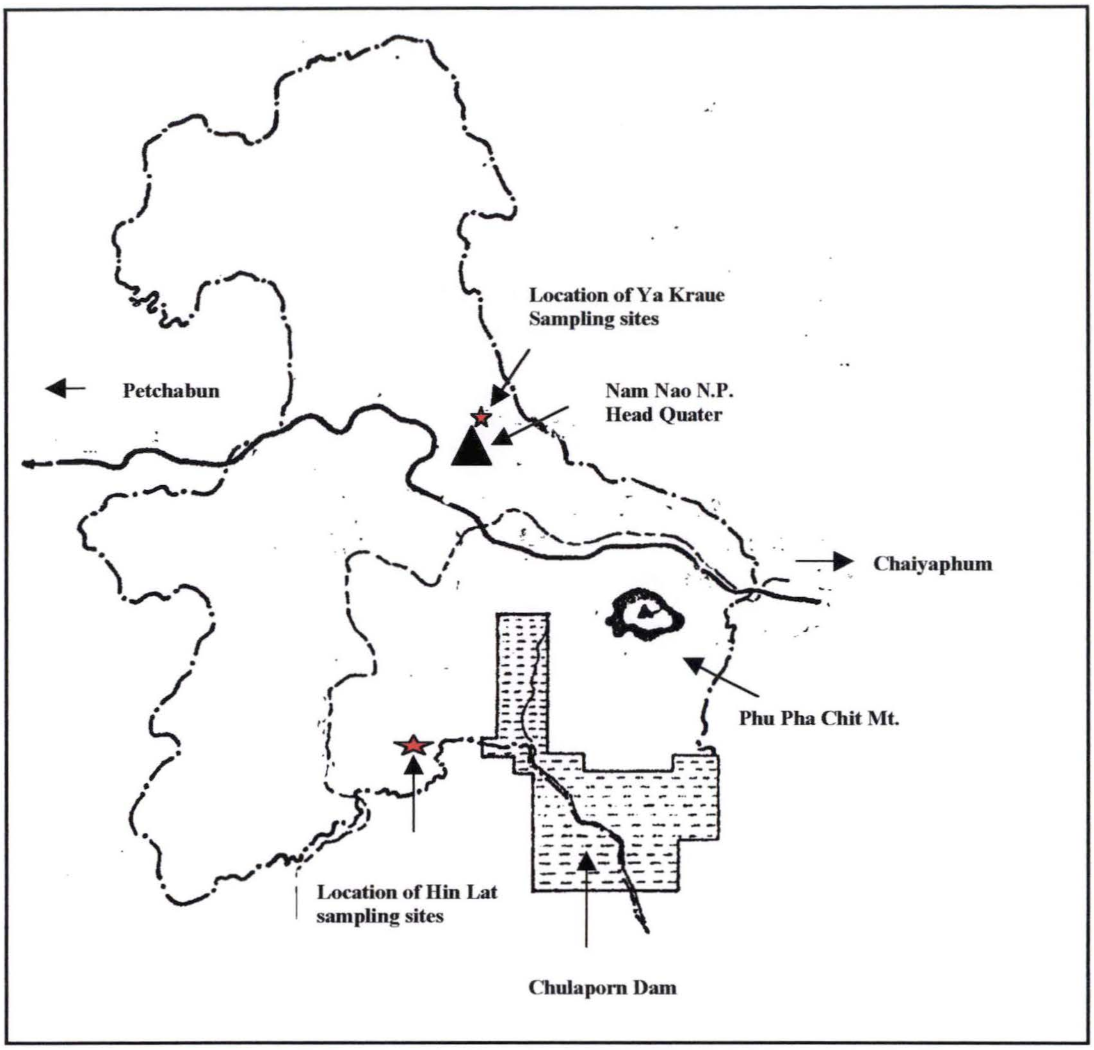


Figure 2.2 Map of Nam Nao National Park

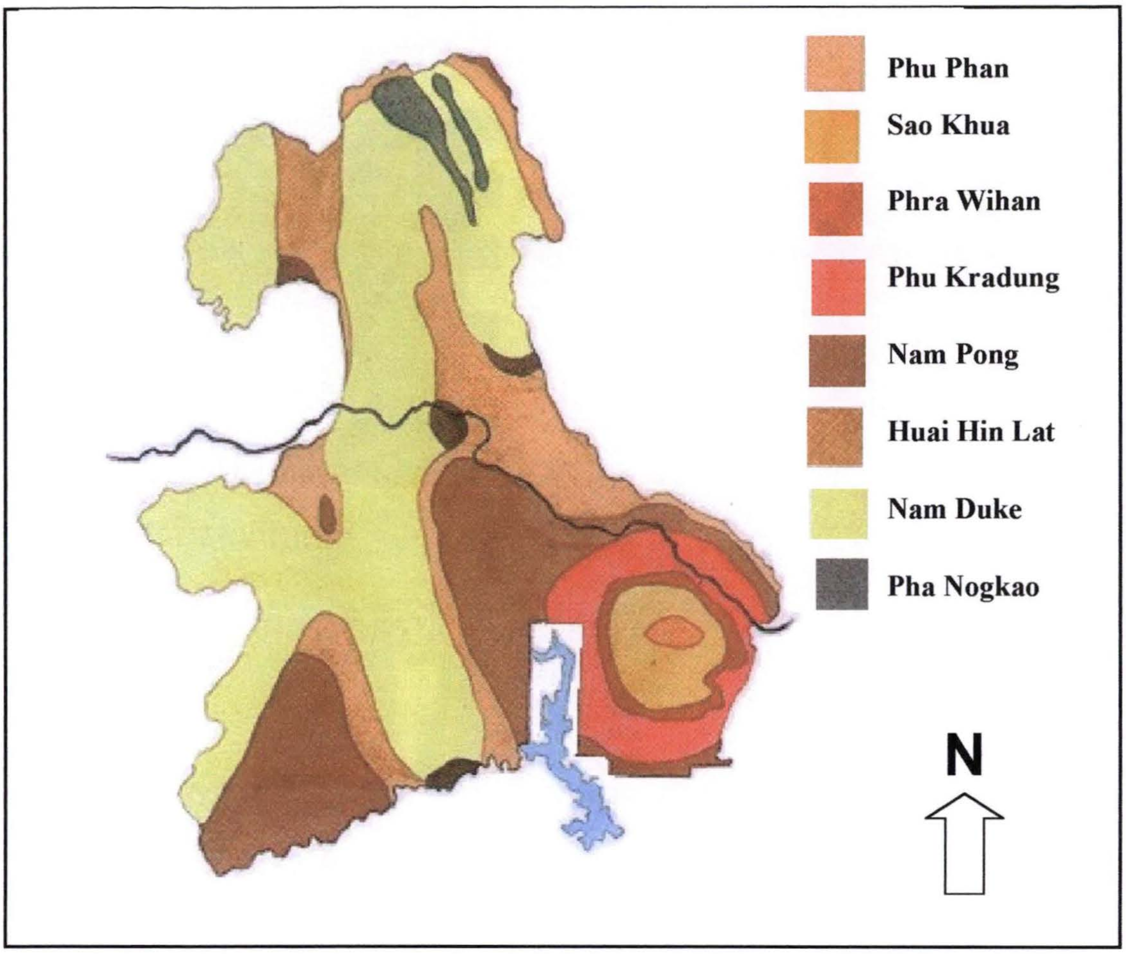


2.3 GEOLOGY

Nam Nao National Park is underlain by 2 main groups of rocks (Royal Forestry Department, 1987-1991): the Ratburi group of the Permian period (about 280 million years old), and the Khorat group from the Mesozoic Era (about 230 million years old).

The Ratburi series contains limestone and chert, and can be found in the northern and southern part of the park. The Khorat series contains sedimentary rocks. It consists of 6 layers(Figure 2.3): the Phu Phan Formation consists of conglomeratic sandstone (gravel and sand); the Sao Khua Formation consists of sandstone and siltstone; the Phra Wihan Formation consists of sandstone; the Phu Kradung Formation mostly consists of shale and siltstone; the Nam Pong Formation consists of sandstone and conglomerate; and the last layer is the Huai Hin Lat Formation which consists of conglomerate and sandstone. The Khorat rock group can be found mostly in the eastern and western part of the park.

Figure 2.3 Geology map of Nam Nao National Park, Thailand. After Aswachaicharn (1997).

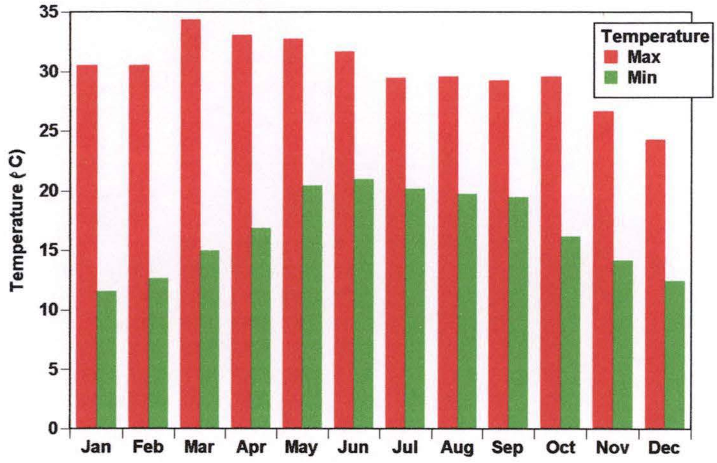


2.4 CLIMATE

The climate at Nam Nao National Park is pleasantly cool all year round. In the cold season, especially between December and January, it can get very cold. According to records between 1976 and 1984, the highest temperature is 31 degree Celsius in April and the lowest is –2 degree Celsius in December, with an average temperature of about 25 degree Celsius.

During this study, the average monthly temperature ranged from a high of 34.4 degree Celsius in March to a minimum of 11.6 degree Celsius in January (Figure 2.4).

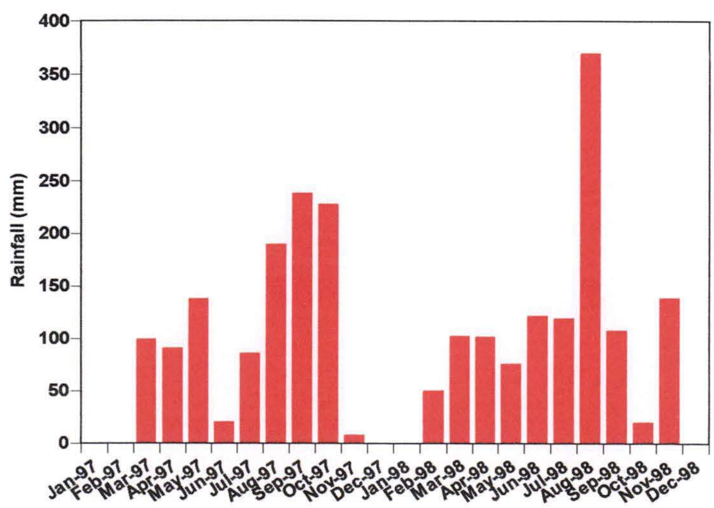
Figure 2.4 The average of maximum and minimum monthly temperature at Nam Nao National Park, Thailand in 1998.



The average annual rainfall is 1,334 mm and rainfall is almost constant through the year at the park. The period with most rain is between April and October. The wettest month is September, whereas there is least rainfall in December.

During this study, the total annual rainfall is 1,102 mm and 1,210 mm in 1997 and 1998 respectively (Figure 2.5). In 1998, rainfall was constant through the year. August was the wettest month with the 370 mm total rainfall, whereas January and December were the lowest rainfall months.

Figure 2.5 Total monthly rainfall (mm) within the Nam Nao National Park catchment area, Thailand during 1997 and 1998.



2.5 RIVERS AND STREAMS

The park terrain with its bountiful forest serves as the primary catchment area for 4 rivers: the Prom, Cheon, Pong, and Pa Sak rivers (Royal Forestry Department, 1987-1991). The Prom river flows into Chulaphorn Dam which is an important source of water for local agriculture. The Cheon and Pong rivers contribute to the Chi river which is the main source of water for the people of the northeast plateau, whereas the Pa Sak river is 350 kilometres long and flows into the Chao Praya river at Ayutthaya province. It is the main source of water for the people of the Central Plain. The streams that originate from this park can be divided into 3 groups: the Prom river group, the Cheon and Pong river group, and the Pa Sak river group.

2.5.1 Prom River Group

Streams, which flow to feed this river, are the Changhan stream, Promlaeng stream, Promnoi stream, Promtueng stream, Promhintok stream, Hin Lat stream, Promyai stream and Promnamsai stream. These streams mainly originate from the Phu Khum Kao mountains. This region is about 880 metres above sea level and covers about 10 square kilometres in area.

2.5.2 Cheon and Pong River Group

Both the Cheon and Pong rivers, which contribute to the Chi river, are fed by many third order streams which flow down from the park. These streams are Sanarmsai stream, Dan-e-pong stream, Yakruea stream Sum-e-loom stream, Toopkop stream, Mod stream, Jarn stream, Nampang stream, Pakong stream and Changlom stream. These streams mainly originate from the Phu Pa Chit Mountain, 1,271 metres above sea level and the highest mountain in Nam Nao National Park.

2.5.3 Pa Sak River Group

Streams, which flow to feed this river, are the Khon Kaen stream, the Nam Duk stream and the Phu stream. These streams originate from the northern and western mountains of the park such as Tum Yai Mountain, Wang Phu Toop Dan Mountain and Dong Suan Myen Mountain.

2.6 FAUNA

Very little research has been carried out on the fauna of Nam Nao National Park. About 200 species of birds were reported by the Faculty of Science, Mahidol University (Royal Forestry Department, 1989). A second survey conducted in 1991 by the International Institute for Aerospace Survey and Earth Science from the Netherlands, reported that 135 species of vertebrate animals were found: 93 species of birds, 24 species of mammals, 3 species of amphibians and 15 species of reptiles. Invertebrate species could be expected to number many thousands but little systematic collection has been done so far.

2.6.1 Mammals

Notable mammals which have been found in the park are *Elephas maximus*, *Sus scrofa*, *Cervus unicolor*, *Capricornis sumatraensis*, *Bos gaurus*, *Bos banteng*, *Panthera tigris*, *Panthera pardus*, *Neofelis neobulosa*, *Selenarctos thibetanus*, *Muntiacus muntjak*, *Cuon alpinus*, *Lepus siamensis*, *Talpa* sp., *Cynocephalus veriegatus*, *Xylobates* spp., *Ratufa bicolar*, *Martes flavigula*, *Tupaia glis*, *Felis temmincki*, *Macaca arctoides* and *Macaca nemestrina*.

2.6.2 Birds

Notable amongst the bird fauna found in this park are *Francolinus pintadeanus*, *Lophura nycthemera*, *Lophura diardi*, *Eudynamyns scolopacea*, *Amaurornis phoenicurus*, *Gallus gallus*, *Ducula badia, Polyplectron bicalcaratum, Stretopelia chinensis, Geopelia striata, Upupa epops, Copsychus malabaricus, Gracula religiosa,* and *Pericrocotus* spp.

2.6.3 Reptiles

Example of reptiles found in the park are *Cyrtodactylus* sp., *Draco* sp., *Varanus bengalensis nebulsosus, Naja naja kaouthia, Ophiophagus hannah,* and *Geochelone elongata.*

2.6.4 Amphibians

Amphibians generally found in the park include members of the Family *Bufonidae, Kaloula* spp., Family *Rhacophoridae,* and Family *Ranidae.*

2.6.5 Fishes

There are many freshwater fishes living in streams in the park but they have never been surveyed systematically.

2.6.6 Invertebrates

Researchers from the faculty of Science at Khon Kaen University (Sangpradub, Inmuang and Harnchavanich, 1997) studied the diversity of aquatic macroinvertebrates in two streams in the park from 1994-1996. They found at least 83 species in 53 families and 15 orders in the Yakruea stream, and 56 species in 40 families and 12 orders in the Promlang stream.

2.7 FLORA AND VEGETATION

Nam Nao National Park consists of beautiful and diverse tropical forest (Figure 2.6). There are more than 410 species of vascular plants comprising the 6 recogniseable plant ecosystems (Institute of Science and Technology Research of Thailand, 1989 and Royal Forestry Department, 1987-1991).

2.7.1 Hill evergreen forest

Hill evergreen forest covers about 7.1 % of the park area. The important trees in this forest include *Castanopsis acuminatissima, Castanopsis* sp., *Lithocarpus garrettianus, Quercus kerrii, Quercus semiserrata, Eugenia cumini, Schima wallichii,* and *Cephalotaxus griffithii.*

2.7.2 Dry evergreen and tropical evergreen forest

This forest covers 71.6 % of the park area. Plants this ecosytem include *Dipterocarpus* spp., *Dalbergia oliveri, Afzelia xylocarpa, Gigantochloa albociliata, Tetrameles nudiflora, Hopea odorata, Sandoricum koetjape, Artocarpus lakoocha, Toona ciliata, Calamus* spp, various bamboos (Family Gramineae) and the fern *Dryopteris* spp.

2.7.3 Dry dipterocarp forest

This forest type is found at 600-1000 metres above sea level and covers 3.6 % of the park area. Plants in this ecosystem include the canopy trees *Shorea obtusa, Shorea siamensis, Dipterocarpus obtusifolius* and the grass *Arundinaria pusilla.*

2.7.4 Mixed deciduous forest

This forest type is normally located near streams and slope of hills. It covers 10.5% of the park area. The dominant trees within this forest are *Pterocarpus macrocarpus, Xylia xylocarpa,* *Lagerstroemia* spp., *Bombax anceps, Irvingia malayana, Morinda coreia, Sindora siamensis,* and the bamboo *Bambusa glaucescens,* and *Thyrsostachys siamensis.*

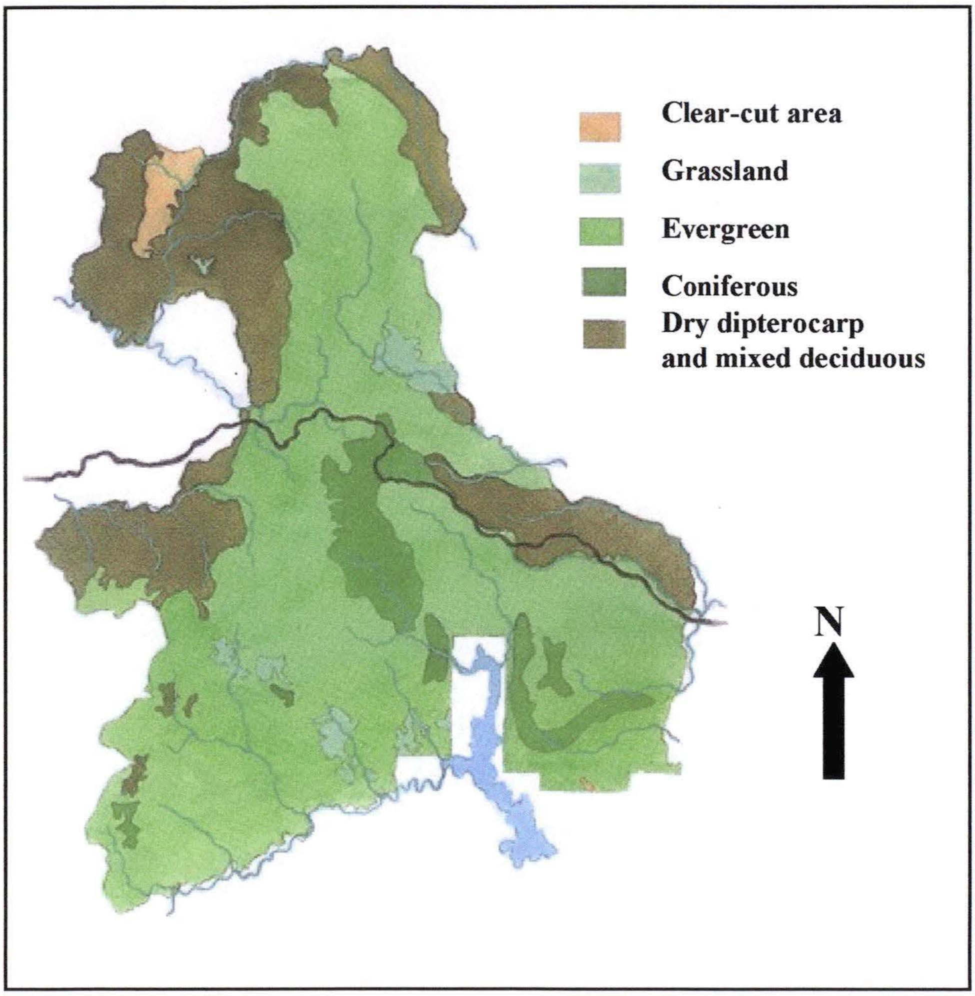
2.7.5 <u>Coniferous forest</u>

This kind of forest is found at 800-1000 metres from sea level and covers 6.2 % of the park area. The main trees within this area are *Pinus merkhusii* and *Pinus kesiya* over an understorey of grass *Imperata cylindrica.*There is a relatively high fire frequency in this forest type.

2.7.6 <u>Bush and grassland</u>

The bush and grassland occupy about 1 % of the park area. Most of the flora in this area is grass and bush and constitutes the grass *Imperata cylindrica,* and the bamboo *Bambusa glaucescens,* with scattered big trees such as *Careya sphaerica* and *Cratoxylum maingayi.*

Figure 2.6 Forestry map of Nam Nao National Park. After Aswachaicharn (1997).



2.8 SAMPLING SITE DESCRIPTIONS

Two second order streams were chosen for this study: Hin Lat stream and Ya Kraue stream.

2.8.1 <u>Hin Lat stream</u> (Figure 2.7)
Hin Lat stream was chosen with various reasons including the pristine nature of the stream, the undisturbed catchment, the variety of substrata present in the stream and its reasonable

accessibility. It is located about 25 km south-east of the head-quarters of the park and about 3 km walking from the Prom Song ranger station. Hin Lat stream is about 10 km long and is a tributary of the Prom river which flows to Chulaporn dam. Three sites were established along a 4 kilometer section of the stream.

2.8.1.1 Site Hin Lat 1 (Figure 2.8 – 2.12)
Grid Reference: 16° 33′ 22.9″ N latitude, 101° 33′ 25.9″ E longitude
Altitude: 850 metres asl
Substrate: mainly bedrock covered with boulders, cobbles, pebbles, gravel, sand and leafpack. some roots of big trees on the stream bank penetrate into the stream (Table 2.1).
Slope: Flat
Riparian Vegetation: mixed deciduous forest. Riparian canopy over 70 % and the predominant species are *Hopea ferrea, Ficus drupacea, Baccaurea parviflora.*
Aquatic Vegetation: *Fagraea* sp., *Lepidagathis dissimilis*
Geology: sandstone

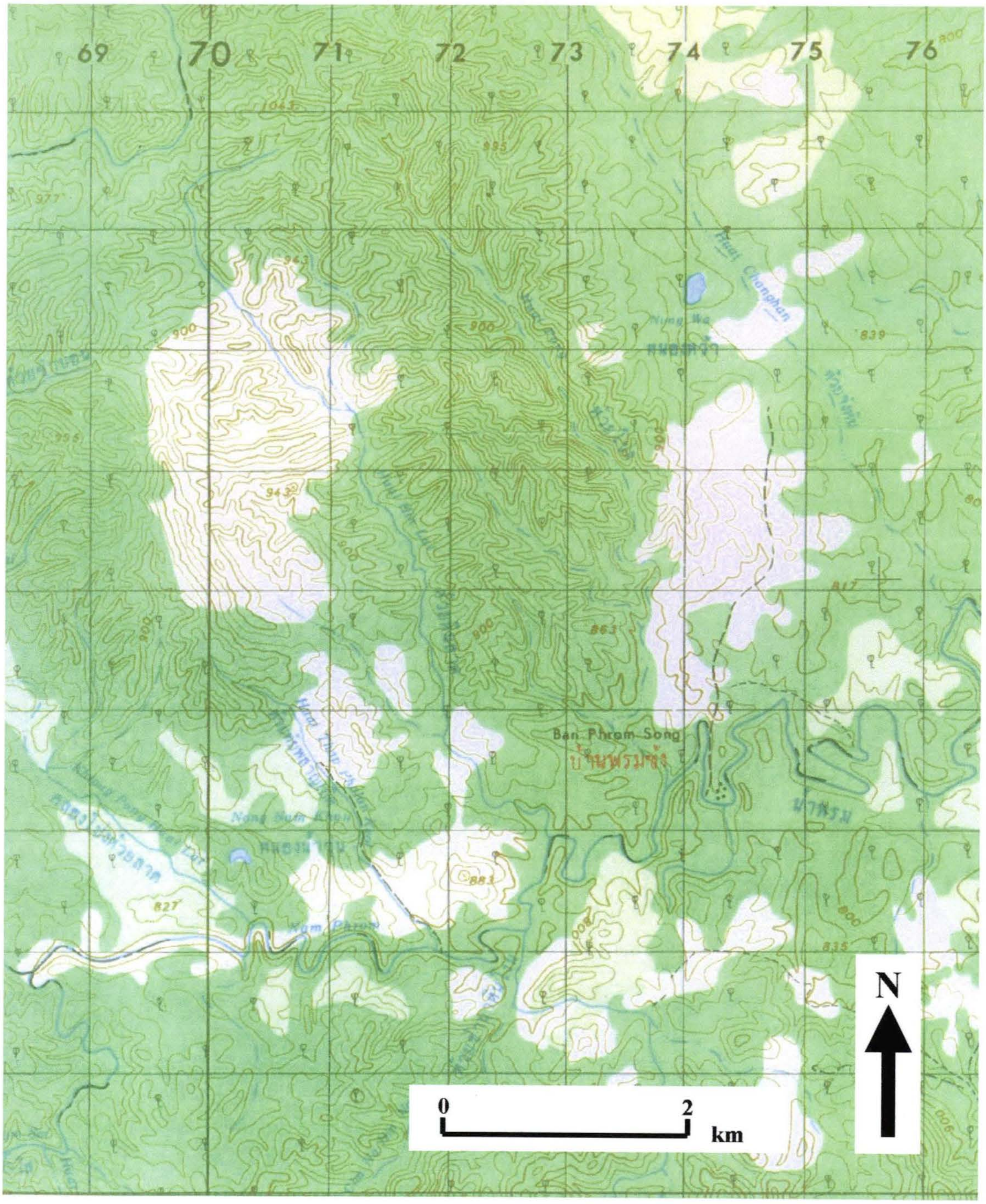
2.8.1.2 Site Hin Lat 2 (Figure 2.13 – 2.14)
Grid Reference: 16° 33′ 22.9″ N latitude, 101° 33′ 25.9″ E longitude
Altitude: 848 metres asl
Substrate: mainly cobbles and pebbles (Table 2.1)
Slope: Flat
Riparian Vegetation: mixed deciduous forest. *Hopea odorata, Hopea ferrea, Xylia* sp.
Aquatic Vegetation: *Lepidagathis dissimilis, Calamus godefroyi*
Geology: sandstone

2.8.1.3 Site Hin Lat 3 (Figure 2.15 – 2.16)
Grid Reference: 16° 33′ 22.8″ N latitude, 101° 33′ 25.8″ E longitude
Altitude: 810 metres asl
Substrate: mainly boulders (Table 2.1)
Slope: Flat
Riparian Vegetation: mixed deciduous forest. *Calamus godefroyi, Bambusa tulda, Bambusa arundinacea, Xylia* sp., *Hopea Ferrea, Ficus praetermissa, Arundinaria pusilla*
Geology: sandstone

Table 2.1 Percentage of substrate composition of study sites at Hin Lat stream, Nam Nao National Park, Thailand.

Site	Bedrock	Boulder	Cobble	Pebble	Gravel	Sand	Leaf pack	Root
Hin Lat 1	10	40	20	3	5	5	10	2
Hin Lat 2	3	10	40	15	10	10	10	2
Hin Lat 3	0	50	20	10	10	5	3	2

Figure 2.7 Map of Hin Lat stream, Nam Nao National Park, Thailand.



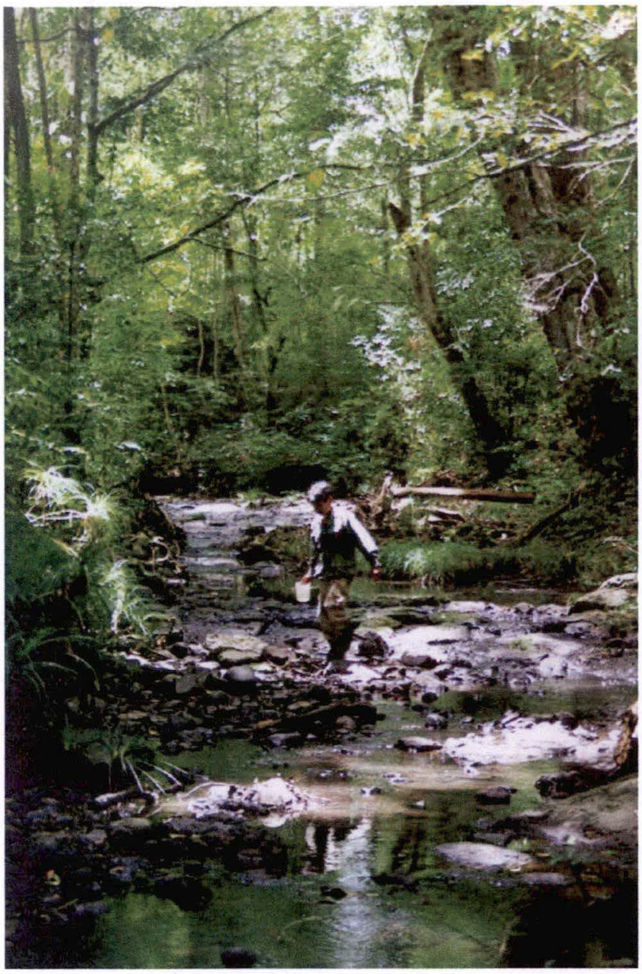


Figure 2.8 Site Hin Lat 1, showing riparian vegetation and substrata characteristics.

Figure 2.9 Site Hin Lat 1, showing substrates.

Figure 2.10 Site Hin Lat 1, showing substrates.

Figure 2.11 Site Hin Lat 1, showing leaf pack substrate.

Figure 2.12 Site Hin Lat 1, showing riparian vegetation: evergreen forest along the stream bank and mixed deciduos forest further the stream bank.

Figure.2.13 Site Hin Lat 2, showing substrates.

Figure 2.14 Site Hin Lat 2, showing substrates and riparian vegetation.

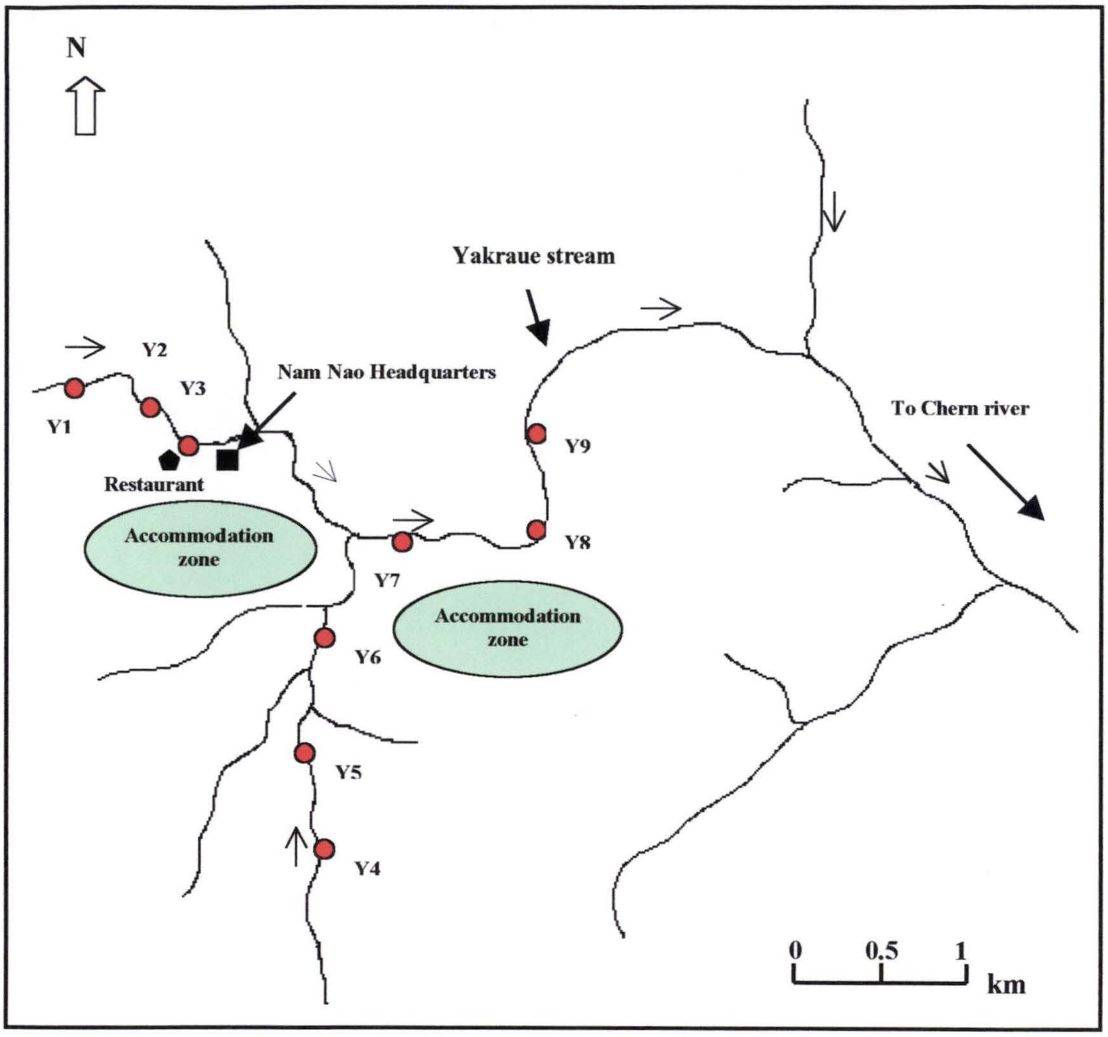
Figure 2.15 Site Hin Lat 3, showing substrates and some of aquatic and riparian

Figure 2.16 Site Hin Lat 3, showing substrates.

2.8.2 Yakraue stream

This stream was chosen because it consists of an upper and lower part in relation to tourism-related impacts. This stream is about 10 kilometres long and is a distributary of the Choen river which flows to the Pong and Chi rivers. Nine sites were established over about 4 kilometres, with 5 sites above the impact zone and 4 sites below the impact zone (Figure 2.17)

Figure 2.17 Map of Yakraue stream and sampling sites.



2.8.2.1 Site Yakraue 1 (Figure 2.18)
Grid Reference: 16° 44′ 11.8″ N latitude, 101° 34′ 65.5″ E longitude
Altitude: 860 metres asl
Substrate: mainly bedrock (Table 2.2)
Slope: Flat
Riparian Vegetation: coniferous forest. *Pinus kesiya, Elaeocarpus hygrophilus, Lithocarpus collettii, Bambusa tulda.*
Aquatic Vegetation: *Pentaspadon velutinus, Cephalanthus tetrandora, Selaginella* spp., *Pentaspadon velutinus*, morse
Geology: sandstone

2.8.2.2 Site Yakraue 2 (Figure 2.19)
Grid Reference: 16° 44′ 42.3″ N latitude, 101° 34′ 27.5″ E longitude
Altitude: 850 metres asl

Substrate: mainly bedrock and overlain by boulders, cobbles (Table 2.2)
Slope: Flat
Riparian Vegetation: mixed deciduos forest. Riparian canopy cover 70 % and the predominant species are *Diospyros montana*, *Hopea ferrea*, *Bambusa tulda*, *Thyrsostachys siamensis*.
Aquatic Vegetation: *Lepidagathis dissimilis*.
Geology: sandstone

2.8.2.3 Site Yakraue 3 (Figure 2.20 – 2.21)
Grid Reference: 16° 44′ 42.3″ N latitude, 101° 34′ 27.5″ E longitude
Altitude: 850 metres asl
Substrate: bedrock covered with cobbles, gravel and sand (Table 2.2)
Slope: Flat
Riparian Vegetation: the same as site Yakraue 2, mixed deciduos forest.
Aquatic Vegetation: the same as site Yakraue 2
Geology: sandstone

2.8.2.4 Site Yakraue 4 (Figure 2.22 – 2.23)
Grid Reference: 16° 44′ 10.6″ N latitude, 101° 34′ 65.1″ E longitude
Altitude: 850 metres asl
Substrate: mainly gravel and cobbles (Table 2.2)
Slope: Flat
Riparian Vegetation: Coniferous forest, *Acacia* sp., *Castanopsis tribuloides*, *Quercus lineata*, *Asytasia salicifolia*.
Aquatic Vegetation:
Geology: sandstone

2.8.2.5 Site Yakraue 5 (Figure 2.24 – 2.25)
Grid Reference: 16° 44′ 16.0″ N latitude, 101° 34′ 46.0″ E longitude
Altitude: 850 metres asl
Substrate: gravel, cobbles, pebbles and leaf pack (Table 2.2)
Slope: Flat
Riparian Vegetation: Coniferous forest, *Quercus lineata*, *Pinus* sp., *Spondias* sp., *Bambusa tulda*,
Aquatic Vegetation: *Cephalanthus tetrandora*, *Pentaspadon velutinus*, *Amomum xanthioides*, *Calamus godefroyi*, and palms.
Geology: sandstone

2.8.2.6 Site Yakraue 6 (Figure 2.26 – 2.28)
Grid Reference: 16° 44′ 21.2″ N latitude, 101° 34′ 44.9″ E longitude
Altitude: 840 metres asl
Substrate: bedrock, gravel, sand, pebbles and cobbles (Table 2.2)
Slope: Flat
Riparian Vegetation: Coniferous forest, *Quercus lineata*, *Pterocarpus* sp., *Castanopsis tribuloides*, *Bambusa tulda*, *Calophyllum inophyllum*, *Calamus rotang*,
Aquatic Vegetation: *Cephalanthus tetrandora*, *Pandanus capusii*, *Pentaspadon velutinus*, *Lasia spinosa*, *Calophyllum inophyllum*, and ferns
Geology: sandstone

2.8.2.7 Site Yakraue 7 (Figure 2.29 – 2.30)
Grid Reference: 16° 44′ 21.8″ N latitude, 101° 34′ 41.7″ E longitude
Altitude: 830 metres asl
Substrate: bedrock, boulders, cobbles, pebbles, gravel and sand (Table 2.2)
Slope: Flat
Riparian Vegetation: Evergreen forest, *Acacia* sp., *Nauclea orientalis*, *Quercus myrsinifolia*,

Fagraea fragrans, Ficus drupacea, Baccaurea parviflora, Urobotrya siamensis, Aphanamixis sp.
Aquatic Vegetation: *Cephalanthus tetrandora, Pandanus capusii, Calamus godefroyi, Pentaspadon velutinus, Pandanus kaida,* and morse.
Geology: sandstone

2.8.2.8 Site Yakraue 8 (Figure 2.31 – 2.32)
Grid Reference: 16° 44′ 39.2″ N latitude, 101° 34′ 74.5″ E longitude
Altitude: 820 metres asl
Substrate: mainly gravel and bedrock (Table 2.2)
Slope: Flat
Riparian Vegetation: Evergreen forest, *Lithocarpus collettii, Quercus myrsinifolia, Ficus drupacae, Thyrsostachy siamensis, Cephalostachyum virgatum*
Aquatic Vegetation: *Calamus godefroyi, Homonoia riparia, Litsea cubeba, Asystasiella neesiana*
Geology: sandstone

2.8.2.9 Site Yakraue 9 (Figure 2.33 – 2.34)
Grid Reference: 16° 44′ 38.6″ N latitude, 101° 34′ 74.0″ E longitude
Altitude: 820 metres asl
Substrate: mainly boulders and cobbles (Table 2.2)
Slope: Flat
Riparian Vegetation: Evergreen forest, *Eugenia aequea, Lithocarpus collettii, Thyrsostachy siamensis, Cephalostachyum virgatum, Holigarna helferi, Ficus montana,*
Aquatic Vegetation: morse, *Litsea cubeba, Homonoia riparia, Asystasiella neesiana*
Geology: sandstone

Table 2.2 Percentage of substrate composition of study sites at Yakraue stream, Nam Nao National Park, Thailand.

Site	Bedrock	Boulder	Cobble	Pebble	Gravel	sand	Leaf pack	Root
Yakraue 1	70	0	0	0	20	5	3	2
Yakraue 2	60	15	10	7	3	2	2	1
Yakraue 3	60	3	15	5	7	5	3	2
Yakraue 4	10	0	15	10	50	10	3	2
Yakraue 5	0	0	20	15	50	10	5	0
Yakraue 6	40	0	10	10	20	15	3	2
Yakraue 7	40	10	20	7	10	10	3	0
Yakraue 8	30	3	10	10	40	5	2	0
Yakraue 9	10	30	25	15	10	5	3	2

Figure 2.18 Site Yakraue 1, showing substrates and riparian vegetation.

Figure 2.19 Site Yakraue 2, showing substrates and riparian vegetation.

Figure 2.20 Site Yakraue 3, showing aquatic and riparian vegetation.

Figure 2.21 Site Yakraue 3, showing the pointsource of wastewater from Nam Nao cafeteria just immediately above this site.

Figure 2.22 Site Yakraue 4, showing riparian vegetation.

Figure 2.23 Site Yakraue 4, showing substrates.

Figure 2.24 Site Yakraue 5, showing riparian vegetation.

Figure 2.25 Site Yakraue 5, showing substrates.

Figure 2.27 Site Yakraue 6, showing

Figure 2.26 Site Yakraue 6, showing riparian

Figure 2.28 Site Yakraue 6, showing riparian vegetation.

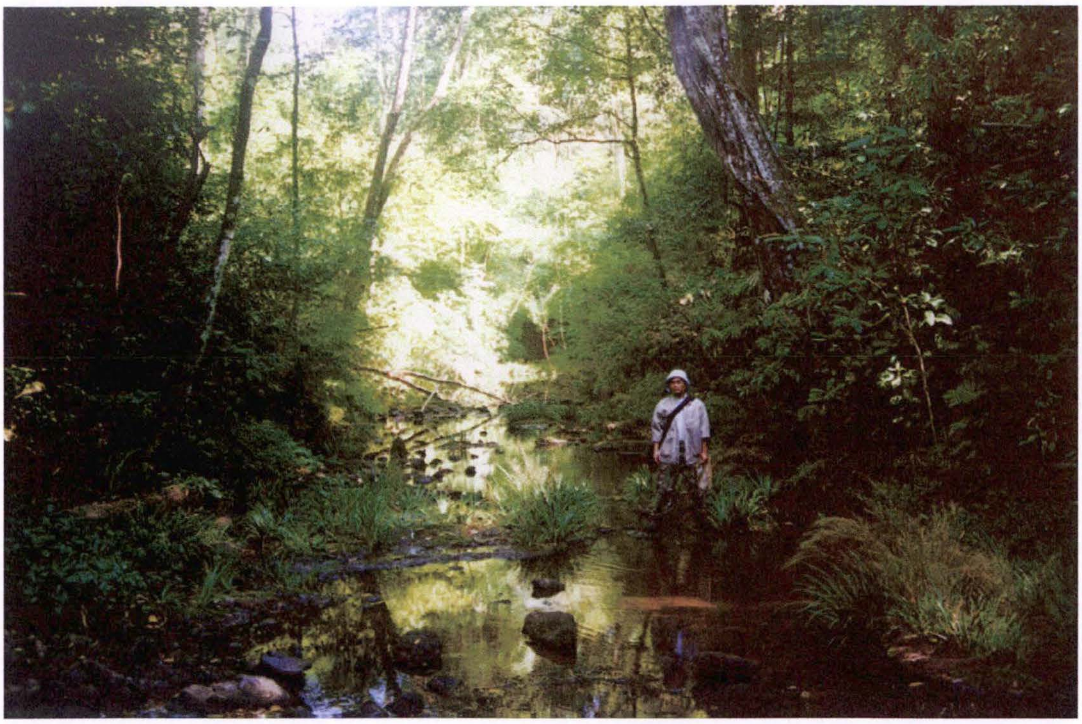


Figure 2.29 Site Yakraue 7, showing aquatic and riparian vegetation.

Figure 2.30 Site Yakraue 7, showing substrates.

Figure 2.31 Site Yakraue 8, showing substrates.

Figure 2.32 Site Yakraue 8, showing riparian vegetation.

Figure 2.33 Site Yakraue 9, showing some substrates and riparian vegetation.

Figure 2.34 Site Yakraue 9, showing some substrates.

2.9 SAMPLING TIMES

There were 6 sampling occasions in 1998, approximately two months apart:
In February, April, June, August, October, and December.

2.10 ENVIRONMENTAL VARIABLES

Physicochemical parameters of the streams at each sampling site were recorded at the same time as the biological sampling schedule. These parameters included:

Stream depth and *stream width* measurement used a metre rule and a measuring tape.
The *site elevation* and *grid references* measurement used a barometer and a Global Positioning System-GPS, Model Ensign XL.

The *current velocity* at the first to fifth sampling times was estimated by timing how long a floating stick took to travel over a metre distance. At the sixth sampling occasion, flow rate in the middle of the streams was measured by a Genuine Gurley Current Meter Model D625,.

pH was determined with a pH pen.
Dissolved Oxygen and *water temperature* were measured by a Dissolved Oxygen Metre YSI Model 57.
Air Temperature was measured in degrees Celsius in the shade by a mercury thermometer.
Electric Conductivity and *Total Dissolved Solid (TDS)* were measured by a Traceable™ Conductivity Meter Model 4062.
The substrate was recorded as a percentage of particle size categories: bedrock, boulder (>25 cm), cobble (6-24 cm), pebble (2-5 cm), gravel, sand, leaf pack and roots.

2.11 MACROINVERTEBRATE SAMPLING

Ten replicates in the first sampling, and thereafter 6 replicates, of aquatic macroinvertebrates were taken using a Wildco® Surber Stream Bottom Sampler (0.30 x 0.30 m with 500 μm mesh aperture) over approximately a 30 metres stretch of the stream. Six replicates were found to be adequate to detect significant differences between substrates. The collected samples were contained in plastic bags and then preserved with 70 percent ethyl alcohol and kept in ice boxes. Each sampling cycle took about 5 days. After returning to the Freshwater Laboratory at Khon Kaen University, all samples were sorted and stored in vials of 70 percent ethyl alcohol. The aquatic macroinvertebrate orders Ephemeroptera, Plecoptera and Trichoptera (the EPT taxa) were chosen for this study and identified to family level using keys in An Introduction to the Aquatic Insects of North America (Meritt and Cummins, 1996), Aquatic Insects of China Useful for Monitoring Water Quality (Yang, Morse and Tian, 1994), Revision of the Classification of the Eastern Hemisphere Leptophlebiidae (Ephemeroptera) (Peters and Edmunds, 1970), A Preliminary Picture Atlas for the Identification of Trichoptera of Thailand (Malicky, 1997) and Taxonomic and Biological Studies on Caddis Flies (Trichoptera: Insecta) from Peninsular Malaysia (Ismail, 1992).

2.12 STUDY DESIGN

In order to answer the 3 research questions posed earlier, the study was designed as follows:

1. Hin Lat stream was chosen for the substrate preference study. Three sites were selected: Hin Lat 1, Hin Lat 2 and Hin Lat 3. Aquatic macroinvertebrates were quantitatively collected from these sites from various substrate types which included boulder, cobble, pebble, gravel, sand, root and leaf pack. This effectively had the design of a stratified random sample, with substrates representing the strata. Analysis for substrate preferences by each EPT family was by both univariate and multivariate approaches. Samples for this study were taken on 3 occasions: in February, August and October. Separate to the substrate preference study, macroinvertebrate samples were also collected from these sites in April, June and December in order to examine community changes through time.

2. Benthic macroinvertebrates were quantitatively collected from different elements of the stream system, notably pools, riffles and runs, from both Hin Lat stream at between site Hin Lat 1 and 2 (on 1 occasion), and from Yakraue stream at sites Yakraue 7 (1 occasion) and site Yakraue 9 (4 occasions). These samples were analysed using ANOVA for any evidence of differences in the EPT taxa inhabiting the different elements of the stream.

3. For the purpose of establishing a baseline dataset for a stream likely to have increasing tourism development pressure, a longitudinal study of EPT distribution was initiated in Yakraue stream. Nine sites were selected along the stream: Yakraue1-9. At most sites, six replicate samples of benthic macroinvertebrates were collected every 2 months from these sites and analysed for patterns of taxon distribution through time and space. Although this design cannot unequivocally determine the existing impacts of low level tourism on the aquatic ecosystem, the data will be useful to evaluate these impacts in this stream subsequently. An ideal BACI (Before-After-Control-Impact) design (Cooper & Barmuta 1993) is not possible given the pre-existing nature of the restaurant facility. Therefore, two "control" sections of stream (upstream of the facility and a similar nearby tributary) were sampled at multiple sites and times as a next best option. These should give a reasonable idea of any unimpacted background fauna.

2.13 DATA ANALYSIS

Univariate statistics were used for summarising water quality, benthic community structure, individuals and species variations. Data was checked for its conformity with assumptions needed to satisfy parametric tests and these were applied where appropriate. Transformations of data which were not normally distributed or lacked independence of variances was often unsuccessful, so non-parametric tests were applied to such data. SigmaStat software was employed for these purposes (Jandel Corporation, 1992-1994).

In order to compare benthic communities between sites and seasons, or combinations of the two, multivariate methods were generally employed. Various modules within the PATN ecological analysis software package (Belbin, 1995) were used. UPGMA cluster analysis was used to compare benthic assemblages in various biotopes, and in pool, riffle and run sections of streams. The Kruskal-Wallis test was used to determine species, which are significant discriminators. A classification method, TWINSPAN (Two-Way Indicator Species Analysis, (Hill, 1979)), was useful in detecting groups of sites, which shared similar assemblages. It also determines indicator taxa, which are especially influential in determining the makeup of the groups.

An ordination method, multidimensional scaling, allowed the faunal relationships between sites to be readily summarised in a biplot. Taxa that are highly correlated with the ordination can be plotted as vectors in the same ordination space to facilitate interpretation of the patterns generated. The significance of these correlation was determined by a Monte Carlo method (option MCAO in the PATN program). It was found that a 3 dimensional solution generally reduced stress to an acceptable figure (below 0.15) so that good confidence could be had in the results.

3. RESULTS

3.1 ENVIRONMENTAL VARIABLES

In order to describe the aquatic environment at each sampling site from which benthic macroinvertebrate samples were collected, basic physico-chemical parameters were measured. This enabled the consideration of their potential influence on the macroinvertebrate communities. The measured parameters included current velocity, stream depth, stream width, water temperature, air temperature, pH, total dissolved solid (TDS), conductivity and dissolved oxygen (DO).

The results of measured parameters of each site and stream are described separately as follow:

3.1.1 Hin Lat stream

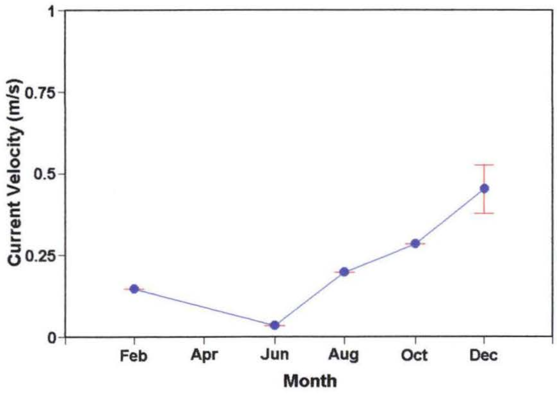
3.1.1.1 Current Velocity

There was a strong seasonal change in the current velocity at all sites measured (Figure 3.1). This trend in current velocity was similar at all sites within streams also. It declined gradually through the hot, dry season, reaching the lowest peak at about 0.04 m/s by the wet season month of June, but rapidly increased during the wet season to reach an annual maximum of about 0.5 m/s during the cool, dry season in December.

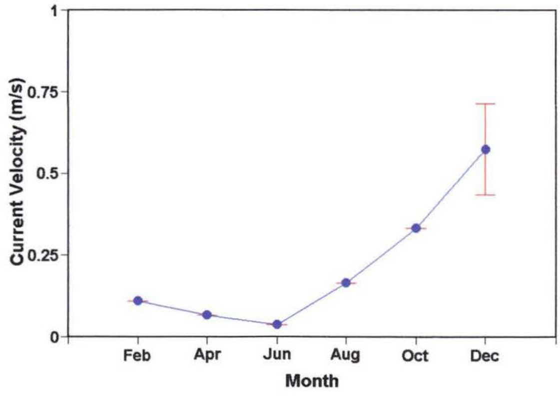
There was not significant difference of current velocity among sampling sites within Hin Lat stream.

Figure 3.1 Current velocity (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in current velocity at Hin Lat stream. Current velocity was measured by a floating stick in February-October, but with a meter in December.

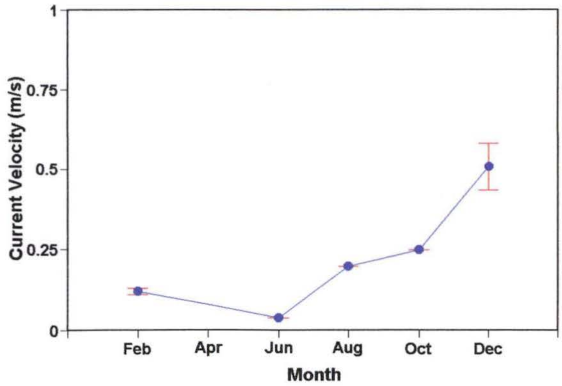
(a) Site Hin Lat 1



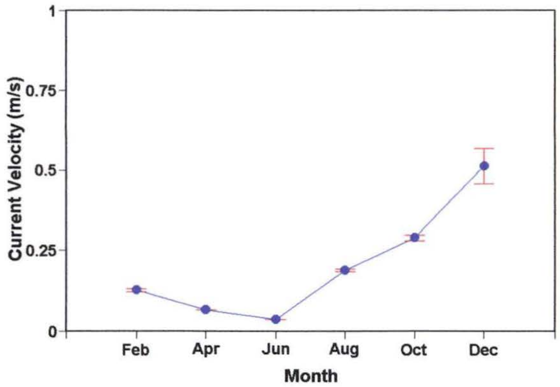
(b) Site Hin Lat 2



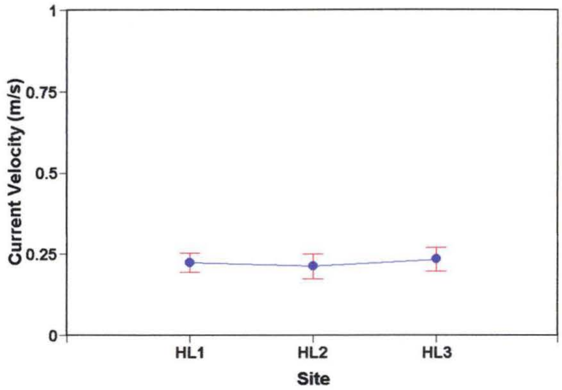
(c) Site Hin Lat 3



(d) Current velocity all year round at Hin Lat stream



(e) Longitudinal current velocity changes at Hin Lat stream



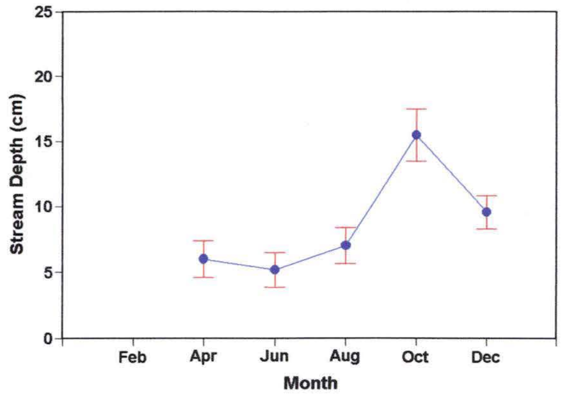
3.1.1.2 Stream Depth

There was a clear seasonal change in stream depth at site Hin Lat 1 and Hin Lat 3 but not much changes at site Hin Lat 2 (Figure 3.2). This may be because substrata of site Hin lat 2 is constantly flat. However, all sites still show the same trend in water depth. It declined gradually through the hot, dry season, reaching about 5 cm by the wet season month of June, but slowly increased during the wet season to reach an annual maximum of about 10-15 cm in August and October. During the cool, dry season of December, the stream depth slowly dropped to the minimum peak again.

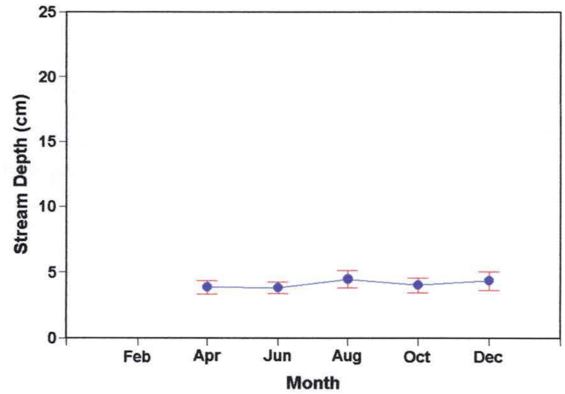
The mean all year round depth at Hin lat stream sampling sites, site Hin Lat 1 was the deepest site with about 10 cm , whereas, site Hin Lat 2 was the shallowest site with about 5 cm in depth.

Figure 3.2 Stream depth (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in stream depth at Hin Lat stream.

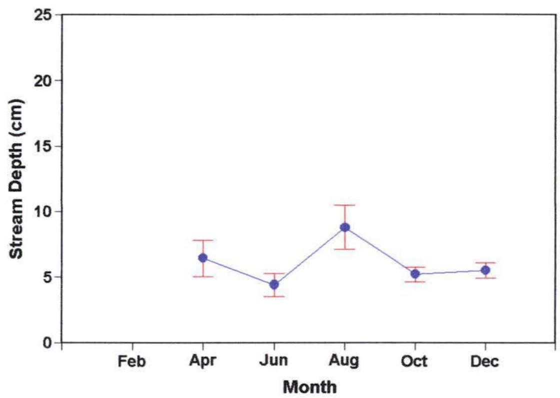
(a) Site Hin Lat 1



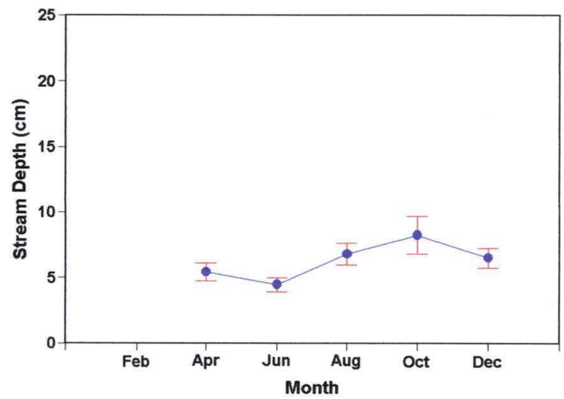
(b) Site Hin Lat 2



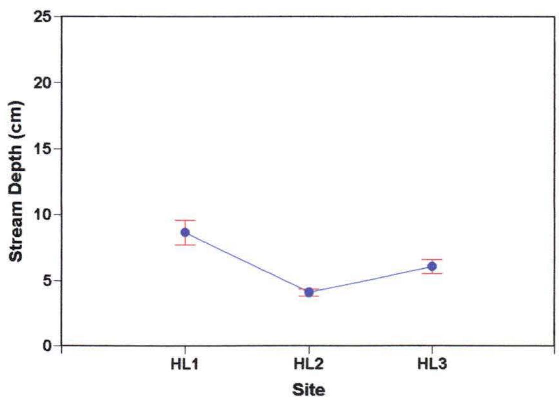
(c) Site Hin Lat 3



(d) Stream depth all year round at Hin Lat stream



(e) Longitudinal changes of stream depth at Hin Lat stream

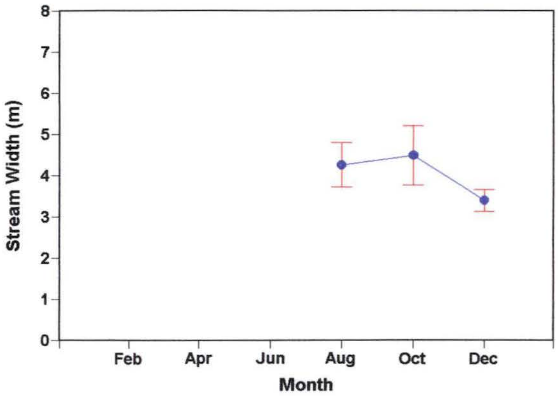


3.1.1.3 Stream Width

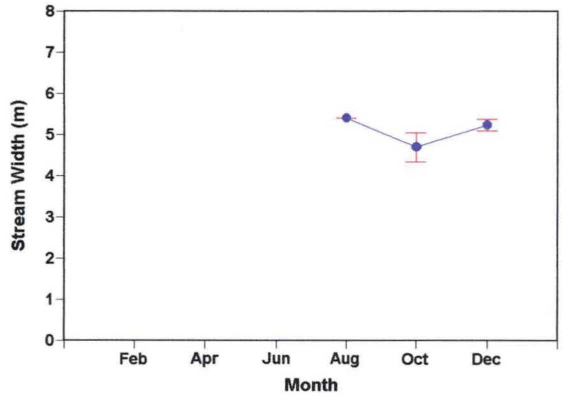
There was not a clear change in stream width at each site during this study in August, October and December (Figure 3.3), although stream width was not measured in February, April and June. However, the mean width at each site from all month data shows that the upper stream sites were narrower than the lower stream sites.

Figure 3.3 Stream width (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in stream width at Hin Lat stream.

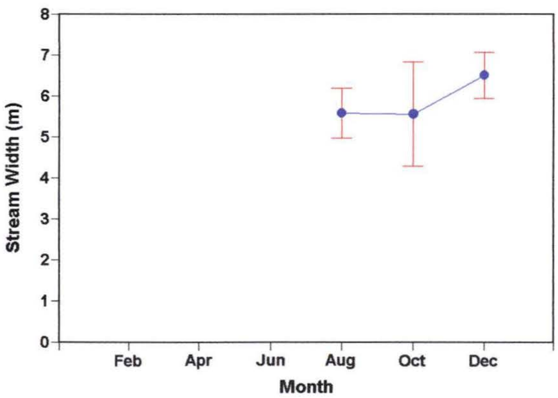
(a) Site Hin Lat 1



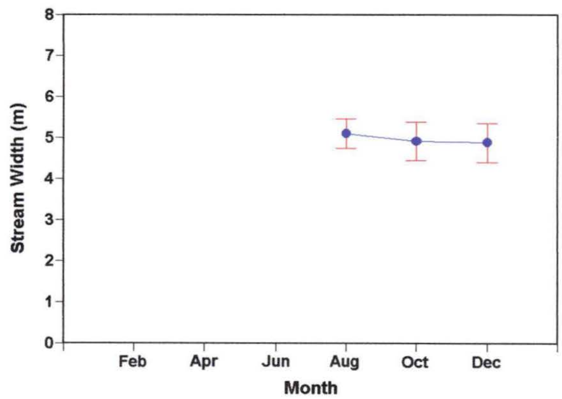
(b) Site Hin Lat 2



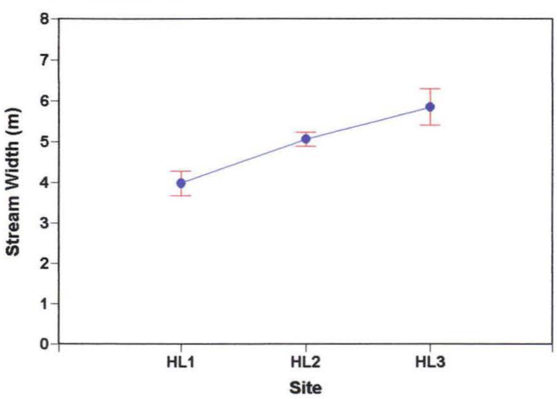
(c) Site Hin Lat 3



(d) Stream width all year round at Hin Lat stream



(e) Longitudinal stream width changes at Hin Lat stream

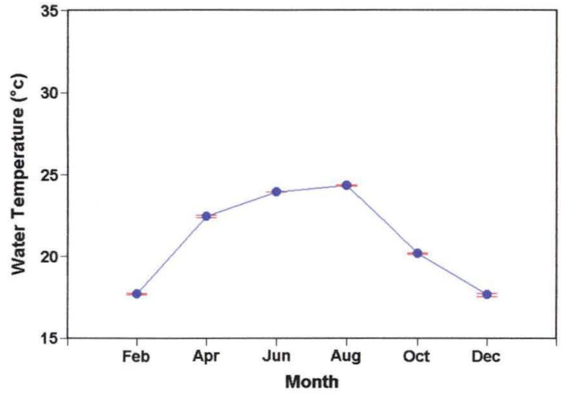


3.1.1.4 Water Temperature

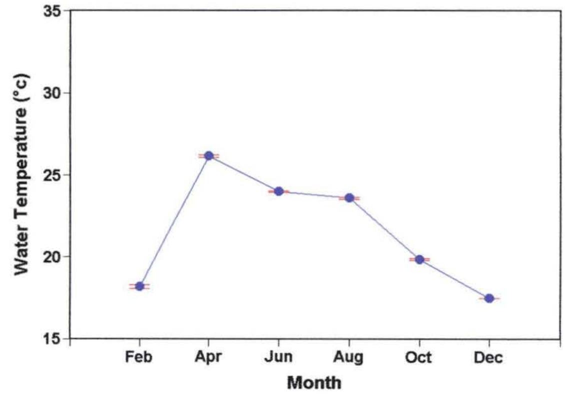
There was a strong seasonal change in the water temperature of the streams at all sites measured (Figure 3.4). This trend in water temperature was similar at all sites within streams also. Water temperature increased gradually through the hot dry and the wet season, reaching the maximum range about 24 °C and 26 °C, but gradually declined during the end of the wet season to reach the annual minimum of about 17 °C in the cool, dry season.

Figure 3.4 Water temperature (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in water temperature at Hin Lat stream.

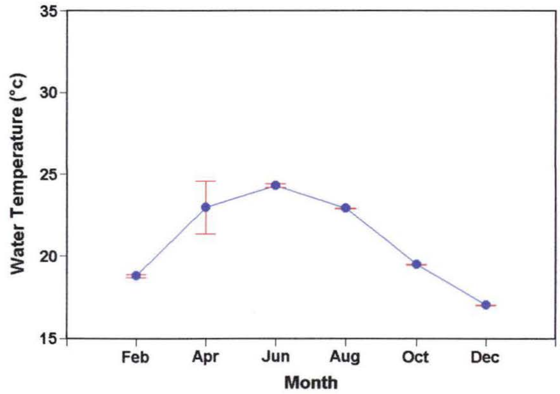
(a) Site Hin Lat 1



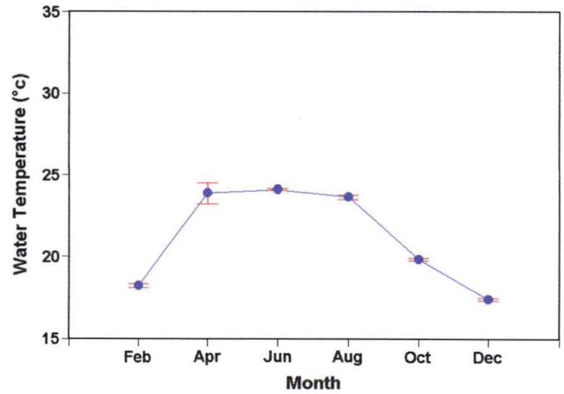
(b) Site Hin Lat 2



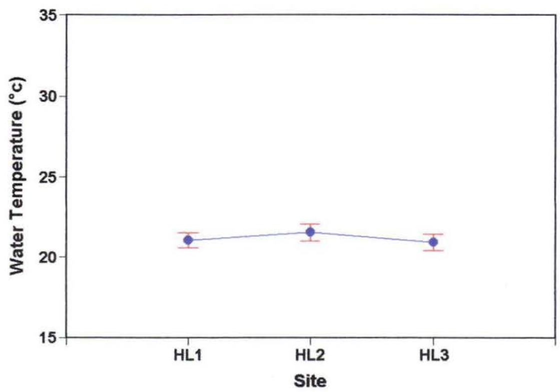
(c) Site Hin Lat 3



(d) Water temperature all year round at Hin Lat stream



(e) Longitudinal water temperature changes at Hin Lat stream

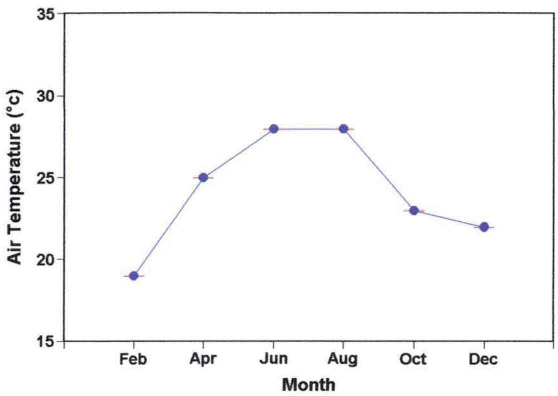


3.1.1.5 Air Temperature

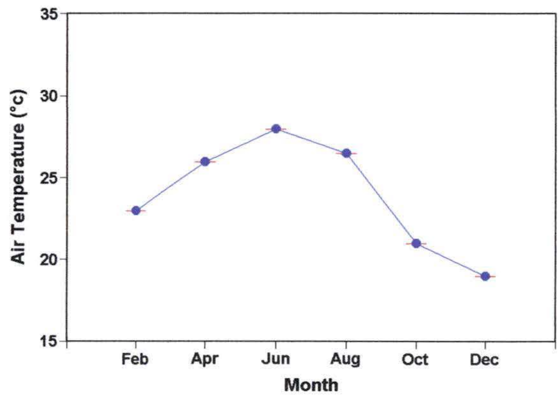
Air temperature had the same trend as water temperature. There was a strong seasonal change in air temperature of the streams at all sites measured (Figure 3.5). This trend was similar at all sites within streams also. Air temperature increased gradually through the hot dry and the wet season, reaching the annual maximum range about 28 °C and 30 °C during June and August, but significantly decreased during the end of the wet season to reach the annual minimum range between 17 °C and 22 °C in the cool, dry season.

Figure 3.5 Air temperature (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in air temperature at Hin Lat stream.

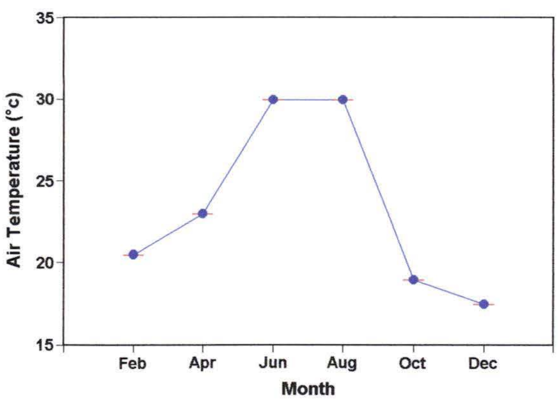
(a) Site Hin Lat 1



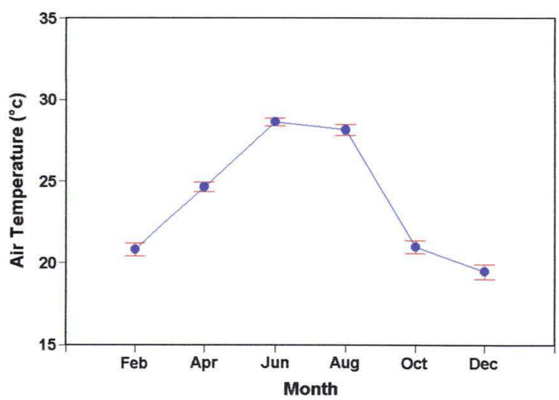
(b) Site Hin Lat 2



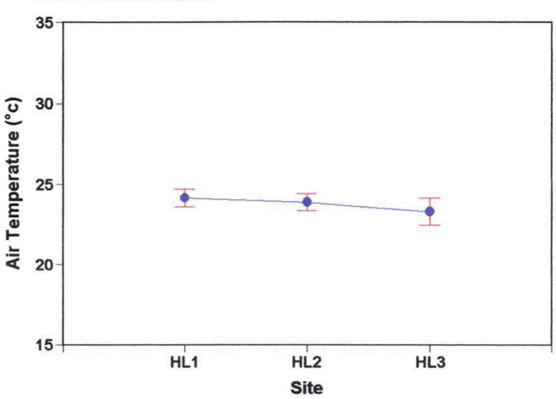
(c) Site Hin Lat 3



(d) Air temperature all year round at Hin Lat stream



(e) Longitudinal air temperature changes at Hin Lat stream

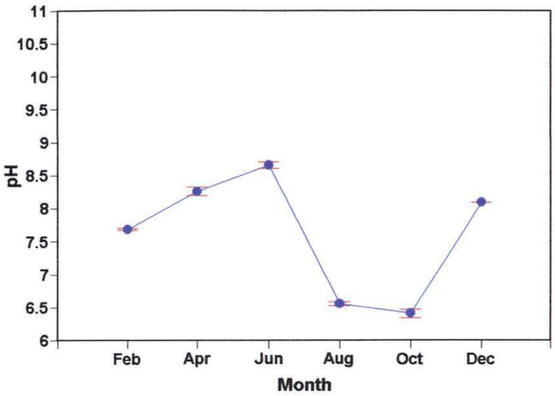


3.1.1.6 pH

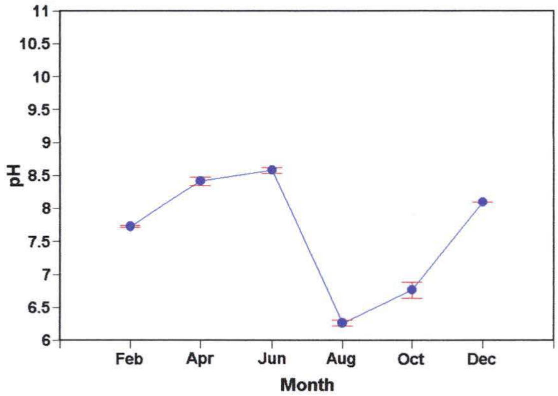
There was a strong seasonal change in pH of the streams at all sites measured (Figure 3.6). This trend in pH was similar at all sites within streams also. The pH rose gradually through the dry season, reaching about 8.5, but rapidly declined to around 6.3 following the onset of the wet season. By October the pH is rising again to reach above 7.5 in December.

Figure 3.6 pH (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in pH at Hin Lat stream.

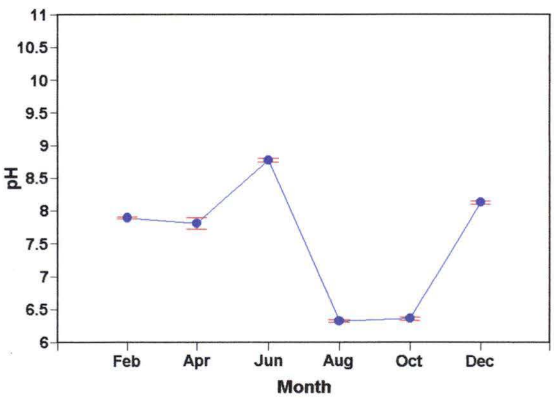
(a) Site Hin Lat 1



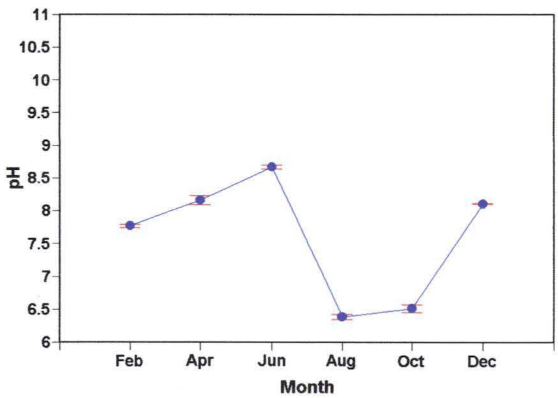
(b) Site Hin Lat 2



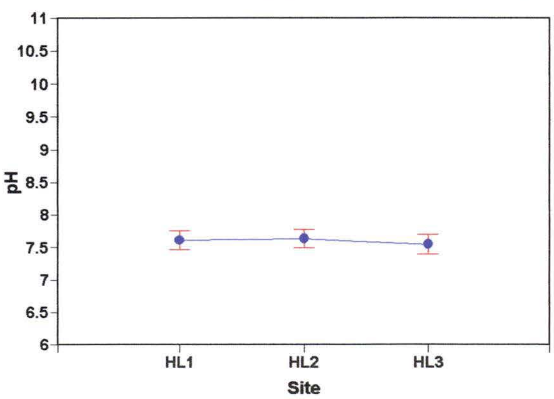
(c) Site Hin Lat 3



(d) pH all year round at Hin Lat stream



(e) Longitudinal pH changes at Hin Lat stream

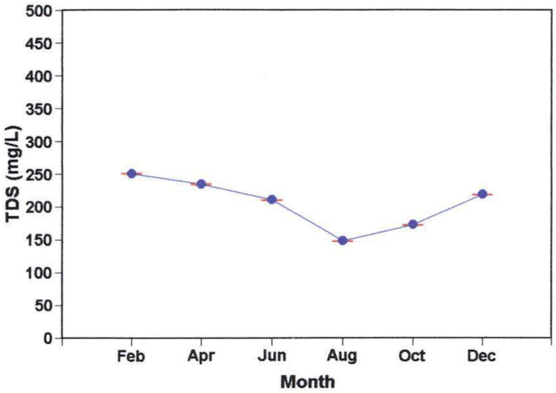


3.1.1.7 Total Dissolved Solid (TDS)

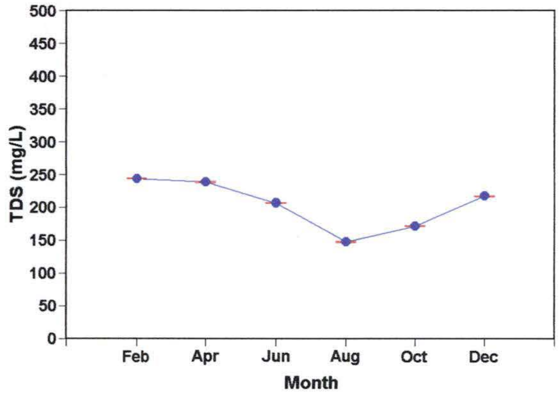
There was a strong seasonal change in TDS at all sites measured (Figure 3.7). This trend in TDS was similar at all sites within streams also. It declined gradually through the hot, dry season, reaching the range 140-160 mg/L by the wet season month of August, but rapidly increased to reach an annual maximum of about 250 mg/L during the cool, dry season.

Figure 3.7 TDS (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in TDS at Hin Lat stream.

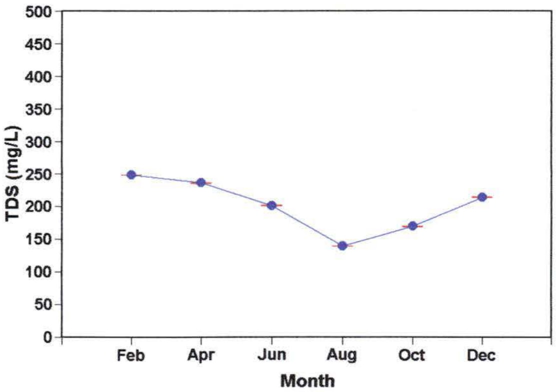
Site Hin Lat 1



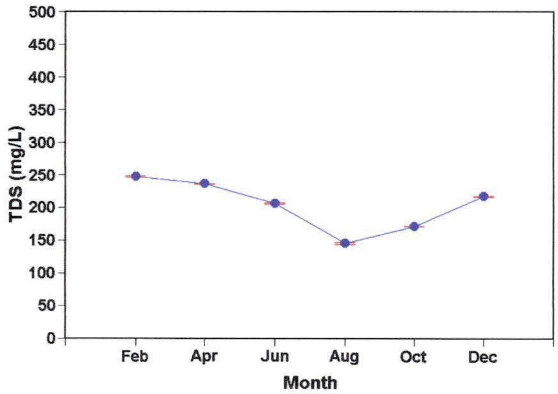
Site Hin Lat 2



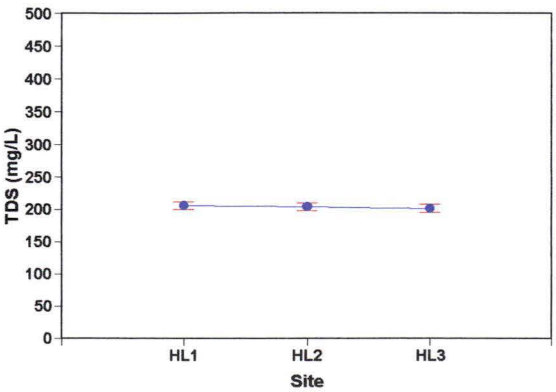
(c)Site Hin Lat 3



(d) TDS all year round at Hin Lat stream



(e) Longitudinal TDS changes at Hin Lat stream



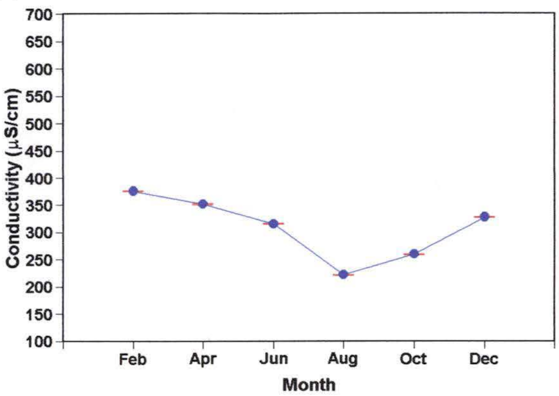
3.1.1.8 Electrical Conductivity (EC)

There was a strong seasonal change in electrical conductivity at all sites measured (Figure 3.8). This trend in conductivity was similar at all sites within streams also. It declined gradually through the hot, dry season, reaching the range 210-223 µS/cm by the wet season month of August, but rapidly increased to reach an annual maximum of about 322 µS/cm during the cool, dry season of December.

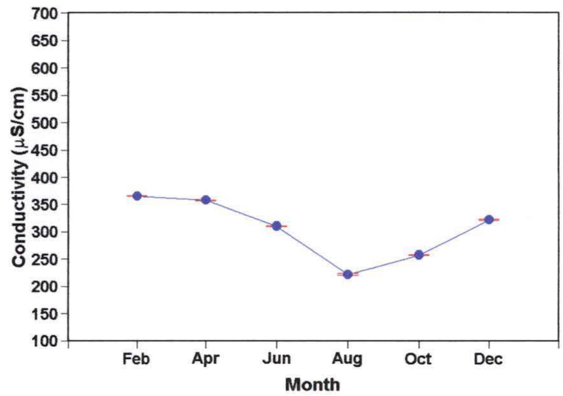
There was no significant difference in the conductivity among sites within the stream.

Figure 3.8 Electrical conductivity (mean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in conductivity at Hin Lat stream.

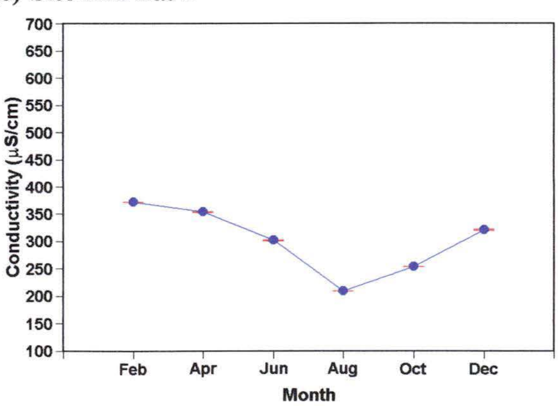
(a) Site Hin Lat 1



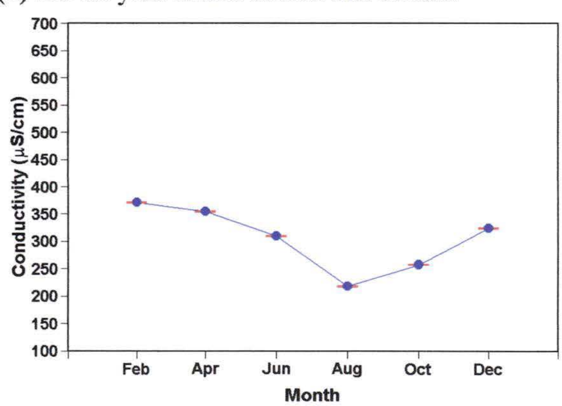
(b) Site Hin Lat 2



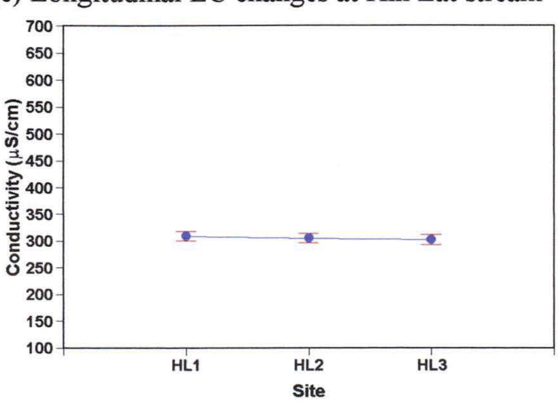
(c) Site Hin Lat 3



(d) EC all year round at Hin Lat stream



(e) Longitudinal EC changes at Hin Lat stream



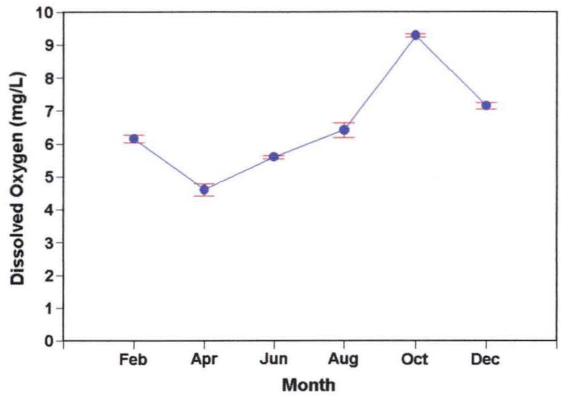
3.1.1.9 Dissolved Oxygen (DO)

There was a strong seasonal change in the dissolved oxygen at all sites measured (Figure 3.9). This trend was similar at all sites within streams also. It declined gradually through the hot, dry season, reaching the range 4.0-4.6 mg/L by the hottest month of April, then gradually increased through the wet season to reach an annual maximum of about 9.3 mg/L in October. By the end of the wet season, DO was dropping again to reach above 7.1-7.8 mg/L at the beginning of the cool, dry season of December.

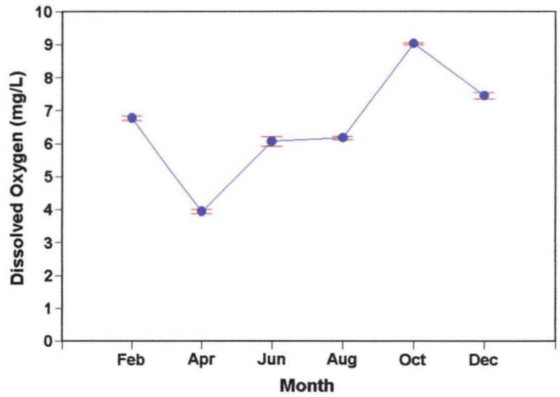
There was not significant difference in DO among sites within the stream sites.

Figure 3.9 Dissolved oxygen (nean ± S.E.) in each sampling month at Hin Lat stream, 1998: a. Site Hin Lat 1, b. Site Hin Lat 2, c. Site Hin Lat 3, d. Hin Lat stream (combined data of the 3 sites), and e. Longitudinal variability in DO at Hin Lat stream.

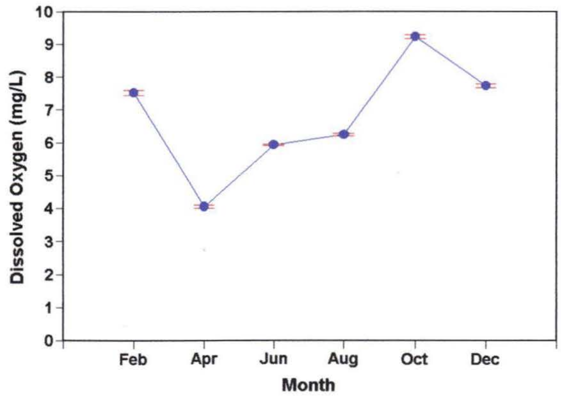
(a) Site Hin Lat 1



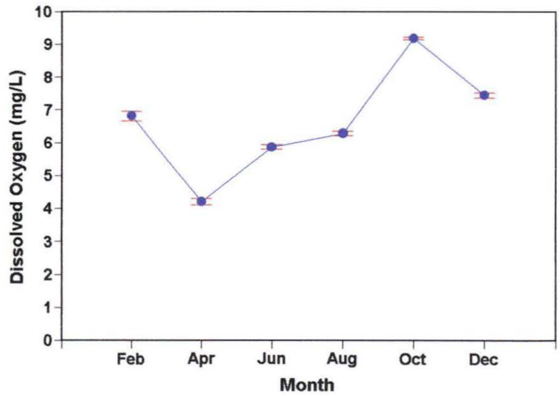
(b) Site Hin Lat 2



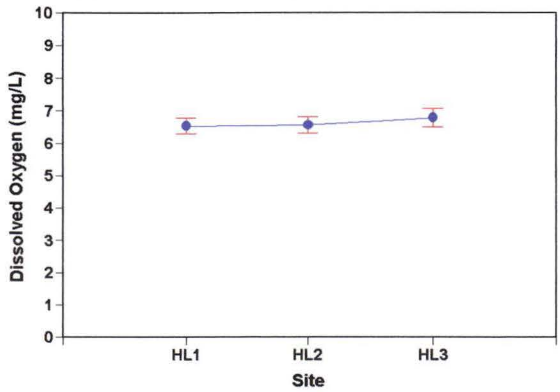
(c) Site Hin Lat 3



(d) DO all year round at Hin Lat stream



(e) Longitudinal DO changes at Hin Lat stream



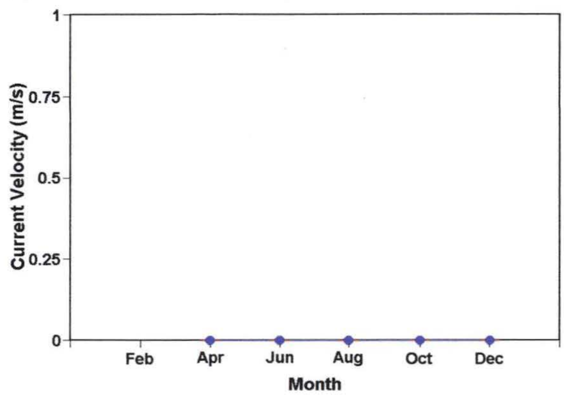
3.1.2 Yakraue Stream

3.1.2.1 Current velocity

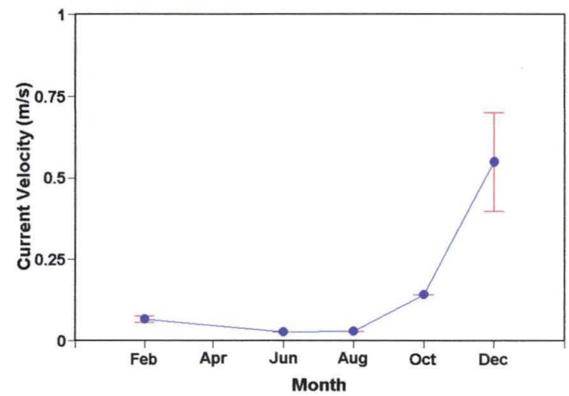
There was a slightly seasonal change in the current velocity at all sites measured (Figure 3.10). This trend was mostly similar at all sites within streams also. It declined gradually through the beginning of the wet season, reaching the lowest peak at about 0.02-0.05 m/s in June, but gradually increased during the wet season to reach an annual maximum of about 0.5 m/s during the cool, dry season in December.

Figure 3.10 Current velocity (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in current velocity at Yakraue stream. Current velocity was measured by a floating stick in February-October, but with a meter in December.

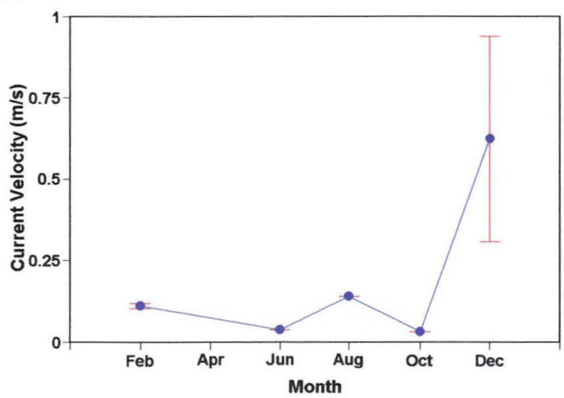
(a) Site Yakraue 1



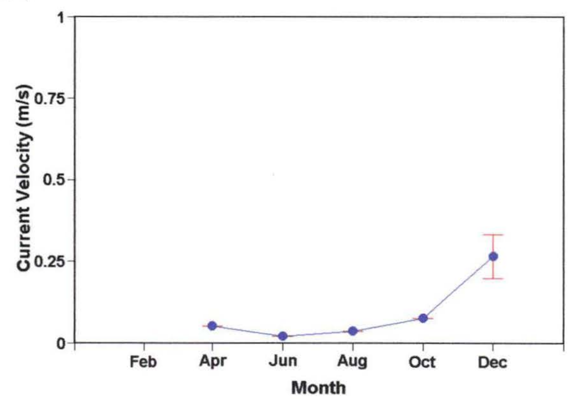
(b) Site Yakraue 2



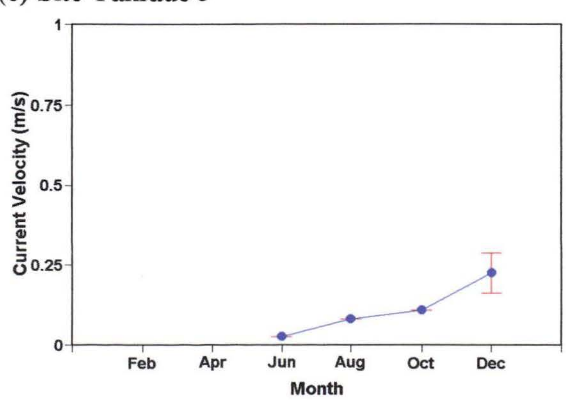
(c) Site Yakraue 3



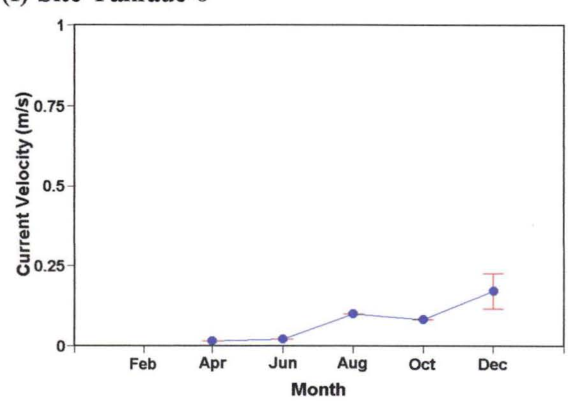
(d) Site Yakraue 4



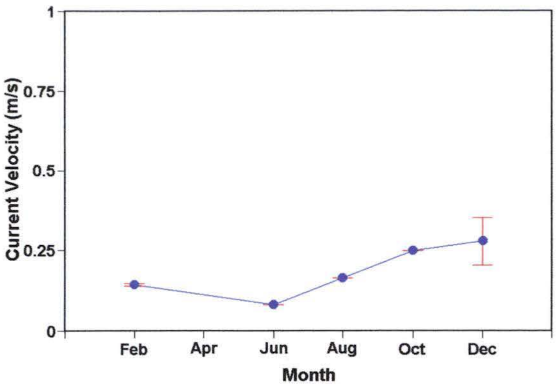
(e) Site Yakraue 5



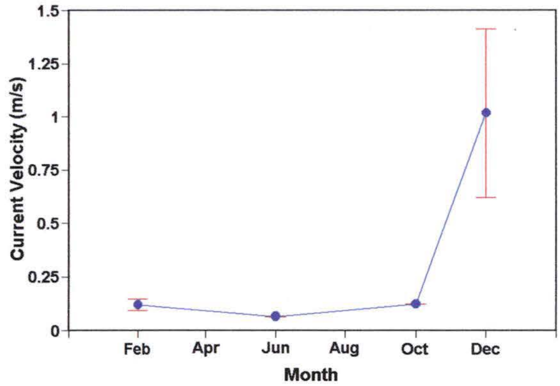
(f) Site Yakraue 6



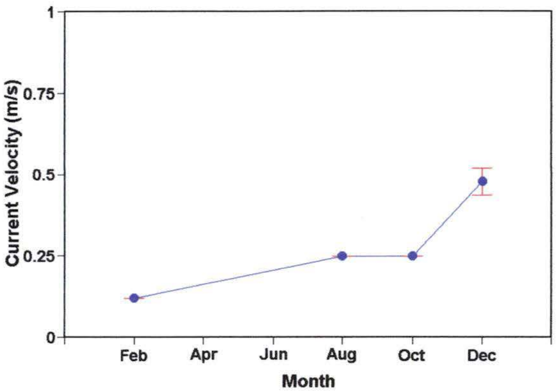
(g) Site Yakraue 7



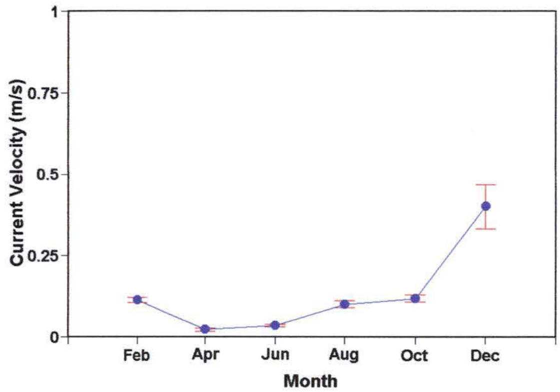
(h) Site Yakraue 8



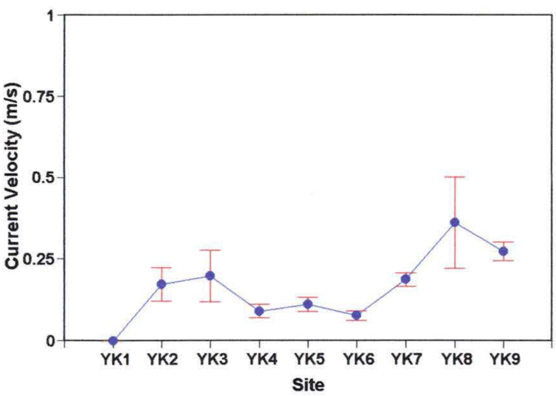
(i) Site Yakraue 9



(j) Current velocity all year round at Yakraue stream



(k) Longitudinal current velocity changes at Yakraue stream

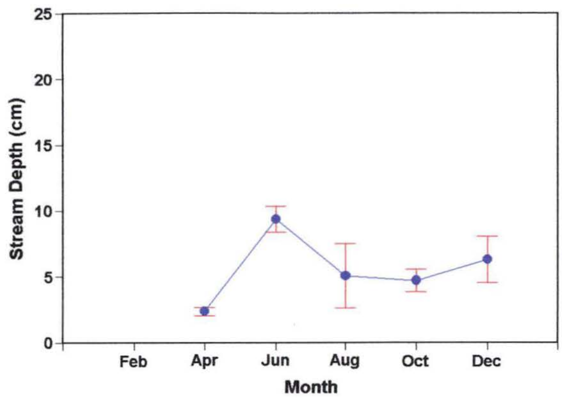


3.1.2.2 Stream Depth

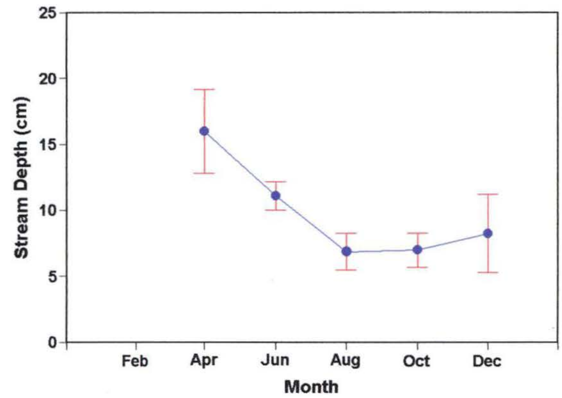
There was not a clear trend in stream depth at Yakraue stream (Figure 3.11). The mean stream depth varied between 2 and 15 cm all year round.

Figure 3.11 Stream depth (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in stream depth at Yakraue stream.

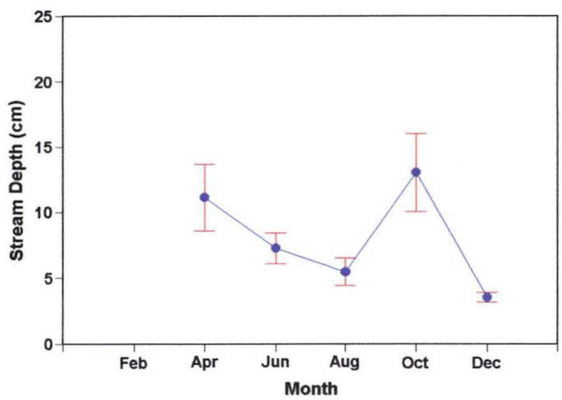
(a) Site Yakraue 1



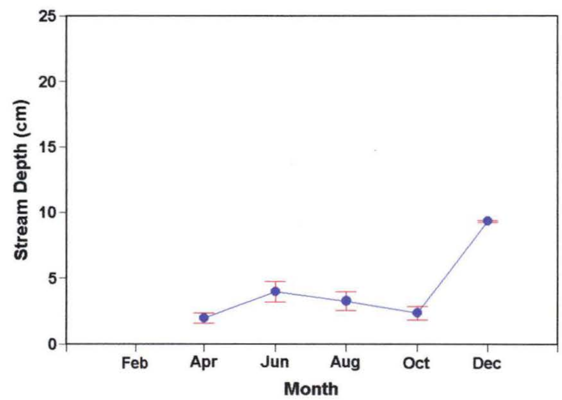
(b) Site Yakraue 2



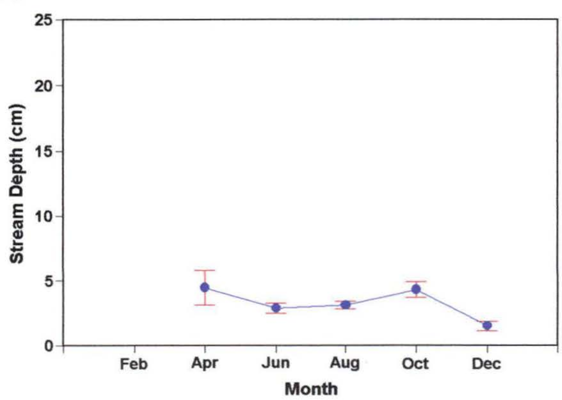
(c) Site Yakraue 3



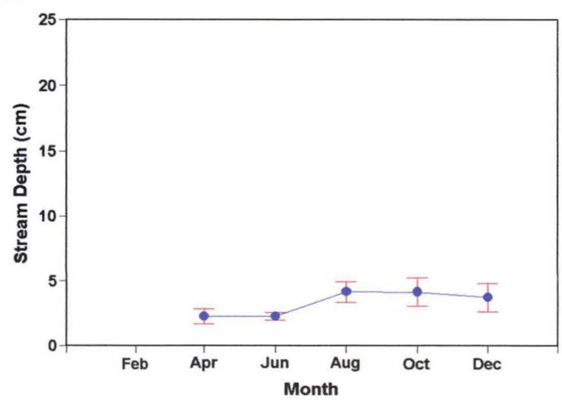
(d) Site Yakraue 4



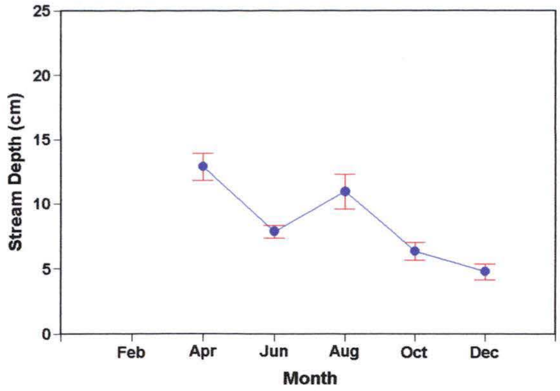
(e) Site Yakraue 5



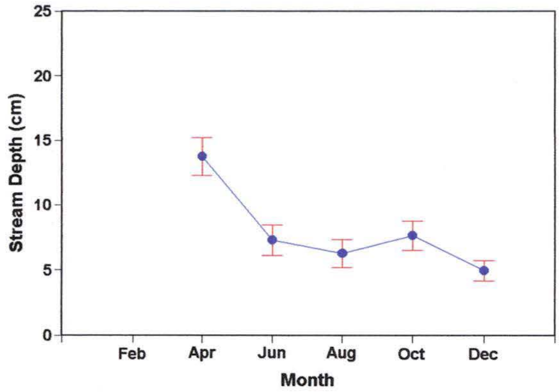
(f) Site Yakraue 6



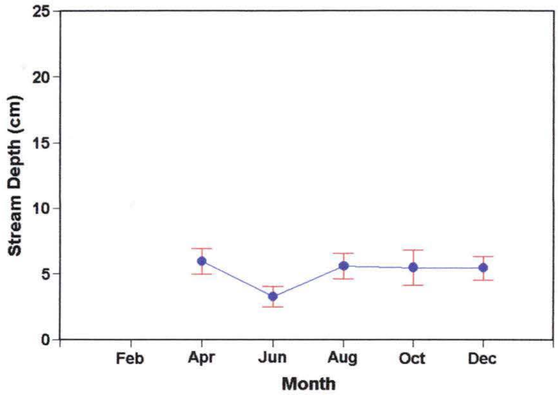
(g) Site Yakraue 7



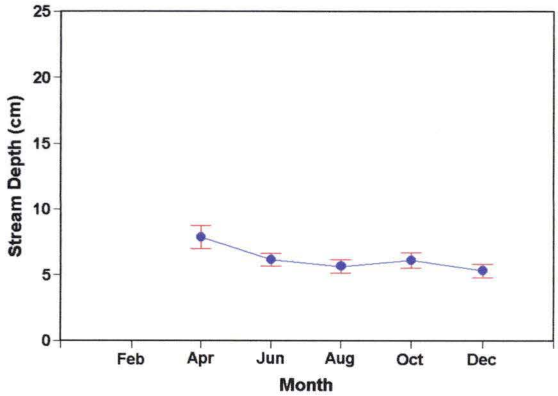
(h) Site Yakraue 8



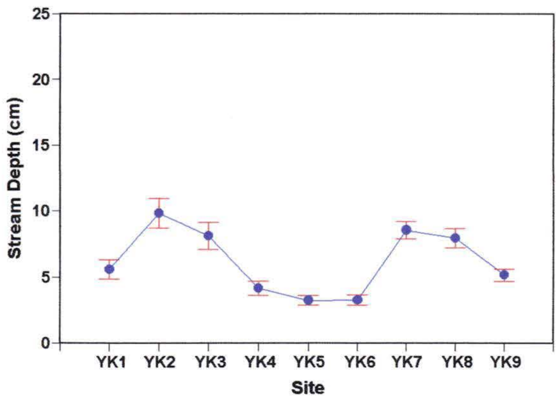
(i) Site Yakraue 9



(j) Stream depth all year round at Yakraue stream



(k) Longitudinal stream depth changes at Yakraue stream



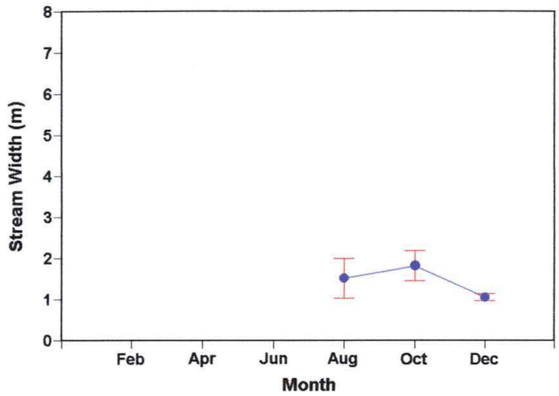
3.1.2.3 Stream Width

There was not a clear change in stream width at each site during this study in August, October and December, although stream width was not measured in February, April and June (Figure 3.12).

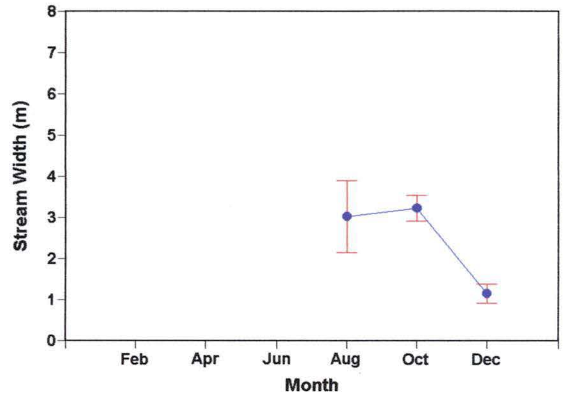
However, the mean width at each site was wider in the wet season than in the cool, dry season and the upper stream sites were narrower than the lower stream sites excepted for site Yakraue 9.

Figure 3.12 Stream width (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in stream width at Yakraue stream.

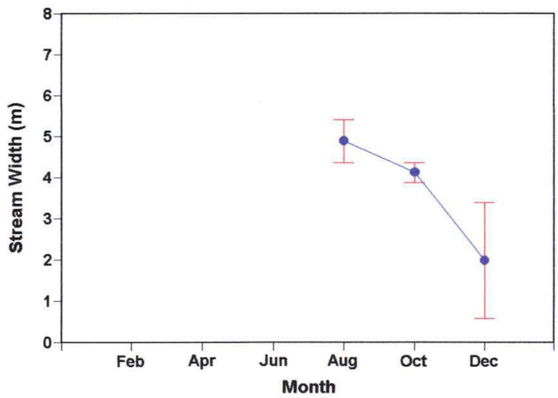
(a) Site Yakraue 1



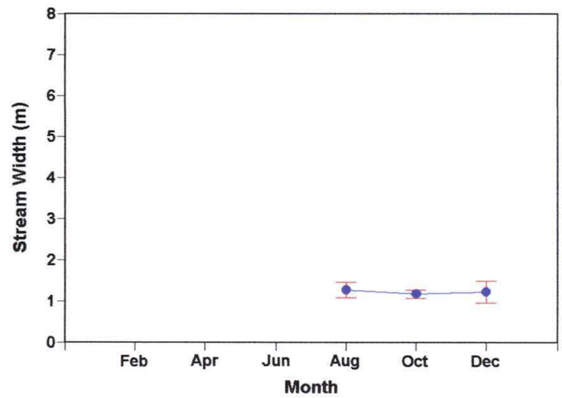
(b) Site Yakraue 2



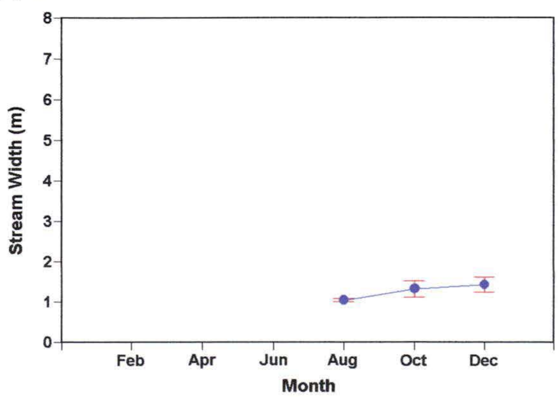
(c) Site Yakraue 3



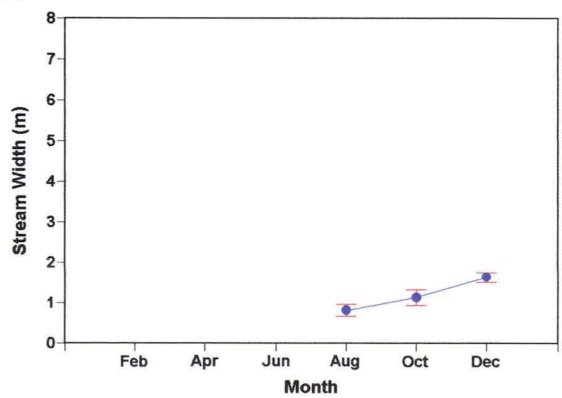
(d) Site Yakraue 4



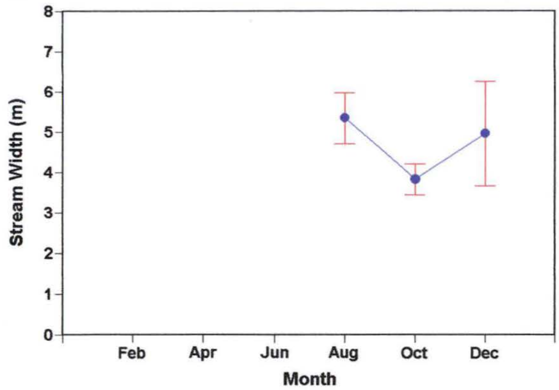
(e) Site Yakraue 5



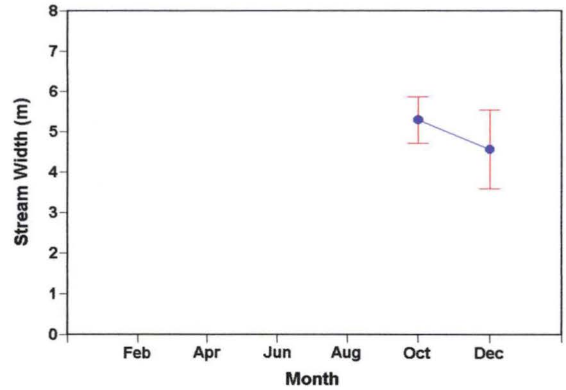
(f) Site Yakraue 6



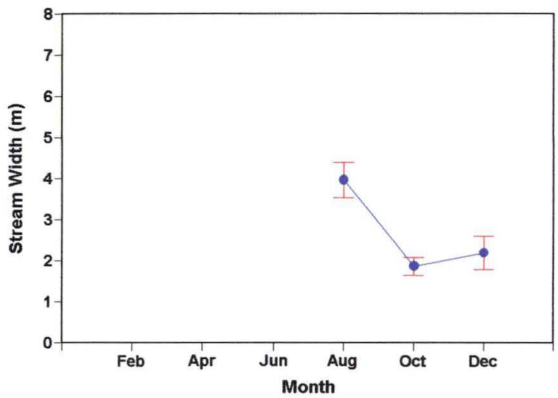
(g) Site Yakraue 7



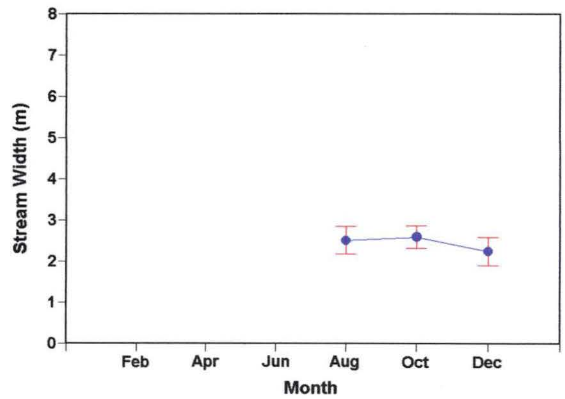
(h) Site Yakraue 8



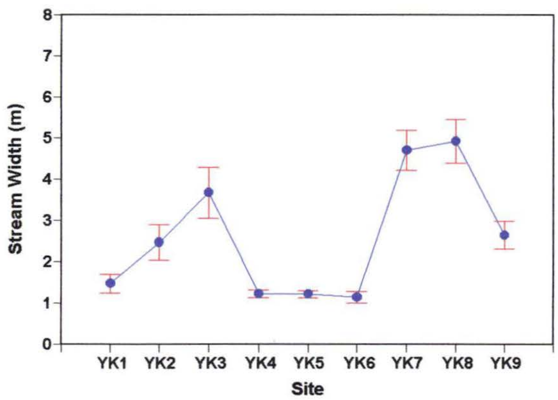
(i) Site Yakraue 9



(j) Stream width all year round at Yakraue stream



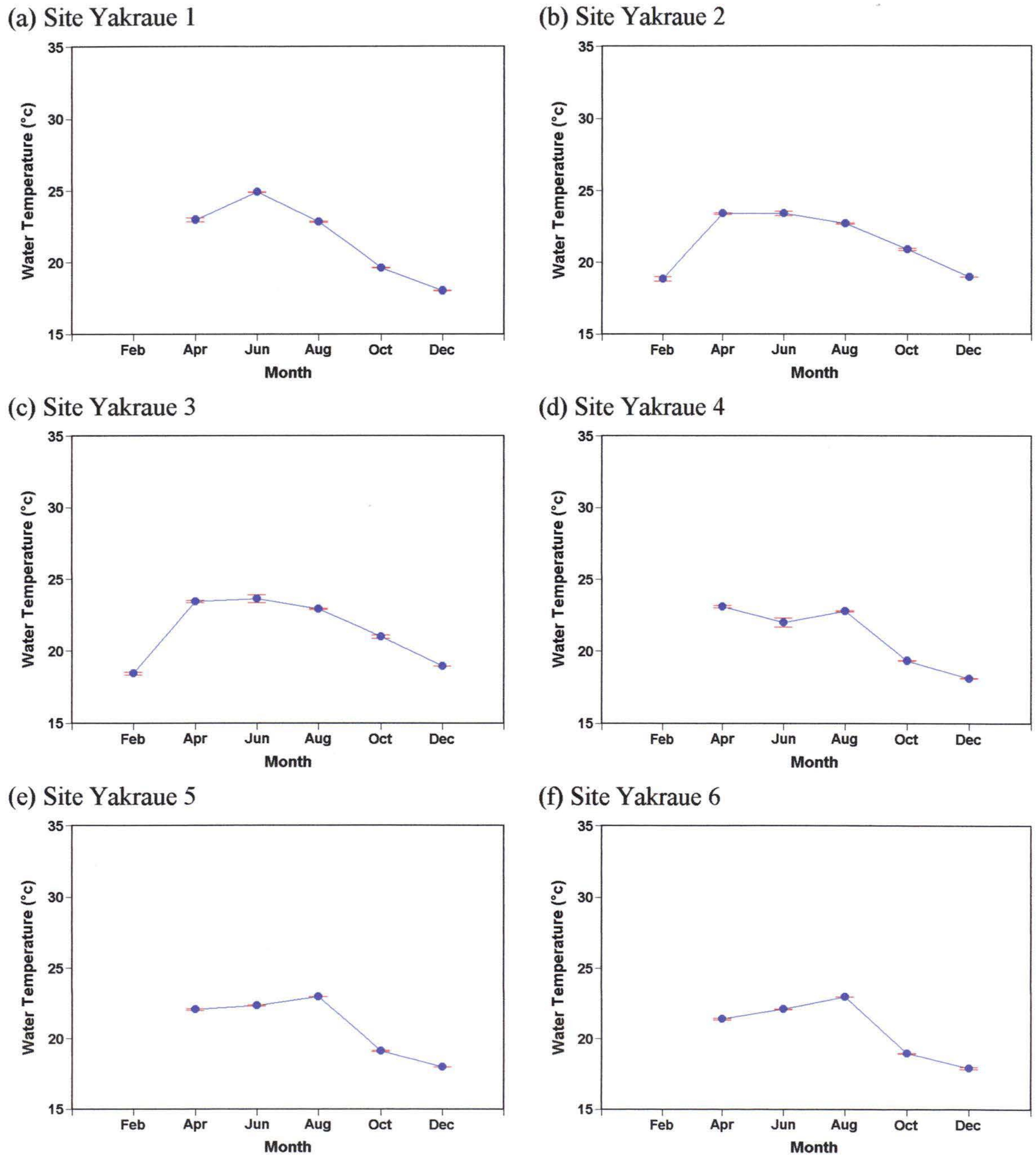
(k) Longitudinal stream width changes at Yakraue stream



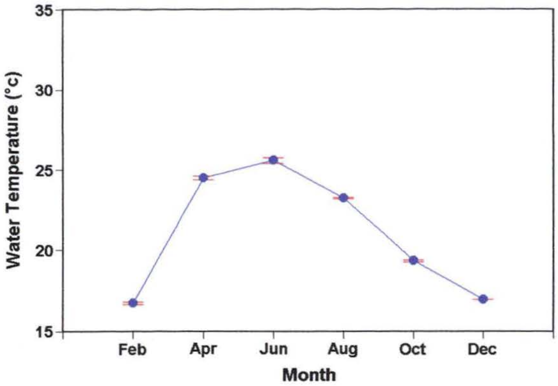
3.1.2.4 Water Temperature

There was a strong seasonal change in water temperature of the streams at all sites measured (Figure 3.13). This trend was similar at all sites within streams also. Water temperature increased gradually through the hot, dry and the wet season, reaching the maximum range about 22 °C and 26 °C, but gradually declined during the end of the wet season to reach the annual minimum of about 16 °C in the cool, dry season.

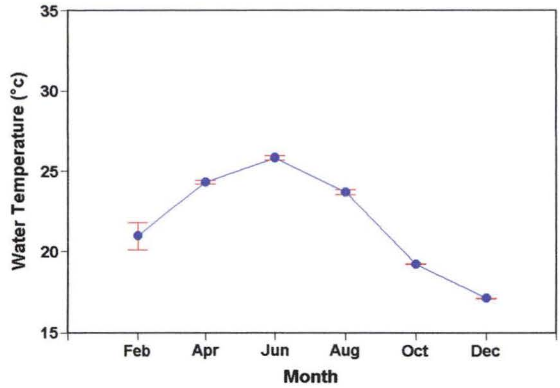
Figure 3.13 Water temperature (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in water temperature at Yakraue stream.



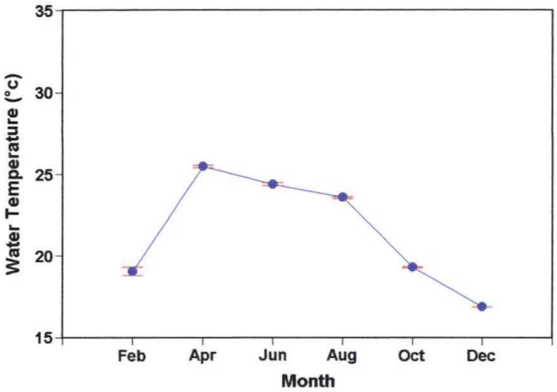
(g) Site Yakraue 7



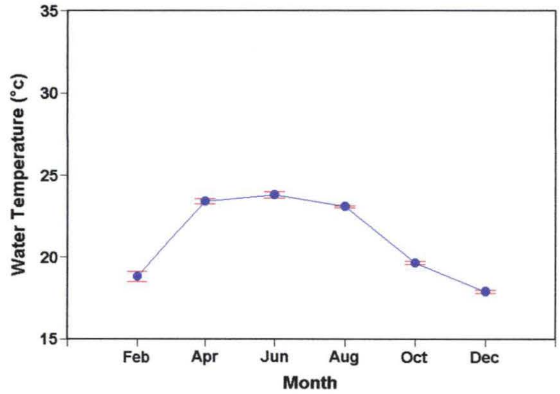
(h) Site Yakraue 8



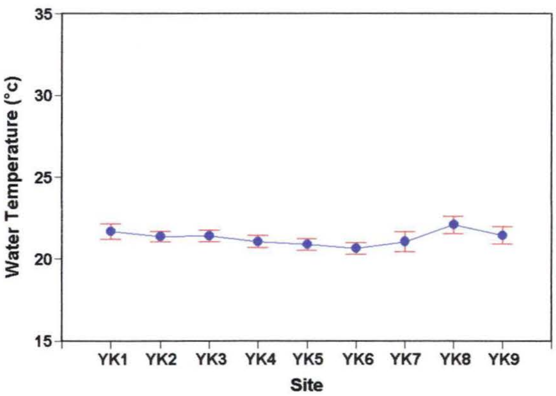
(i) Site Yakraue 9



(j) Water temperature all year round at Yakraue stream



(k) Longitudinal water temperature changes at Yakraue stream

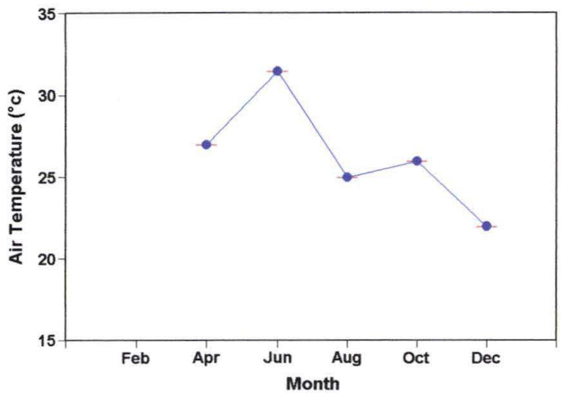


3.1.2.5 Air Temperature

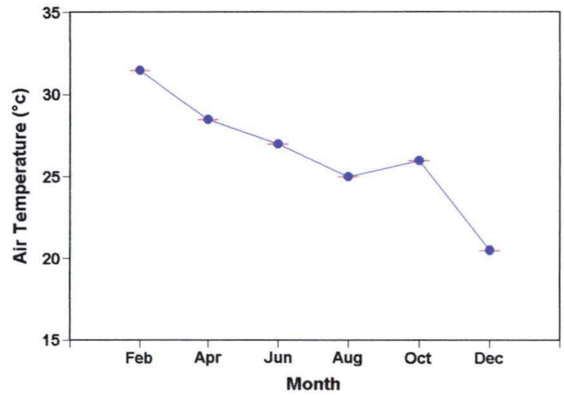
Air temperature had the same trend as water temperature. There was a strong seasonal change in the water temperature of the streams at all sites measured (Figure 3.14). This trend was mostly similar at all sites within streams also. Air temperature increased gradually through the hot dry and the wet season, reaching the maximum range about 26 °C-32 °C during April, June and August, but significantly decreased during the end of the wet season to reach the annual minimum range between 15 °C and 25 °C in the cool, dry season of December.

Figure 3.14 Air temperature (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in air temperature at Yakraue stream.

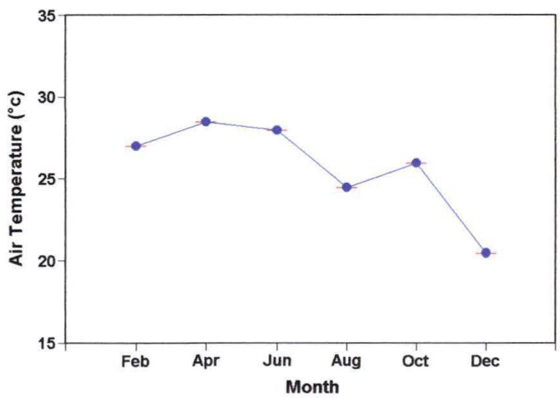
(a) Site Yakraue 1



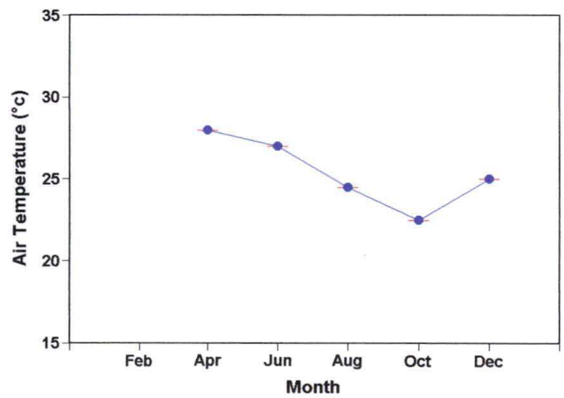
(b) Site Yakraue 2



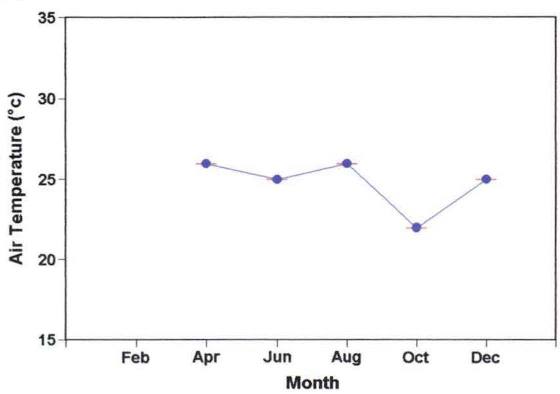
(c) Site Yakraue 3



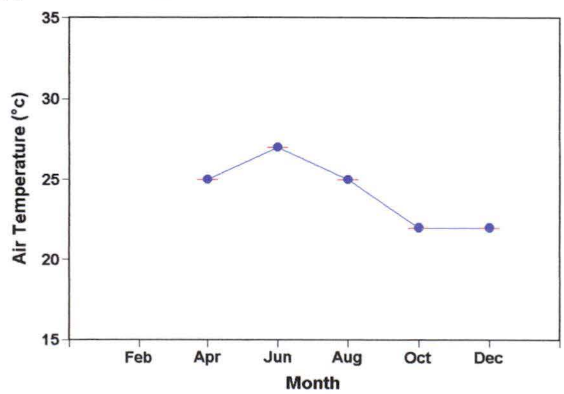
(d) Site Yakraue 4



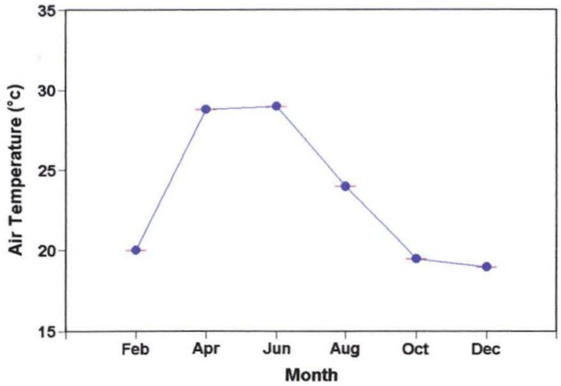
(e) Site Yakraue 5



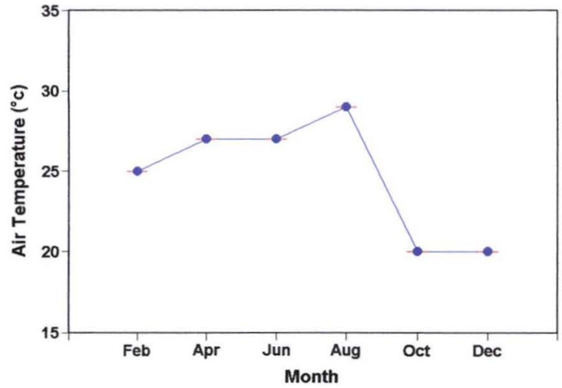
(f) Site Yakraue 6



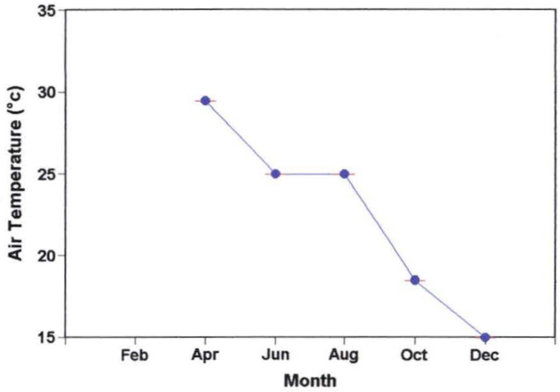
(g) Site Yakraue 7



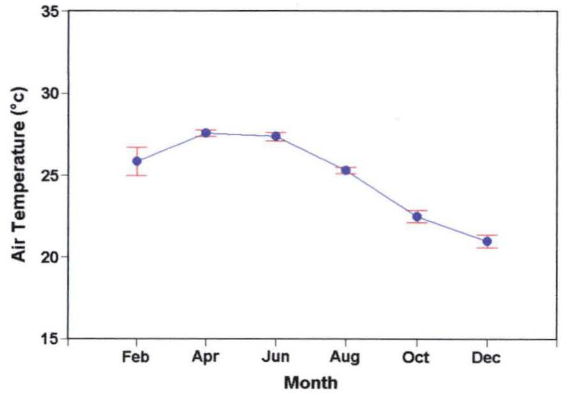
(h) Site Yakraue 8



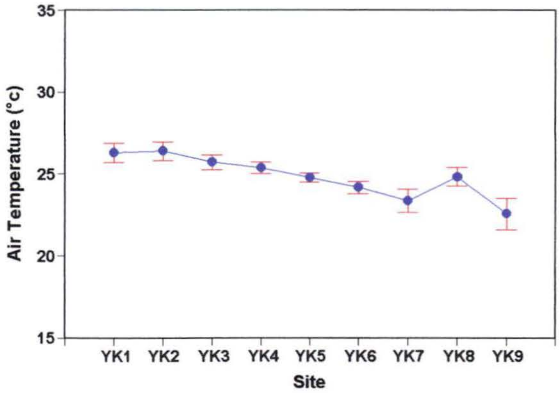
(i) Site Yakraue 9



(j) Air temperature all year round at Yakraue stream



(k) Longitudinal air temperature changes at Yakraue stream

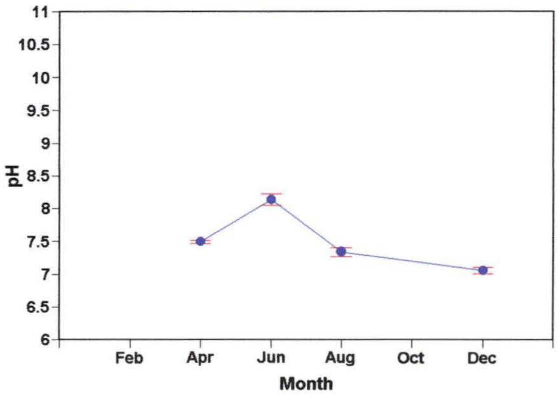


3.1.2.6 pH

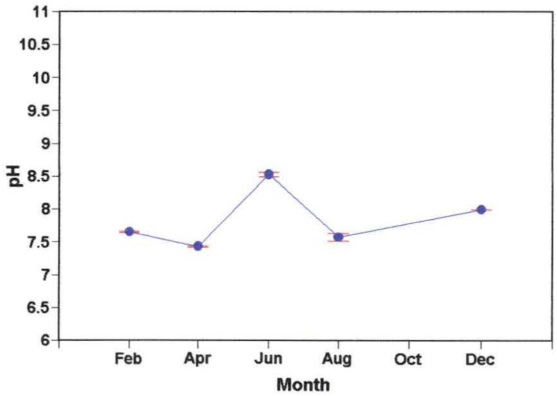
The pH data in October could not be measured because of an equipment calibration problem. However, all sites demonstrated a strong seasonal change in the pH (Figure 3.15). This trend was similar at all sites within streams also. The pH dropped gradually through the dry season, reaching about 7.5-8, but significantly increased to around 8.2-10.2 at the beginning of the wet season of June. During the wet season, pH was dropping again to reach the minimum peak of about 6.7-7.5 in August. By the end of wet season, pH was gradually rising again to reach about 8-8.2 in December, which is the beginning of the cool, dry season.

Figure 3.15 pH (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in pH at Yakraue stream.

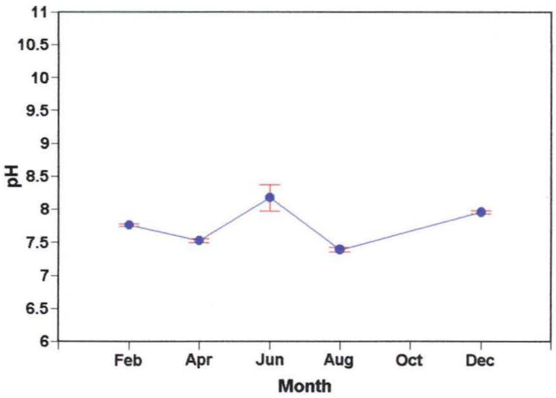
(a) Site Yakraue 1



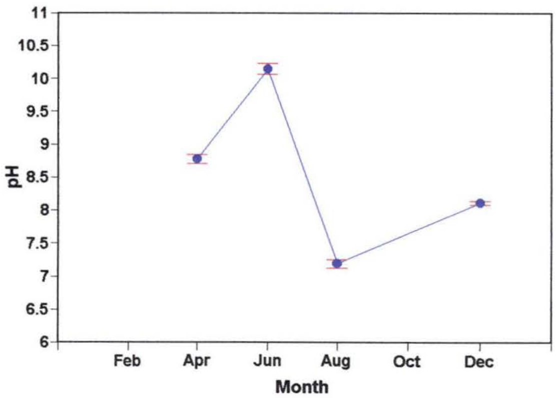
(b) Site Yakraue 2



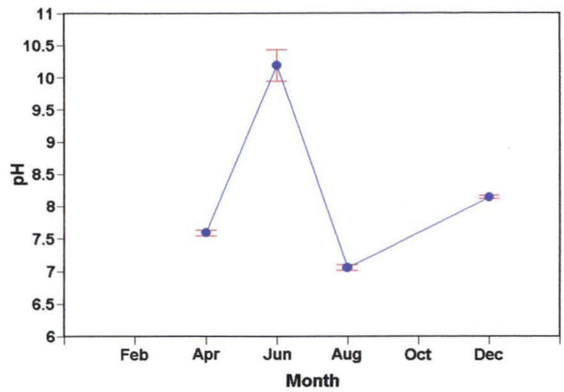
(c) Site Yakraue 3



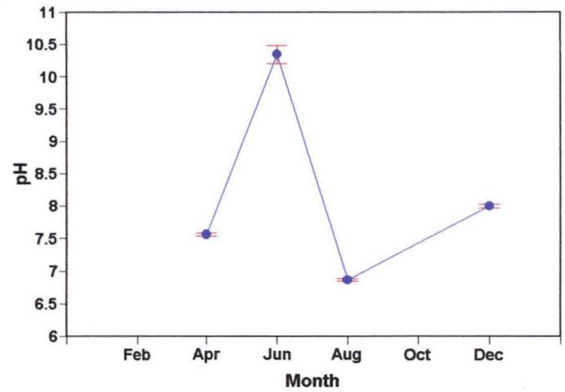
(d) Site Yakraue 4



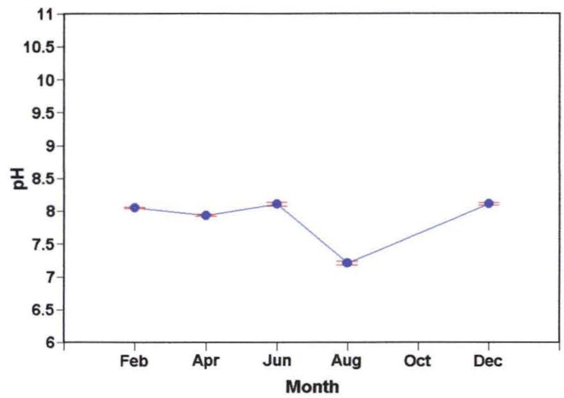
(e) Site Yakraue 5



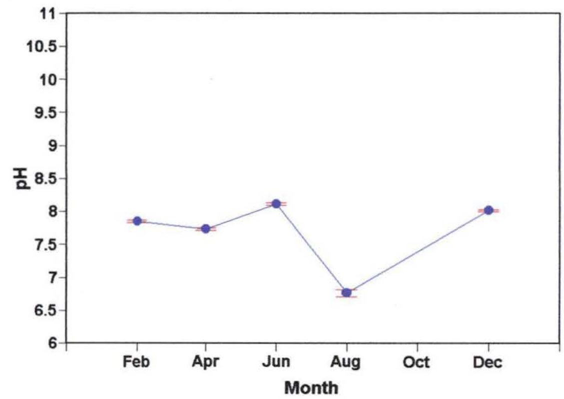
(f) Site Yakraue 6



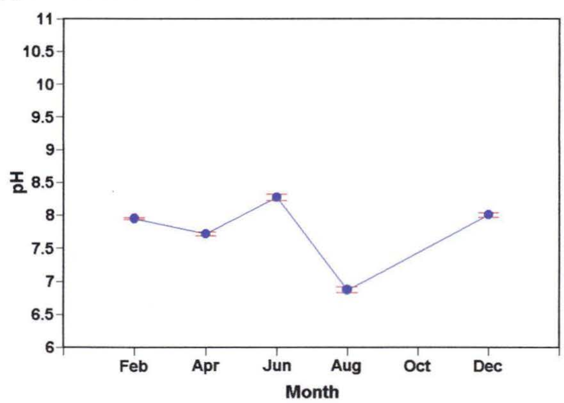
(g) Site Yakraue 7



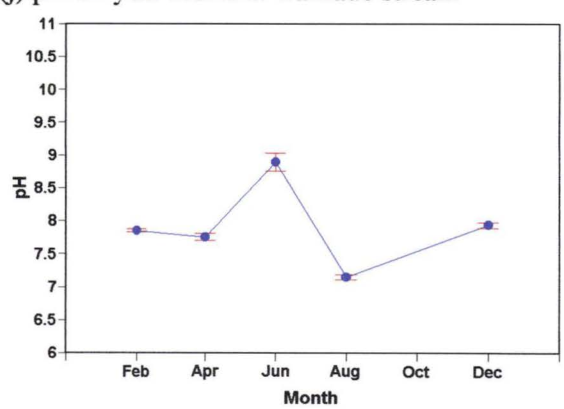
(h) Site Yakraue 8



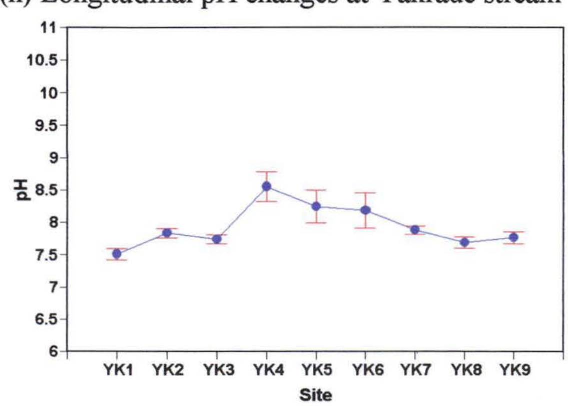
(i) Site Yakraue 9



(j) pH all year round at Yakraue stream



(h) Longitudinal pH changes at Yakraue stream



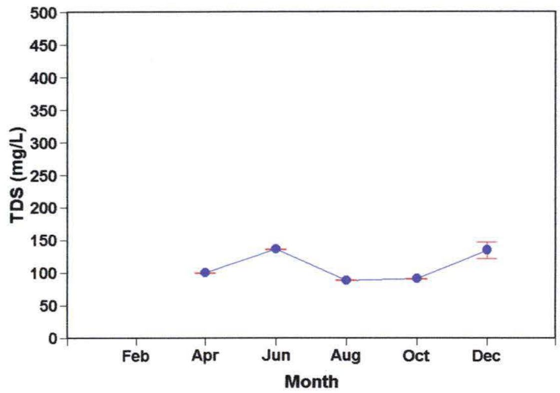
3.1.2.7 Total Dissolved Solid (TDS)

There was a strong seasonal change in the TDS at all sites measured, although site Yakraue 1 had relatively low total dissolved solid (Figure 3.16). This trend in TDS was similar at all sites within streams also. It declined rapidly through the hot, dry season, reaching the range about 110-300 mg/L by the hottest month of April, but rapidly increased to reach an annual maximum range of about 350-470 mg/L during the beginning of the wet season of June. During the wet season, TDS was markedly dropping again to reach about 150-350 mg/L at the end of the wet season in October, and then rapidly rose again to reach approximately annual peak of about 350-450 mg/L through the cool, dry season of December.

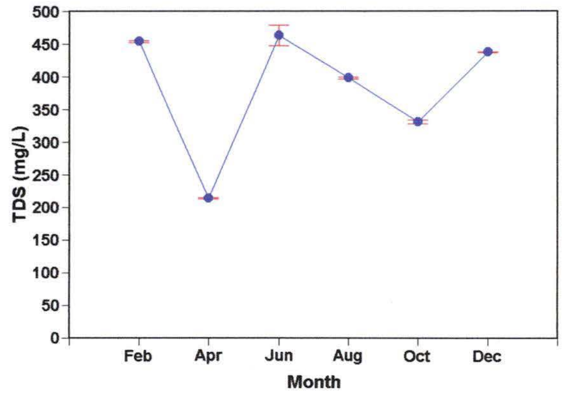
Site Yakraue 1 had significantly low TDS, where as site Yakraue 2 and Yakraue 3 had notable high TDS. The other sites of Yakraue stream had not much difference in TDS along the stream.

Figure 3.16 Total dissolved solid (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in TDS at Yakraue stream.

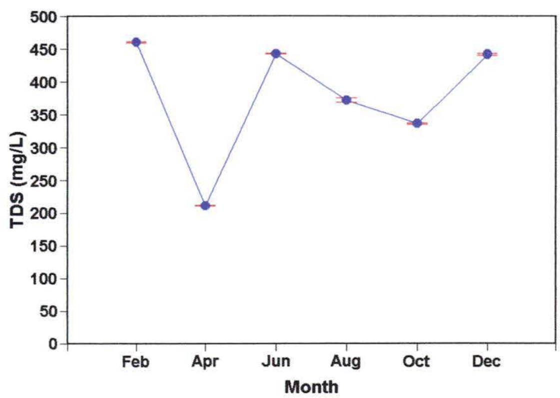
(a) Site Yakraue 1



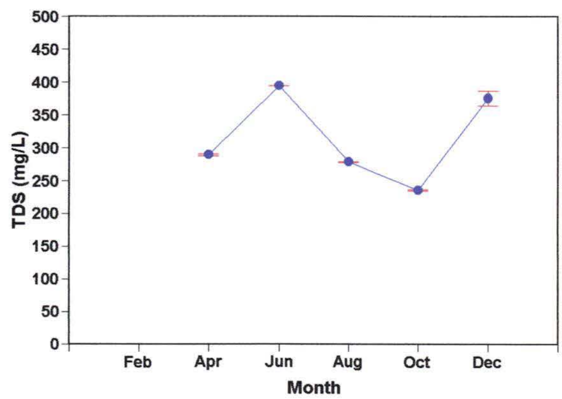
(b) Site Yakraue 2



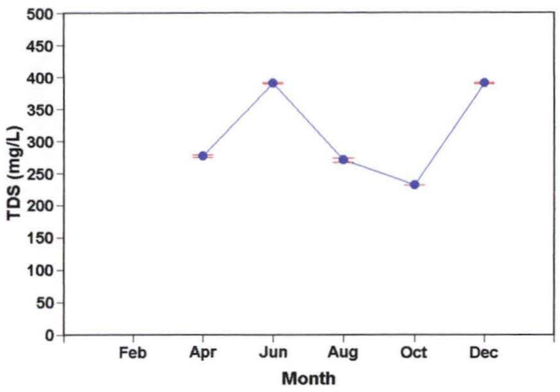
(c) Site Yakraue 3



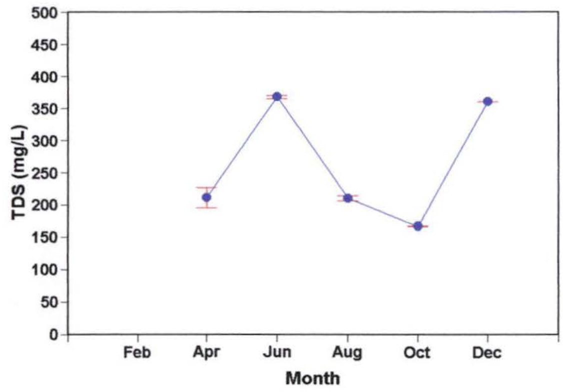
(d) Site Yakraue 4



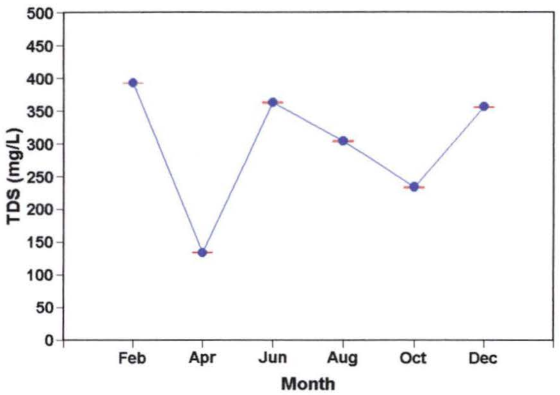
(e) Site Yakraue 5



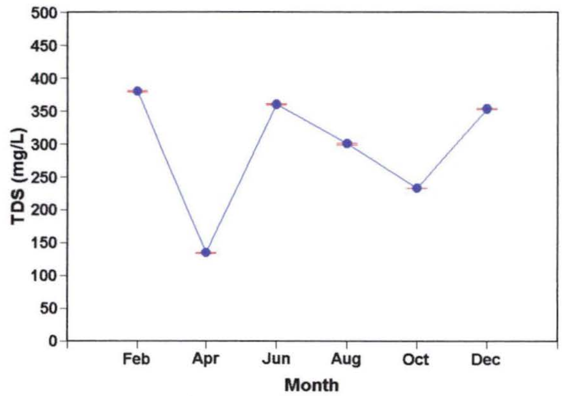
(f) Site Yakraue 6



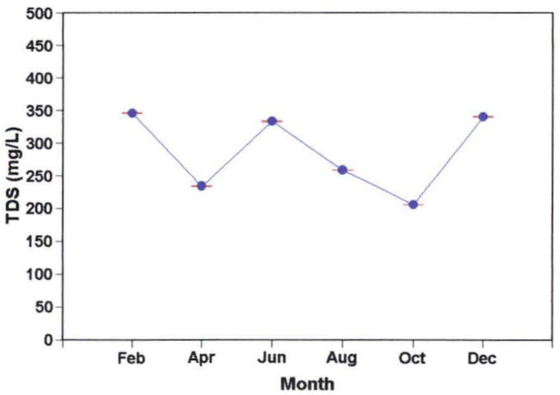
(g) Site Yakraue 7



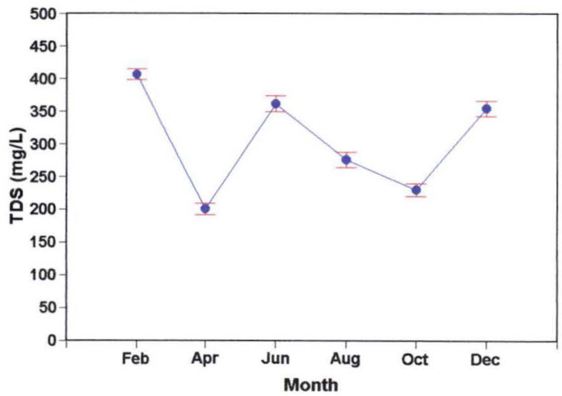
(h) Site Yakraue 8



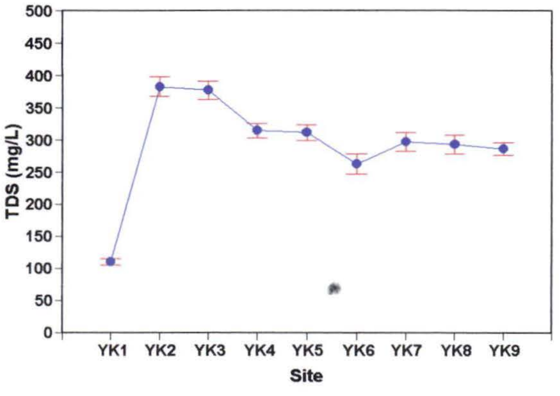
(i) Site Yakraue 9



(j) TDS all year round at Yakraue stream



(k) Longitudinal TDS changes at Yakraue stream



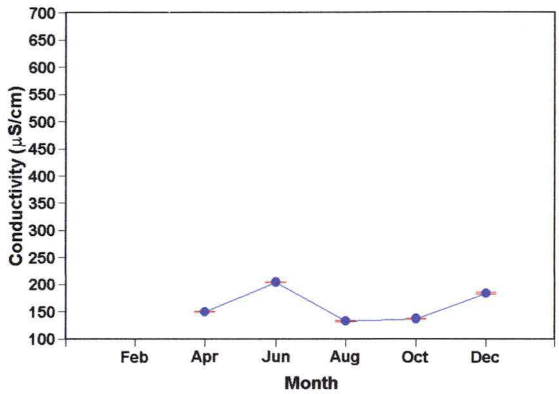
3.1.2.8 Electrical Conductivity (EC)

There was a strong seasonal change in the electrical conductivity at all sites measured, although site Yakraue 1 had relatively low conductivity (Figure 3.17). This trend was similar at all sites within streams also. It declined rapidly through the hot, dry season, reaching the range 150-420 µS/cm by the hottest month of April, but rapidly increased to reach an annual maximum range of about 500-773 µS/cm during the beginning of the wet season of June. During the wet season, conductivity was gradually dropping again to reach about 250-550 µS/cm at the end of the wet season and then rapidly rose again to reach approximately annual peak of about 670 µS/cm through the cool, dry season of December.

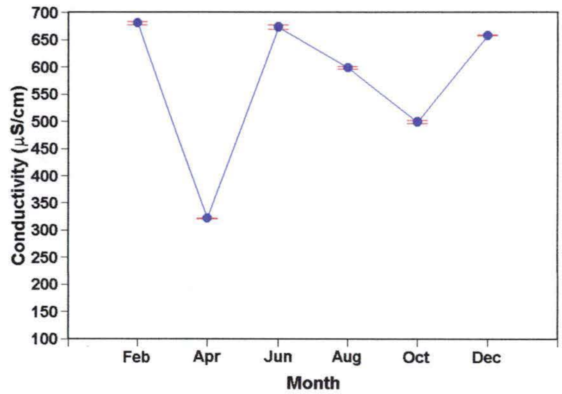
Site Yakraue 1 had significantly low conductivity, where as site Yakraue 2 and Yakraue 3 had notable high conductivity. The other sites of Yakraue stream had not much difference in conductivity along the stream.

Figure 3.17 Electrical conductivity (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in conductivity at Yakraue stream.

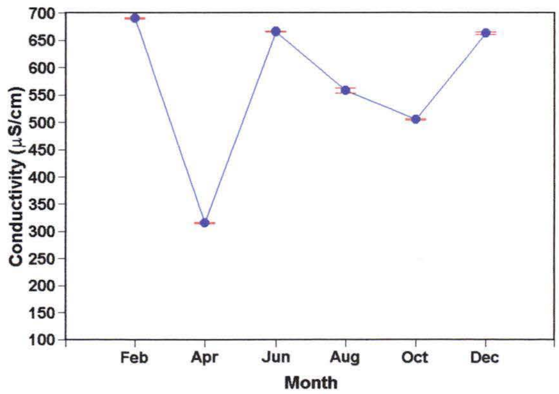
(a) Site Yakraue 1



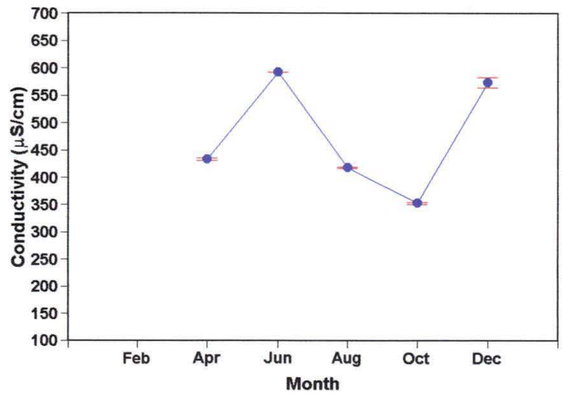
(b) Site Yakraue 2



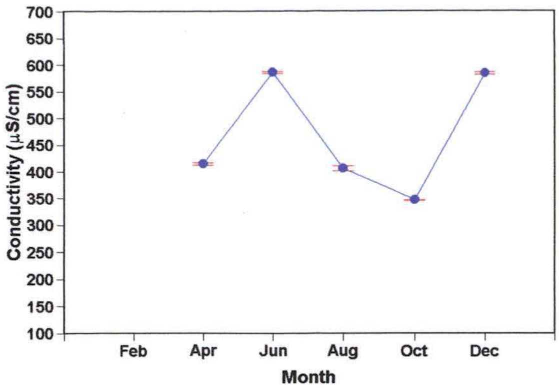
(c) Site Yakraue 3



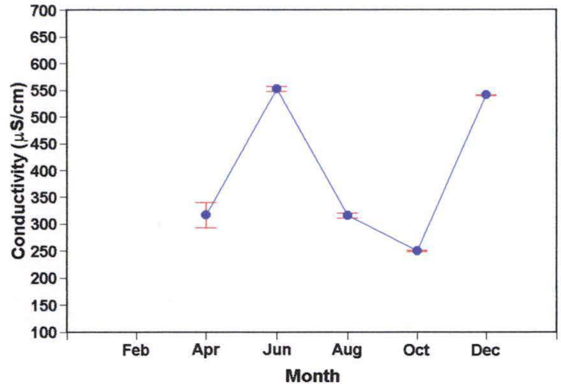
(d) Site Yakraue 4



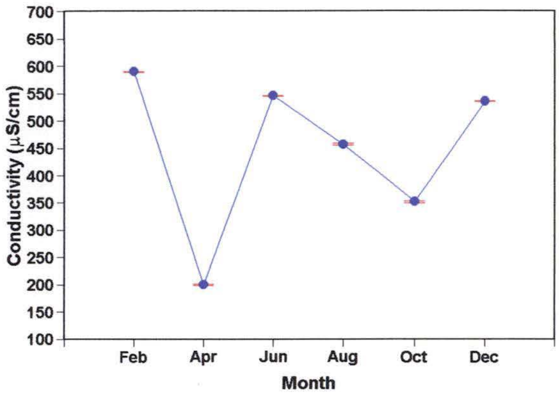
(e) Site Yakraue 5



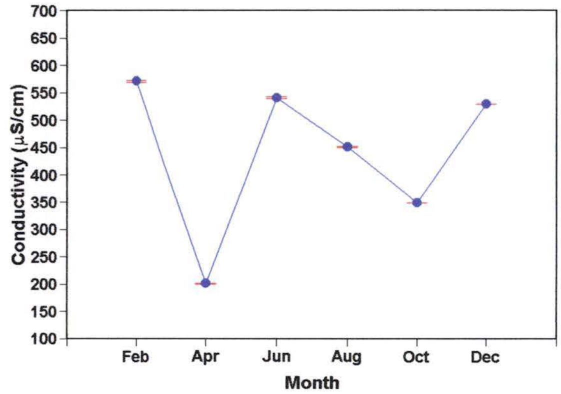
(f) Site Yakraue 6



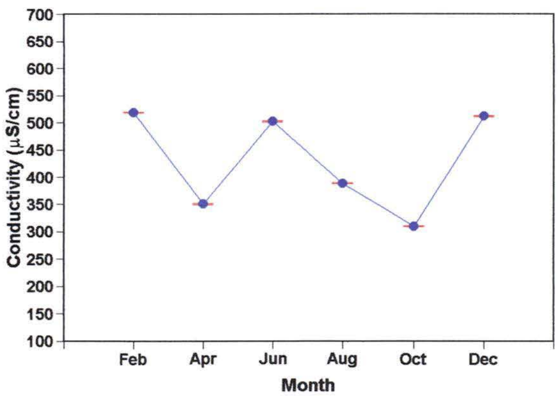
(g) Site Yakraue 7



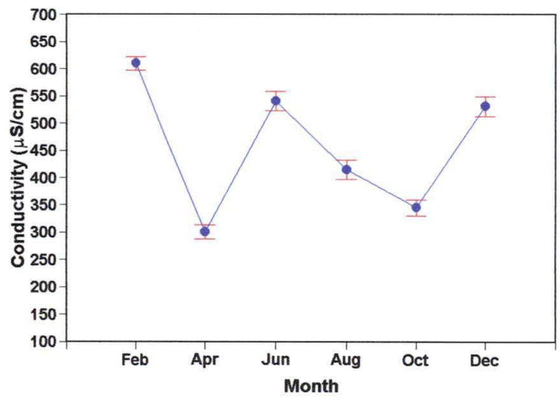
(h) Site Yakraue 8



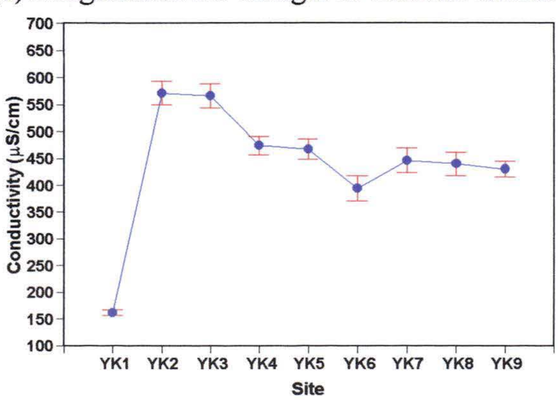
(i) Site Yakraue 9



(j) EC all year round at Yakraue stream



(k) Longitudinal EC changes at Yakraue stream



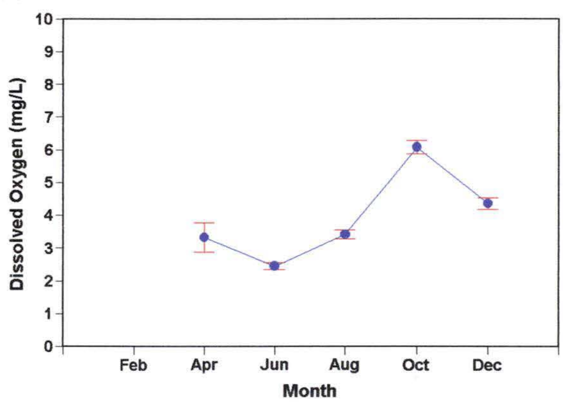
3.1.2.9 Dissolved Oxygen (DO)

At the upper part of the stream sites included Yakraue 1, Yakraue 2, Yakraue 3, Yakraue 4, Yakraue 5 and yakraue 6 demonstrated a strong seasonal change in dissolved oxygen; whereas the lower part of the stream sites included Yakraue 7, Yakraue 8 and Yakraue 9 did not show as strong seasonal change as the upper sites (Figure 3.18). This trend was similar at all upper sites of the stream. It declined gradually through the hot, dry season, reaching the range of about 2.5-4.2 mg/L by April and June then gradually increased through the wet season to reach an annual maximum range of about 6.3-8.0 mg/L in October. By the end of the wet season, DO was dropping again to reach about 4.2-7 mg/L at the beginning of the cool, dry season of December.
The lower sites, although, did not show a clear trend of seasonal change in DO but all the sites had the average DO quite high all year round.

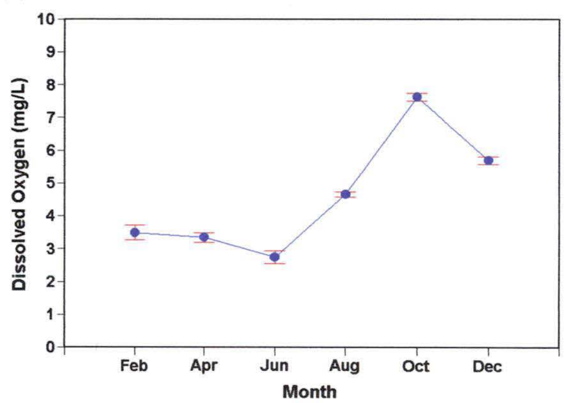
Yakraue stream also demonstrated a trend of longitudinal change in DO. The upper sites had lower DO than the lower sites.

Figure 3.18 Dissolved oxygen (mean ± S.E.) in each sampling month at Yakraue stream, 1998: a. Site Yakraue 1, b. Site Yakraue 2, c. Site Yakraue 3, d. Site Yakraue 4, e. Site Yakraue 5, f. Site Yakraue 6, g. Site Yakraue 7, h. Site Yakraue 8, i. Site Yakraue 9, j. Yakraue stream (combined data of all sites), and k. Longitudinal variability in DO at Yakraue stream.

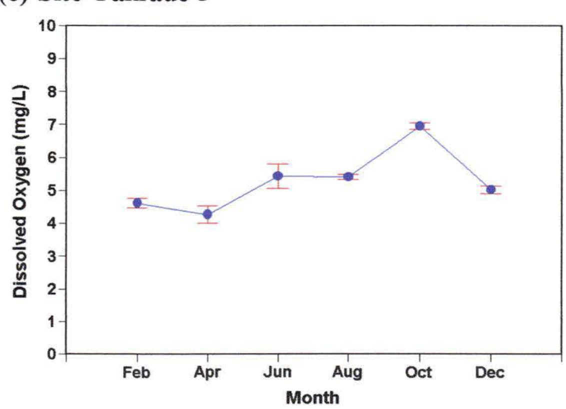
(a) Site Yakraue 1



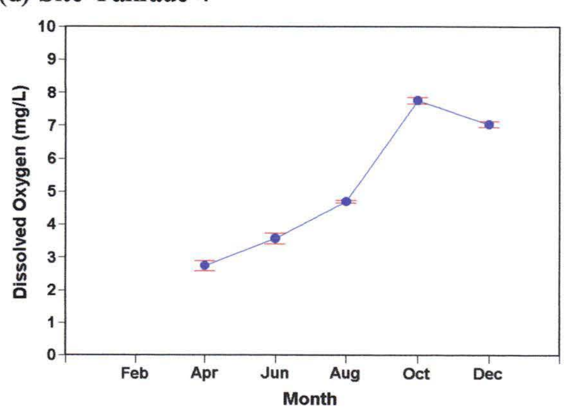
(b) Site Yakraue 2



(c) Site Yakraue 3



(d) Site Yakraue 4



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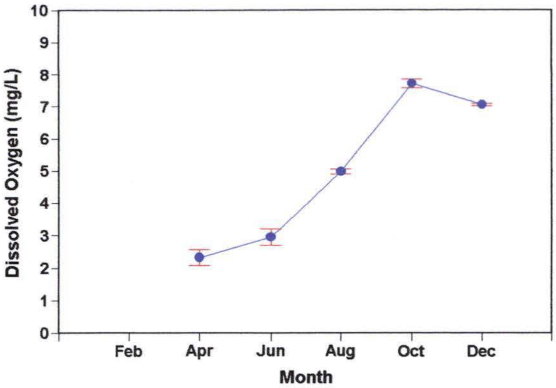
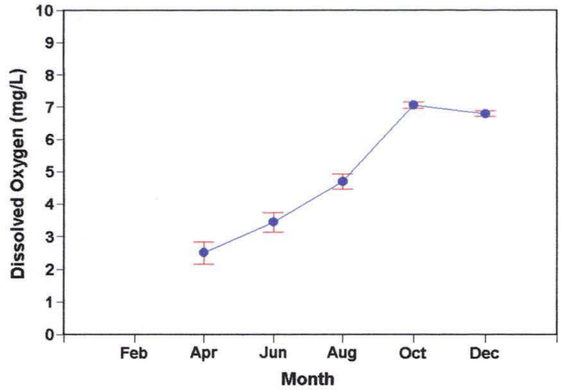
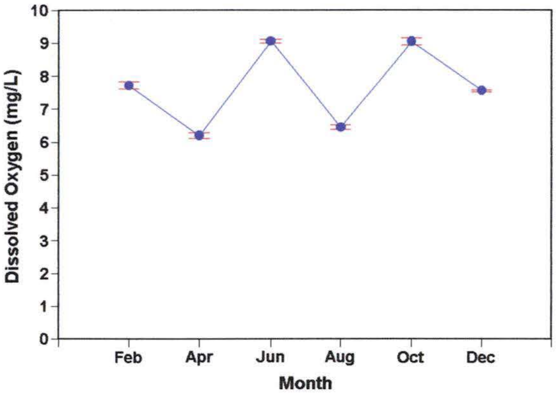


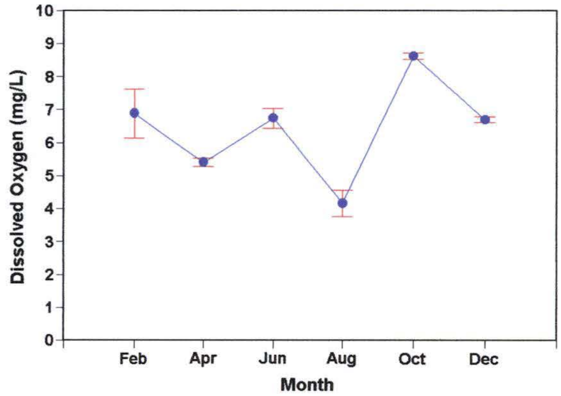
(f) Site Yakraue 6



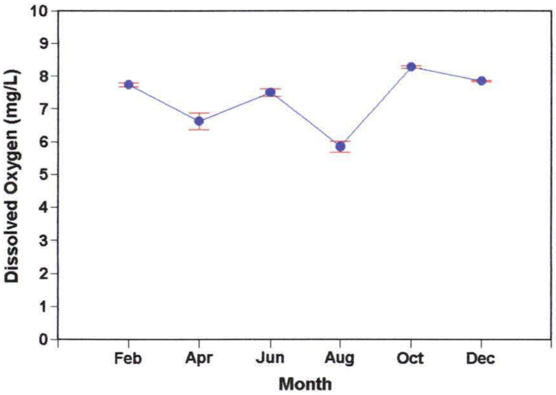
(g) Site Yakraue 7



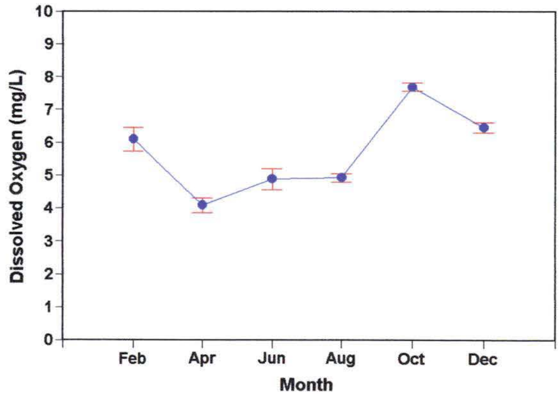
(h) Site Yakraue 8



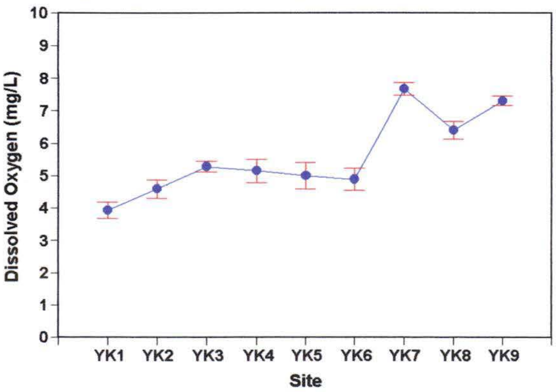
(i) Site Yakraue 9



(j) DO all year round at Yakraue stream



(k) Longitudinal DO changes at Yakraue stream



3.1.3 Summary

The various water quality parameters of Hin Lat and Yakraue streams exhibited strongly seasonality in this study. This pattern conforms to the typical tropical Asian streams as described by Dudgeon (1999). Dudgeon stated that almost all such streams show marked seasonality which is dominated by flow regime and temperature. The former is largely determined by the northeast and southwest monsoon and usually one, but sometimes two peaks of discharge are present.
Nam Nao National Park is in the southwest monsoon area, so most streams within this park will have one peak of flow regime. Hin Lat and Yakraue streams clearly show this type of seasonality.

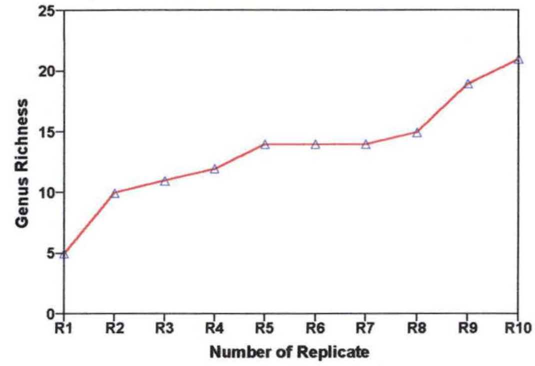
3.2 QUESTION 1: Do EPT taxa colonise different substrate types preferentially?

3.2.1 How many samples are adequate?

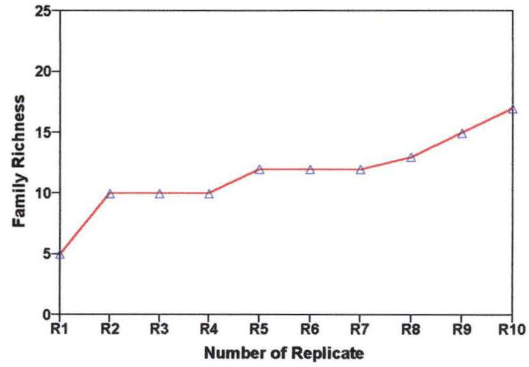
At the first sampling, 10 replicate samples of each substrate were taken in order to determine how many replicates should be collected to validly represent the communities of macroinvertebrates. The data are summarized as collector curves in Figures 3.19, 3.20 and 3.21. For most substrates, the cumulative taxon richness leveled off after about 6 replicates, suggesting that this could be most suitable in terms of time and labor efficiency.

Figure 3.19 Taxon richness collector curves of each substrate at Site Hin Lat 1, Hin Lat stream, Nam Nao National Park, February 1998.

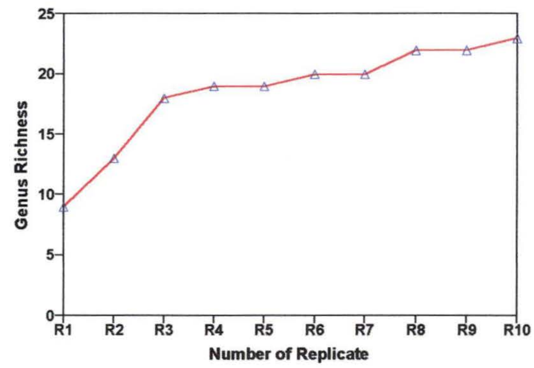
(1.1) Boulder



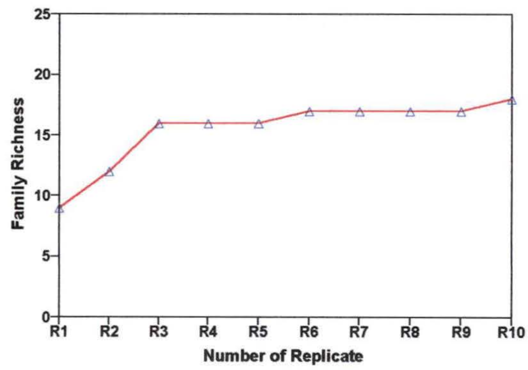
(1.2) Boulder



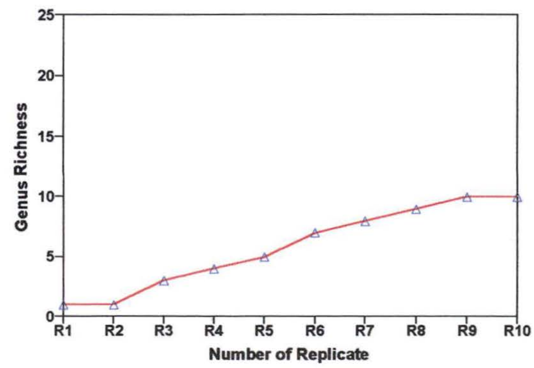
(2.1) Cobble



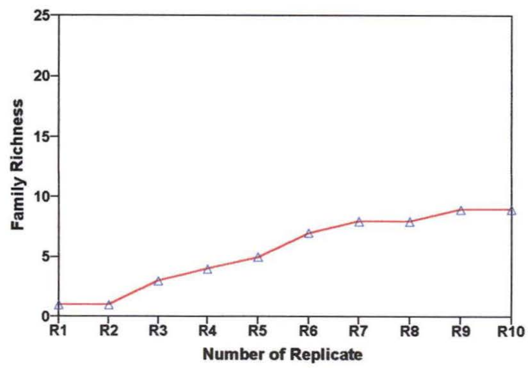
(2.2) Cobble



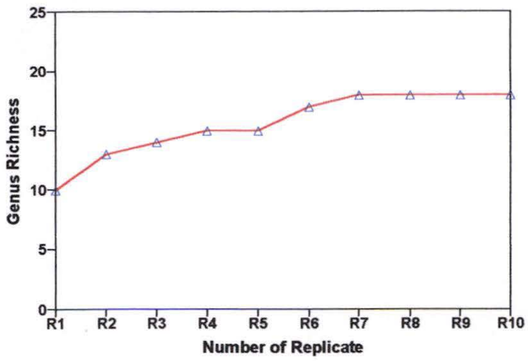
(3.1) Pebble



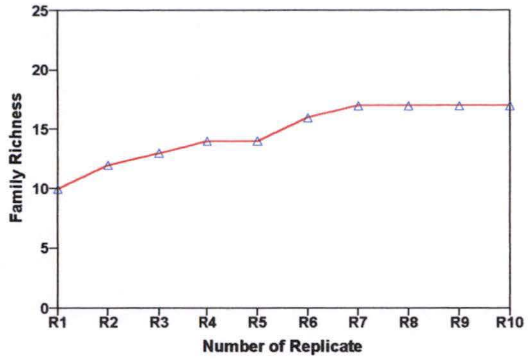
(3.2) Pebble



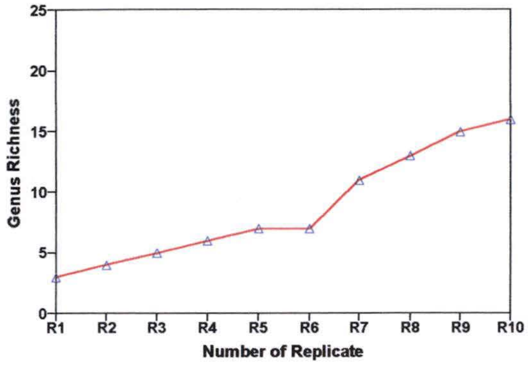
4.1 Gravel



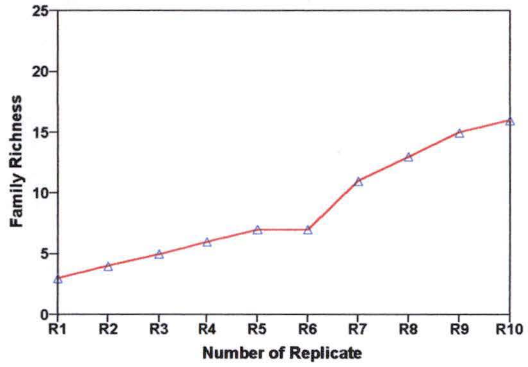
4.2 Gravel



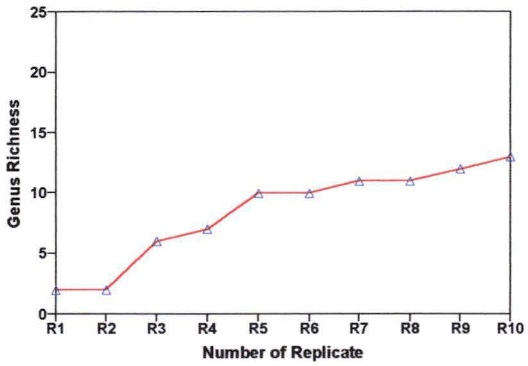
5.1 Sand



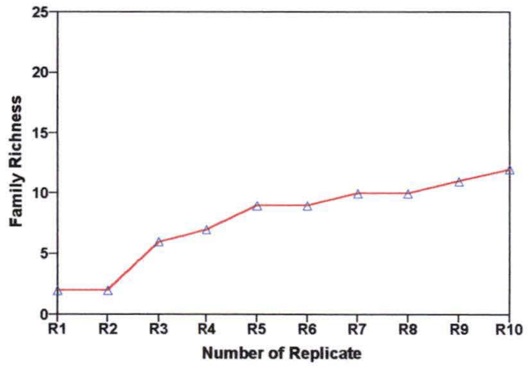
5.2 Sand



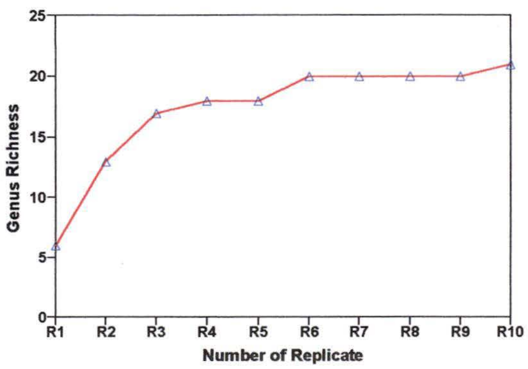
6.1 Leaf Pack



(6.2) Leaf Pack



(7.1) Root



(7.2) Root

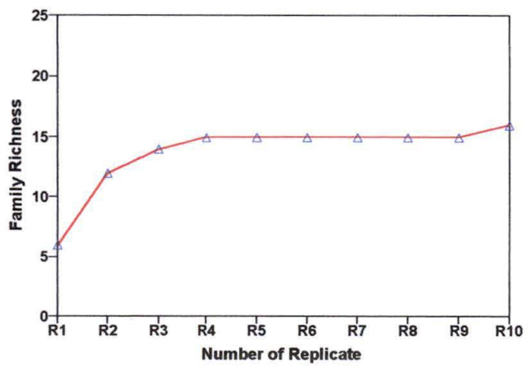
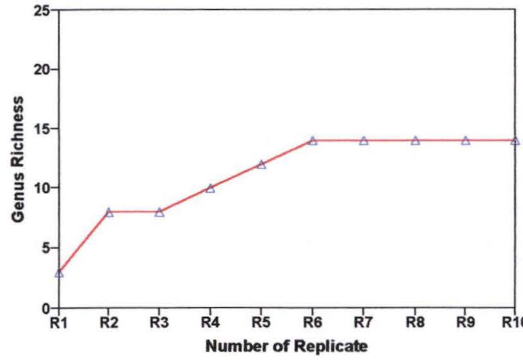
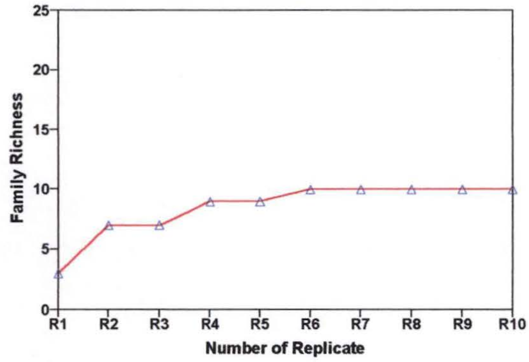


Figure 3.20 Taxon richness collector curves of each substrate at Site Hin Lat 2, Hin Lat stream, Nam Nao National Park, February 1998.

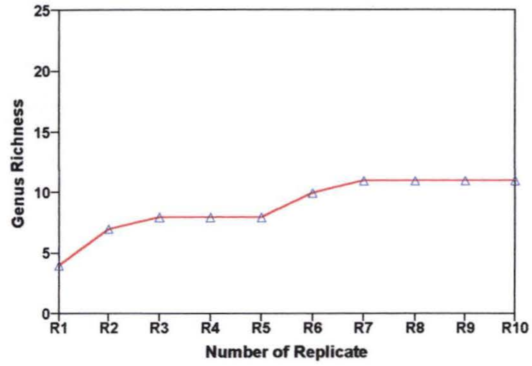
1.1 Boulder



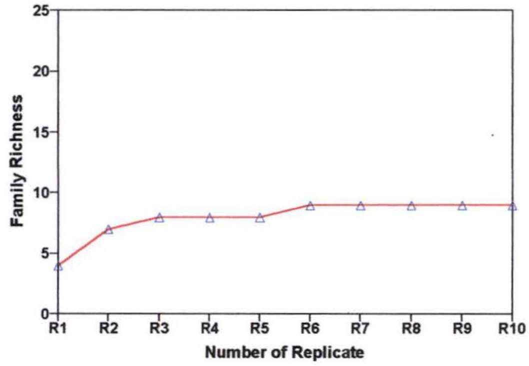
1.2 Boulder



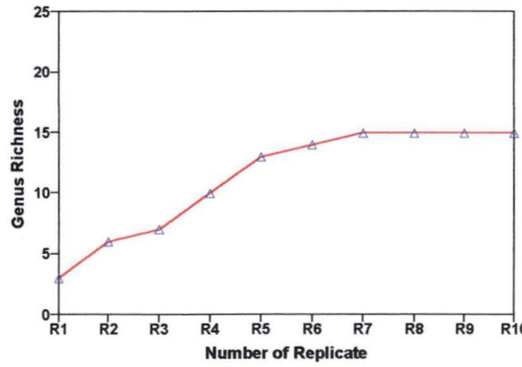
2.1 Cobble



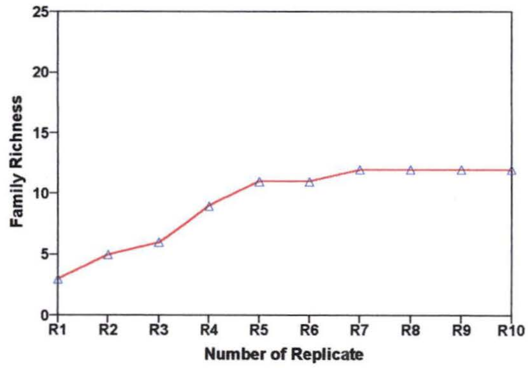
2.2 Cobble



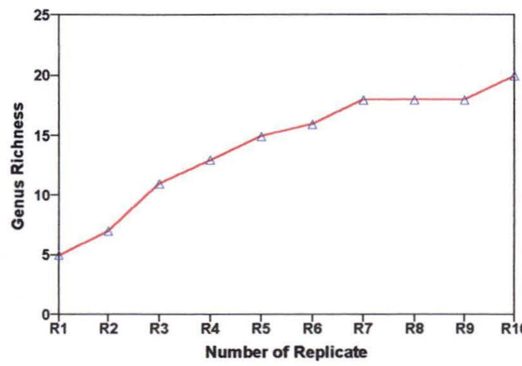
3.1 Pebble



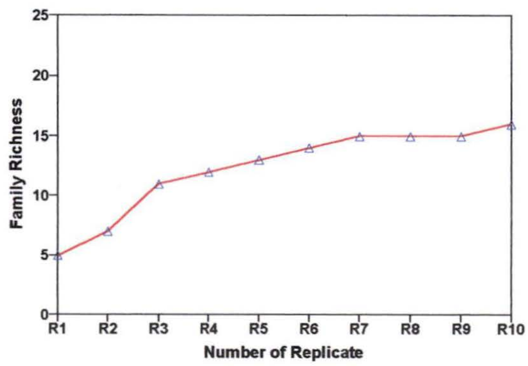
3.2 Pebble



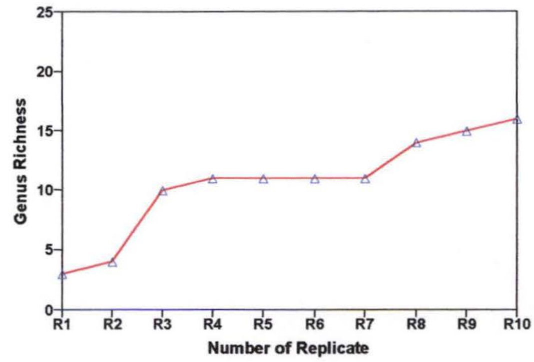
4.1 Leaf Pack



4.2 Leaf Pack



5.1 Root



5.2 Root

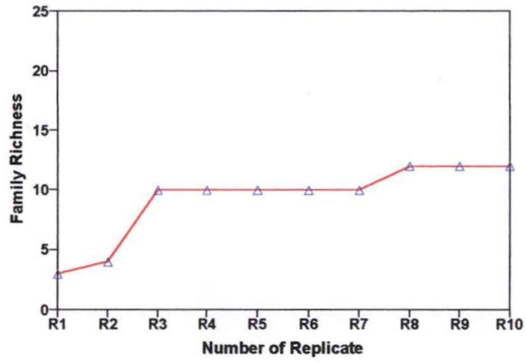
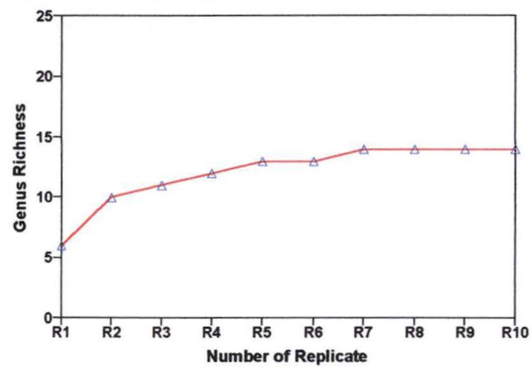
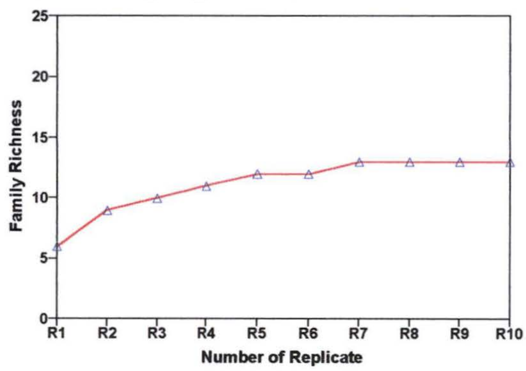


Figure 3.21 Taxon richness collector curves of random sampling substrates at Site Hin Lat 3, Hin Lat stream, Nam Nao National Park, February 1998.

Random sampling substrates



Random sampling substrates



3.2.2 EPT Preferential Substrates Study

Substrata at each site were classified into 7 different types depending on particle size distributions (Allan, 1995): boulders, cobbles, pebbles, gravel, sand, leaf pack and root. Collectively these represented the full range of substrates present.

There were found to be differences in the relative abundance of some substrates among sites, e.g. sand substrate was very rare at sites Hin Lat 2 and Hin Lat 3. At the initial sampling in February, samples were taken from all 7 substrate types at site Hin Lat 1, and 5 substrate types at site Hin Lat 2 (boulders, cobbles, pebbles, leaf pack and root). In the August and October cycles, sand substrates were abandoned at all sites and samples were taken from the 6 remaining substrate types.

Root means the roots of riparian trees and shrubs, which penetrated into the stream water.
The mean dimensions of some of the substrates sampled in this study are shown in Tables 3.1 and 3.2.

Table 3.1 Classification of substratum particle size

Particle size diameter (mm)	Category name
---	Bedrock
> 256	Boulder
64-256	Cobble
16-64	Pebble
2-16	Gravel
0.063-0.125	Sand
-	Leaf Pack
-	Root

Table 3.2 Some substratum particle size (cm) (mean ± S.E.) measured in this study

Substrate	Width (cm)	Length (cm)	Depth (cm)	Dry Mass (gm)
Boulder	19.5 ± 1.1	28.0 ± 1.1	12.6 ± 0.7	-
Cobble	6.1 ± 0.2	9.0 ± 0.2	4.0 ±0.1	-
Leaf Pack	-	-	-	94.3 ± 8.2*

* Leaf pack per Surber sampler (900 cm^2).

3.2.2.1 Overview of the Data

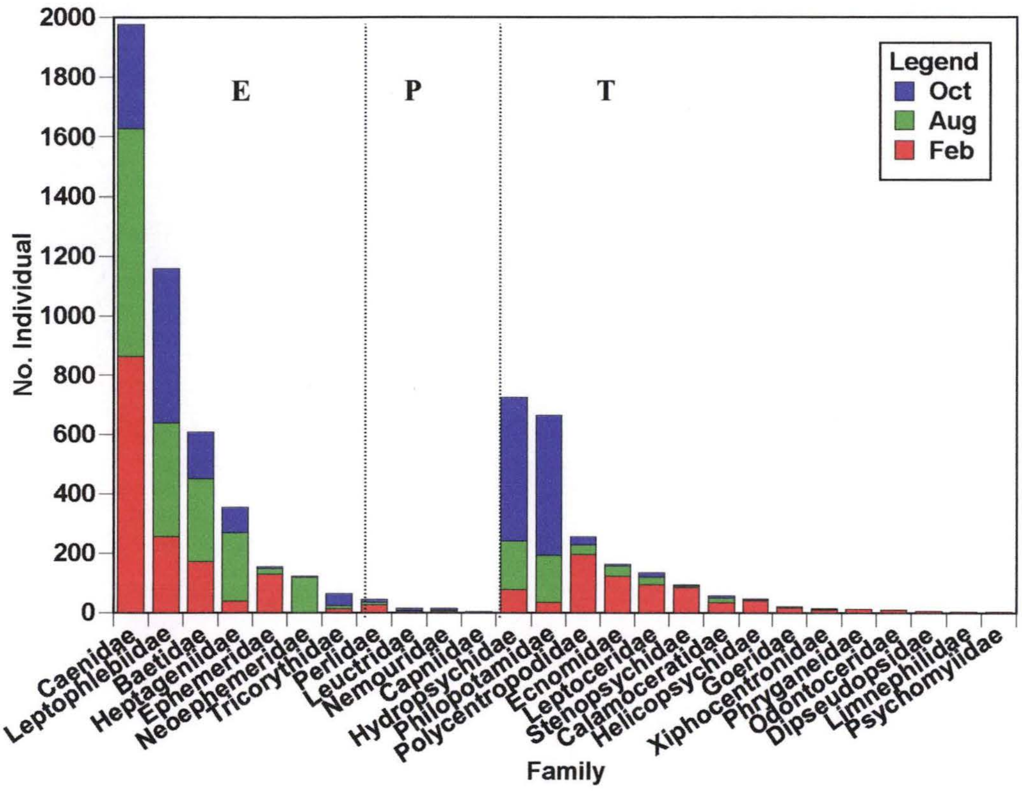
In this chapter, the data is progressively explored at increasingly focussed levels of resolution, beginning with the dataset combining all sites and months, then within sites and within months. Taxonomic resolution follows a hierarchy from all EPT taxa, between orders, between families within orders, and between genera within families.

There was a grand total of 6,727 EPT individuals, representing 26 families and 63 genera, collected from the 3 sites along Hin Lat stream (Hin Lat 1, Hin Lat 2 and Hin Lat 3) in February, August and October 1998 (Table 3.3 and 3.4).

Mayflies were the most abundant order (4,440 individuals) and accounted for two-thirds (66 %) of all EPT individuals collected. Caddisflies were the second most abundant group with 2,210 individuals, and accounting for one-third (33 %) of the total. Stoneflies were by far the rarest group (n = 77), and accounted for only 1 % of all EPT individuals.

Within orders, family representation was highly uneven (Figure 3.22), with typically one or two very dominant families followed by a long tail of rarer families. The two most common Ephemeroptera families were Caenidae (n = 1,976) and Leptophlebiidae (n = 1,160) and accounted for just under half of the total EPT individuals collected. Neoephemeridae and Tricorythidae were the two rarest Ephemeroptera families with 122 and 64 individuals recovered. Stoneflies were very rare in Hin Lat stream; Perlidae was the most common family, contributing 44 individuals. Hydropsychidae and Philopotamidae were the two best represented families of Trichoptera with 725 and 665 individuals; and accounted for 11 % and 10 % respectively of the total EPT individuals collected. The two rarest Trichoptera families were Limnephilidae and Psychomyiidae with 4 individuals each.

Figure 3.22 Sorted abundance of each EPT family collected in February, August and October 1998 at Hin Lat stream, Nam Nao National Park, Thailand.



In term of taxonomic richness, Trichoptera was the most diverse Order with 15 families and 31 genera which accounted for 58 % and 49 % of all EPT families and genera collected respectively. Ephemeroptera was the second most diverse group with 7 families and 23 genera; and accounted for 27 % and 37 % of the total EPT families and genera collected respectively. Plecoptera was found only 4 families and 9 genera; and accounted for 15 % and 14 % of the total EPT families and genera collected respectively.

There was remarkably little difference in the total number of individuals collected between sites, ranging from 2,080 to 2,326 individuals, but a notable trend in taxonomic richness. Site Hin Lat 1 had the highest EPT richness with 26 families and 54 genera recorded (Table 3.3). Site Hin Lat 2 had the second highest richness with 21 families and 44 genera, while site Hin Lat 3 had the least EPT richness with 21 families and 39 genera.

Table 3.3 Richness and abundance of EPT taxa collected at each site in February, August and October 1998 at Hin Lat stream, Nam Nao National Park, Thailand (combined data).

Site	No. of Family/No. of Genus/No.of individual			
	Ephemeroptera	Plecoptera	Trichoptera	Total EPT
HL1	7/22/1,619	4/7/28	15/25/679	26/54/2,326
HL2	7/20/1,454	3/6/26	11/18/841	21/44/2,321
HL3	7/17/1,367	3/5/23	11/17/690	21/39/2,080
Total	7/23/4,440	4/9/77	15/31/2,210	26/63/6,727

Numbers of individuals collected in each sampling month were within a small range of 2,216 to 2,271 individuals, but richness differed somewhat between months (Table 3.4). February dry season samples had the highest EPT richness with 24 families and 44 genera, whereas August wet season samples had the lowest with 20 families and 37 genera.

Table 3.4 Richness and abundance of EPT taxa collected in each sampling month at Hin Lat stream, Nam Nao National Park, Thailand (combined data).

Month	No. of Family/No. of Genus/No. of individual			
	Ephemeroptera	Plecoptera	Trichoptera	Total EPT
February	6/17/1,468	3/4/32	15/23/740	24/44/2,240
August	7/18/1,808	3/3/14	10/16/449	20/37/2,271
October	7/12/1,164	4/9/31	11/20/1,021	22/41/2,216
Total	7/23/4,440	4/9/77	15/31/2,210	26/63/6,727

Each substrate yielded EPT taxa within the range 854 - 1,322 individuals, 19 - 21 families and 36 – 42 genera (Table 3.5). The low numbers of specimens associated with the sand substrate is because it was sampled only once (in February at site Hin Lat 2). The sand data therefore were not included in the following analysis.

Table 3.5 Richness and abundance of EPT taxa collected from each substrate type at Hin Lat stream, Nam Nao National Park, Thailand (combined data).

Substrate	No. of Family/No. of Genus/No. of individual			
	Ephemeroptera	Plecoptera	Trichoptera	Total EPT
Boulder	7/20/768	3/5/16	9/14/398	19/39/1,182
Cobble	7/19/915	2/4/11	12/18/396	21/41/1,322
Gravel	7/18/556	3/4/12	11/14/286	21/36/854
Leaf Pack	7/18/727	3/5/15	11/17/259	21/40/1,001
Pebble	7/17/670	3/5/11	11/18/547	21/40/1,228
Root	7/19/716	3/4/11	11/19/273	21/42/1,000
Sand	4/4/88	1/1/1	11/11/51	16/16/140
Total	7/23/4,440	4/9/77	15/31/2,210	26/63/6,727

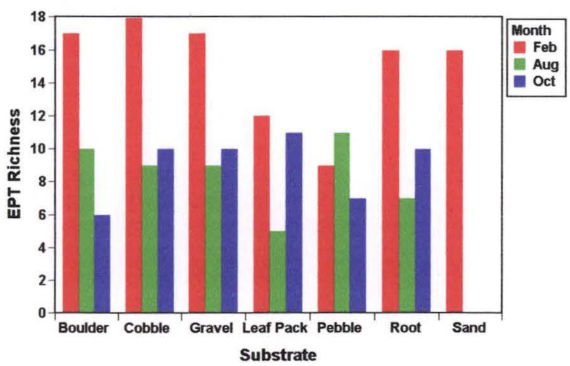
The distribution of EPT families and individuals over each site, month and substrate at Hin Lat stream is summarized in Table 3.6 and Figure 3.23. There were differences in the number of families and individuals collected from each substrate within each site between months. For example, at site Hin Lat 1, the highest diversity of families and individuals was associated with cobbles in February, whereas in August and October, numbers peaked in pebbles and leaf pack respectively. At site Hin Lat 2, families and individuals were most abundant in leaf pack in February, but from pebbles in August and October, and at site Hin Lat 3, they were collected in highest numbers from pebbles and gravel in August and October respectively.

Table 3.6 Summary number of EPT families and individuals associated with each substrate in each sampling month at site Hin Lat 1, Hin Lat 2 and Hin Lat 3; Hin Lat stream, Nam Nao National Park, Thailand, 1998.

Site	Substrate	February		August		October	
		No. Fam.	No. ind.	No. Fam.	No. ind.	No. Fam.	No. ind.
Hin Lat 1	Boulder	17	326	10	68	6	45
	Cobble	18	399	9	68	10	46
	Gravel	17	240	9	42	10	64
	Leaf Pack	12	111	5	27	11	89
	Pebble	9	27	11	61	7	44
	Root	16	315	7	152	10	63
	Sand	16	140	-	-	-	-
Hin Lat 2	Boulder	10	86	8	143	8	125
	Cobble	9	60	11	204	9	169
	Gravel			6	95	8	136
	Leaf Pack	16	267	11	105	9	89
	Pebble	12	85	12	222	10	228
	Root	12	184	11	72	9	50
Hin Lat 3	Boulder	-	-	10	189	9	200
	Cobble	-	-	12	172	11	204
	Gravel	-	-	11	62	11	215
	Leaf Pack	-	-	10	132	11	181
	Pebble	-	-	13	363	12	198
	Root	-	-	13	94	13	70

Figure 3.23 Summary EPT family richness and abundance associated with each substrate in each month and site at Hin Lat stream, Nam Nao National Park, Thailand, 1998.

Site Hin Lat 1



Site Hin Lat 1

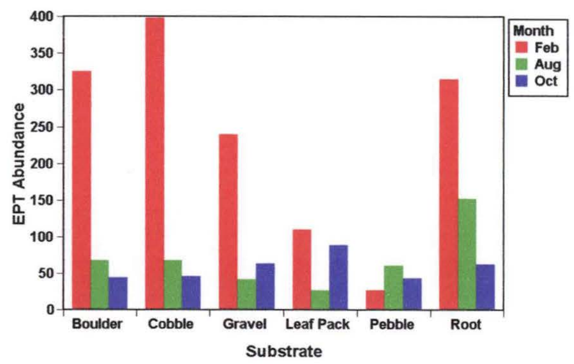
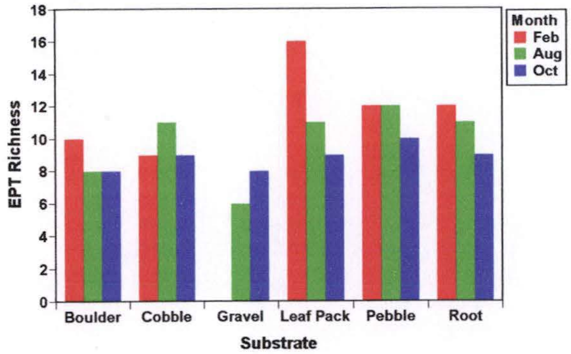
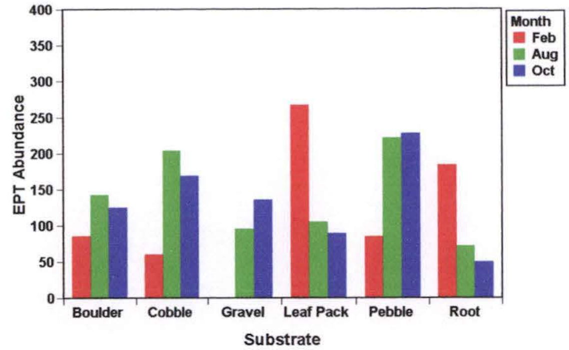


Figure 3.23 (continued)

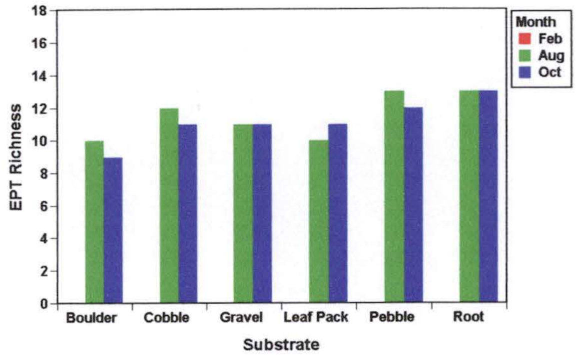
Site Hin Lat 2



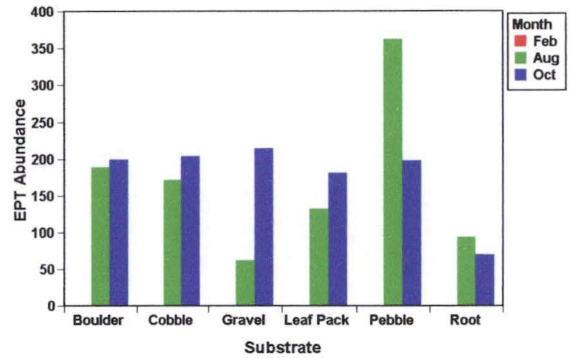
Site Hin Lat 2



Site Hin Lat 3



Site Hin Lat 3



3.2.2.2 Comparing EPT richness and density between substrates (combined data set)

Table 3.7 summarizes the EPT family and genus richness of each substrate type. There was no significant different between substrate types in terms of family richness (One Way ANOVA $H_5 = 5.894$, $P = 0.317$; $H_5 = 5.605$, $P = 0.347$; $H_5 = 3.160$, $P = 0.675$ and $F_{5, 54} = 1.931$, $P = 0.104$ for All EPT taxa, Ephemeroptera, Plecoptera and Trichoptera respectively) and genus richness (One Way ANOVA $H_5 = 6.749$, $P = 0.240$; $H_5 = 5.574$, $P = 0.350$; $H_5 = 2.904$, $P = 0.715$ and $H_5 = 3.800$, $P = 0.579$ for All EPT taxa, Ephemeroptera, Plecoptera and Trichoptera respectively).

Table 3.7 Family and genus richness (mean ± S.E.) of the EPT groups collected from each substrate types at Hin Lat stream, Nam Nao National Park, Thailand in February, August and October 1998.

Substrate	Family/Genus richness (mean ± S.E.)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Boulder	5.3 ± 0.4/9.5 ± 1.3	1.3 ± 0.3/1.4 ± 0.3	5.2 ± 0.3/6.8 ± 0.6	11.8 ± 0.7/17.7 ± 2.1
Cobble	5.4 ± 0.6/9.1 ± 1.5	0.9 ± 0.2/1.0 ± 0.3	6.5 ± 0.6/7.5 ± 0.8	12.8 ± 1.1/17.6 ± 2.1
Gravel	3.9 ± 0.7/6.3 ± 1.4	0.8 ± 0.4/0.8 ± 0.4	4.4 ± 0.7/5.1 ± 0.8	9.1 ± 1.5/12.2 ± 2.3
Leaf Pack	4.9 ± 0.6/8.2 ± 1.5	0.8 ± 0.2/1.0 ± 0.3	6.0 ± 0.4/7.0 ± 0.6	11.7 ± 0.9/16.2 ± 2.1
Pebble	4.0 ± 0.6/7.3 ± 1.5	0.7 ± 0.2/0.8 ± 0.2	4.6 ± 0.6/6.0 ± 0.9	9.3 ± 1.4/14.1 ± 2.6
Root	5.1 ± 0.4/8.8 ± 1.0	0.8 ± 0.2/0.8 ± 0.2	4.9 ± 0.8/5.8 ± 1.0	10.8 ± 1.1/15.4 ±2.0

Similarly, there was also no significant difference between substrates in terms of animal density at either the order level or for all EPT taxa collectively (Table 3.8, One Way ANOVA $H_5 = 5.885$, $P = 0.318$, $F_{5, 54} = 1.788$, $P = 0.131$, $H_5 = 1.802$, $P = 0.876$ and $F_{5, 54} = 0.392$, $P = 0.852$ for all EPT, Ephemeroptera, Plecoptera and Trichoptera respectively).

Table 3.8 Density (mean ± S.E. individuals per sample) of the EPT groups collected from each substrate types at Hin Lat stream, Nam Nao National Park, Thailand in February, August and October 1998.

Substrate	Density (mean ± S.E. individuals per sample)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Boulder	14.7 ± 1.5	0.8 ± 0.1	9.0 ± 0.8	20.4 ± 0.7
Cobble	17.2 ± 1.0	0.9 ± 0.2	8.7 ± 1.1	25.0 ± 2.1
Gravel	12.9 ± 2.1	0.6 ± 0.2	6.1 ± 1.0	18.3 ± 2.3
Leaf Pack	14.5 ± 2.0	1.1 ± 0.4	5.9 ± 0.5	19.7 ± 2.3
Pebble	9.4 ± 2.3	0.7 ± 0.2	8.6 ± 1.4	17.2 ± 3.3
Root	15.3 ±2.5	0.9 ± 0.2	11.1 ± 7.2	22.2 ± 3.9

However, there were significant differences in the substrate related density of some EPT taxa at higher taxonomic resolution, namely at family and genus levels. About one third (n = 8) of the 26 families present in the dataset demonstrated significant differences in density between substrates (Table 3.9). These included 2 families of mayflies (Baetidae and Caenidae), 1 family of stoneflies (Nemouridae) and 5 families of caddisflies (Ecnomidae, Leptoceridae, Limnephilidae, Polycentropodidae and Stenopsychidae).

The baetid mayflies were significantly associated with roots and leaf packs (One Way ANOVA on ranks, H_5 = 18.761, P = 0.002). They were six times more common on root and leaf pack than on gravel substrate where they had their lowest density. In contrast, caenid mayflies were strongly associated with cobbles (One Way ANOVA on ranks, H_5 = 14.538, P = 0.013). The caenid density was highest on cobbles and lowest on pebbles with 14.0 ± 2.9 and 4.3 ± 1.3 individuals per sample respectively. Stoneflies were very rare in Hin Lat stream and only nemourid stoneflies showed a strong association with boulders (One Way ANOVA on ranks, H_5 = 13.835, P = 0.017). They were present on boulders with 0.6 ± 0.2 individuals per sample but totally absent on cobble and gravel substrates.

The ecnomid, polycentropodid and stenopsychid caddisflies were strongly associated with coarser substrates such as boulders, cobbles and pebbles (One Way ANOVA on ranks H_5 = 19.026, P = 0.002; H_5 = 15.017, P = 0.010 and H_5 = 29.165, P = <0.001 respectively). Ecnomid caddisflies were five times more abundant among boulders and cobbles than from gravel which had 0.5 ± 0.2 individuals per sample. Polycentropodid density was four times higher on cobbles than on leaf pack and pebbles. The stenopsychid caddisflies also reached their highest density on cobbles with 2.4 ± 0.3 individuals per sample and had low density on gravel, leaf pack and root substrates with 0.3 ± 0.2, 0.4 ± 0.2 and 0.1 ± 0.1 individuals per sample respectively.

It was apparent that leptocerid and limnephilid caddisflies were significantly associated with finer substrates, e.g. root and gravel (One Way ANOVA on ranks H_5 = 22.125, P = <0.001 and H_5 = 15.517, P = 0.008 respectively). The mean density of leptocerids was highest on root substrates (9.8 ± 7.1 individuals per sample) and much lower on boulders, cobbles, pebbles and gravel (range of 0.1 ± 0.1 - 0.2 ± 0.1 individuals per sample). Limnephilids were present only on gravel substrates and were absent on all of the other substrates.

Table 3.9 Summary of responses of the EPT family to substrate types at Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean ± S.E density (individuals per sample). F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Family *Combined data set*	**N**	**Boulder**	**Cobble**	**Gravel**	**Leaf Pack**	**Pebble**	**Root**	**Sig.**	**ANOVA value**	**Preference**
Baetidae	10	2.5 ± 0.8ab	2.3 ± 0.6ab	0.9 ± 0.3b	5.7 ± 1.2a	2.1 ± 0.7ab	5.8 ± 1.5a	s	H_5 = 18.761, P = 0.002	Root and leaf pack
Caenidae	10	8.7 ± 1.2ab	14.0 ± 2.9a	8.9 ± 1.8ab	8.0 ± 2.2ab	4.3 ± 1.3b	6.1 ± 0.6ab	s	H_5 = 14.538, P = 0.013	Cobble
Ephemeridae	10	2.7 ± 0.8	2.8 ± 0.8	0.6 ± 0.3	1.8 ± 1.0	0.5 ± 0.2	1.5 ± 0.5	ns	H_5 = 13.222, P = 0.021	
Heptageniidae	10	2.4 ± 0.3	2.9 ± 0.7	1.0 ± 0.4	1.1 ± 0.4	2.7 ± 0.7	1.3 ± 0.5	ns	H_5 = 9.985, P = 0.076	
Leptophlebiidae	10	4.0 ± 0.6	5.8 ± 0.6	3.6 ± 0.9	3.5 ± 0.8	3.4 ± 0.8	4.0 ± 1.0	ns	$F_{5, 54}$ = 1.308, P = 0.275	
Neoephemeridae	10	0.4 ± 0.2	0.9 ± 0.3	0.1 ± 0.1	5.1 ± 2.9	0.2 ± 0.1	1.6 ± 0.9	ns	H_5 = 11.580, P = 0.041	
Tricorythidae	10	0.6 ± 0.2	0.5 ± 0.2	0.8 ± 0.2	0.7 ± 0.3	0.6 ± 0.3	0.5 ± 0.3	ns	H_5 = 1.423, P = 0.922	
Capniidae	10	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	H_5 = 10.169, P = 0.071	
Leuctridae	10	0.2 ± 0.1	0.4 ± 0.2	0.5 ± 0.3	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	ns	H_5 = 5.116, P = 0.402	
Nemouridae	10	0.6 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.2 ± 0.1ab	0.4 ± 0.3ab	0.3 ± 0.2ab	s	H_5 = 13.835, P = 0.017	Boulder
Perlidae	10	0.5 ± 0.2	0.5 ± 0.2	0.4 ± 0.2	0.9 ± 0.4	0.4 ± 0.2	0.6 ± 0.2	ns	H_5 = 1.260, P = 0.939	
Calamoceratidae	10	0.7 ± 0.3ab	0.8 ± 0.2ab	0.2 ± 0.2ab	1.2 ± 0.4a	0.1 ± 0.1b	1.0 ± 0.2ab	s	$F_{5, 54}$ = 3.006, P = 0.018	Leaf pack
Dipseudopsidae	10	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	ns	H_5 = 10.172, P = 0.070	
Ecnomidae	10	2.7 ± 0.6a	2.9 ± 0.8a	0.5 ± 0.2b	1.7 ± 0.4ab	0.6 ± 0.3ab	1.7 ± 0.5ab	s	H_5 = 19.026, P = 0.002	Boulder and cobble
Goeridae	10	0.0 ± 0.0	0.2 ± 0.1	0.9 ± 0.7	0.2 ± 0.2	0.4 ± 0.2	0.0 ± 0.0	ns	H_5 = 7.194, P = 0.207	
Helicopsychidae	10	0.3 ± 0.2	0.2 ± 0.1	0.4 ± 0.3	1.3 ± 0.6	1.3 ± 1.1	0.3 ± 0.2	ns	H_5 = 4.296, P = 0.508	
Hydropsychidae	10	3.2 ± 0.8	3.0 ± 0.6	3.4 ± 1.0	3.6 ± 0.6	4.4 ± 1.1	0.9 ± 0.3	ns	$F_{5, 54}$ = 2.348, P = 0.053	
Leptoceridae	10	0.1 ± 0.1b	0.2 ± 0.1b	0.2 ± 0.1b	0.5 ± 0.2ab	0.2 ± 0.1b	9.8 ± 7.1a	s	H_5 = 22.125, P = <0.001	Root
Limnephilidae	10	0.0 ± 0.0b	0.0 ± 0.0b	0.4 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 15.517, P = 0.008	Gravel
Odontoceridae	10	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	ns	H_5 = 5.000, P = 0.416	
Philopotamidae	10	3.9 ± 1.1	2.5 ± 0.9	2.6 ± 0.8	4.5 ± 1.1	5.8 ± 1.8	1.2 ± 0.6	ns	H_5 = 7.926, P = 0.160	
Phryganeidae	10	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	ns	H_5 = 5.268, P = 0.384	
Polycentropodidae	10	3.3 ± 0.7ab	4.9 ± 1.2a	1.8 ± 0.4ab	1.3 ± 0.3b	1.3 ± 0.3b	2.5 ± 0.9ab	s	H_5 = 15.017, P = 0.010	Cobble
Psychomyiidae	10	0.0 ± 0.0	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	ns	H_5 = 7.311, P = 0.198	
Stenopsychidae	10	1.8 ± 0.5ab	2.4 ± 0.3a	0.3 ± 0.2bc	0.4 ± 0.2bc	1.9 ± 0.5ac	0.1 ± 0.1b	s	H_5 = 29.165, P = <0.001	Cobble and pebble
Xiphocentronidae	10	0.6 ± 0.3	0.2 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0.0 ± 0.0	ns	H_5 = 6.464, P = 0.264	

At the genus level, about one quarter of the taxa (14 of 63 genera collected) revealed significant substrate associations (Table 3.10). These genera can be categorized into two groups: those that prefer finer (root, leaf pack and gravel) substrates, and those that prefer coarser (boulder, cobble and pebble) substrates. The former group included *Baetis* (F. Baetidae), *Centroptilum* (F. Baetidae), *Paraleptophlebia* (F. Leptophlebiidae), *Thraulus* (F. Leptophlebiidae), *Anisocentropus* (F. Calamoceratidae), *Leptocerus* (F. Leptoceridae) and *Apatania* (F. Limnephilidae). These genera were present at highest density on root and leaf pack. Only the genus *Apatania* was strongly associated with gravelly substrates, and was absent elsewhere.

Caenis (F. Caenidae), *Leptophlebia* (F. Leptophlebiidae), *Ecnomus* (F. Ecnomidae), *Macrostemum* (F. Hydropsychidae) and *Stenopsyche* (F. Stenopsychidae) made up the coarser substrate preferential group. They demonstrated preference for boulders, cobbles and pebbles and achieved their highest density on these substrates.

Table 3.10 Summary of responses of the EPT genus to substrate types at Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean ± S.E density (individuals per sample). F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Genus	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sig.	ANOVA value	Preference
Baetis	10	3.2 ± 1.5ab	2.6 ± 0.7ab	0.9 ± 0.3b	5.4 ± 1.2a	2.0 ± 0.6ab	6.5 ± 2.5a	s	H_5 = 17.423, P = 0.004	Root and leaf pack
Centroptilum	10	0.5 ± 0.2ab	0.2 ± 0.1b	0.2 ± 0.2b	0.3 ± 0.2b	0.0 ± 0.0b	1.8 ± 0.7a	s	H_5 = 19.736, P = 0.001	Root
Caenis	10	8.7 ± 1.2ab	14.0 ± 2.9a	8.9 ± 1.8ab	8.0 ± 2.2ab	4.3 ± 1.3b	6.1 ± 0.6ab	s	H_5 = 14.538, P = 0.013	Cobble
Leptophlebia	10	2.4 ± 0.6a	4.2 ± 1.3a	2.5 ± 1.1ab	0.2 ± 0.2b	0.0 ± 0.0b	0.5 ± 0.5b	s	H_5 = 24.713, P = <0.001	Boulder and cobble
Paraleptophlebia	10	0.5 ± 0.2ab	0.5 ± 0.3ab	0.0 ± 0.0b	0.0 ± 0.0b	0.1 ± 0.1b	2.4 ± 1.0a	s	H_5 = 13.542, P = 0.019	Root
Thraulus	10	0.4 ± 0.3ab	0.1 ± 0.1b	0.0 ± 0.0b	1.8 ± 0.5a	0.3 ± 0.3b	0.7 ± 0.4ab	s	H_5 = 18.304, P = 0.003	Leaf pack
Anisocentropus	10	0.7 ± 0.3ab	0.7 ± 0.3ab	0.1 ± 0.1ab	1.2 ± 0.4a	0.0 ± 0.0b	1.0 ± 0.2a	s	H_5 = 18.940, P = 0.002	Leaf pack and root
Ecnomus	10	2.7 ± 0.6a	2.9 ± 0.8a	0.5 ± 0.2b	1.7 ± 0.4ab	0.6 ± 0.3ab	1.7 ± 0.5ab	s	H_5 = 19.026, P = 0.002	Boulder and cobble
Macrostemum	10	1.5 ± 0.4ab	1.7 ± 0.3a	1.5 ± 0.3ab	1.3 ± 0.4ab	2.4 ± 0.5a	0.2 ± 0.1b	s	$F_{5, 54}$ = 4.028, P =0.004	Cobble and pebble
Leptocerus	10	0.1 ± 0.1b	0.1 ± 0.1b	0.0 ± 0.0b	0.4 ± 0.2b	0.0 ± 0.0b	10.0 ± 7.0a	s	H_5 = 31.001, P = <0.001	Root
Apatania	10	0.0 ± 0.0b	0.0 ± 0.0b	0.4 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 15.517, P = 0.008	Gravel
Polycentropus	10	0.4 ± 0.2ab	0.2 ± 0.2ab	0.0 ± 0.0b	0.0 ± 0.0b	0.7 ± 0.3a	0.0 ± 0.0b	s	H_5 = 16.125, P = 0.006	Pebble
Pseudoneureclipsis	10	3.7 ± 1.0ab	4.8 ± 1.2a	1.8 ± 0.4ab	1.3 ± 0.3b	1.0 ± 0.3b	2.5 ± 0.9ab	s	H_5 = 15.623, P = 0.008	Cobble
Stenopsyche	10	1.8 ± 0.5ab	2.4 ± 0.3a	0.3 ± 0.2bc	0.4 ± 0.2bc	1.9 ± 0.5ac	0.1 ± 0.1b	s	H_5 = 29.165, P = <0.001	Cobble and pebble

3.2.2.3 Comparing EPT richness and density associated with each substrate within each site (using combined data of each site)

3.2.2.3.1 Site Hin Lat 1

Table 3.11 summarizes the EPT genus richness of each substrate type at site Hin Lat 1. Genus level richness was significantly highest on cobbles (11.4 ± 1.1 genera per sample) and lowest on leaf pack (6.0 ± 0.8 genera per sample) (One Way ANOVA on ranks, H_5 = 15.753, P = 0.008). However, only Trichoptera demonstrated a significant difference in genus richness between substrates (One Way ANOVA, $F_{5, 54}$ = 4.695, P = 0.001). It had high genus richness on cobbles and gravel (with 5.4 ± 0.6 and 4.6 ± 0.8 genera per sample respectively); and had low genus richness on leaf pack and pebbles (with 2.2 ± 0.3 and 2.7 ± 0.4 genera per sample respectively).

Ephemeroptera and Plecoptera did not show any significant difference in genus richness between substrates at site Hin Lat 1 (One Way ANOVA $F_{5, 54}$ = 2.387, P = 0.050 and H_5 = 10.204, P = 0.070 respectively).

Table 3.11 Genus richness (mean ± S.E.) of the EPT groups collected from each substrate types at site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in February, August and October 1998.

Substrate	Genus richness (mean ± S.E.)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Boulder	5.9 ± 0.8	0.7 ± 0.2	4.3 ± 0.4ab	10.9 ± 1.1ab
Cobble	5.3 ± 0.8	0.7 ± 0.3	5.4 ± 0.6a	11.4 ± 1.1a
Gravel	3.8 ± 0.7	0.5 ± 0.2	4.6 ± 0.8ac	8.9 ± 1.5ab
Leaf Pack	3.5 ± 0.6	0.3 ± 0.2	2.2 ± 0.3b	6.0 ± 0.8b
Pebble	3.3 ± 0.7	0.0 ± 0.0	2.7 ± 0.4bc	6.0 ± 1.0ab
Root	5.0 ± 0.6	0.3 ± 0.2	3.6 ± 0.6ab	8.9 ± 1.1ab

Table 3.12 summarizes the mean density of the EPT taxa at order, family and genus levels, which were significantly different between each substrate type.

At order level, Ephemeroptera demonstrated significant preference for cobbles, boulders and root and maintained its lowest density on pebbles. Similarly, Trichoptera showed a preference for coarser substrates with high densities on cobbles and boulders, and low density on pebbles and leaf pack. Plecoptera did not show any significant preferences.

At family level, 8 of 26 families found at site Hin Lat 1 demonstrated significant differences in mean density between substrates. Baetidae, Leptoceridae and Limnephlidae were strongly associated with finer substrates (root and gravel). Baetid mayflies were present at high density on root (4.8 ± 1.6 individuals per sample) and at low density on cobbles, gravel and pebbles (range 0.6 ± 0.3 and 0.9 ± 0.5 individuals per sample). Leptocerid caddisflies were also present at highest density on root (10.1 ± 7.0 individuals per sample) but were present at low density on all of the other substrates (within the range of 0.1 ± 0.1 and 0.3 ± 0.2 individuals per sample). Limnephilid caddises were found only on gravel subtrates (0.4 ± 0.2 individuals per sample) and were totally absent on the other substrates.

On the other hand, Caenidae, Ecnomidae, Hydropsychidae, Polycentropodidae and Stenopsychidae were strongly associated with coarser substrates (boulders and cobbles); only Caenidae and Hydropsychidae also associated with gravel. Caenids were also present at high density on cobbles, gravel and boulders and at low density on pebbles. Hydropsychids were present at relatively high density on cobbles, boulders and gravel but present at lowest density on leaf pack. The ecnomid, polycentropodid and stenopsychid caddises were present at highest density on cobbles. However, the

Table 3.12 Summary of responses of the EPT taxa to substrate types within each site at Hin Lat stream, Nam Nao N.P., Thailand, 1998. Values are mean ± S.E density (individuals per sample). F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sig.	ANOVA value	Preference
HIN LAT 1										
Order										
Ephemeroptera	10	15.8 ± 2.3a	20.6 ± 4.1a	12.3 ± 2.2ab	8.6 ± 1.2ab	4.1 ± 1.1b	16.3 ± 3.8a	s	H_5 = 23.057, P = <0.001	Cobble, boulder and root
Trichoptera	10	7.9 ± 1.4ac	11.4 ± 2.5a	3.9 ± 0.5ab	2.6 ± 0.6bc	2.1 ± 0.3b	12.7 ± 7.2ab	s	H_5 = 26.343, P = <0.001	Cobble and boulder
Family										
Baetidae	10	1.0 ± 0.4ab	0.9 ± 0.5b	0.7 ± 0.3b	2.6 ± 1.8ab	0.6 ± 0.3b	4.8 ± 1.6a	s	H_5 = 15.897, P = 0.007	Root
Caenidae	10	10.4 ± 1.9a	13.9 ± 3.0a	10.6 ± 2.1a	5.3 ± 0.8ab	2.1 ± 0.7b	6.3 ± 1.3ab	s	H_5 = 21.385, P = <0.001	Cobble, gravel and boulder
Ecnomidae	10	2.4 ± 0.7ab	3.2 ± 0.9a	0.5 ± 0.2ab	0.6 ± 0.3ab	0.3 ± 0.2b	2.0 ± 0.6ab	s	H_5 = 18.195, P = 0.003	Cobble
Hydropsychidae	10	1.6 ± 0.4a	2.6 ± 1.4a	1.6 ± 0.4a	0.1 ± 0.1b	1.1 ± 0.3ab	0.7 ± 0.3ab	s	H_5 = 15.720, P = 0.008	Cobble, gravel and boulder
Leptoceridae	10	0.1 ± 0.1b	0.2 ± 0.1b	0.2 ± 0.1b	0.3 ± 0.2b	0.2 ± 0.1b	10.1 ± 7.0a	s	H_5 = 21.392, P = <0.001	Root
Limnephilidae	10	0.0 ± 0.0b	0.0 ± 0.0b	0.4 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 15.517, P = 0.008	Gravel
Polycentropodidae	10	4.1 ± 1.1ab	5.6 ± 1.3a	2.3 ± 0.6ab	0.7 ± 0.3b	0.8 ± 0.2b	2.6 ± 1.0ab	s	H_5 = 17.817, P = 0.003	Cobble
Stenopsychidae	10	0.6 ± 0.3ab	1.6 ± 0.5a	0.3 ± 0.2ab	0.0 ± 0.0b	0.1 ±0.1b	0.0 ± 0.0b	s	H_5 = 21.282, P = <0.001	Cobble
Genus										
Centroptilum	10	0.3 ± 0.2ab	0.2 ± 0.1ab	0.2 ± 0.2ab	0.3 ± 0.2ab	0.0 ± 0.0b	1.4 ± 0.8a	s	H_5 = 11.711, P = 0.039	Root
Caenis	10	10.4 ± 1.9a	13.9 ± 3.0a	10.6 ± 2.1a	5.3 ± 0.8ab	2.1 ± 0.7b	6.3 ± 1.3ab	s	H_5 = 21.385, P = <0.001	Cobble, gravel and boulder
Nixe	10	0.6 ± 0.2a	0.2 ± 0.1ab	0.1 ± 0.1ab	0.0 ± 0.0b	0.0 ± 0.0b	0.4 ± 0.4ab	s	H_5 = 13.146, P = 0.022	Boulder
Leptophlebia	10	2.7 ± 0.9ac	4.2 ± 1.3a	2.5 ± 1.1ab	0.0 ± 0.0b	0.0 ± 0.0b	0.5 ± 0.5bc	s	H_5 = 23.461, P = <0.001	Cobble and boulder
Paraleptophlebia	10	0.0 ± 0.0b	0.4 ± 0.4b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	2.4 ± 1.0a	s	H_5 = 22.223, P = <0.001	Root
Ecnomus	10	2.4 ± 0.7ab	3.2 ± 0.9a	0.5 ± 0.2ab	0.6 ± 0.3ab	0.3 ± 0.2b	2.0 ± 0.6ab	s	H_5 = 18.195, P = 0.003	Cobble
Leptocerus	10	0.1 ± 0.1b	0.1 ± 0.1b	0.0 ± 0.0b	0.2 ± 0.1b	0.0 ± 0.0b	10.1 ± 7.0a	s	H_5 = 31.695, P = <0.001	Root
Apatania	10	0.0 ± 0.0b	0.0 ± 0.0b	0.4 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 15.517, P = 0.008	Gravel

* for gravel, there were only 6 replicates.

Table 3.12 (continued) Summary of responses of the EPT taxa to substrate types within each site at Hin Lat stream, Nam Nao N.P., Thailand, 1998. Values are mean ± S.E density (individuals per sample). F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sig.	ANOVA value	Preference
Pseudoneureclipsis	10	4.1 ± 1.1ab	5.6 ± 1.3a	2.3 ± 0.6ab	0.7 ± 0.3b	0.8 ± 0.2b	2.6 ± 1.0ab	s	H_5 = 17.817, P = 0.003	Cobble
Stenopsyche	10	0.6 ± 0.3ab	1.6 ± 0.5a	0.3 ± 0.2ab	0.0 ± 0.0b	0.1 ± 0.1b	0.0 ± 0.0b	s	H_5 = 21.282, P = <0.001	Cobble
HIN LAT 2										
Order										
Trichoptera	10*	6.1 ± 1.6ab	6.4 ± 0.7ab	9.4 ± 0.6a	6.7 ± 0.6ab	11.0 ± 1.6a	2.2 ± 0.5b	s	H_5 = 26.396, P = <0.001	Pebble and gravel
Family										
Baetidae	10*	1.3 ± 0.4bc	2.0 ± 1.0bc	1.6 ± 0.4ab	6.0 ± 1.1a	1.6 ± 0.7b	7.6 ± 2.5ac	s	H_5 = 22.851, P = <0.001	Leaf pack and root
Ecnomidae	10*	1.0 ± 0.6ab	1.1 ± 0.2ab	0.0 ± 0.0b	1.8 ± 0.6a	0.5 ± 0.3ab	0.4 ± 0.2ab	s	H_5 = 16.358, P = 0.006	Leaf pack
Hydropsychidae	10*	3.7 ± 1.4ab	3.1 ± 0.7ab	7.3 ± 0.7a	3.5 ± 0.6ab	7.4 ± 2.1a	0.4 ± 0.2b		H_5 = 21.131, P = <0.001	Gravel and pebble
Genus										
Baetis	10*	1.1 ± 0.4b	2.0 ± 1.0b	1.6 ± 0.4ab	6.0 ± 1.1a	1.5 ± 0.7b	6.8 ± 2.5ab	s	H_5 = 20.132, P = 0.001	Leaf pack
Procloeon	10*	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.3 ± 0.2a	s	H_5 = 14.321, P = 0.014	Root
Nixe	10*	2.5 ± 0.8ab	4.0 ± 1.1a	1.8 ± 0.6ab	1.1 ± 0.5ab	3.9 ± 1.7ab	0.4 ± 0.3b	s	H_5 = 12.169, P = 0.033	Cobble
Atalophlebia	10*	0.0 ± 0.0b	0.0 ± 0.0b	1.7 ± 1.1a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 16.970, P = 0.005	Gravel
Choroterpes	10*	0.8 ± 0.8b	0.7 ± 0.3ab	0.3 ± 0.2ab	1.4 ± 0.7ab	1.4 ± 0.3ab	3.1 ± 1.1a	s	H_5 = 15.196, P = 0.010	Root
Leptophlebia	10*	1.3 ± 0.5a	0.0 ± 0.0b	0.0 ± 0.0b	0.2 ± 0.2b	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 30.230, P = <0.001	Boulder
Thraulodes	10*	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.1 ± 0.1b	0.6 ± 0.3a	s	H_5 = 15.371, P = 0.009	Root
Ecnomus	10*	1.0 ± 0.6ab	1.1 ± 0.2ab	0.0 ± 0.0b	1.8 ± 0.6a	0.5 ± 0.3ab	0.4 ± 0.2ab	s	H_5 = 16.358, P = 0.006	Leaf pack
Cheumatopsyche	10*	3.0 ± 1.1ab	2.4 ± 0.7ab	4.5 ± 0.3a	2.6 ± 0.5ab	4.8 ± 1.4a	0.1 ± 0.1b	s	H_5 = 16.068, P = 0.007	Gravel and pebble
Macrostemum	10*	1.3 ± 0.4ab	1.7 ± 0.3ab	2.8 ± 0.6a	1.3 ± 0.4ab	3.0 ± 0.9a	0.2 ± 0.1b	s	H_5 = 18.653, P = 0.002	Gravel and pebble
HIN LAT 3										
Order										
Ephemeroptera	6	20.3 ± 3.2ab	24.4 ± 4.4ab	13.8 ± 2.5ab	17.5 ± 2.8ab	27.2 ± 4.0a	10.8 ± 1.9b	s	H_5 = 16.091, P = 0.007	Pebble
Trichoptera	6	11.5 ± 3.0ab	8.0 ± 2.3ab	14.4 ± 5.0ab	14.0 ± 4.0ab	19.1 ± 3.7a	3.2 ± 0.8b	s	H_5 = 14.682, P = 0.012	Pebble
Family										
Caenidae	6	8.3 ± 2.3ab	7.1 ± 1.2ab	6.5 ± 1.7ab	2.8 ± 0.5b	13.5 ± 3.1a	5.1 ± 0.9ab	s	H_5 = 16.548, P = 0.005	Pebble

* for gravel, there were only 6 replicates.

Table 3.12 (continued) Summary of responses of the EPT taxa to substrate types within each site at Hin Lat stream, Nam Nao N.P., Thailand, 1998. Values are mean ± S.E density (individuals per sample). F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sig.	ANOVA value	Preference
Heptageniidae	6	3.4 ± 0.4ab	3.0 ± 0.9ab	1.7 ± 0.9ab	1.7 ± 0.4ab	3.8 ± 0.7a	0.7 ± 0.3b	s	$F_{5,30} = 3.471$, P = 0.014	Pebble
Leptophlebiidae	6	4.5 ± 1.0ab	8.3 ± 1.8a	7.0 ± 2.0a	7.0 ± 0.7a	6.9 ± 0.9a	0.9 ± 0.3b	s	$F_{5,30} = 4.676$, P = 0.003	Cobble, gravel, leaf pack, pebble
Neoephemeridae	6	0.0 ± 0.0b	0.8 ± 0.5ab	0.2 ± 0.2ab	10.2 ± 4.7a	0.2 ± 0.2ab	2.3 ± 1.5ab	s	$H_5 = 14.296$, P = 0.014	Leaf pack
Nemouridae	6	0.8 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	0.2 ± 0.2ab	0.7 ± 0.5ab	0.0 ± 0.0b	s	$H_5 = 17.320$, P = 0.004	Boulder
Calamoceratidae	6	0.0 ± 0.0b	0.3 ± 0.2ab	0.2 ± 0.2ab	0.3 ± 0.2ab	0.0 ± 0.0b	0.9 ± 0.2a	s	$H_5 = 14.599$, P = 0.012	Root
Hydropsychidae	6	5.6 ± 1.2a	3.8 ± 0.9ab	5.7 ± 2.5ab	5.4 ± 1.2a	5.5 ± 1.6ab	0.6 ± 0.4b	s	$H_5 = 13.016$, P = 0.023	Boulder and leaf pack
Leptoceridae	6	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.5 ± 0.2a	s	$H_5 = 15.909$, P = 0.007	Root
Philopotamidae	6	9.1 ± 3.1ab	4.7 ± 1.7ab	8.0 ± 2.6ab	9.5 ± 2.7ab	13.5 ± 1.9a	0.8 ± 0.5b	s	$F_{5,30} = 3.713$, P = 0.010	Pebble
Genus										
Baetis	6	5.4 ± 2.4ab	6.2 ± 1.5a	1.0 ± 0.3b	1.3 ± 0.6ab	4.3 ± 0.6ab	2.8 ± 0.7ab	s	$H_5 = 16.184$, P = 0.006	Cobble
Caenis	6	8.3 ± 2.3ab	7.1 ± 1.2ab	6.5 ± 1.7ab	2.8 ± 0.5b	13.5 ± 3.1a	5.1 ± 0.9ab	s	$H_5 = 16.548$, P = 0.005	Pebble
Nixe	6	3.4 ± 0.4ab	3.0 ± 0.9ab	1.7 ± 0.9ab	1.7 ± 0.4ab	3.8 ± 0.7a	0.7 ± 0.3b	s	$F_{5,30} = 3.471$, P = 0.014	Pebble
Atalophlebioides	6	3.7 ± 1.5ab	13.0 ± 2.9a	7.8 ± 2.4a	3.3 ± 0.9ab	3.2 ± 1.6ab	0.0 ± 0.0b	s	$H_5 = 18.411$, P = 0.002	Cobble and gravel
Choroterpes	6	0.0 ± 0.0b	1.3 ± 0.8ab	0.5 ± 0.5b	4.3 ± 1.1a	0.0 ± 0.0b	0.6 ± 0.3ab	s	$H_5 = 20.528$, P = <0.001	Leaf pack
Cryptopenella	6	0.8 ± 0.4ab	0.8 ± 0.5ab	1.2 ± 0.8ab	0.0 ± 0.0b	5.3 ± 1.0a	0.7 ± 0.3ab	s	$H_5 = 18.337$, P = 0.003	Pebble
Minyphlebia	6	2.0 ± 1.2ab	1.2 ± 0.5ab	0.0 ± 0.0b	3.0 ± 1.3a	0.5 ± 0.3ab	0.0 ± 0.0b	s	$H_5 = 14.457$, P = 0.013	Leaf pack
Thraulodes	6	0.8 ± 0.7ab	0.3 ± 0.2ab	0.3 ± 0.3ab	0.2 ± 0.2ab	1.7 ± 0.6a	0.0 ± 0.0b	s	$H_5 = 11.948$, P = 0.036	Pebble
Thraulus	6	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	2.0 ± 0.7a	0.0 ± 0.0b	0.2 ± 0.2ab	s	$H_5 = 18.200$, P = 0.003	Leaf pack
Neoephemera	6	0.0 ± 0.0b	0.8 ± 0.5ab	0.2 ± 0.2ab	10.2 ± 4.7a	0.2 ± 0.2ab	2.3 ± 1.5ab	s	$H_5 = 14.296$, P = 0.014	Leaf pack
Chimarra	6	8.6 ± 3.1ab	4.5 ± 1.7ab	8.0 ± 2.6ab	9.5 ± 2.7ab	13.4 ± 1.9a	0.8 ± 0.4b	s	$H_5 = 17.753$, P = 0.003	Pebble
Polycentropus	6	0.7 ± 0.3ab	0.3 ± 0.3ab	0.0 ± 0.0b	0.0 ± 0.0b	1.2 ± 0.3a	0.0 ± 0.0b	s	$H_5 = 17.572$, P = 0.004	Pebble

* for gravel, there were only 6 replicates.

ecnomids were at the lowest density on pebbles while polycentropodids were present at low density on leaf pack and pebbles. Stenopsychidae were totally absent from leaf pack and root, and had very low density on pebbles.

At the genus level, 10 of 54 genera at site Hin Lat 1 showed significant substrate preference. *Centroptilum* (F. Baetidae), *Paraleptophlebia* (F. Leptophlebiidae), *Leptocerus* (F. Leptoceridae) and *Apatania* (F. Limnephilidae) demonstrated a strong association with finer substrates (root and gravel). Whereas *Caenis* (F. Caenidae), *Nixe* (F. Heptageniidae), *Leptophlebia* (F. Leptophlebiidae), *Ecnomus* (F. Ecnomidae), *Pseudoneureclipsis* (F. Polycentropodidae) and *Stenopsyche* (F. Stenopsychidae) demonstrated a preference for coarser substrates such as cobbles and boulders. *Caenis* also had a strong association with gravel.

Centroptilum, *Paraleptophlebia* (mayflies) and *Leptocerus* (caddis) were most common on root substrates. *Centroptilum* avoided pebbles while *Paraleptophlebia* was totally absent from boulders, gravel, leaf pack and pebbles, but sparingly present on cobbles. *Leptocerus* was totally absent on gravel and pebbles, but present at low density on boulders, cobbles and leaf pack.

Apatania was one of the few taxa strongly associated with gravel substrates but totally absent on the other substrates.

Caenis was present at high density on cobbles, boulders and gravel (within the range of 10.4 ± 1.9 and 13.9 ± 3.0 individuals per sample) but present at lowest density on pebbles (2.1 ± 0.7 individuals per sample).

Nixe was present at highest density on boulders but absent on leaf pack and pebbles.

Leptophlebia, *Ecnomus*, *Pseudoneureclipsis* and *Stenopsyche* density were highest on cobbles. However, they avoided different substrates e.g. *Leptophlebia* and *Stenopsyche* avoided leaf pack, pebbles and root; *Ecnomus* had the lowest density on pebbles; and *Pseudoneureclipsis* avoided leaf pack and pebbles.

3.2.2.3.2 Site Hin Lat 2

EPT taxa were evenly distributed over all the substrates at site Hin Lat 2. Table 3.13 summarizes EPT genus richness of each substrate type. There was no significant difference between substrates in taxa richness for all EPT, Ephemeroptera, Plecoptera and Trichoptera (One Way ANOVA $F_{5,50} = 0.434$, P = 0.823; $F_{5,50} = 0.0746$, P = 0.996; $H_5 = 8.299$, P = 0.141; $H_5 = 7.602$, P = 0.180 respectively)

Table 3.13 Genus richness (mean ± S.E.) of the EPT groups collected from each substrate types at site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in February, August and October 1998.

Substrate	Genus richness (mean ± S.E.)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Boulder	4.9 ± 0.8	0.1 ± 0.1	3.2 ± 0.7	8.2 ± 1.3
Cobble	4.9 ± 1.1	0.3 ± 0.2	4.2 ± 0.4	9.4 ± 1.6
Gravel	5.5 ± 0.7	0.0 ± 0.0	3.7 ± 0.2	9.2 ± 0.5
Leaf Pack	4.8 ± 0.8	0.5 ± 0.2	5.0 ± 0.5	10.3 ± 1.1
Pebble	5.1 ± 1.1	0.5 ± 0.2	3.8 ± 0.6	9.4 ± 1.8
Root	4.7 ± 0.7	0.5 ± 0.2	2.7 ± 0.6	7.9 ± 1.0

There were significant differences between substrates in term of animal density at order, family and genus levels (Table 3.12).

At order level, only Trichoptera demonstrated significant preference for pebbles and gravel and was present at lowest density on root substrate. Ephemeroptera and Plecoptera did not show any significant difference in densities between substrates.

At family level, only 3 of 21 families at site Hin Lat 2 showed significant differences in mean density between substrates. Baetidae and Ecnomidae were strongly associated with finer substrates (leaf pack and root). Baetid mayflies were present at high density on leaf pack and root (with 6.0 ± 1.1 and 7.6 ± 2.5 individuals per sample respectively) and at low density on all of the other substrates (between 1.3 ± 0.4 and 2.0 ± 1.0 individuals per sample). The ecnomid caddises were also present at high density on leaf pack but absent from gravel.
In contrast, Hydropsychidae demonstrated a strong association for intermediate sized substrates (pebbles and gravel) and had their lowest density on roots.

At genus level, 10 of 44 genera at site Hin Lat 2 showed significant differences in terms of substrate preferences. *Baetis* (F. Baetidae), *Procloeon* (F. Baetidae), *Atalophlebia* (F. Leptophlebiidae), *Choroterpes* (F. Leptophlebiidae), *Thraulodes* (F. Leptophlebiidae), *Ecnomus* (F. Ecnomidae) demonstrated a strong association with finer substrates (root and leaf pack), whereas *Nixe* (F. Heptageniidae) and *Leptophlebia* (F. Leptophlebiidae) preferred coarser substrates (cobbles and boulders). *Cheumatopsyche* (F. Cheumatopsychidae) and *Macrostemum* (F. Hydropsychidae) associated with both fine and coarse substrates (pebbles and gravel).

However, taxa, which often preferred the same substrate types, commonly avoided different substrates. For example, *Baetis* avoided cobbles and pebbles whereas *Ecnomus* was absent from gravel. *Procloeon, Choroterpes* and *Thraulodes* mayflies were present at highest density on roots but *Procloen* was absent on all of the other substrates, *Choroterpes* was rarest on boulders, and *Thraulodes* was totally absent from boulders, cobbles, gravel and leaf pack.
Atalophlebia density was highest on gravel substrate but totally absent on the other substrates.

Nixe was present at the highest density on cobbles with 4.0 ± 1.1 individuals per sample but present at the lowest density on root with 0.4 ± 0.3 individuals per sample.

Leptophlebia was present at the highest density on boulders with 1.3 ± 0.5 individuals per sample. It was totally absent on cobble, gravel, pebbles and root; and present at low density on leaf pack with 0.2 ± 0.2 individuals per sample.

Cheumatopsyche and *Macrostemum* caddises were present at high density on pebbles and gravel with the range of 4.5 ± 0.3 - 4.8 ± 1.4 and 2.8 ± 0.6 - 3.0 ± 0.9 individuals per sample respectively. Both genera largely avoided roots (0.1 ± 0.1 and 0.2 ± 0.1 individuals per sample respectively).

3.2.2.3.3 <u>Site Hin Lat 3</u>

Table 3.14 summarizes EPT genus richness for each substrate type.
Only Plecoptera differed in richness between substrates (One Way ANOVA on ranks $H_5 = 14.126$, $P = 0.015$) with boulders supporting the highest genus richness (1.3 ± 0.2 genera per sample) and cobbles and roots the lowest. Ephemeroptera, Trichoptera, and all EPT orders collectively, did not show any significant difference in taxa richness between substrate types (One Way ANOVA $F_{5, 30} = 2.707$, $P = 0.039$, $H_5 = 9.427$, $P = 0.093$ and $F_{5, 30} = 2.532$, $P = 0.050$ respectively).

Table 3.14 Genus richness (mean ± S.E.) of the EPT groups collected from each substrate types at site Hin Lat 3, Hin Lat stream, Nam Nao National Park, Thailand in February, August and October 1998.

Substrate	Genus richness (mean ± S.E.)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Boulder	6.7 ± 0.7	1.3 ± 0.2a	4.0 ± 0.6	12.0 ± 1.0
Cobble	7.7 ± 0.6	0.2 ± 0.2b	4.0 ± 0.6	11.8 ± 0.7
Gravel	5.5 ± 0.8	0.5 ± 0.2ab	3.7 ± 0.3	9.7 ± 0.9
Leaf Pack	8.2 ± 0.9	0.3 ± 0.3ab	2.8 ± 0.3	11.3 ± 1.1
Pebble	6.7 ± 0.3	0.7 ± 0.2ab	4.7 ± 0.2	12.0 ± 0.4
Root	5.2 ± 0.9	0.2 ± 0.2b	3.2 ± 0.5	8.5 ± 1.2

The density of animals differed significantly between substrates at order, family and genus levels. Table 12 summarizes the mean density of the EPT taxa, which were significantly different between each substrate type.

At order level, both Ephemeroptera and Trichoptera demonstrated a preference for pebbles and avoided roots. They were present at the highest density on pebbles (27.2 ± 4.0 and 19.1 ± 3.7 individuals per sample respectively) and showed lowest density on roots (10.8 ± 1.9 and 3.2 ± 0.8 respectively).

At family level, 9 of 21 families found at site Hin Lat 3 showed significant differences in density between substrates. Caenidae, Heptageniidae, Nemouridae and Philopotamidae demonstrated a preference for coarse substrates being present at highest density on pebbles and boulders. In contrast, Neoephemeridae, Calamoceratidae and Leptoceridae preferred finer substrates (leaf pack and root). Leptophlebiidae and Hydropsychidae exploited both coarser and finer substrates, however they were most common on cobbles and boulders.

Caenidae, Heptageniidae and Philopotamidae were present at highest density on pebbles (13.5 ± 3.1, 3.8 ± 0.7 and 13.5 ± 1.9 individuals per sample respectively). Caenidae was found at the lowest density on leaf pack with 2.8 ± 0.5 individuals per sample. Heptageniidae and Philopatamidae were present at the lowest density on roots with 0.7 ± 0.3 and 0.8 ± 0.5 individuals per sample respectively.

Nemouridae, while rare at this site, was most abundant on boulders with 0.8 ± 0.2 individuals per sample but absent on cobbles, gravel and root.

Neoephemeridae was present at highest density on leaf pack with 10.2 ± 4.7 individuals per sample but absent on boulders.

Calamoceratidae and Leptoceridae were present at highest density on roots with 0.9 ± 0.2 and 0.5 ± 0.2 individuals per sample respectively. Calamoceratid caddises were also present in moderate numbers on cobbles, gravel and leaf pack but absent on boulders and pebbles. In contrast, the leptocerid caddises were absent on all of the other substrates.

Leptophlebiidae was present at the highest density on cobbles with 8.3 ± 1.8 individuals per sample and also present at high density on gravel and leaf pack. It was present at lowest density on root.

Hydropsychidae was present at high density on boulders and leaf pack with 5.6 ± 1.2 and 5.4 ± 1.2 individuals per sample and also present in moderate numbers on cobbles, gravel and pebbles.

At genus level, 12 of the 39 genera found at site Hin Lat 3, showed significant differences in terms of substrate preferences. *Baetis* (F. Baetidae), *Caenis* (F. Caenidae), *Nixe* (F. Heptageniidae), *Atalophlebioides* (F. Leptophlebiidae), *Cryptopenella* (F. Leptophlebiidae), *Thraulodes* (F. Leptophlebiidae), *Chimarra* (F. Philopotamidae) and *Polycentropus* (F. Polycentropodidae) demonstrated a strong association with coarser substrates (cobbles and pebbles). Whereas *Choroterpes* (F. Leptophlebiidae), *Minyphlebia* (F. Leptophlebiidae), *Thraulus* (F. Leptophlebiidae) and *Neoephemera* (F. Neoephemeridae) demonstrated a preference for finer substrates, notably leaf pack.

Baetis showed a strong preference for cobbles (6.2 ± 1.5 individuals per sample) and was present at lowest density on gravel, however it was also present in moderate numbers on the other substrates.

Atalophlebioides was present at high density on cobbles and gravel but absent from roots.

Caenis, Nixe, Cryptopenella, Thraulodes, Chimarra and *Polycentropus* demonstrated a significant preference for pebbles. However, they significantly avoided different substrate types.

Choroterpes, Minyphlebia, Thraulus, Neoephemera were present at the highest density on leaf pack with 4.3 ± 1.1, 3.0 ± 1.3, 2.0 ± 0.7 and 10.2 ± 4.7 individuals per sample respectively.

3.2.2.3.4 Summary

Habitat differences were manifest at both family and genus level, with 14 families and 24 genera showing evidence of substrate preferences based upon their distribution. There was generally good agreement in the preferences for particular substrates at family and genus level. For example, Baetidae clearly preferred root and leaf pack substrates at both sites Hin Lat 1 and 2; Caenidae and *Caenis* preferred coarser substrates (boulders, cobbles, pebbles and gravel) at site Hin Lat 1 and 3; Hydropsychidae clearly preferred coarser substrates (boulders, cobbles, pebbles and gravel) at all sites, and Leptoceridae strongly preferred root substrates at site Hin Lat 1 and 3.

At genus level, *Nixe* preferred boulders, cobbles and pebbles at site Hin Lat 1, 2 and 3 respectively. *Leptophlebia* preferred boulders and cobbles at site Hin Lat 1 and 2. *Choroterpes* preferred finer substrates (root and leaf pack) at site Hin Lat 2 and 3.

However, there were some examples of inconsistent habitat association in a few taxa. The family Ecnomidae and the genus *Ecnomus* demonstrated a preference for cobbles at site Hin Lat 1, whereas at site Hin Lat 2, they preferred leaf pack. *Baetis* and *Thraulodes* preferred leaf pack and root respectively at site Hin Lat 2, whereas at site Hin Lat 3 they were most abundant among cobbles and pebbles.

Most of the taxa, which showed significant difference in substrate preferences, did so at only one or a few sites and therefore conclusions could not be generalized. For example, Heptageniidae and Philipotamidae demonstrated a preference for pebbles. Nemouridae preferred for boulders, Polycentropodidae and Stenopsychidae preferred for cobbles; Limnephilidae preferred for gravel; Neoephemeridae preferred for leaf pack; Calamoceratidae preferred for root. Leptophlebiidae was especially catholic in its preferences and was variously associated with cobbles, pebbles, gravel and leaf pack.

At genus level, *Centroptilum, Procloen, Paraleptophlebia* and *Leptocerus* preferred roots. *Minyphlebia, Thraulus* and *Neoephemera* preferred leaf pack. *Pseudoneureclipsis* and *Stenopsyche* preferred cobbles. *Cheumatopsyche* and *Macrostemum* preferred pebbles and gravel. *Atalophlebioides* preferred cobbles and gravel. *Atalophlebia* and *Apatania* preferred gravel. *Cryptopenella, Chimarra* and *Polycentropus* preferred pebbles.

3.2.2.4 Comparing EPT family richness and density associated with each substrate within each site and month

3.2.2.4.1 February Data Set

3.2.2.4.1.1 Site Hin Lat 1

A total of 1,557 individuals, representing 24 families and 39 genera of EPT taxa was collected from site Hin Lat 1 in February 1998 (Figure 3.24). Ephemeroptera was the most abundant order with 6 families, 14 genera and 1,015 individuals. The three most abundant families of Ephemeroptera were Caenidae, Leptophlebiidae and Ephemeridae. However, Trichoptera, was the most taxonomically diverse order with 15 families and 21 genera. The three most abundant families of Trichoptera were Polycentropodidae, Leptoceridae and Ecnomidae. Plecoptera was poorly represented with only 3 families, 4 genera and 18 individuals, and was Perlidae most abundant with 13 individuals.

Figure 3.24 Abundance of EPT families found at Site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in February 1998.

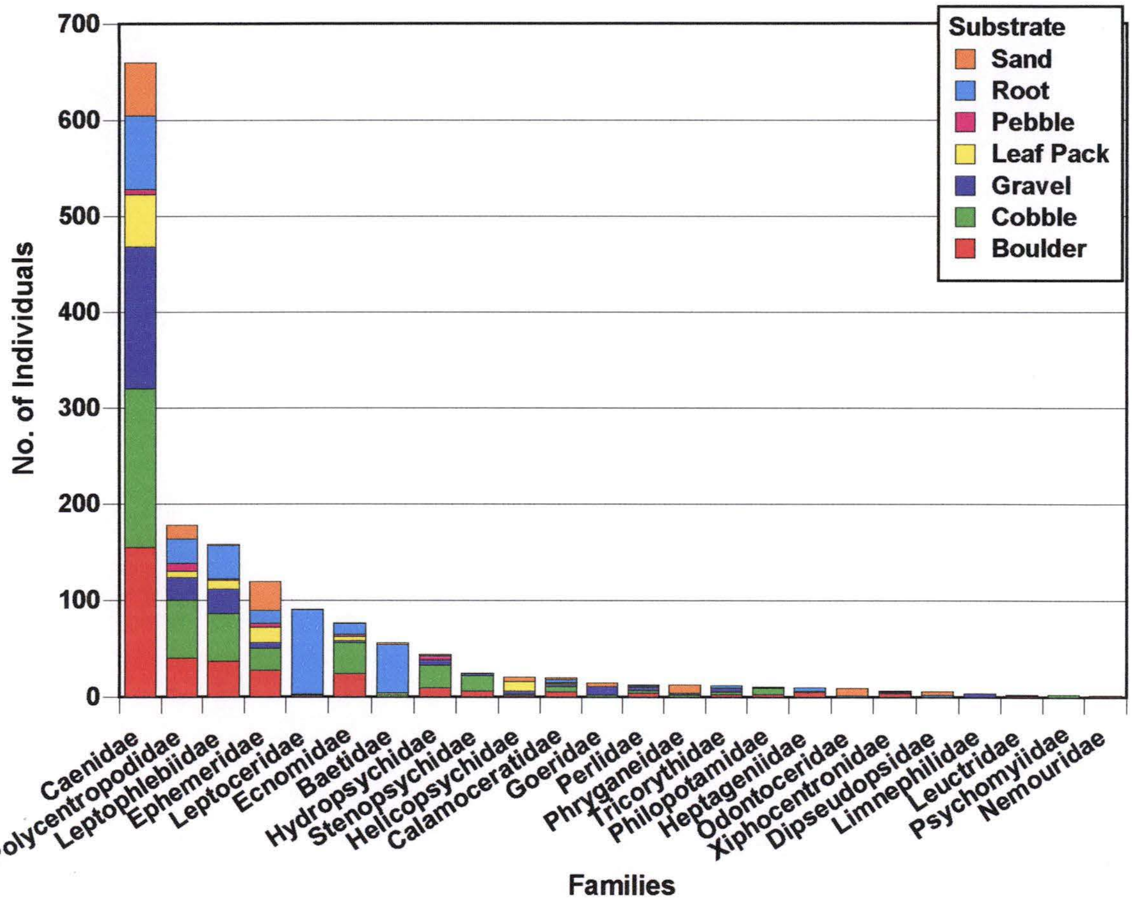


Table 3.15 summarizes EPT family richness and abundance found on each substrate type at site Hin Lat 1 in February 1998. Cobbles had the highest EPT family richness and abundance with 18 families and 399 individuals, while pebbles had the least with only 9 families and 27 individuals.

Table 3.15 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in February 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sand
Ephemeroptera	Richness	5	6	4	4	3	6	4
	Abundance	227	242	183	83	10	182	88
Plecoptera	Richness	3	2	2	1	0	2	1
	Abundance	6	4	4	1	0	2	1
Trichoptera	Richness	9	10	11	7	6	8	11
	Abundance	93	153	53	26	17	131	51
Total	Richness	17	18	17	12	9	16	16
	Abundance	326	399	240	110	27	315	140

3.2.2.4.1.1.1 _Substrate Preferences_

All of the EPT taxa at order levels demonstrated a significant difference in term of substrate preferences, whereas, there were only 9 families and 9 genera, which demonstrated significant preferences (Table 3.16). These families included 4 families of Ephemeroptera (Baetidae, Caenidae, Heptageniidae and Leptophlebiidae), and 5 families of Trichoptera (Ecnomidae, Hydropsychidae, Limnephilidae, Polycentropodidae and Stenopsychidae). Plecoptera at family level did not show any significant preferences.

The 9 genera included 4 genera of Ephemeroptera (*Baetis, Caenis, Nixe* and *Leptophlebia*) and 5 genera of Trichoptera (*Ecnomus, Cheumatopsyche, Apatania, Pseudoneureclipsis* and *Stenopsyche*)

3.2.2.4.1.1.1.1 *Order Level*

Ephemeroptera

There was a significant effect of substrates on the mean density of Ephemeroptera at site Hin Lat 1, February 1998 (One Way ANOVA, $F_{6, 63} = 11.446$, P = <0.001). By Tukey Multiple Comparison Method, mean density of Ephemeroptera differed ($p < 0.05$) between cobbles and pebbles; cobbles and sand; boulders and pebbles; boulders and sand; gravel and pebbles; root and pebbles; leaf pack and pebbles; and between sand and pebbles.

At site Hin Lat 1, Ephemeroptera demonstrated a preference for cobbles, boulders, gravel, root, leaf pack and sand, but strongly avoided pebbles.

Plecoptera

There was a significant effect of substrate on the median density of Plecoptera at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 13.390$, P = 0.037). By Dunn's Multiple Comparison Method, median density of Plecoptera differed ($p < 0.05$) between boulders and pebbles.

Plecoptera demonstrated a preference for boulders and avoided pebbles. They were present in moderate numbers on cobbles, gravel, leaf pack, root and sand.

Table 3.16 Summary of responses of aquatic taxa to substrate types in various months at Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean density of individuals per Surber sample ± se. F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	Month	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sand	Significance value	Preference
HIN LAT 1											
Order											
Ephemeroptera	Feb	10	22 7 ± 5.0a	24 2 ± 4 6a	18 3 ± 2 9ac	8.3 ± 2 1ac	1 0 ± 0 4b	18 2 ± 4 5ac	8 8 ± 3 7c	$F_{6,63}$ =11 446, P = <0 001	Cobble, boulder, gravel and root
Plecoptera	Feb	10	0 6 ± 0.2a	0 4 ± 0 2ab	0 4 ± 0.2ab	0.1 ± 0.1ab	0.0 ± 0.0b	0 2 ± 0 2ab	0 1 ± 0 1ab	H_6 = 13 390, P = 0.037	Boulder
Trichoptera	Feb	10	9 3 ± 1 5ac	15 3 ± 2 7a	5 3 ± 1.2ab	2 6 ± 0.7bc	1 7 ± 0 4b	13 1 ± 7 2ab	5 1 ± 1 6bc	$F_{6,63}$ = 5 766, P = <0.001	Cobble and boulder
Ephemeroptera	Aug	6	10 3 ± 2.7ab	10.5 ± 2.1ab	6 0 ± 2.4b	4 3 ± 1.3b	8 3 ± 2.7ab	18 2 ± 4.0a	NA	$F_{5,30}$ = 3 405, P = 0.015	Root
Trichoptera	Aug	6	0 8 ± 0 4b	0 8 ± 0 3b	1 0 ± 0.3b	0 2 ± 0 2b	1 8 ± 0.6b	7 2 ± 1.6a	NA	$F_{5,30}$ =10.256, P = <0.001	Root
Family											
Baetidae	Feb	10	0.0 ± 0 0b	0 2 ± 0.1b	0 0 ± 0 0b	0 2 ± 0.2b	0 0 ± 0.0b	5 0 ± 1 8a	0 2 ± 0 2b	H_6 = 35 637, P = <0 001	Root
Caenidae	Feb	10	15.5 ± 4.4a	16 5 ± 3 8a	14 8 ± 2 6a	5 5 ± 1 1ab	0 5 ± 0 2b	7 7 ± 2 1ab	5 5 ± 3 2ab	H_6 = 28 840, P = <0 001	Cobble, boulder and gravel
Heptageniidae	Feb	10	0 5 ± 0 2a	0.1 ± 0.1ab	0 0 ± 0 0b	0.0 ± 0 0b	0 0 ± 0 0b	0 4 ± 0 4ab	0 0 ± 0.0b	H_6 = 15 829, P = 0 015	Boulder
Leptophlebiidae	Feb	10	3 7 ± 0 9a	4 9 ± 1 1a	2 5 ± 1 1ab	1 0 ± 0 5ab	0 1 ± 0 1b	3 5 ± 2.1ab	0 1 ± 0.1b	H_6 = 28.215, P = <0 001	Cobble and boulder
Ecnomidae	Feb	10	2 4 ± 0.7ac	3 2 ± 0 9a	0 2 ± 0 1bc	0 5 ± 0 3ab	0 2 ± 0 2b	1 1 ± 0 5ab	0 1 ± 0 1b	H_6 = 26.238, P = <0 001	Cobble and boulder
Hydropsychidae	Feb	10	0 9 ± 0 4ab	2 4 ± 1 4a	0 5 ± 0.2ab	0.0 ± 0 0b	0 4 ± 0 2ab	0 1 ± 0 1b	0.1 ± 0.1b	H_6 = 18 105, P = 0 006	Cobble
Limnephilidae	Feb	10	0 0 ± 0 0b	0 0 ± 0 0b	0 4 ± 0 2a	0 0 ± 0 0b	0 0 ± 0 0b	0.0 ± 0 0b	0.0 ± 0 0b	H_6 = 18 529, P = 0.005	Gravel
Polycentropodidae	Feb	10	4 0 ± 1 2ab	6 0 ± 1.3a	2.3 ± 0 6ab	0 7 ± 0 3b	0 8 ± 0 3b	2 5 ± 1.1ab	1.5 ± 0 9b	H_6 = 18 457, P = 0 005	Cobble
Stenopsychidae	Feb	10	0 6 ± 0 3ab	1 6 ± 0 5a	0.2 ± 0 1ab	0 0 ± 0.0b	0.1 ± 0 1b	0 0 ± 0.0b	0 0 ± 0 0b	H_6 = 27 403, P = <0 001	Cobble
Caenidae	Aug	6	4.7 ± 1 5a	6 2 ± 1.6a	3.3 ± 1 8ab	0 3 ± 0 2b	4.7 ± 1.9ab	9 2 ± 3 2a	NA	$F_{5,30}$ = 5 003, P = 0 002	Root, cobble and boulder
Leptophlebiidae	Aug	6	1 3 ± 0 5ab	1 5 ± 0 6ab	1 0 ± 0 8b	1 7 ± 0.6ab	1 7 ± 0.6ab	5 3 ± 0 9a	NA	H_5 = 13 304, P = 0 021	Root
Ecnomidae	Aug	6	0 2 ± 0 2b	0 3 ± 0 2ab	0 5 ± 0 2ab	0 0 ± 0 0b	0 3 ± 0 2ab	3 5 ± 1.1a	NA	H_5 = 15 041, P = 0 010	Root
Leptoceridae	Aug	6	0 0 ± 0 0b	0 2 ± 0 2b	0 0 ± 0 0b	0 2 ± 0.2b	0 2 ± 0 2b	3.5 ± 0 8a	NA	H_5 = 25 204, P = <0 001	Root
Leptophlebiidae	Oct	6	2 8 ± 0 9ab	1 5 ± 0 6ab	3 8 ± 0 5a	3 2 ± 2.4ab	2 5 ± 0 9ab	0 3 ± 0 3b	NA	$F_{5,30}$ = 2 633, P = 0 043	Gravel
Hydropsychidae	Oct	6	1 5 ± 0.4ab	0.2 ± 0 2b	2.5 ± 0 6a	0.2 ± 0 2b	1 5 ± 0.6ab	1 0 ± 0 5ab	NA	H_5 = 15 249, P = 0.009	Gravel
Genus											
Baetis	Feb	10	0.0 ± 0.0b	0 1 ± 0 1ab	0 0 ± 0 0b	0 0 ± 0 0b	0 0 ± 0 0b	3 3 ± 1.9a	0.0 ± 0 0b	H_6 = 19 967, P = 0.003	Root
Caenis	Feb	10	15 5 ± 4 4a	16 5 ± 3 8a	14 8 ± 2 6a	5 5 ± 1 1ab	0 6 ± 0 2b	7 7 ± 2.1ab	5 5 ± 3 2ab	H_6 = 27 275, P = <0 001	Cobble, gravel and boulder
Nixe	Feb	10	0.5 ± 0 2a	0 0 ± 0 0b	0 0 ± 0 0b	0 0 ± 0 0b	0 0 ± 0 0b	0.4 ± 0.4ab	0.0 ± 0.0b	H_6 = 19.086, P = 0 004	Boulder
Leptophlebia	Feb	10	2 4 ± 0 9ab	4.1 ± 1 3a	2 5 ± 1 1ab	0 0 ± 0 0b	0.0 ± 0.0b	0.5 ± 0.5ab	0.0 ± 0 0b	H_6 = 24.615, P = <0 001	Cobble
Ecnomus	Feb	10	2 4 ± 0 7ac	3.2 ± 0 9a	0 2 ± 0 1bc	0.5 ± 0 3ab	0 2 ± 0 2bc	1 1 ± 0 5ab	0 1 ± 0 1b	H_6 = 25 564, P = <0 001	Cobble and boulder
Cheumatopsyche	Feb	10	0 0 ± 0 0b	1.7 ± 1 3a	0 2 ± 0 2ab	0.0 ± 0 0b	0 0 ± 0.0b	0 1 ± 0 1ab	0.0 ± 0 0b	H_6 = 15 942, P = 0 014	Cobble
Apatania	Feb	10	0 0 ± 0 0b	0 0 ± 0 0b	0.4 ± 0 2a	0.0 ± 0 0b	0 0 ± 0.0b	0 0 ± 0 0b	0 0 ± 0 0b	H_6 = 18 228, P = 0 006	Gravel
Pseudoneureclipsis	Feb	10	4 0 ± 1 1ab	6 0 ± 1 3a	2 3 ± 0.6ab	0 7 ± 0 3b	0 9 ± 0.3ab	2 5 ± 1 1ab	1 5 ± 0 9b	H_6 = 17 829, P = 0 007	Cobble
Stenopsyche	Feb	10	0 6 ± 0 3ab	1 6 ± 0 5a	0 2 ± 0 1ab	0 0 ± 0 0b	0 1 ± 0 1b	0 0 ± 0 0b	0 0 ± 0.0b	H_6 = 26 934, P = <0.001	Cobble

Table 3.16 (continued) Summary of responses of aquatic taxa to substrate types in various months at Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean density of individuals per Surber sample ± se. F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	Month	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sand	Significance value	Preference
Baetis	Aug	6	1 2 ± 0 3ab	0 2 ± 0 2b	0 7 ± 0 3ab	0 0 ± 0 0b	0 3 ± 0 2ab	2 7 ± 0 8a	NA	H_5 = 16.535, P = 0.005	Root
Caenis	Aug	6	4 7 ± 1.5ab	6 2 ± 1 6ab	3.3 ± 1 8ab	0 4 ± 0 2b	4.7 ± 1 9ab	9 2 ± 3.2a	NA	H_5 = 13 584, P = 0 018	Root
Paraleptophlebia	Aug	6	0 0 ± 0 0b	0 0 ± 0 0b	0 0 ± 0 0b	0 0 ± 0 0b	0.0 ± 0 0b	4 0 ± 1 2a	NA	H_5 = 27 223, P = <0.001	Root
Neoephemera	Aug	6	0 5 ± 0 3ab	0 5 ± 0 2ab	0 0 ± 0 0b	2 4 ± 1.1a	0 2 ± 0 2ab	0 0 ± 0 0b	NA	H_5 = 13 537, P = 0.019	Leaf pack
Ecnomus	Aug	6	0 2 ± 0 2b	0 3 ± 0 2ab	0 5 ± 0 2ab	0 0 ± 0 0b	0 3 ± 0 2ab	3.5 ± 1 1a	NA	H_5 = 14 443, P = 0.013	Root
Leptocerus	Aug	6	0 0 ± 0.0b	0.0 ± 0 0b	0 0 ± 0.0b	0.0 ± 0 0b	0.0 ± 0 0b	3 5 ± 0.8a	NA	H_5 = 33.614, P = <0 001	Root
Baetis	Oct	6	0.0 ± 0 0b	0 5 ± 0 5ab	0.3 ± 0 2ab	1.3 ± 0 6ab	0 8 ± 0 5ab	2 5 ± 0 9a	NA	H_5 = 12 247, P = 0 032	Root
Cheumatopsyche	Oct	6	1 0 ± 0.4ab	0 0 ± 0 0b	1 8 ± 0 3a	0.2 ± 0 2ab	1 5 ± 0 6ab	1.0 ± 0.5ab	NA	H_5 = 14 923, P = 0.011	Gravel
HIN LAT 2											
Order											
Ephemeroptera	Feb	10	5.1 ± 1 3c	1.2 ± 0 3b	NA	19.4 ± 4 3a	3 3 ± 0 8bc	16 3 ± 3 7a	NA	$F_{4,45}$ =18 380, P = <0 001	Leaf pack, root and boulder
Trichoptera	Feb	10	3 5 ± 0 8ab	4.8 ± 0 4a	NA	6 4 ± 0 9a	5 0 ± 1 1ab	1.8 ± 0 5b	NA	H_4 = 15.663, P = 0 004	Leaf Pack and cobble
Ephemeroptera	Aug	6	18 3 ± 4 2ab	29.3 ± 3 5a	13.3 ± 3.9ab	15 7 ± 2 4ab	25 2 ± 5 8ab	9 2 ± 3 3b	NA	$F_{5,30}$ = 3 577, P = 0 012	Cobble
Trichoptera	Oct	6	13 7 ± 4.2ab	12 8 ± 2 8ab	13.3 ± 1 5ab	7 7 ± 1 1ab	26 2 ± 5 1a	2 2 ± 0 8b	NA	H_5 = 20 655, P = <0 001	Pebble
Family											
Baetidae	Feb	10	0.5 ± 0 2ab	0 1 ± 0 1b	NA	4.6 ± 1 5ab	0.1 ± 0 1b	6 2 ± 2 6a	NA	H_4 = 19 579, P = <0 001	Root
Caenidae	Feb	10	1 1 ± 1 0b	0.0 ± 0 0b	NA	12 9 ± 4 4a	0 7 ± 0 3b	5 6 ± 1 0a	NA	H_4 = 31 418, P = <0 001	Leaf pack and root
Leptophlebiidae	Feb	10	2 1 ± 0 7ab	0 7 ± 0 3b	NA	1 1 ± 0 7b	2 1 ± 0 6ab	3 7 ± 1 1a	NA	H_4 = 13.584, P = 0.009	Root
Hydropsychidae	Feb	10	0 2 ± 0 1ab	1 4 ± 0 3a	NA	1 1 ± 0 3ab	0 4 ± 0 2ab	0 1 ± 0 1b	NA	H_4 = 14 815, P = 0 005	Cobble
Caenidae	Aug	6	5 5 ± 1 5ab	12 7 ± 2 6a	7 2 ± 2 4ab	5 5 ± 2 3ab	8 0 ± 2 5ab	1 8 ± 0 6b	NA	$F_{5,30}$ = 2 948, P = 0.028	Cobble
Heptageniidae	Aug	6	3 2 ± 1.2ab	7.7 ± 1 1a	1.5 ± 0 8bc	1 8 ± 0 8ab	7 0 ± 2.2ac	0 5 ± 0 5b	NA	H_5 = 21.366, P = <0 001	Cobble and pebble
Hydropsychidae	Aug	6	2 5 ± 1.6b	3 2 ± 1 1ab	2.3 ± 0 8b	0.7 ± 0 3b	9 5 ± 2 8a	0.5 ± 0 2b	NA	$F_{5,30}$ = 6 090, P = <0 001	Pebble
Hydropsychidae	Oct	6	8 2 ± 2 7ab	7.0 ± 1.7ab	9 5 ± 1 2a	6 0 ± 1.1ab	15 2 ± 2 1a	0 0 ± 0.0b	NA	H_5 = 22 354, P = <0.001	Pebble and gravel
Leptoceridae	Oct	6	0 0 ± 0 0b	0.0 ± 0.0b	0 0 ± 0 0b	0.0 ± 0 0b	0 0 ± 0.0b	1 3 ± 0 7a	NA	H_5 = 15 873, P = 0.007	Root
Philopotamidae	Oct	6	5 3 ± 1 8ac	5 5 ± 1 5ac	2.8 ± 0 7ab	1 0 ± 0.5bc	10 8 ± 3.4a	0.0 ± 0 0b	NA	H_5 = 21 980, P = <0.001	Pebble, cobble and boulder
Genus											
Baetis	Feb	10	0 3 ± 0 2ab	0 1 ± 0 1b	NA	4 6 ± 1 5ab	0 1 ± 0 1b	5 8 ± 2.6a	NA	H_4 = 17 059, P = 0 002	Root
Caenis	Feb	10	1 1 ± 1.0b	0 0 ± 0 0b	NA	12 9 ± 4.4a	0 7 ± 0.3b	5.6 ± 0 9a	NA	H_4 = 31.418, P = <0.001	Leaf pack and root
Nixe	Feb	10	1 4 ± 0 5a	0.4 ± 0.2ab	NA	0.0 ± 0.0b	0.0 ± 0.0b	0 1 ± 0 1ab	NA	H_4 = 14.516, P = 0.006	Boulder
Choroterpes	Feb	10	0 1 ± 0.1b	0 6 ± 0 3ab	NA	1 1 ± 0.7ab	1.7 ± 0.6a	3 5 ± 1 2a	NA	H_4 = 17 571, P = 0.001	Root and pebble
Leptophlebia	Feb	10	1 3 ± 0 5a	0 0 ± 0.0b	NA	0 0 ± 0.0b	0.0 ± 0 0b	0 0 ± 0 0b	NA	H_4 = 31.717, P = <0 001	Boulder
Cheumatopsyche	Feb	10	0 0 ± 0 0b	0 1 ± 0.1b	NA	0.9 ± 0 3a	0 0 ± 0 0b	0.0 ± 0 0b	NA	H_4 = 17 987, P = 0 001	Leaf pack
Macrostemum	Feb	10	0 2 ± 0 1b	1 3 ± 0.3a	NA	0 1 ± 0.1b	0 4 ± 0 2ab	0 0 ± 0.0b	NA	H_4 = 17 071, P = 0 002	Cobble

Table 3.16 (continued) Summary of responses of aquatic taxa to substrate types in various months at Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean density of individuals per Surber sample ± se. F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	Month	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sand	Significance value	Preference
Procloeon	Aug	6	0.0 ± 0.0b	0 0 ± 0 0b	0 0 ± 0 0b	0.0 ± 0.0b	0.0 ± 0.0b	0 5 ± 0.2a	NA	H_5 = 15 909, P = 0 007	Root
Caenis	Aug	6	5.5 ± 1.5ab	12.7 ± 2.6a	7 2 ± 2.4ab	5.5 ± 2.3ab	8.0 ± 2 5ab	1 8 ± 0 6b	NA	$F_{5,30}$ = 2.948, P = 0.028	Cobble
Nixe	Aug	6	3.2 ± 1 2ab	7.7 ± 1.1a	1 5 ± 0 8bc	1.8 ± 0.7ab	7.0 ± 2.2ac	0 5 ± 0 5b	NA	H_5 = 21 366, P = <0.001	Cobble and pebble
Cryptopenella	Aug	6	5.5 ± 1.7a	6.0 ± 1.2a	2 7 ± 1 2ab	1.5 ± 1 0ab	5.8 ±2 1a	0 2 ± 0.2b	NA	H_5 = 18 517, P = 0 002	Cobble, boulder and pebble
Cheumatopsyche	Aug	6	1.3 ± 0 8ab	1.3 ± 0.6ab	1 2 ± 0 5ab	0.2 ± 0 2b	4.5 ± 1.2b	0.2 ± 0.2b	NA	H_5 = 17.072, P = 0.004	Pebble
Macrostemum	Aug	6	1.2 ± 0.8ab	1.8 ± 0.7ab	1.2 ± 0.4ab	0.5 ± 0 3b	5 0 ± 1 9a	0 3 ± 0.2b	NA	H_5 = 13.410, P = 0 020	Pebble
Atalophlebioides	Oct	6	5.7 ± 2 0ab	8.3 ± 1 8a	3 0 ± 1 4ab	3 3 ± 1 8ab	7.3 ± 2 2ab	0 0 ± 0.0b	NA	$F_{5,30}$ = 3 280, P = 0.018	Cobble
Choroterpes	Oct	6	0.0 ± 0 0b	0.0 ± 0.0b	0 0 ± 0 0b	0.0 ± 0 0b	0.0 ± 0.0b	1.5 ± 1.1a	NA	H_5 = 15.882, P = 0.007	Root
Cheumatopsyche	Oct	6	6.7 ± 2.3ab	5.8 ± 1.4ab	6.3 ± 0.7a	4 0 ± 0 8ab	11 5 ± 1 5a	0 0 ± 0 0b	NA	H_5 = 21 785, P = <0.001	Pebble and gravel
Macrostemum	Oct	6	1.5 ± 0.6ab	1.2 ± 0.5ab	3.2 ± 0.9a	2.0 ± 0.4ab	3.7 ± 1.1a	0 0 ± 0 0b	NA	$F_{5,}$ 30 = 4.146, P = 0 006	Pebble and gravel
Chimarra	Oct	6	5 3 ± 1.8ac	5.5 ± 1.5ac	2.8 ± 0.7ab	1.0 ± 0.4bc	10 8 ± 3.4a	0 0 ± 0.0b	NA	H_5 = 21.980, P = <0 001	Pebble, cobble and boulder
HIN LAT 3											
Order											
Ephemeroptera	Aug	6	26.0 ± 7.4ab	24.3 ± 4.4ab	8.2 ± 1 7b	21.2 ± 5.8ab	39 7 ± 8.0a	13.3 ± 4.6b	NA	$F_{5,30}$ = 5.107, P = 0.002	Pebble
Plecoptera	Aug	6	1.0 ± 0.0a	0.0 ± 0 0b	0.0 ± 0 0b	0.0 ± 0.0b	0 2 ± 0.2b	0.2 ± 0.2b	NA	H_5 = 25.625, P = <0 001	Boulder
Trichoptera	Aug	6	4 5 ± 1 9ab	4.3 ± 2 6ab	2 2 ± 1 1b	0.8 ± 0.5b	20.7 ± 6.7a	2.2 ± 0.8ab	NA	H_5 = 16.213, P = 0.006	Pebble
Family											
Baetidae	Aug	6	7.2 ± 2 7ac	7.2 ± 1.9a	1 2 ± 0 3bc	0 8 ± 0.5b	5.8 ± 1.5ac	2.3 ± 0.9ab	NA	$F_{5,30}$ = 5 316, P = 0 001	Cobble, boulder and pebble
Caenidae	Aug	6	13 7 ± 4.8ac	9.2 ± 2.0ab	4 8 ± 1 0bc	2.3 ± 0.6b	21.8 ± 7 3a	6 7 ± 2.3ab	NA	$F_{5,30}$ = 5.660, P = <0 001	Pebble and boulder
Ephemeridae	Aug	6	0.0 ± 0 0b	1 7 ± 0 7a	0.2 ± 0 2ab	0.0 ± 0.0b	0.0 ± 0.0b	0 3 ± 0.3ab	NA	H_5 = 14.657, P = 0.012	Cobble
Heptageniidae	Aug	6	2.8 ± 0.7ab	2.7 ± 1.4ab	0.3 ± 0.2b	0.2 ± 0.2b	4 3 ± 0.7a	0 5 ± 0.3b	NA	H_5 = 21.896, P = <0.001	Pebble
Leptophlebiidae	Aug	6	1.8 ± 0.7b	2 5 ± 0.8ab	1 5 ± 0 8b	7 5 ± 1 7a	7 3 ± 1 2a	1 0 ± 0.4b	NA	$F_{5,30}$ = 8 125, P = <0 001	Leaf pack and pebble
Neoephemeridae	Aug	6	0 0 ± 0.0b	0 8 ± 0 5ab	0.2 ± 0.2ab	10 2 ± 4.7a	0.2 ± 0.2ab	2.5 ± 1.6ab	NA	H_5 = 13 583, P = 0.018	Leaf pack
Nemouridae	Aug	6	0.7 ± 0 2a	0 0 ± 0 0b	0.0 ± 0.0b	0 0 ± 0 0b	0 2 ± 0 2ab	0.0 ± 0.0b	NA	H_5 = 17 387, P = 0 004	Boulder
Hydropsychidae	Aug	6	1.0 ± 0.5ab	0.7 ± 0 5ab	0.5 ± 0.5b	0 2 ± 0.2b	5 3 ± 3.0a	0.2 ± 0.2b	NA	H_5 = 15 170, P = 0 010	Pebble
Philopotamidae	Aug	6	2.5 ± 1.2ab	3.0 ± 1.9ab	1 0 ± 0.5ab	0 3 ± 0 3b	13 3 ± 4.6a	0 2 ± 0.2b	NA	H_5 = 14.077, P = 0 015	Pebble
Leptophlebiidae	Oct	6	5.7 ± 1.5ab	14.2 ± 3.2a	8.3 ± 2.2a	6.5 ± 1.4ab	6 5 ± 1.2ab	0.7 ± 0.3b	NA	H_5 = 17 531, P = 0.004	Cobble and gravel
Philopotamidae	Oct	6	12.5 ± 4.8a	4.8 ± 1.8ab	9.0 ± 2.5a	9.7 ± 2 6a	11 7 ± 2.9a	1.2 ± 0.8b	NA	$F_{5,30}$ = 4 331, P = 0.004	Boulder, pebble, gravel and leaf pack
Genus											
Baetis	Aug	6	6 7 ± 2.6ab	7.0 ± 1.9a	1.0 ± 0.3ab	0.7 ± 0.5b	5.7 ± 1 6ab	2 2 ± 0.8ab	NA	H_5 = 18.131, P = 0.003	Cobble
Caenis	Aug	6	13 7 ± 4.8ab	9 2 ± 2 0ab	4 8 ± 1.0ab	2 3 ± 0 6b	21.8 ± 7.3a	6.7 ± 2.3ab	NA	H5 = 17 335, P = 0.004	Pebble
Ephemera	Aug	6	0.0 ± 0.0b	1.7 ± 0.7a	0.2 ± 0 2ab	0.0 ± 0.0b	0.0 ± 0 0b	0.3 ± 0 3ab	NA	H_5 = 14 657, P = 0.012	Cobble
Nixe	Aug	6	2 8 ± 0.7ab	2 7 ± 1 4ab	0.3 ± 0.2b	0 2 ± 0 2b	4 3 ± 0.7a	0 5 ± 0.3b	NA	H_5 = 21.896, P = <0.001	Pebble

Table 3.16 (continued) Summary of responses of aquatic taxa to substrate types in various months at Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean density of individuals per Surber sample ± se. F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference identifies the substrate types which supports significantly ($P<0.05$) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	Month	N	Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root	Sand	Significance value	Preference
Choroterpes	Aug	6	0 0 ± 0 0b	1.3 ± 0 8ab	0 0 ± 0 0b	5 3 ± 1 9a	0.0 ± 0 0b	0 7 ± 0 3ab	NA	H_5 = 23 612, P = <0 001	Leaf pack
Cryptopenella	Aug	6	0 8 ± 0.4ab	0.8 ± 0.5ab	1.2 ± 0 8ab	0 0 ± 0 0b	5 7 ± 1 2a	0 2 ± 0.2b	NA	H_5 = 19.941, P = 0 001	Pebble
Thraulodes	Aug	6	0 8 ± 0 7ab	0 3 ± 0 2ab	0 3 ± 0 3ab	0 2 ± 0.2ab	1 7 ± 0 6a	0 0 ± 0 0b	NA	H_5 = 11 948, P = 0.036	Pebble
Thraulus	Aug	6	0 0 ± 0 0b	0 0 ± 0.0b	0 0 ± 0 0b	2.0 ± 0 7a	0 0 ± 0 0b	0.2 ± 0 2ab	NA	H_5 = 18.200, P = 0.003	Leaf pack
Neoephemera	Aug	6	0 0 ± 0 0b	0.8 ± 0.5ab	0 2 ± 0 2ab	10.2 ± 4.7a	0.2 ± 0 2ab	2 5 ± 1.6ab	NA	H_5 = 13 583, P = 0 018	Leaf pack
Amphinemura	Aug	6	0 7 ± 0.2a	0.0 ± 0.0b	0 0 ± 0.0b	0.0 ± 0.0b	0 2 ± 0 2ab	0 0 ± 0 0b	NA	H_5 = 17.387, P = 0 004	Boulder
Cheumatopsyche	Aug	6	0 5 ± 0.2ab	0.3 ± 0 2ab	0 0 ± 0.0b	0.2 ± 0 2ab	2 2 ± 1 0a	0.2 ± 0.2ab	NA	H_5 = 13 125, P = 0 022	Pebble
Macrostemum	Aug	6	0 5 ± 0.3ab	0.3 ± 0.3ab	0.5 ± 0 5ab	0 0 ± 0.0b	3.2 ± 2 0a	0.0 ± 0.0b	NA	H_5 = 14 227, P = 0 014	Pebble
Chimarra	Aug	6	2 3 ± 1 0ab	3.0 ± 1.9ab	1 0 ± 0 5ab	0 3 ± 0 3b	13.3 ± 4.6a	0.2 ± 0.2b	NA	H_5 = 14 147, P = 0.015	Pebble
Polycentropus	Aug	6	0 7 ± 0 3ab	0 0 ± 0.0b	0 0 ± 0 0b	0.0 ± 0 0b	1.2 ± 0.3a	0.0 ± 0.0b	NA	H_5 = 21.658, P = <0 001	Pebble
Atalophlebioides	Oct	6	3 7 ± 1 5ab	13 0 ± 2 9a	7.8 ± 2 4a	3 3 ± 0.9ab	3 2 ± 1 6ab	0 0 ± 0.0b	NA	H_5 = 18.411, P = 0.002	Cobble and gravel
Minyphlebia	Oct	s	2 0 ± 1 2ab	1 2 ± 0 5ab	0 0 ± 0 0b	3 0 ± 1 3a	0 5 ± 0 3ab	0 0 ± 0.0b	NA	H_5 = 14.457, P = 0.013	Leaf pack

Trichoptera

There was a significant effect of substrate on the mean density of Trichoptera at site Hin Lat 1, February 1998 (One Way ANOVA, $F_{6, 63} = 5.766$, P = <0.001). By Tukey Multiple Comparison Method, mean density of Trichoptera differed ($p < 0.05$) between cobbles and pebbles; cobbles and leaf pack; cobbles and sand; and between boulders and pebbles

Trichoptera clearly demonstrated a preference for cobbles and boulders; and avoided pebbles, leaf pack and sand. They were present in moderate numbers on gravel and root.

3.2.2.4.1.1.1.2 *Family Level*

Baetidae

There was a significant effect of substrate on the median density of Baetidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks $H_6 = 35.637$, P = <0.001). By Dunn's Multiple Comparison Method, median density of Baetidae differed ($p < 0.05$) between root and all the other substrates (pebbles, gravel, boulders, sand, leaf pack and cobbles).

Baetidae clearly demonstrated a preference for root and avoided all the other substrates such as boulders, cobbles, pebbles, gravel, sand and leaf pack. They were absent on boulders, pebbles and gravel.

Caenidae

There was a significant effect of substrate on the median density of Caenidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 28.840$, P = <0.001). By Dunn's Multiple Comparison Method, median density of Caenidae differed ($p < 0.05$) between cobbles and pebbles; gravel and pebbles; and between boulders and pebbles.

Caenidae clearly demonstrated a preference for cobbles, gravel and boulders; and strongly avoided pebbles. They were present in moderate numbers on leaf pack, root and sand.

Heptageniidae

There was a significant effect of substrate on the median density of Heptageniidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 15.829$, P = 0.015). By Dunn's Multiple Comparison Method, median density of Heptageniidae differed ($p < 0.05$) between boulders and sand; boulders and pebbles; boulders and leaf pack; and between boulders and gravel.

Heptageniidae clearly demonstrated a preference for coarser substrates such as boulders and avoided finer substrates such as sand, pebbles, leaf pack and gravel. They were present in moderate numbers on cobbles and root.

Ecnomidae

There was a significant effect of substrate on the median density of Ecnomidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 26.238$, P = <0.001). By Dunn's Multiple Comparison Method, median density of Ecnomidae differed ($p < 0.05$) between cobbles and sand; cobbles and pebbles; cobbles and gravel; boulders and sand; and between boulders and pebbles.

Ecnomidae clearly demonstrated a preference for coarser substrates such as cobbles and boulders; and avoided finer substrates such as sand, pebbles and gravel. They were present in moderate numbers on root and leaf pack.

Hydropsychidae

There was a significant effect of substrate on the median density of Hydropsychidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 18.105$, $P = 0.006$). By Dunn's Multiple Comparison Method, median density of Hydropsychidae differed ($p < 0.05$) between cobbles and leaf pack; cobbles and sand; and between cobbles and root.

Hydropsychidae clearly demonstrated a preference for cobbles and avoided finer substrates such as leaf pack, sand and root. They were present in moderate numbers on boulders, pebbles and gravel.

Leptophlebiidae

There was a significant effect of substrate on the median density of Leptophlebiidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 28.215$, $P = <0.001$). By Dunn's Multiple Comparison Method, median density of Leptophlebiidae differed ($p < 0.05$) between cobbles and sand; cobbles and pebbles; boulders and sand; and between boulders and pebbles.

Leptophlebiidae clearly demonstrated a preference for coarser substrates such as cobbles and boulders; and avoided finer substrates such as sand and pebbles. They were present in moderate numbers on root, gravel and leaf pack.

Limnephilidae

There was a significant effect of substrate on the median density of Limnephilidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 18.529$, $P = 0.005$). By Dunn's Multiple Comparison Method, median density of Limnephilidae differed ($p < 0.05$) between gravel and all the other substrates (boulders, cobbles, leaf pack, pebbles, root and sand).

Limnephilidae clearly demonstrated a preference for gravel and avoided all the other substrates (boulders, cobbles, leaf pack, pebbles, root and sand).

Polycentropodidae

There was a significant effect of substrate on the median density of Polycentropodidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 18.457$, $P = 0.005$). By Dunn's Multiple Comparison Method, median density of Polycentropodidae differed ($p < 0.05$) between cobbles and leaf pack; cobbles and sand; and between cobbles and pebbles.

Polycentropodidae clearly demonstrated a preference for cobbles and avoided leaf pack, sand and pebbles. They were present in moderate numbers on boulders, gravel and root.

Stenopsychidae

There was a significant effect of substrate on the median density of Stenopsychidae at site Hin Lat 1, February 1998 (One Way ANOVA on ranks, $H_6 = 27.403$, $P = <0.001$). By Dunn's Multiple Comparison Method, median density of Stenopsychidae differed ($p < 0.05$) between cobbles and sand; cobbles and root; cobbles and leaf pack; and between cobbles and pebbles.

Stenopsychidae clearly demonstrated a preference for cobbles and avoided sand, root, leaf pack and pebbles. They were present in moderate numbers on boulders and gravel.

3.2.2.4.1.1.1.3 *Genus level*

Nixe, Leptophlebia, Ecnomus, Cheumatopsyche, Pseudoneureclipsis and *Stenopsyche* were significantly associated with boulder and cobble substrates. They were present at the highest density on these substrates. *Nixe* was present at the highest density on boulders with 0.5 ± 0.2 individuals per sample but absent on cobbles, gravel, leaf pack, pebble and sand. *Leptophlebia, Cheumatopsyche, Pseudoneureclipsis* and *Stenopsyche* were present at the highest density on cobbles with 4.1 ± 1.3, 1.7 ± 1.3, 6.0 ± 1.3 and 1.6 ± 0.5 individuals per sample respectively. However, they avoided different substrates. For example, *Leptophlebia* was absent on leaf pack, pebbles and sand. *Cheumatopsyche* was absent on boulders, leaf pack, pebbles and sand. *Pseudoneureclipsis* was present at low density on leaf pack and sand within the range of 0.7 ± 0.3 and 1.5 ± 0.9 individuals per sample. *Stenopsyche* was absent on leaf pack, root and sand; and present at low density on pebbles.

Caenis showed significant preferences for cobbles, gravel and boulders. It was present at high density on these substrates with the range of 14.8 ± 2.6 and 16.5 ± 3.8 individuals per sample, but present at the lowest density on pebbles with 0.6 ± 0.2 individuals per sample.

Whereas, *Baetis* and *Apatania* significantly demonstrated a preference for finer substrates such as root and gravel. *Baetis* was only present on root with mean density of 3.3 ± 1.9 individuals per sample but absent on all the other substrates. *Apatania* was only present on gravel with 0.4 ± 0.2 individuals per sample but absent on all the other substrates.

3.2.2.4.1.2 Site Hin Lat 2

A total of 683 individuals, representing 17 families, 30 genera of EPT taxa was collected from site Hin Lat 2 in February 1998 (Figure 3.25). The composition of EPT group at this site is similar to site Hin Lat 1. Ephemeroptera was the most abundant order with 5 families, 13 genera and 453 individuals. The three most abundant families were Caenidae, Baetidae and Leptophlebiidae, representing 203, 115 and 97 individuals respectively. Whereas, Trichoptera, was the most diverse order with 10 Families, 15 genera and 216 individuals. The three most abundant families of Trichoptera were Stenopsychidae, Ecnomidae and Hydropsychidae, representing 60, 44 and 32 individuals respectively. Plecoptera was also poorly presented with only 2 families, 2 genera and 14 individuals. The most outstanding family of Plecoptera was Perlidae with 13 individuals.

Figure 3.25 Abundance of EPT families found at Site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in February 1998.

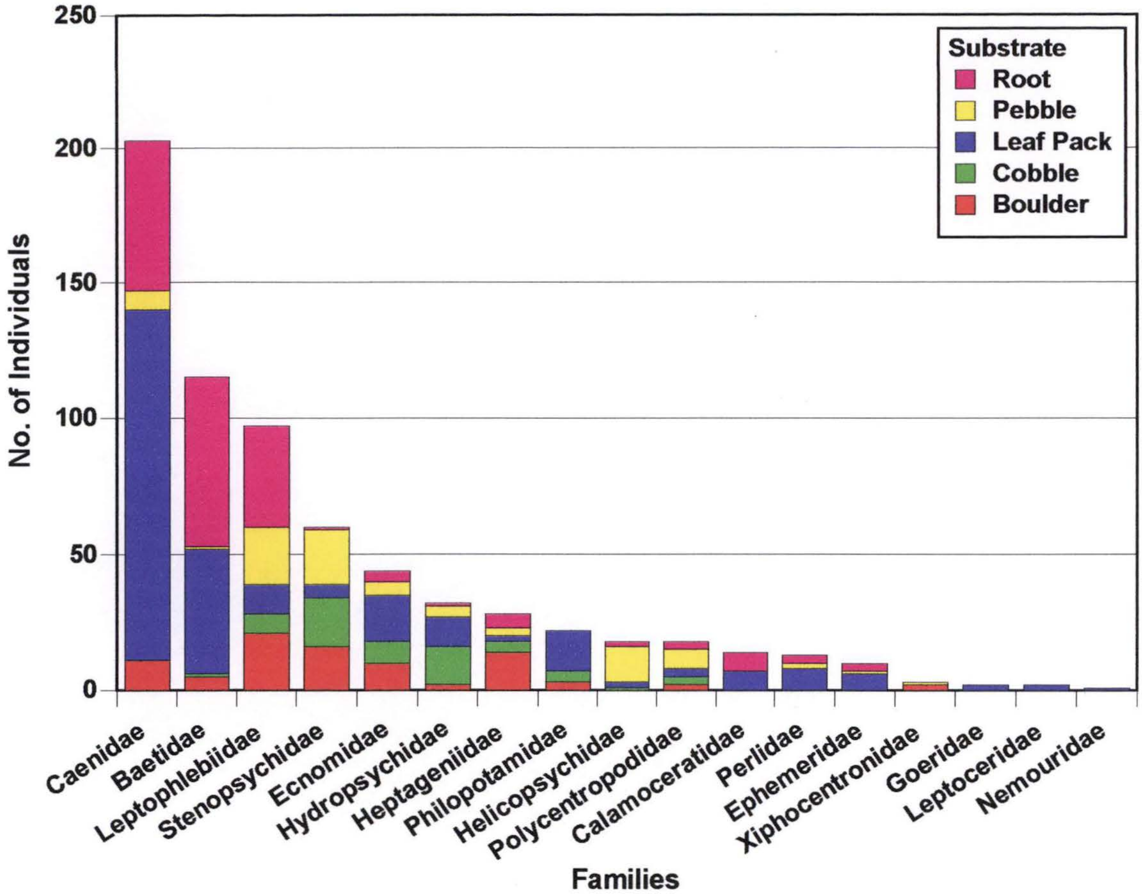


Table 3.17 summarizes EPT family richness and abundance found on each substrate type at site Hin Lat 2 in February 1998. Leaf pack substrate had the highest EPT family richness and abundance with 16 families and 268 individuals; whereas, cobbles had the least EPT family richness and abundance with 9 families and 60 individuals.

Table 3.17 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in February 1998.

Order		Boulder	Cobble	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	4	3	5	5	5
	Abundance	51	12	194	33	163
Plecoptera	Richness	0	0	2	1	1
	Abundance	0	0	9	2	3
Trichoptera	Richness	6	6	9	6	6
	Abundance	35	48	65	50	18
Total	Richness	10	9	16	12	12
	Abundance	86	60	268	85	184

3.2.2.4.1.2.1 *Substrate Preferences*

Both Ephemeroptera and Trichoptera at order level demonstrated a significant difference in term of substrate preferences (Table 3.16). At family level, there were only 4 families, which showed significant preferences. These families included 3 families of Ephemeroptera (Baetidae, Caenidae and Leptophlebiidae), and 1 family of Trichoptera (Hydropsychidae).

There were 7 genera, which demonstrated significant differences in substrate preferences. These genera were *Baetis*, *Caenis, Nixe, Choroterpes, Leptophlebia Cheumatopsyche* and *Macrostemum.*

Plecoptera did not show any significant preferences at all levels.

3.2.2.4.1.2.1.1 *Order Level*

Ephemeroptera

There was a significant effect of substrate on the mean density of Ephemeroptera at site Hin Lat 2, February 1998 (One Way ANOVA, $F_{4, 45} = 18.380$, P = <0.001). By Tukey Multiple Comparison Method, mean density of Ephemeroptera differed ($p < 0.05$) between all of the finer substrates (leaf pack and root) and all of the coarser substrates (cobbles, pebbles and boulders). The mean density difference also exists between boulders and cobbles.

Ephemeroptera clearly demonstrated a preference for finer substrates such as leaf pack and root and avoided coarser substrates such as cobbles pebbles and boulders. However, among the coarser substrates, they preferred boulders.

Trichoptera

There was a significant effect of substrate on the median density of Trichoptera at site Hin Lat 2, February 1998 (One Way ANOVA on ranks, $H_4 = 15.663$, $P = 0.004$). By Dunn's Multiple Comparison Method, median density of Trichoptera differed ($p < 0.05$) between leaf pack and root; and between cobbles and root.

Trichoptera clearly demonstrated a preference for leaf pack and cobbles; and avoided root. They were present in moderate numbers on boulders and pebbles.

3.2.2.4.1.2.1.2 *Family Level*

Baetidae

There was a significant effect of substrate on the median density of Baetidae at site Hin Lat 2, February 1998 (One Way ANOVA on ranks, $H_4 = 19.579$, P = <0.001). By Dunn's Multiple Comparison Method, median density of Baetidae differed ($p < 0.05$) between root and pebbles; and between root and cobbles.

Baetidae clearly demonstrated a preference for root and avoided cobbles and pebbles. They were present in moderate numbers on boulders and leaf pack.

Caenidae

There was a significant effect of substrate on the median density of Caenidae at site Hin Lat 2, February 1998 (One Way ANOVA on ranks, $H_4 = 31.418$, P = <0.001). By Dunn's Multiple Comparison Method, median density of Caenidae differed ($p < 0.05$) between all of the finer substrates (leaf pack and root) and all of the coarser substrates (cobbles, boulders and pebbles)

Caenidae clearly demonstrated a preference for finer substrates such as leaf pack and root; and avoided coarser substrates such as cobbles, boulders and pebbles.

Leptophlebiidae

There was a significant effect of substrate on the median density of Leptophlebiidae at site Hin Lat 2, February 1998 (One Way ANOVA on ranks, $H_4 = 13.584$, $P = 0.009$). By Dunn's Multiple Comparison Method, median density of Leptophlebiidae differed ($p < 0.05$) between root and cobbles; and between root and leaf pack.

Leptophlebiidae demonstrated a preference for root and avoided cobbles and leaf pack. They were present in moderate numbers on boulders and pebbles.

Hydropsychidae

There was a significant effect of substrate on the median density of Hydropsychidae at site Hin Lat 2, February 1998 (One Way ANOVA on ranks, $H_4 = 14.815$, $P = 0.005$). By Dunn's Multiple Comparison Method, median density of Hydropsychidae differed ($p < 0.05$) between cobbles and root.

Hydropsychidae clearly demonstrated a preference for cobbles and avoided root. They were present in moderate numbers on boulders, leaf pack and pebbles.

3.2.2.4.1.2.1.3 *Genus Level*

There were 7 of 30 genera at site Hin Lat 2 in February (*Baetis*, *Caenis*, *Nixe*, *Choroterpes*, *Leptophlebia Cheumatopsyche* and *Macrostemum)* which had preferences for some specific substrates.

Baetis, *Caenis* and *Cheumatopsyche* preferred finer substrates (root and leaf pack). The *Baetis* mayfly was present at the highest density on root with 5.8 ± 2.6 individuals per sample but present at the lowest density on cobbles and pebbles with 0.1 ± 0.1 individuals per sample each. The *Caenis* mayfly was present at high density on leaf pack and root with 12.9 ± 4.4 and 5.6 ± 0.9 individuals per sample respectively; but absent on cobbles and present at low density on boulders and pebbles with 1.1 ± 1.0 and 0.7 ± 0.3 individuals per sample respectively. *Cheumatopsyche* caddis was present at the highest density on leaf pack with 0.9 ± 0.3 individuals per sample; but absent on boulders, pebbles and root.

Nixe and *Leptophlebia* mayflies significantly preferred for boulders. They were present at the highest density on boulders with 1.4 ± 0.5 and 1.3 ± 0.5 individuals per sample respectively. *Nixe* was absent on leaf pack and pebbles; and *Leptophlebia* was absent on all the other substrates.

Macrostemum strongly associated with cobbles. It was present at the highest density on cobbles with 1.3 ± 0.3 individuals per sample but absent on root and present at low density on boulders and leaf pack with 0.2 ± 0.1 and 0.1 ± 0.1 individuals per sample respectively.

Choroterpes significantly preferred for both root and pebble substrates. It was present at high density on these substrates with 3.5 ± 1.2 and 1.7 ± 0.6 individuals per sample respectively but present at the lowest density on boulders with 0.1 ± 0.1 individuals per sample.

3.2.2.4.2 <u>August Data Set</u>

3.2.2.4.2.1 Site Hin Lat 1

A total of 418 individuals, representing 16 families and 27 genera of EPT taxa was collected from site Hin Lat 1 in August 1998 (Figure 3.26). Ephemeroptera was the most diverse and abundant order with 6 families, 14 genera and 346 individuals. The three most abundant families were Caenidae, Leptophlebiidae and Baetidae, representing 170, 75 and 41 individuals respectively. Trichoptera was the second most diverse and abundant order with 9 families, 12 genera and 71 individuals. The three most abundant families of Trichoptera were Ecnomidae, Leptoceridae and Hydropsychidae, representing 29, 24 and 6 individuals respectively. Plecoptera was very rare with only 1 individual of Leuctridae.

Figure 3.26 Abundance of EPT families found at Site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in August 1998.

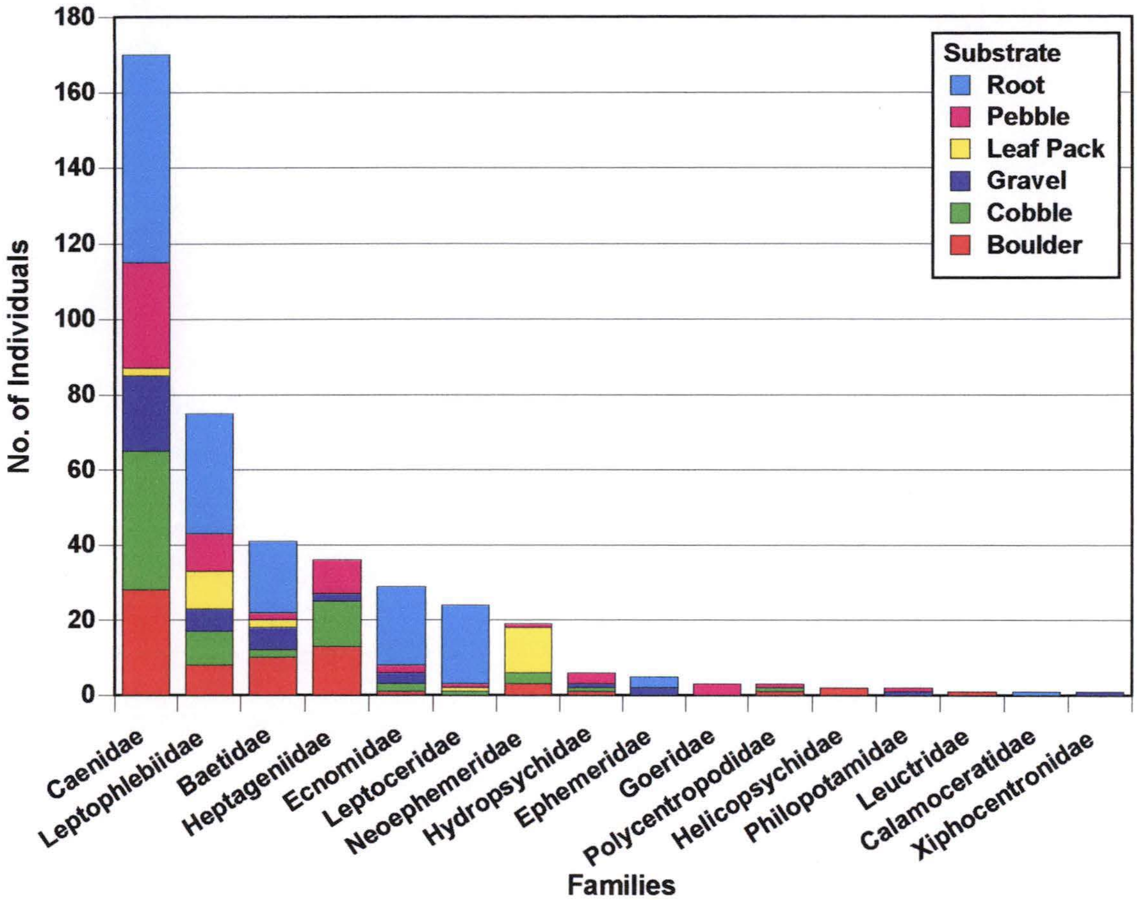


Table 3.18 summarizes the EPT family richness and abundance found on each substrate type at site Hin Lat 1 in August 1998. Pebble substrate had the highest EPT family richness and root had the most EPT abundance. Whereas, leaf pack had the least EPT family richness and abundance with 5 families and 27 individuals.

Table 3.18 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in August 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	5	5	5	4	5	4
	Abundance	62	63	36	26	50	109
Plecoptera	Richness	1	0	0	0	0	0
	Abundance	1	0	0	0	0	0
Trichoptera	Richness	4	4	4	1	6	3
	Abundance	5	5	6	1	11	43
Total	Richness	10	9	9	5	11	7
	Abundance	68	68	42	27	61	152

3.2.2.4.2.1.1 *Substrate Preferences*

Both Ephemeroptera and Trichoptera at order levels demonstrated a significant difference in term of substrate preferences (Table 3.16). At family levels, there were only 4 families, which showed significant preferences. These families included 2 families of Ephemeroptera (Caenidae and Leptophlebiidae), and 2 families of Trichoptera (Ecnomidae and Leptoceridae).

At genus level, there were 6 genera included *Baetis, Caenis, Paraleptophlebia, Neoephemera, Ecnomus and Leptocerus* which significantly denstrated differences in substrate prefernces.

Plecoptera did not show any significant preference at both Order and Family level.

3.2.2.4.2.1.1.1 *Order Level*

Ephemeroptera

There was a significant effect of substrate on the mean density of Ephemeroptera at site Hin Lat 1, August 1998 (One Way ANOVA, $F_{5, 30} = 3.405$, $P = 0.015$). By Tukey Multiple Comparison Methods, mean density of Ephemeroptera differed ($p < 0.05$) between root and leaf pack; and between root and gravel.

Ephemeroptera clearly demonstrated a preference for root and avoided leaf pack and gravel. They were present in moderate numbers on boulders, cobbles and pebbles.

Trichoptera

There was a significant effect of substrate on the mean density of Trichoptera at site Hin Lat 1, August 1998 (One Way ANOVA, $F_{5, 30} = 10.256$, $P = <0.001$). By Tukey Multiple Comparison Methods, mean density of Trichoptera differed ($p < 0.05$) between root and all the other substrates (leaf pack, boulders, cobbles, gravel and pebbles).

Trichoptera clearly demonstrated a preference for root and avoided all the other substrates (leaf pack, boulders, cobbles, gravel and pebbles).

3.2.2.4.2.1.1.2 *Family Level*

Caenidae

There was a significant effect of substrate on the mean density of Caenidae at site Hin Lat 1, August 1998 (One Way ANOVA, $F_{5, 30} = 5.003$, $P = 0.002$). By Tukey Multiple Comparison Methods, mean density of Caenidae differed ($p < 0.05$) between root and leaf pack; between cobbles and leaf pack; and between boulders and leaf pack.

Caenidae clearly demonstrated a preference for root, cobbles and boulders; and strongly avoided leaf pack. They were present in moderate numbers on gravel and pebbles.

Leptophlebiidae

There was a significant effect of substrate on the median density of Leptophlebiidae at site Hin Lat 1, August 1998 (One Way ANOVA on ranks, $H_5 = 13.304$, $P = 0.021$). By Dunn's Multiple Comparison Methods, median density of Leptophlebiidae differed ($p < 0.05$) between root and gravel.

Leptophlebiidae clearly demonstrated a preference for root and avoided gravel. They were present in moderate numbers on boulders, cobbles, leaf pack and pebbles.

Ecnomidae

There was a significant effect of substrate on the median density of Ecnomidae at site Hin Lat 1, August 1998 (One Way ANOVA on ranks, $H_5 = 15.041$, $P = 0.010$). By Dunn's Multiple Comparison Methods, median density of Ecnomidae differed ($p < 0.05$) between root and leaf pack; and between root and boulders.

Ecnomidae clearly demonstrated a preference for root and avoided leaf pack and boulders. They were present in moderate numbers on cobbles, gravel and pebbles.

Leptoceridae

There was a significant effect of substrate on the median density of Leptoceridae at site Hin Lat 1, August 1998 (One Way ANOVA on ranks, $H_5 = 25.204$, $P = <0.001$). By Dunn's Multiple Comparison Methods, median density of Leptoceridae differed ($p < 0.05$) between root and all the other substrates (gravel, boulders, pebbles, leaf pack and cobbles).

Leptoceridae strongly demonstrated a preference for root and avoided all the other substrates (gravel, boulders, pebbles, leaf pack and cobbles).

3.2.2.4.2.1.1.2 *Genus Level*

There were 6 from 27 genera found at site Hin Lat 1 in August included *Baetis, Caenis, Paraleptophlebia, Neoephemera, Ecnomus and Leptocerus* which demonstrated significant differences in term of substrate preferences.

All of these genera strongly preferred for finer substrates (root and leaf pack).

The *Baetis, Caenis, Paraleptophlebia, Ecnomus* and *Leptocerus* genera were significantly present at the highest density on root with 2.7 ± 0.8, 9.2 ± 3.2, 4.0 ± 1.2, 3.5 ± 1.1 and 3.5 ± 0.8 individuals per sample respectively. Whereas, the *Neoephemera* mayfly was found at the highest density on leaf pack with 2.4 ± 1.1 individuals per sample.

However, they avoided different substrate types. For examples; *Baetis* avoided cobbles and leaf pack; *Caenis* avoided leaf pack; *Paraleptophlebia* and *Leptocerus* were absent on all the other substrates; *Neoephemera* was absent on gravel and root; *Ecnomus* avoided boulders and leaf pack.

3.2.2.4.2.2 Site Hin Lat 2

A total of 841 individuals, representing 16 families and 26 genera of EPT taxa was collected from site Hin Lat 2 in August 1998 (Figure 3.27). Both Ephemeroptera and Trichoptera had equal family richness with 7 families. However, Ephemeroptera was more abundant than Trichoptera. There were 666 individuals of Ephemeroptera, whereas, Trichoptera was presented with only 170 individuals. The three most abundant families of Ephemeroptera were Caenidae, Leptophlebiidae and Heptageniidae with 244, 179 and 130 individuals respectively. The three most abundant families of Trichoptera were Hydropsychidae, Philopotamidae and Calamoceratidae with 112, 35 and 6 individuals respectively. Plecoptera was poorly presented with only 2 families and 5 individuals.

Figure 3.27 Abundance of EPT families found at Site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in August 1998.

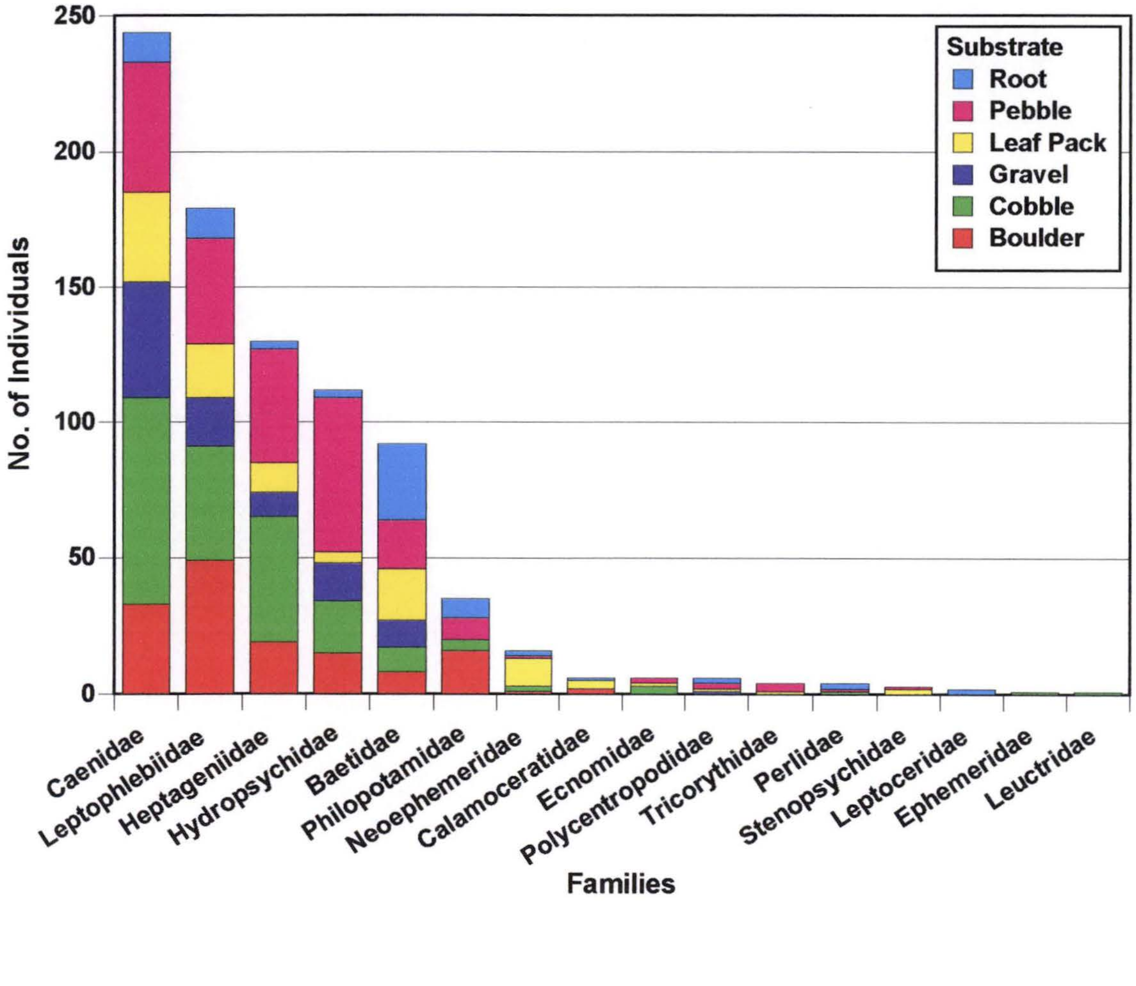


Table 3.19 summarizes EPT family richness and abundance found on each substrate type at site Hin Lat 2 in August 1998. Pebble substrate had the highest EPT family richness and abundance with 12 families and 222 individuals, whereas, gravel had the least EPT family richness with 6 families and 95 individuals.

Table 3.19 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in August 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	5	6	4	6	6	5
	Abundance	110	176	80	94	151	55
Plecoptera	Richness	0	2	0	0	1	1
	Abundance	0	2	0	0	1	2
Trichoptera	Richness	3	3	2	5	5	5
	Abundance	33	26	15	11	70	15
Total	Richness	8	11	6	11	12	11
	Abundance	143	204	95	105	222	72

3.2.2.4.2.2.1 _Substrate Preferences_

Only Ephemeroptera at order level demonstrated a significant difference in term of substrate preferences, whereas, Trichoptera and Plecoptera did not show any significant preferences (Table 3.16). At family level, there were only 3 families, which demonstrated a significant preference. These families included 2 families of Ephemeroptera (Caenidae and Heptageniidae), and 1 family of Trichoptera (Hydropsychidae).

There were 6 genera included 4 genera of Ephemeroptera (*Procloeon, Caenis, Nixe* and *Cryptopenella*) and 2 genera of Trichoptera (*Cheumatopsyche* and *Macrostemum*) which showed significant differences in substrate preferences.

3.2.2.4.2.2.1.1 *Order Level*

Ephemeroptera

There was a significant effect of substrate on the mean density of Ephemeroptera at site Hin Lat 2, August 1998 (One Way ANOVA, $F_{5, 30} = 3.577$, $P = 0.012$). By Tukey Multiple Comparison Methods, mean density of Ephemeroptera differed ($p < 0.05$) between cobbles and root.

Ephemeroptera demonstrated a preference for cobbles and avoided root. They were present in moderate numbers on boulders, gravel, leaf pack and pebble.

3.2.2.4.2.2.1.2 *Family Level*

Caenidae

There was a significant effect of substrate on the mean density of Caenidae at site Hin Lat 2, August 1998 (One Way ANOVA, $F_{5, 30} = 2.948$, $P = 0.028$). By Tukey Multiple Comparison Methods, mean density of Caenidae differed ($p < 0.05$) between cobbles and root.

Caenidae clearly demonstrated a preference for cobbles and avoided root. They were present in moderate numbers on boulders, gravel, leaf pack and pebbles.

Heptageniidae

There was a significant effect of substrate on the median density of Heptageniidae at site Hin Lat 2, August 1998 (One Way ANOVA on ranks, $H_5 = 21.366$, P = <0.001). By Dunn's Multiple Comparison Methods, median density of Heptageniidae differed ($p < 0.05$) between cobbles and root; between cobbles and gravel; and between pebbles and root.

Heptageniidae clearly demonstrated a preference for cobbles and pebbles; and avoided root and gravel. They were present in moderate numbers on boulders and leaf pack.

Hydropsychidae

There was a significant effect of substrate on the mean density of Hydropsychidae at site Hin Lat 2, August 1998 (One Way ANOVA, $F_{5, 30} = 6.090$, P = <0.001). By Tukey Multiple Comparison Methods, mean density of Hydropsychidae differed ($p < 0.05$) between pebbles and the other 4 substrates (root, leaf pack, boulders and gravel).

Hydropsychidae clearly demonstrated a preference for pebbles and avoided root, leaf pack, boulders and gravel. They were present in moderate numbers on cobbles.

3.2.2.4.2.2.1.2 *Genus Level*

There were 6 from 26 genera found at Site Hin Lat 2 in August included *Procloeon, Caenis, Nixe, Cryptopenella, Cheumatopsyche* and *Macrostemum*, which showed significant differences in term of substrate preferences (Table 3.16).

Procloeon strongly demonstrated a preference for root substrate, as it was only present on root with mean density of 0.5 ± 0.2 individuals per sample; but absent on all the other substrates.

Whereas, *Caenis, Nixe, Cryptopenella, Cheumatopsyche* and *Macrostemum* significantly associated with coarser substrates such as cobbles, boulders and pebbles. *Caenis* was present at the highest density on cobbles with 12.7 ± 2.6 but present at the lowest density on root with 1.8 ± 0.6 individuals per sample. *Nixe* was present at high density on cobbles and pebbles with 7.7 ± 1.1 and 7.0 ± 2.2 individuals per sample respectively; but at low density on root and gravel with 0.5 ± 0.5 and 1.5 ± 0.8 individuals per sample respectively.

Cryptopenella was present at high density on cobbles, boulders and pebbles within the range of 5.5 ± 1.7 and 6.0 ± 1.2 individuals per sample. Whereas, the *baetis* mean density was lowest on root substrate with 0.2 ± 0.2 individuals per sample.

Both *Cheumatopsyche* and *Macrostemum* were present at the highest density on pebbles with 4.5 ± 1.2 and 5.0 ± 1.9 individuals per sample respectively; but at the lowest density on root with 0.2 ± 0.2 and 0.3 ± 0.2 individuals per sample respectively.

3.2.2.4.2.3 Site Hin Lat 3

A total of 1,012 individuals, representing 19 families and 31 genera of EPT taxa was collected from site Hin Lat 3 in August 1998 (Figure 3.28). Ephemeroptera was the most abundant Order with 7 families and 796 individuals. The three most abundant families were Caenidae, Baetidae and Leptophlebiidae with 351, 147 and 130 individuals respectively, whereas, Trichoptera had the most family richness with 10 families and 208 individuals. The three most abundant families of Trichoptera were Philopotamidae, Hydropsychidae and Polycentropodidae with 122, 47 and 23 individuals respectively. Plecoptera was poorly presented with only 2 families and 8 individuals.

Figure 3.28 Abundance of EPT families found at Site Hin Lat 3, Hin Lat stream, Nam Nao National Park, Thailand in August 1998.

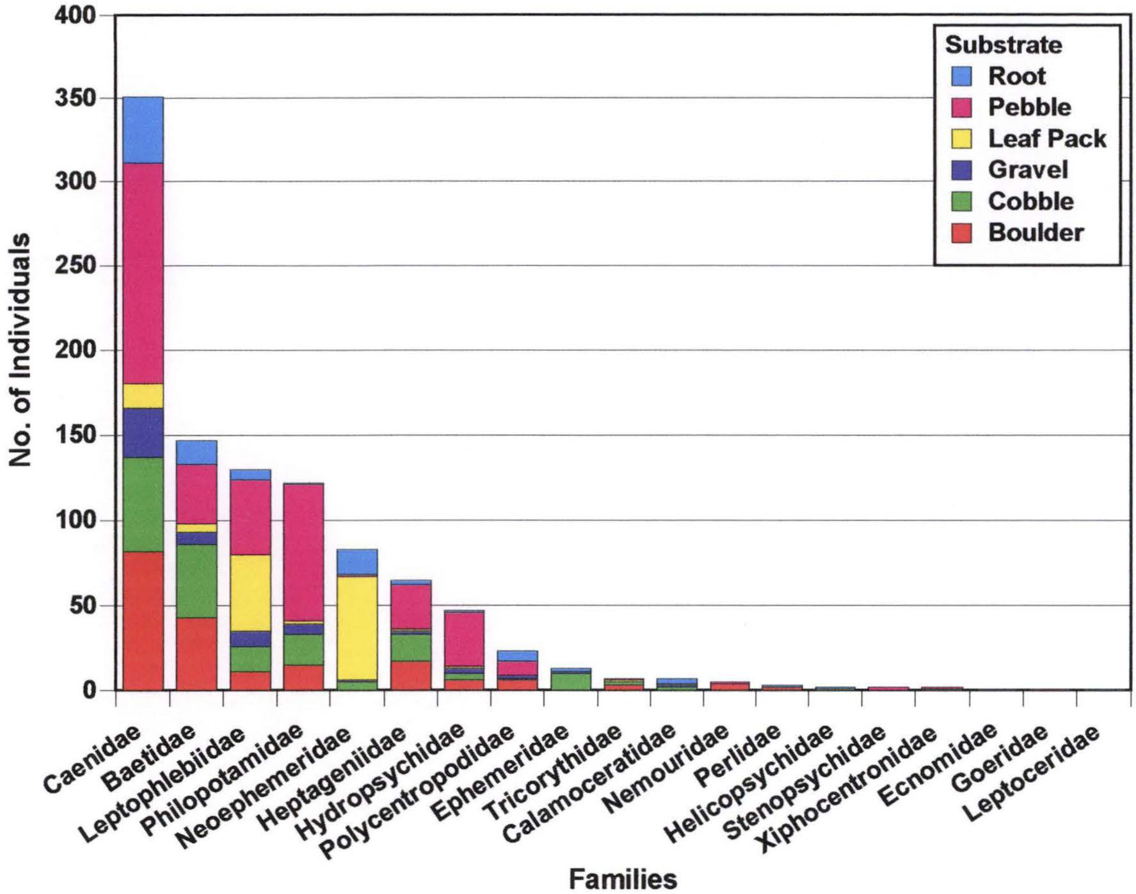


Table 3.20 summarizes EPT family richness and abundance found on each substrate type at Hin Lat 3 in August 1998. The EPT taxa were well presented over all substrates and family richness differed little between them. Pebbles supported the most EPT taxa with 363 individuals, whereas, gravel had the least with 62 individuals.

Table 3.20 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 3, Hin Lat stream, Nam Nao National Park, Thailand in August 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	5	7	6	6	6	6
	Abundance	156	146	49	127	238	80
Plecoptera	Richness	2	0	0	0	1	1
	Abundance	6	0	0	0	1	1
Trichoptera	Richness	3	5	5	4	6	6
	Abundance	27	26	13	5	124	13
Total	Richness	10	12	11	10	13	13
	Abundance	189	172	62	132	363	94

3.2.2.4.2.3.1 *Substrate Preferences*

All of the EPT taxa at order level demonstrated a significant difference in term of substrate preferences (Table 3.16). Whereas at family level, there were only 9 families, which demonstrated significant preferences. These families included 6 families of Ephemeroptera (Baetidae, Caenidae, Ephemeridae, Heptageniidae, Leptophlebiidae and Neoephemeridae); 2 families of Trichoptera (Hydropsychidae and Philopotamidae); and 1 family of Plecoptera (Nemouridae)

At genus level, there were 14 from 31 genera found at site Hin Lat 3 in August, which demonstrated significant differences in substrate preferences. These genera included 9 genera of mayflies (*Baetis, Caenis, Ephemera, Nixe, Choroterpes, Cryptopenella, Thraulodes, Thraulus* and *Neoephemera*), 1 genus of stonefly (*Amphinemura*) and 4 genera of caddis flies (*Cheumatopsyche, Macrostemum, Chimarra, Polycentropus*)

3.2.2.4.2.3.1.1 *Order Level*

Ephemeroptera

There was a significant effect of substrate on the mean density of Ephemeroptera at site Hin Lat 3, August 1998 (One Way ANOVA, $F_{5,30} = 5.107$, $P = 0.002$).
Ephemeroptera clearly demonstrated a preference for pebbles and avoided gravel and root. They were present in moderate numbers on boulders, cobbles and leaf pack.

Plecoptera

There was a significant effect of substrate on the median density of Plecoptera at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 25.625$, $P = <0.001$). By Dunn's Multiple Comparison Methods, median density of Plecoptera differed ($p < 0.05$) between boulders and all of the other substrates (cobbles, gravel, leaf pack, pebbles and root).

Plecoptera clearly demonstrated a preference for boulders and avoided all of other substrates such as cobbles, gravel, leaf pack, pebbles and root.

Trichoptera

There was a significant effect of substrate on the median density of Trichoptera at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 16.213$, $P = 0.006$). By Dunn's Multiple Comparison Methods, median density of Trichoptera differed ($p < 0.05$) between pebbles and leaf pack; and between pebbles and gravel.

Trichoptera clearly demonstrated a preference for pebbles; and avoided leaf pack and gravel. They were present in moderate numbers on boulders, cobbles and root.

3.2.2.4.2.3.1.2 *Family Level*

Baetidae

There was a significant effect of substrate on the mean density of Baetidae at site Hin Lat 3, August 1998 (One Way ANOVA, $F_{5,30} = 5.316$, $P = 0.001$). By Tukey Multiple Comparison Methods, mean density of Baetidae differed ($p < 0.05$) between cobbles and leaf pack; between cobbles and gravel; between pebbles and leaf pack; and between boulders and leaf pack.

Baetidae clearly demonstrated a preference for cobbles, pebbles and boulders; and avoided gravel and leaf pack. They were present in moderate numbers on root.

Caenidae

There was a significant effect of substrate on the mean density of Caenidae at site Hin Lat 3, August 1998 (One Way ANOVA, $F_{5, 30} = 5.660$, $P = <0.001$). By Tukey Multiple Comparison Methods, mean density of Caenidae differed ($p < 0.05$) between pebbles and leaf pack; between pebbles and gravel; and between boulders and leaf pack.

Caenidae clearly demonstrated a preference for pebbles and boulders; and avoided gravel and leaf pack. They were present in moderate numbers on cobbles and root.

Ephemeridae

There was a significant effect of substrate on the median density of Ephemeridae at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 14.657$, $P = 0.012$). By Dunn's Multiple Comparison Methods, median density of Ephemeridae differed ($p < 0.05$) between cobbles and pebbles; cobbles and leaf pack; and between cobbles and boulders.

Ephemeridae clearly demonstrated a preference for cobbles and avoided pebbles, leaf pack and boulders. They were present in moderate numbers on gravel and root.

Heptageniidae

There was a significant effect of substrate on the median density of Heptageniidae at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 21.896$, $P = <0.001$). By Dunn's Multiple Comparison Methods, median density of Heptageniidae differed ($p < 0.05$) between pebbles and leaf pack; between pebbles and gravel; and between pebbles and root.

Heptageniidae clearly demonstrated a preference for pebbles; and avoided leaf pack, gravel and root. They were present in moderate numbers on cobbles and boulders.

Hydropsychidae

There was a significant effect of substrate on the median density of Hydropsychidae at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 15.170$, $P = 0.010$). By Dunn's Multiple Comparison Methods, median density of Hydropsychidae differed ($p < 0.05$) between pebbles and root; pebbles and leaf pack; and pebbles and gravel.

Hydropsychidae clearly demonstrated a preference for pebbles; and avoided root, leaf pack and gravel. They were present in moderate numbers on cobbles and boulders.

Leptophlebiidae

There was a significant effect of substrate on the mean density of Leptophlebiidae at site Hin Lat 3, August 1998 (One Way ANOVA, $F_{5, 30} = 8.125$, $P = <0.001$). By Tukey Multiple Comparison Methods, mean density of Leptophlebiidae differed ($p < 0.05$) between pebbles and root; pebbles and gravel; and pebbles and boulders. The mean density difference also exists between leaf pack and root; leaf pack and gravel; and leaf pack and boulders.

Leptophlebiidae clearly demonstrated a preference for pebbles and leaf pack; and avoided root, gravel and boulders. They were present in moderate numbers on cobbles.

Nemouridae

There was a significant effect of substrate on the median density of Nemouridae at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 17.387$, $P = 0.004$). By Dunn's Multiple Comparison

Methods, median density of Nemouridae differed ($p < 0.05$) between boulders and root; boulders and leaf pack; boulders and gravel; and boulders and cobbles.

Nemouridae clearly demonstrated a preference for boulders; and avoided root, leaf pack, gravel and cobbles. They were present in moderate numbers on pebbles.

Neoephemeridae

There was a significant effect of substrate on the median density of Neoephemeridae at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 13.583$, $P = 0.018$). By Dunn's Multiple Comparison Methods, median density of Neoephemeridae differed ($p < 0.05$) between leaf pack and boulders.

Neoephemeridae demonstrated a preference for leaf pack and avoided boulders. They were present in moderate numbers on cobbles, gravel, pebbles and root.

Philopotamidae

There was a significant effect of substrate on the median density of Philopotamidae at site Hin Lat 3, August 1998 (One Way ANOVA on ranks, $H_5 = 14.077$, $P = 0.015$). By Dunn's Multiple Comparison Methods, median density of Philopotamidae differed ($p < 0.05$) between pebbles and root; and pebbles and leaf pack.

Philopotamidae clearly demonstrated a preference for pebbles; and avoided root and leaf pack. They were present in moderate numbers on gravel, cobbles and boulders.

3.2.2.4.2.3.1.3 *Genus Level*

From the 14 genera which demonstrated significant differences in substrate preferences, *Choroterpes, Thraulus* and *Neoephemera* were finer substrate preference group as they were significantly present at high density on leaf pack substrate. Whereas, *Baetis, Caenis, Ephemera, Nixe, Cryptopenella, Thraulodes, Amphinemura, Cheumatopsyche, Macrostemum, Chimarra* and *Polycentropus,* were coarser substrate preference group. They were significantly present at high density on boulders, cobbles and pebbles.

All of *Choroterpes, Thraulus* and *Neoephemera* were present at the highest density on leaf pack with 5.3 ± 1.9, 2.0 ± 0.7 and 10.2 ± 4.7 individuals persample respectively. However, they avoided some different substrates. For examples, *Choroterpes* was absent on boulders, gravel and pebbles. *Thraulus* was absent on all of the coarser substrates (boulders, cobbles, gravel and pebbles). *Neoephemera* was absent on boulders.

Baetis and *Ephemera* were significantly demonstrated a preference for cobbles. They were present at the highest density on cobbles with 7.0 ± 1.9 and 1.7 ± 0.7 individuals per sample respectively. The *Baetis* mayfly was present at the lowest density on leaf pack with 0.7 ± 0.5 individuals per sample. Whereas, the *Ephemera* mayfly was absent on boulders, leaf pack and pebbles.

All of the *Caenis, Nixe, Cryptopenella, Thraulodes, Cheumatopsyche, Macrostemum, Chimarra* and *Polycentropus* genera were strongly demonstrated a preference for pebbles. They were present at the highest density on pebbles with 21.8 ± 7.3, 4.3 ± 0.7, 5.7 ± 1.2, 1.7 ± 0.6, 2.2 ± 1.0, 3.2 ± 2.0, 13.3 ± 4.6 and 1.2 ± 0.3 individuals per sample respectively. However, they avoided some different substrates. For example, *Caenis* avoided leaf pack. *Nixe, Cryptopenella, Macrostemum* and *Chimarra* avoided leaf pack and root. *Thraulodes* avoided root. *Cheumatopsyche* avoided gravel. *Polycentropus* avoided cobbles, gravel, leaf pack and root.

Amphinemura was strongly demonstrated a preference for boulders. It was present at the highest density on boulders with 0.7 ± 0.2 individuals per sample but absent on cobbles, gravel, leaf pack and root.

3.2.2.4.3 <u>October Data Set</u>

3.2.2.4.3.1 Site Hin Lat 1

A total of 351 individuals, representing 17 families and 25 genera of EPT taxa was collected from site Hin Lat 1 in October 1998 (Figure 3.29). Ephemeroptera was the most abundant order with 5 families and 258 individuals. The three most abundant families were Caenidae, Leptophlebiidae and Baetidae, representing 113, 85 and 55 individuals respectively. Whereas, Trichoptera, was the most diverse order with 8 families and 84 individuals. The three most abundant families of Trichoptera were Hydropsychidae, Philopotamidae and Ecnomidae, representing 41, 26 and 4 individuals respectively. Plecoptera was poorly presented with only 4 families and 9 individuals.

Figure 3.29 Abundance of EPT families found at Site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in October 1998.

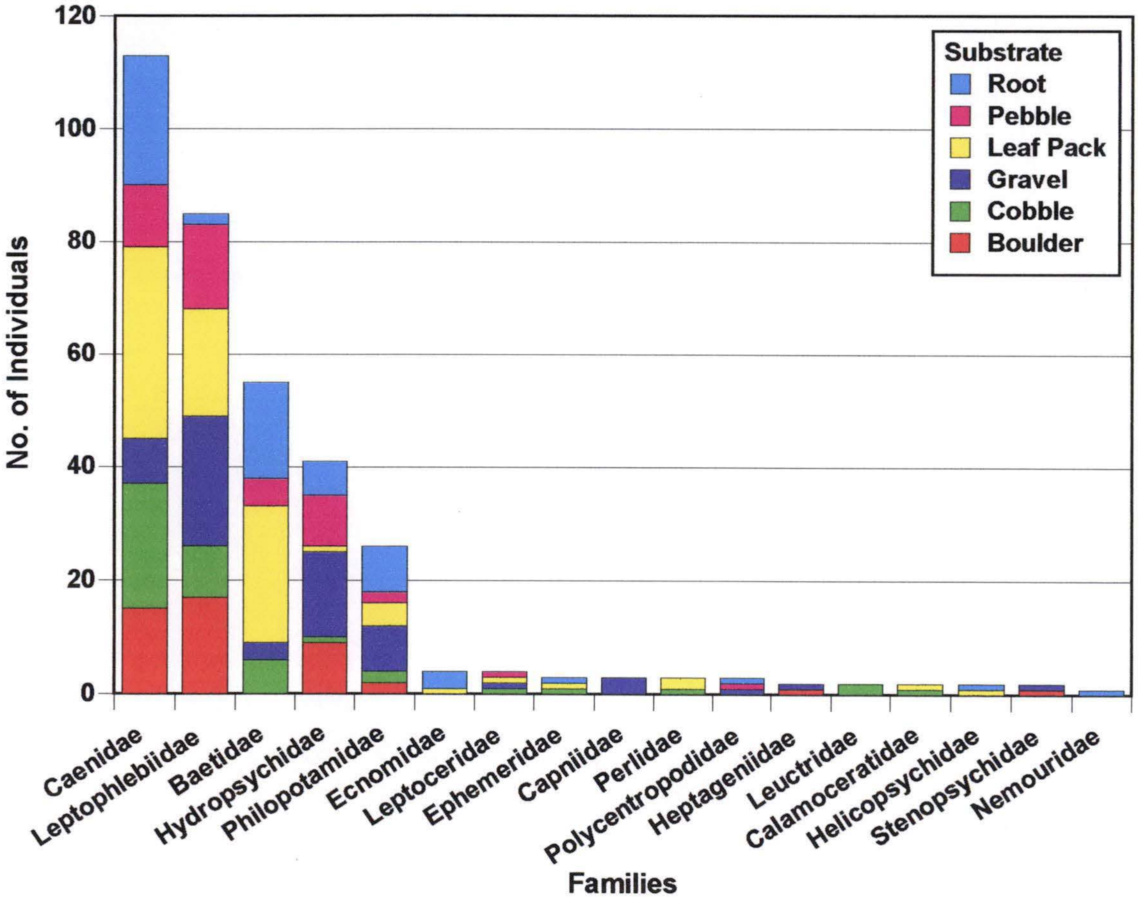


Table 3.21 summarizes EPT family richness and abundance found on each substrate type at site Hin Lat 1 in August 1998. The EPT taxa were well presented over all substrates. Family richness and abundance at all substrates varied between 6 and 11 families; and between 45 and 89 individuals respectively.

Table 3.21 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 1, Hin Lat stream, Nam Nao National Park, Thailand in October 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	3	4	4	4	3	4
	Abundance	33	38	35	78	31	43
Plecoptera	Richness	0	2	1	1	0	1
	Abundance	0	3	3	2	0	1
Trichoptera	Richness	3	4	5	6	4	5
	Abundance	12	5	26	9	13	19
Total	Richness	6	10	10	11	7	10
	Abundance	45	46	64	89	44	63

3.2.2.4.3.1.1 <u>*Substrate Preferences*</u>

At order level, there were not any of EPT taxa, which demonstrated a significant difference in term of substrate preferences. There were only two families included Leptophlebiidae and Hydropsychidae, which showed significant substrate preferences (Table 3.16).

At genus level, there were 2 genera from 25 genera found at site Hin Lat 1 in October, which showed significantly differences in term of substrate preferences. These genera were *Baetis* and *Cheumatopsyche* (Table 3.16)

3.2.2.4.3.1.1.1 *Family Level*

Leptophlebiidae

There was a significant effect of substrate on the mean density of Leptophlebiidae at site Hin Lat 1, October 1998 (One Way ANOVA, $F_{5,\ 30} = 2.633$, $P = 0.043$). By Tukey Multiple Comparison Methods, mean density of Leptophlebiidae differed ($p < 0.05$) between gravel and root.

Leptophlebiidae demonstrated a preference for gravel and avoided root. They were present in moderate numbers on boulders, cobbles, pebbles and leaf pack.

Hydropsychidae

There was a significant effect of substrate on the median density of Hydropsychidae at site Hin Lat 1, October 1998 (One Way ANOVA on ranks, $H_5 = 15.249$, $P = 0.009$). By Dunn's Multiple Comparison Methods, median density of Hydropsychidae differed ($p < 0.05$) between gravel and leaf pack; and gravel and cobbles.

Hydropsychidae demonstrated a preference for gravel; and avoided leaf pack and cobbles. They were present in moderate numbers on boulders, pebbles and root.

3.2.2.4.3.1.1.2 *Genus Level*

There were only 2 genera (*Baetis* and *Cheumatopsyche*) from 25 genera found at site Hin Lat 1 in October, which showed significant difference in substrate preferences.

Baetis demonstrated a strong preference for root substrate. It was present at the highest density on root with 2.5 ± 0.9 individuals per sample but absent on boulders.

Cheumatopsyche preferred for gravel substrate. It was present on gravel with the highest density (1.8 ± 0.3 individuals per sample) but absent on cobbles.

3.2.2.4.3.2 Site Hin Lat 2

A total of 797 individuals, representing 15 families and 21 genera of EPT taxa was collected from site Hin Lat 2 in October 1998 (Figure 3.30). Ephemeroptera and Trichoptera had equal family richness with 6 families each. However, Trichoptera was the most abundant order with 455 individuals. The three most abundant families of Trichoptera and Ephemeroptera were Hydropsychidae, Philopotamidae, Polycentropodidae, Leptophlebiidae Caenidae, and Baetidae, representing 275, 153, 15, 185, 75 and 47 individuals respectively. Plecoptera was poorly presented with only 3 families and 7 individuals. The most outstanding family of Plecoptera was Perlidae with 4 individuals.

Figure 3.30 Abundance of EPT families found at Site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in October 1998.

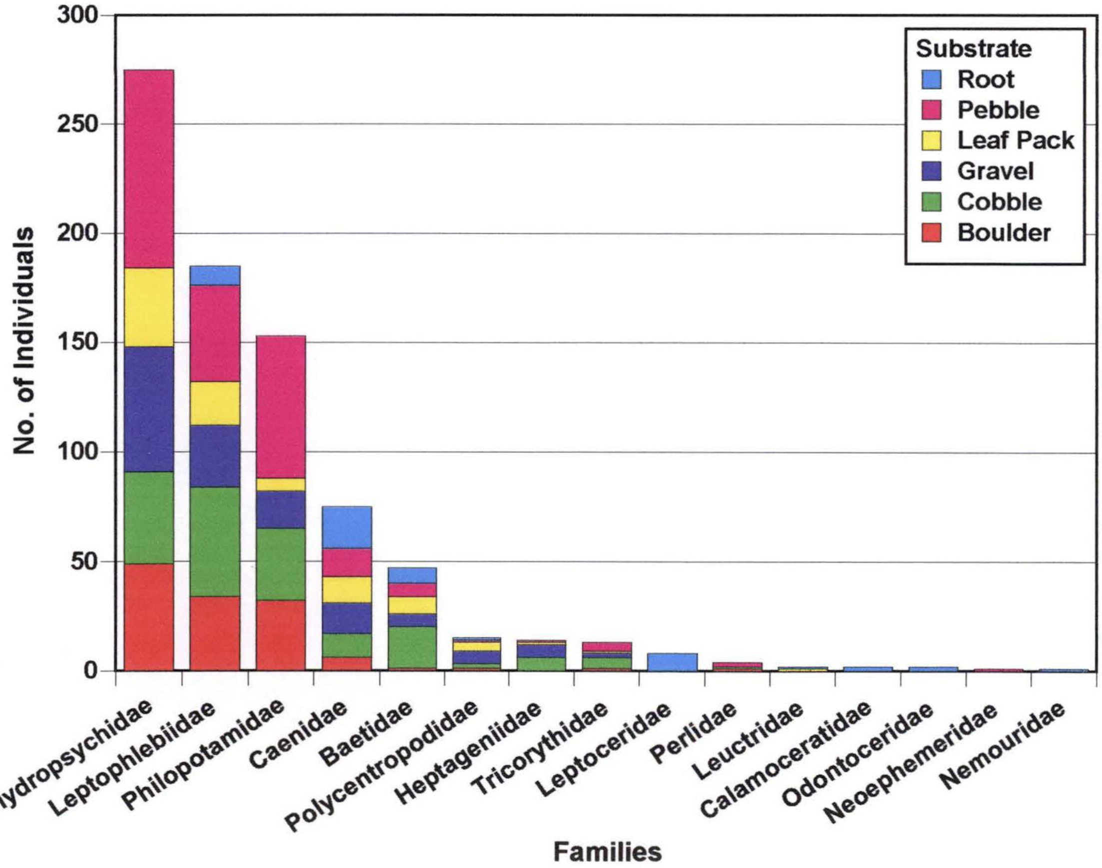


Table 3.22 summarizes EPT family richness and abundance found on each substrate type at site Hin Lat 2 in October 1998. There was not much different in the EPT family richness between substrates. However, pebbles had the most EPT abundance, with 228 individuals, whereas, root had the least, with only 50 individuals.

Table 3.22 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 2, Hin Lat stream, Nam Nao National Park, Thailand in October 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	4	5	5	5	6	3
	Abundance	42	91	56	42	69	35
Plecoptera	Richness	1	1	0	1	1	2
	Abundance	1	1	0	1	2	2
Trichoptera	Richness	3	3	3	3	3	4
	Abundance	82	77	80	46	157	13
Total	Richness	8	9	8	9	10	9
	Abundance	125	169	136	89	228	50

3.2.2.4.3.2.1 _Substrate Preferences_

Only Trichoptera at order level demonstrated significant differences in term of substrate preferences at site Hin Lat 2 in October 1998. At family level, there were only 3 families of Trichoptera (Hydropsychidae, Leptoceridae and Philopotamidae) which showed significant differences (Table 3.16).

At genus level, there were 5 genera from 21 genera found, which showed significant differences. These genera included 2 genera of Ephemeroptera (*Atalophlebioides* and *Choroterpes)* and 3 genera of Trichoptera (*Cheumatopsyche, Macrostemum* and *Chimarra*).

Plecoptera did not show any significant substrate preferences at all levels.

3.2.2.4.3.2.1.1 *Order Level*

Trichoptera

There was a significant effect of substrate on the median density of Trichoptera at site Hin Lat 2, October 1998 (One Way ANOVA on ranks, H_5 = 20.655, P = <0.001). By Dunn's Multiple Comparison Methods, median density of Trichoptera differed ($p < 0.05$) between pebbles and root.

Trichoptera clearly demonstrated a preference for pebbles and avoided root. They were present in moderate numbers on boulders, cobbles, gravel and leaf pack.

3.2.2.4.3.2.1.2 *Family Level*

Hydropsychidae

There was a significant effect of substrate on the median density of Hydropsychidae at site Hin Lat 2, October 1998 (One Way ANOVA on ranks, H_5 = 22.354, P = <0.001). By Dunn's Multiple Comparison Methods, median density of Hydropsychidae differed ($p < 0.05$) between pebbles and root; and gravel and root.

Hydropsychidae clearly demonstrated a preference for pebbles and gravel; and avoided root. They were present in moderate numbers on boulders, cobbles and leaf pack.

Leptoceridae

There was a significant effect of substrate on the median density of Leptoceridae at site Hin Lat 2, October 1998 (One Way ANOVA on ranks, H_5 = 15.873, P = 0.007). By Dunn's Multiple Comparison Methods, median density of Leptoceridae differed ($p < 0.05$) between root and all the other substrates i.e. pebbles, leaf pack, gravel, cobbles and boulders.

Leptoceridae clearly demonstrated a preference for root substrate and avoided all the other substrates such as boulders, cobbles, pebbles, gravel and leaf pack.

Philopotamidae

There was a significant effect of substrate on the median density of Philopotamidae at site Hin Lat 2, October 1998 (One Way ANOVA on ranks, H_5 = 21.980, P = <0.001). By Dunn's Multiple Comparison Methods, median density of Philopotamidae differed ($p < 0.05$) between pebbles and root; pebbles and leaf pack; cobbles and root; and boulders and root.

Philopotamidae clearly demonstrated a preference for coarser substrates such as pebbles, cobbles and boulders; and avoided root. They were present in moderate numbers on gravel and leaf pack.

3.2.2.4.3.2.1.3 *Genus Level*

There were only 5 genera from 21 genera found at site Hin Lat 2 in October, which showed significant differences in substrate preferences. *Choroterpes* strongly preferred for finer substrate (root), whereas, *Atalophlebioides* and *Chimarra* clearly preferred for coarser substrates (boulders, cobbles and pebbles). However, *Cheumatopsyche* and *Macrostemum* demonstrated preferences for both finer and coarser substrates (pebbles and gravel).

Choroterpes was strongly preferred for root substrate. It was present at the highest density on root with 1.5 ± 1.1 individuals per sample but totally disappeared on the other substrates.

Atalophlebioides showed a preference for cobbles. It was present at the highest density on cobbles with 8.3 ± 1.8 individuals per sample but absent on root. It was also present on the other substrates within the range of 3.0 ± 1.4 and 7.3 ± 2.2 individuals per sample.

Chimarra showed significant preferences for pebbles, cobbles and boulders. It was present on these substrates at high density within the range of 5.3 ± 1.8 - 10.8 ± 3.4 individuals per sample. It was present at low density on leaf pack with 1.0 ± 0.4 individuals per sample and absent on root.

Both *Cheumatopsyche* and *Macrostemum* clearly demonstrated preferences for pebbles and gravel; and avoided root. They were present at high density on pebbles and gravel within the range of 6.3 ± 0.7 - 11.5 ± 1.5 and 3.2 ± 0.9 - 3.7 ± 1.1 individuals per sample respectively. Both of them were absent on root.

3.2.2.4.3.3 Site Hin Lat 3

A total of 1,068 individuals, representing 20 families and 30 genera of EPT taxa was collected from site Hin Lat 3 in October 1998 (Figure 3.31). Ephemeroptera was the most abundant order with 7 families and 571 individuals. The three most abundant families were Leptophlebiidae, Caenidae, and Heptageniidae with 251, 160 and 69 individuals respectively. Whereas, Trichoptera, was the most diverse Order with 10 Families and 482 individuals. The three most abundant families of Trichoptera were Philopotamidae, Hydropsychidae and Polycentropodidae with 293, 168 and 9 individuals respectively. Plecoptera were poorly presented with only 3 families and 15 individuals. The most outstanding family of Plecoptera was Leuctridae with 6 individuals.

Figure 3.31 Abundance of EPT families found at Site Hin Lat 3, Hin Lat stream, Nam Nao National Park, Thailand in October 1998.

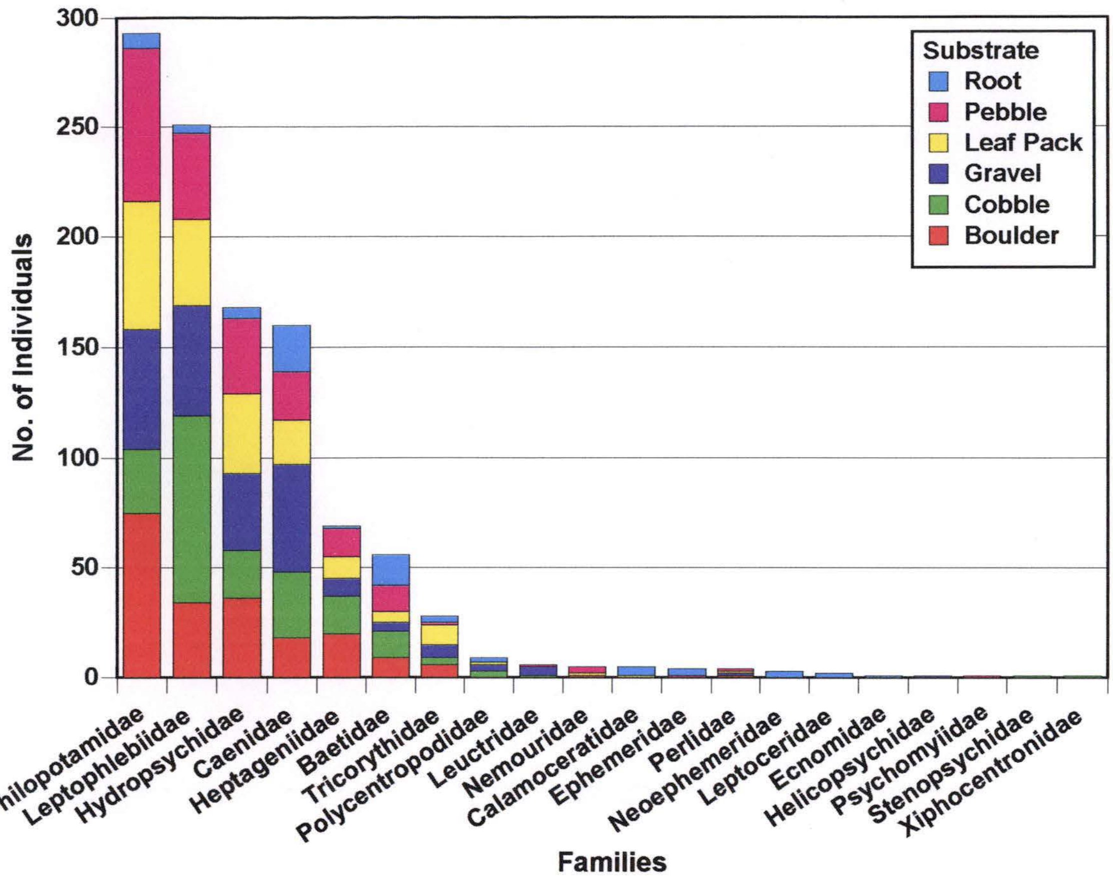


Table 3.23 summarizes EPT family richness and abundance found on each substrate type at site Hin Lat 3 in October 1998. Root substrate had the highest EPT family richness, with 13 families and 70 individuals. Gravel had the most EPT abundance with 11 families and 215 individuals.

Table 3.23 Family richness and abundance of Ephemeroptera, Plecoptera and Trichoptera found at site Hin Lat 3, Hin Lat stream, Nam Nao National Park, Thailand in October 1998.

Order		Boulder	Cobble	Gravel	Leaf Pack	Pebble	Root
Ephemeroptera	Richness	5	5	5	5	6	7
	Abundance	87	147	117	83	88	49
Plecoptera	Richness	2	1	2	2	3	0
	Abundance	2	1	5	2	5	0
Trichoptera	Richness	2	5	4	4	3	6
	Abundance	111	56	93	96	105	21
Total	Richness	9	11	11	11	12	13
	Abundance	200	204	215	181	198	70

3.2.2.4.3.3.1 <u>*Substrate Preferences*</u>

The EPT taxa at order level did not show any significant differences in term of substrate preferences at site Hin Lat 3 in October 1998. At family level, there were only 2 families, which demonstrated significant preferences (Table 3.16). These families were Leptophlebiidae (Ephemeroptera) and Philopotamidae (Trichoptera).

At genus level, there were only 2 genera (*Atalophlebioides* and *Minyphlebia*) of Ephemeroptera, which demonstrated significant differences in substrate preferences.

3.2.2.4.3.3.1.1 *Family Level*

Leptophlebiidae

There was a significant effect of substrate on the median density of Leptophlebiidae at site Hin Lat 3, October 1998 (One Way ANOVA on ranks, H_5 = 17.531, P = 0.004). By Dunn's Multiple Comparison Methods, median density of Leptophlebiidae differed ($p < 0.05$) between cobbles and root; and gravel and root.

Leptophlebiidae demonstrated a preference for cobbles and gravel; and avoided root. They were present in moderate numbers on boulders, pebbles and leaf pack.

Philopotamidae

There was a significant effect of substrate on the mean density of Philopotamidae at site Hin Lat 3, October 1998 (One Way ANOVA, $F_{5, 30}$ = 4.331, P = 0.004). By Tukey Multiple Comparison Methods, mean density of Philopotamidae differed ($p < 0.05$) between pebbles and root; leaf pack and root; boulders and root; and gravel and root.

Philopotamidae demonstrated a preference for pebbles, leaf pack, boulders and gravel; and strongly avoided root. They were present in moderate numbers on cobbles.

3.2.2.4.3.3.1.2 *Genus Level*

Only 2 from 30 genera found at site Hin Lat 3 in October demonstrated significant differences in term of substrate preferences.

Atalophlebioides clearly demonstrated preferences for cobbles and gravel. It was present at high density on these substrates within the range of 13.0 ± 2.9 and 7.8 ± 2.4 individuals per sample but absent on root. It was also present on boulders, leaf pack and pebbles within the range of 3.2 ± 1.6 and 3.7 ± 1.5 individuals per sample.

Minyphlebia was clearly demonstrated a preference for leaf pack. It was present at the highest density on leaf pack with 3.0 ± 1.3 individuals per sample but absent on pebbles and root.

3.2.2.4.4 <u>Summary</u>

Substrate preferences in the fauna differed between sites and time of year. There was a total of 14 families and 24 genera, which demonstrated significant differences in substrate preferences over the 3 sites and 3 sampling months. Table 3.24 summarizes the significant preferential substrates for each taxa at each site and occasion.

In February, more EPT taxa showed different preferences for particular substrates at site Hin Lat 1 than at site Hin Lat 2. At Hin Lat 1, preferences were shown by 3 orders (Ephemeroptera, Plecoptera and Trichoptera); 9 families (Baetidae, Caenidae, Heptageniidae, Leptophlebiidae, Ecnomidae, Hydropsychidae, Limnephilidae, Polycentropodidae and Stenopsychidae); and 9 genera (*Baetis, Caenis, Nixe, Leptophlebia, Ecnomus, Cheumatopsyche, Apatania, Pseudoneureclipsis* and *Stenopsyche*). Whereas, at Hin Lat 2, preferences were demonstrated by 2 orders (Ephemeroptera and Trichotera); 4 families (Baetidae, Caenidae, Leptophlebiidae and Hydropsychidae); and 7 genera (*Baetis, Caenis, Nixe, Choroterpes, Leptophlebia, Cheumatopsyche* and *Macrostemum*).

In August, site Hin Lat 3 had the highest diversity of EPT taxa showing preferences for particular substrates with 3 orders (Epemeroptera, Plecoptera and Trichoptera), 9 families (Baetidae, Caenidae, Ephemeridae, Heptageniidae, Leptophlebiidae, Neoephemeridae, Nemouridae, Hydropsychidae and Philopotamidae) and 14 genera (*Baetis, Caenis, Ephemera, Nixe, Choroterpes, Cryptopenella, Thraulodes, Thraulus, Neoephemera, Amphinemura, Cheumatopsyche, Macrostemum, Chimarra and Polycentropus*). In contrast, site Hin Lat 2 had the least numbers with 1 order (Ephemeroptera), 3 families (Caenidae, Heptageniidae and Hydropsychidae) and 6 genera (*Procloeon, Caenis, Nixe, Cryptopenella, Cheumatopsyche* and *Macrostemum*).

In October, only modest numbers of EPT taxa demostrated preferences for particular substrates. There were only 2 families (Leptophlebiidae and Hydropsychidae) and 2 genera (*Baetis* and *Cheumatopsyche*) at site Hin Lat 1; 1 order (Trichoptera), 3 families (Hydropsychidae, Leptoceridae and Philopotamidae) and 5 genera (*Atalophlebioides, Choroterpes, Cheumatopsyche, Macrostemum* and *Chimarra*) at site Hin Lat 2; and 2 families (Leptophlebiidae and Philopotamidae) and 2 genera (*Atalophlebioides* and *Minyphlebia*) at site Hin Lat 3

There was generally good agreement in the preferences for particular substrates by the various EPT taxa especially at family and genus level. For example, at family level, Heptageniidae, Hydropsychidae and Philopotamidae strongly preferred coarser substrates (boulders, cobbles and pebbles), whereas, Leptoceridae was strongly associated with root substrate.
At genus level, *Atalophlebioiodes*, *Chimarra*, *Cryptopenella*, *Leptophlebia*, *Macrostemum* and *Nixe* clearly preferred coarser substrates (boulders, cobbles and pebbles), whereas, *Choroterpes* and *Neoephemera* demonstrated a strong preferences for finer organic substrates (root and leaf pack)

There were also some examples of inconsistent habitat association in a few taxa. For example, Caenidae, Baetidae, Ecnomidae and Leptophlebiidae at family level; *Baetis*, *Caenis*, *Cheumatopsyche* and *Ecnomus* at genus level. These variously demonstrated preference for both coarser and finer substrates at different sites and months.

However, some taxa could not be generalized in terms of their substrate preferences as they showed significant association on only one occasion. For example at family level, Ephemeridae preferred cobble at site Hin Lat 3 (Aug), Limnephilidae preferred gravel at site Hin Lat 1(Feb), Nemouridae preferred boulders at site Hin Lat 3 (Aug), Neoephemeridae preferred leaf pack at site Hin Lat 3 (Aug), Polycentropodidae and Stenopsychidae preferred cobbles at site Hin Lat 1(Feb).
At genus level, *Amphinemura* preferred boulders at site Hin Lat 3 (Aug), *Apatania* preferred gravel at site Hin Lat 1 (Feb), *Ephemera* preferred cobbles at site Hin Lat 3 (Aug), *Leptocerus* and *Paraleptophlebia* preferrd root at site Hin Lat 1 (Aug), *Minyphlebia* preferrd leaf pack at site Hin Lat 3 (Oct), *Polycentropus* preferred pebbles at site Hin Lat 3 (Aug), *Procloeon* preferred root at site Hin Lat 2 (Aug), *Pseudoneureclipsis* and *Stenopsyche* preferred cobbles at site Hin Lat 1 (Feb), *Thraulodes* and *Thraulus* preferred pebbles and leaf pack respectively at site Hin Lat 3 (Aug).

Table 3.24 Summary preferential substrates of each taxa at each site and month, Hin Lat stream, Nam Nao National Park, Thailand 1998.

Taxa	HL1			HL2			HL3		
	Feb	Aug	Oct	Feb	Aug	Oct	Feb	Aug	Oct
Baetidae	Root	ns	ns	Root	ns	ns	NA	Cobble, boulder, pebble	ns
Caenidae	Cobble, boulder, gravel	Root, cobble, boulder	ns	Leaf pack, root	Cobble	ns	NA	Pebble, boulder	ns
Ecnomidae	Cobble, boulder	Root	ns	ns	ns	ns	NA	ns	ns
Ephemeridae	ns	ns	ns	ns	ns	ns	NA	Cobble	ns
Heptageniidae	Boulder	ns	ns	ns	Cobble, pebble	ns	NA	Pebble	ns
Hydropsychidae	Cobble	ns	Gravel	Cobble	Pebble	Pebble, gravel	NA	Pebble	ns
Leptoceridae	ns	Root	ns	ns	ns	Root	NA	ns	ns
Leptophlebiidae	Cobble, boulder	Root	Gravel	Root	ns	ns	NA	Leaf pack, pebble	Cobble, gravel
Limnephilidae	Gravel	ns	ns	ns	ns	ns	NA	ns	ns
Nemouridae	ns	ns	ns	ns	ns	ns	NA	Boulder	ns
Neoephemeridae	ns	ns	ns	ns	ns	ns	NA	Leaf pack	ns
Philopotamidae	ns	ns	ns	ns	ns	Pebble, cobble, boulder	NA	Pebble	Boulder, pebble, gravel, leaf pack
Polycentropodidae	Cobble	ns	ns	ns	ns	ns	NA	ns	ns
Stenopsychidae	Cobble	ns	ns	ns	ns	ns	NA	ns	ns
Amphinemura	ns	ns	ns	ns	ns	ns	NA	Boulder	ns
Apatania	Gravel	ns	ns	ns	ns	ns	NA	ns	ns
Atalophlebioides	ns	ns	ns	ns	ns	Cobble	NA	ns	Cobble, gravel
Baetis	Root	Root	Root	Root	ns	ns	NA	Cobble	ns
Caenis	Cobble, gravel, boulder	Root	ns	Leaf pack, root	Cobble	ns	NA	Pebble	ns

Table 3.24 (continued) Summary preferential substrates of each taxa at each site and month, Hin Lat stream, Nam Nao National Park, Thailand 1998.

Taxa	HL1			HL2			HL3		
	Feb	Aug	Oct	Feb	Aug	Oct	Feb	Aug	Oct
Cheumatopsyche	Cobble	ns	Gravel	Leaf pack	Pebble	Pebble, gravel	NA	Pebble	ns
Chimarra	ns	ns	ns	ns	ns	Pebble, cobble, boulder	NA	Pebble	ns
Choroterpes	ns	ns	ns	Root, pebble	ns	Root	NA	Leaf pack	ns
Cryptopenella	ns	ns	ns	ns	Cobble, boulder, pebble	ns	NA	Pebble	ns
Ecnomus	Cobble, boulder	Root	ns	ns	ns	ns	NA	ns	ns
Ephemera	ns	ns	ns	ns	ns	ns	NA	Cobble	ns
Leptocerus	ns	Root	ns	ns	ns	ns	NA	ns	ns
Leptophlebia	Cobble	ns	ns	Boulder	ns	ns	NA	ns	ns
Macrostemum	ns	ns	ns	Cobble	Pebble	Pebble, gravel	NA	Pebble	ns
Minyphlebia	ns	ns	ns	ns	ns	ns	NA	ns	Leaf pack
Neoephemera	ns	Leaf pack	ns	ns	ns	ns	NA	Leaf pack	ns
Nixe	Boulder	ns	ns	Boulder	Cobble, pebble	ns	NA	Pebble	ns
Paraleptophlebia	ns	Root	ns	ns	ns	ns	NA	ns	ns
Polycentropus	ns	ns	ns	ns	ns	ns	NA	Pebble	ns
Procloeon	ns	ns	ns	ns	Root	ns	NA	ns	ns
Pseudoneureclipsis	Cobble	ns	ns	ns	ns	ns	NA	ns	ns
Stenopsyche	Cobble	ns	ns	ns	ns	ns	NA	ns	ns
Thraulodes	ns	ns	ns	ns	ns	ns	NA	Pebble	ns
Thraulus	ns	ns	ns	ns	ns	ns	NA	Leaf pack	ns
Ephemeroptera	Cobble, boulder, gravel, root	Root	ns	Leaf pack, root, boulder	Cobble	ns	NA	Pebble	ns
Plecoptera	Boulder	ns	ns	ns	ns	ns	NA	Boulder	ns
Trichoptera	Cobble, boulder	Root	ns	Leaf Pack, cobble	ns	Pebble	NA	Pebble	ns

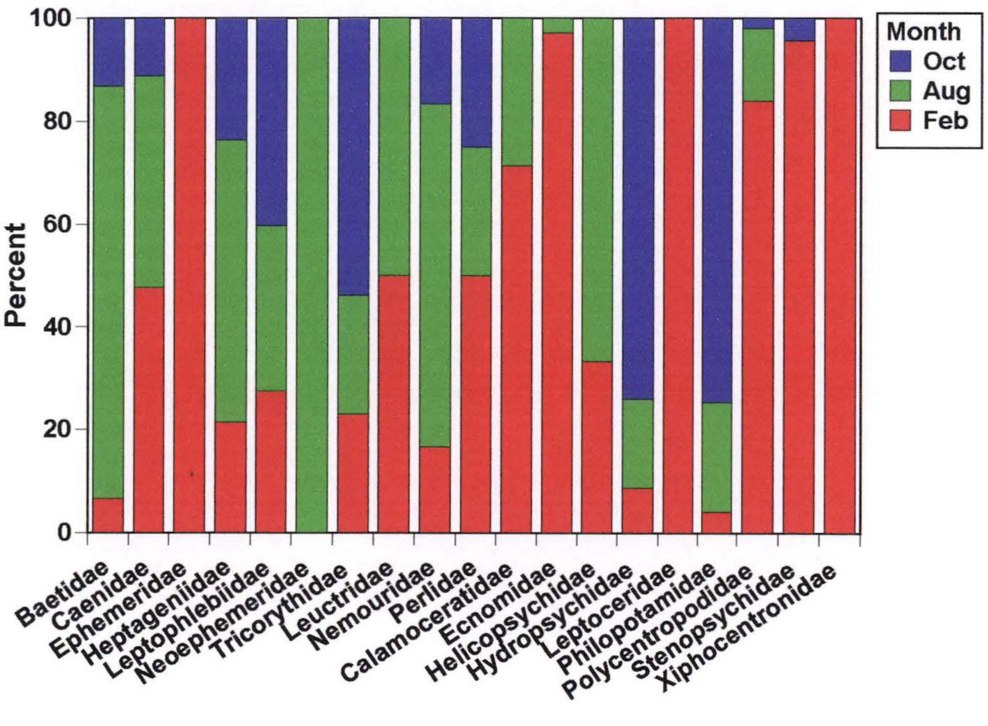
3.2.2.5 Seasonal distribution of individuals within each EPT family associated with each substrate.

There was strong seasonality in patterns of presence, absence and abundance of each family collected from each substrate in the three sampling months: February (cold dry season), August (rainy season) and October (end of rainy season)

3.2.2.5.1 Boulders

Nineteen families were collected from boulder substrates (Figure 3.32) but not all were present year round. Ephemeridae, Leptoceridae and Xiphocentronidae occupied boulders only in February, while Calamoceratidae, Ecnomidae, Polycentropodidae and Stenopsychidae were mostly present in February. Neoephemeridae was only present in August, and Baetidae, Heptageniidae, Nemouridae and Helicopsychidae were most abundant in August. Hydropsychidae and Philopotamidae were present in the highest number in October.

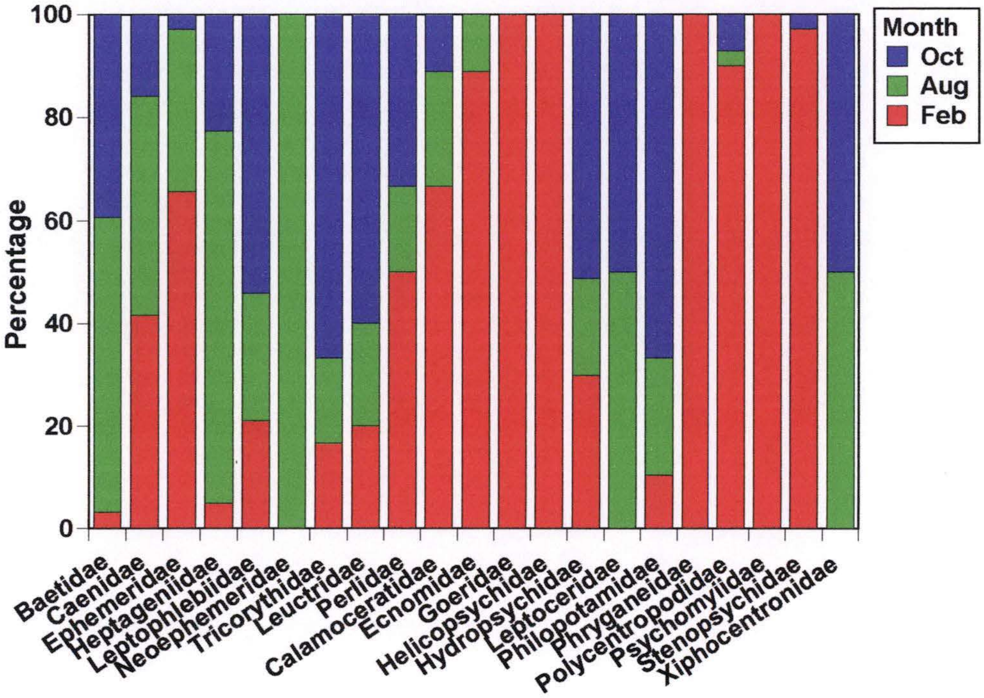
Figure 3.32 Seasonal distribution of individuals in the EPT families associated with boulder substrate at Hin Lat stream, Nam Nao National Park, Thailand, 1998.



3.2.2.5.2 Cobbles

There were 21 families present on cobble substrates (Figure 3.33). Goeridae, Helicopsychidae, Phryganeidae and Psychomyiidae were only present on cobbles in February. Ephemeridae, Calamoceratidae, Ecnomidae, Polycentropodidae and Stenopsychidae were mostly present in February. Neoephemeridae was only present in August. Leptoceridae and Xiphocentroniidae were present on cobbles in August and October.

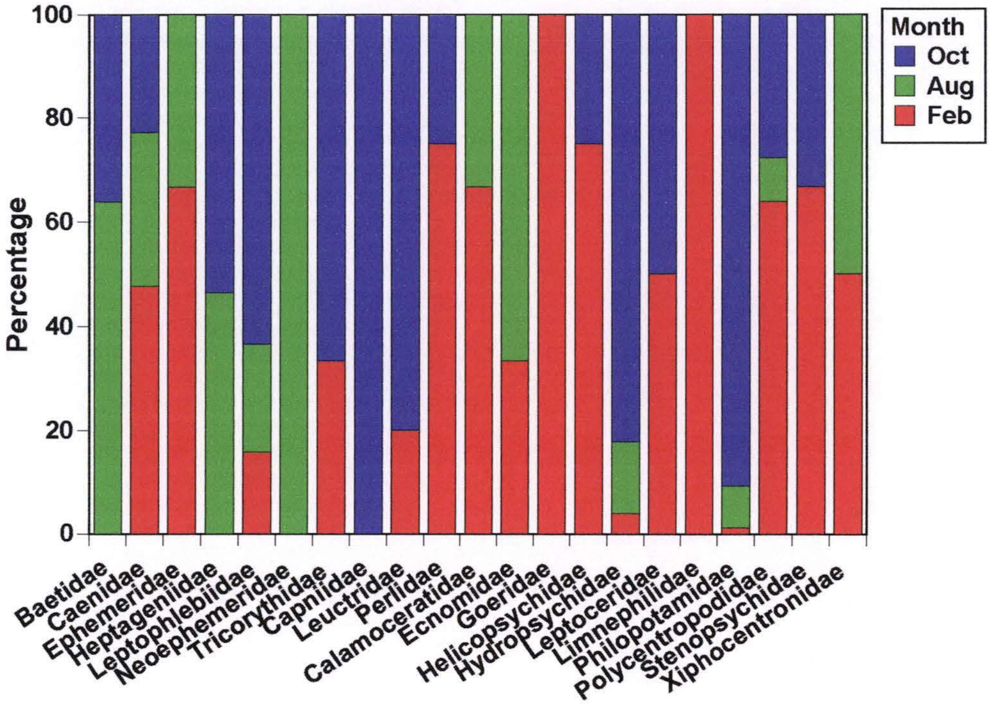
Figure 3.33 Seasonal distribution of individuals in the EPT families associated with cobble substrate at Hin Lat stream, Nam Nao National Park, Thailand, 1998.



3.2.2.5.3 Gravel

There were 21 families collected from gravel (Figure 3.34). Of these, Goeridae and Limnephilidae were only present in February at low water flow, whereas Neoephemeridae and Capniidae were only found in August and October in the wet season. Other gravel associated families were less seasonal.

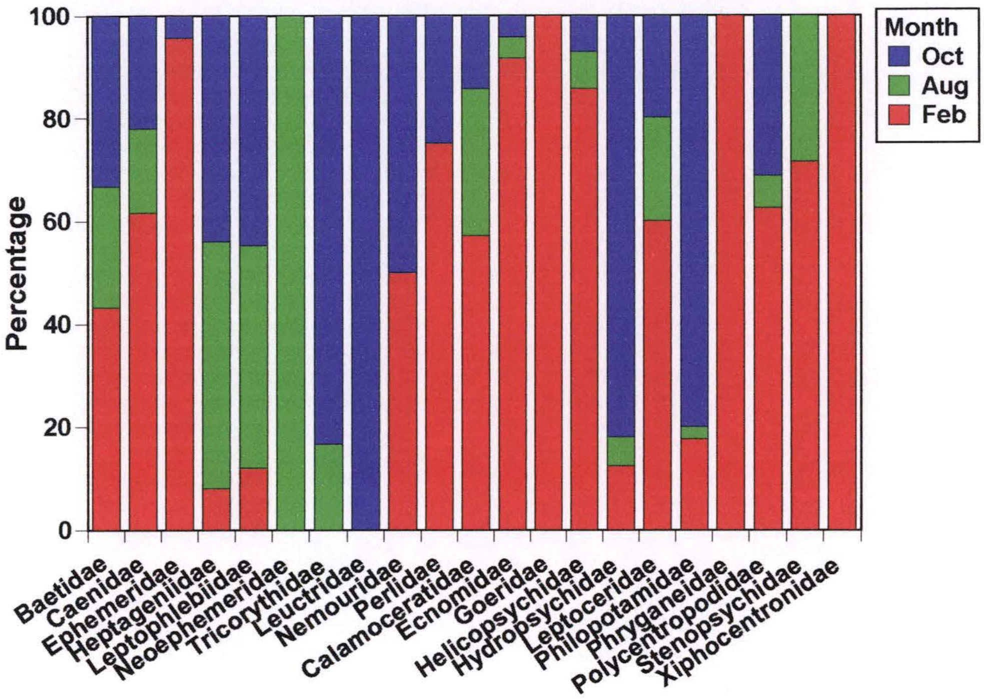
Figure 3.34 Seasonal distribution of individuals in the EPT families associated with gravel substrate at Hin Lat stream, Nam Nao National Park, Thailand, 1998.



3.2.2.5.4 Leaf Pack

There were 21 families of EPT taxa collected from leaf pack (Figure 3.35). Goeridae, Phryganeidae and Xiphocentronidae were only present in February, whereas, Neoephemeridae and Leuctridae were only present in August and October respectively.

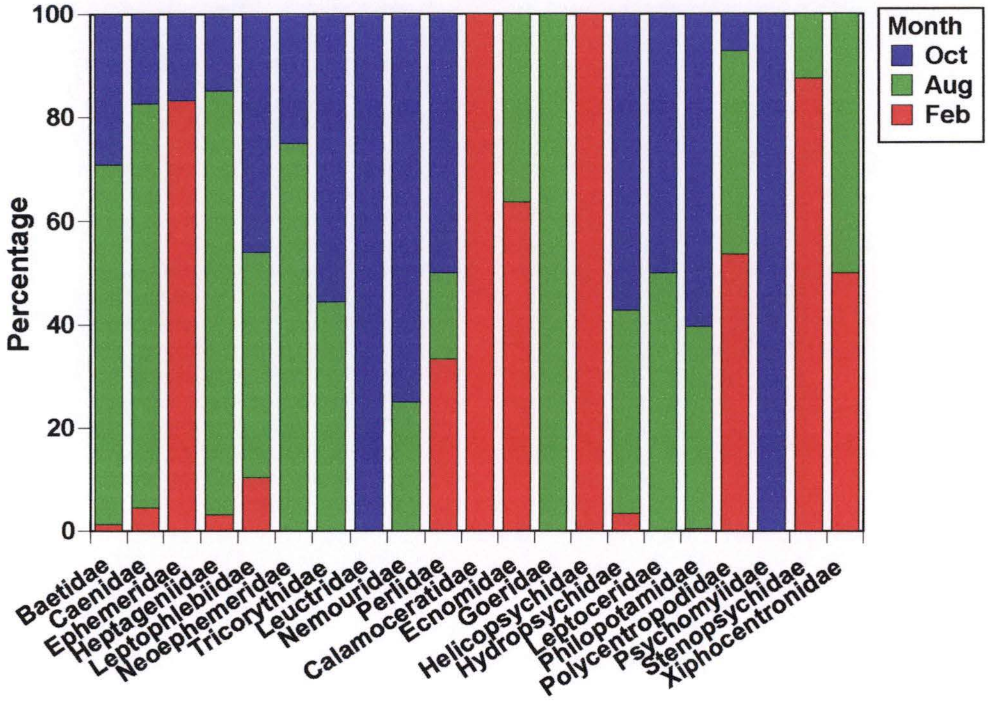
Figure 3.35 Seasonal distribution of individuals in the EPT families associated with leaf pack substrate at Hin Lat stream, Nam Nao National Park, Thailand, 1998.



3.2.2.5.5 Pebbles

There were 21 EPT families present on pebbles (Figure 3.36). Calamoceratidae and Helicopsychidae were only present in February. Whereas, Goeridae was present in August; and Leuctridae and Psychomyiidae were found in October. Neoephemeridae, Tricorythidae, Nemouridae, Leptoceridae and Philopotamidae were found in August and October. Ecnomidae, Stenopsychidae and Xiphocentronidae were found in February and August.

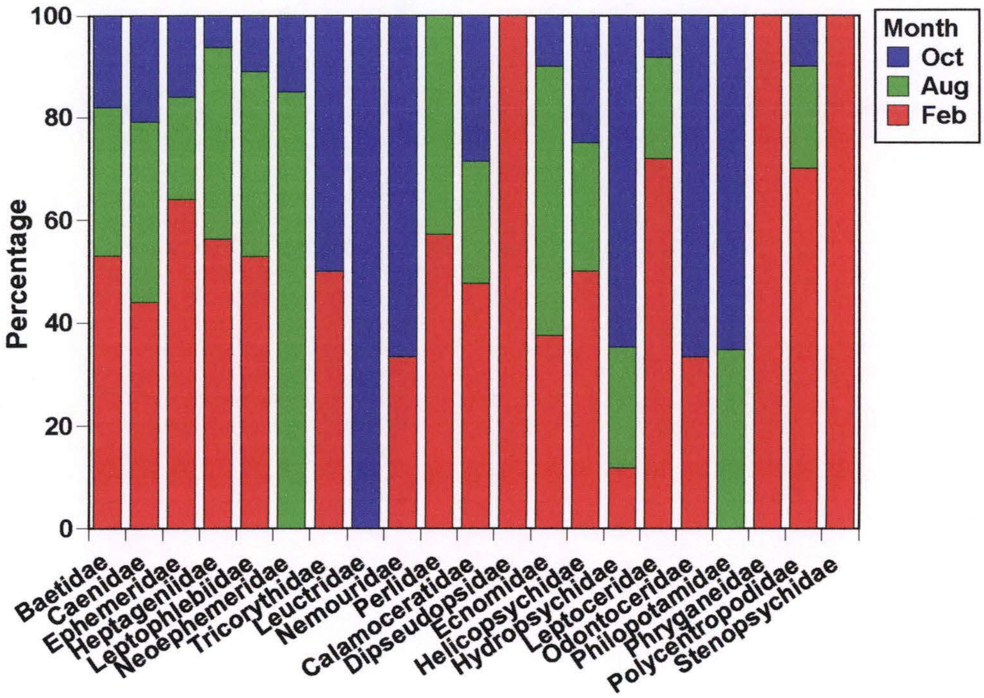
Figure 3.36 Seasonal distribution of individuals in the EPT families associated with pebble substrate at Hin Lat stream, Nam Nao National Park, Thailand, 1998.



3.2.2.5.6 Root

Twenty-one EPT families were collected from root (Figure 3.37). Dipseudopsidae, Phryganeidae and Stenopsychidae were only present in February, whereas Leuctridae was only present in October.

Figure 3.37 Seasonal distribution of individuals in the EPT families associated with root substrate at Hin Lat stream, Nam Nao National Park, Thailand, 1998.



3.2.3 Community patterns

3.2.3.1 TWINSPAN groups

Nine groups of samples can be recognised by TWINSPAN based upon the raw data set (Figure 3.38). Membership ranges from 2 to 10 samples, and mean species richness per group ranges from 10.8 to 16.5 species.
There is a strong seasonal element present in the groupings because the majority of groups consist of samples taken in the same month.

Table 3.25 summarizes variables within each TWINSPAN group.

Figure 3.38 TWINSPAN dendrogram classifying all samples based upon the raw data set of Study 1, Hin Lat stream, Nam Nao National Park, Thailand.

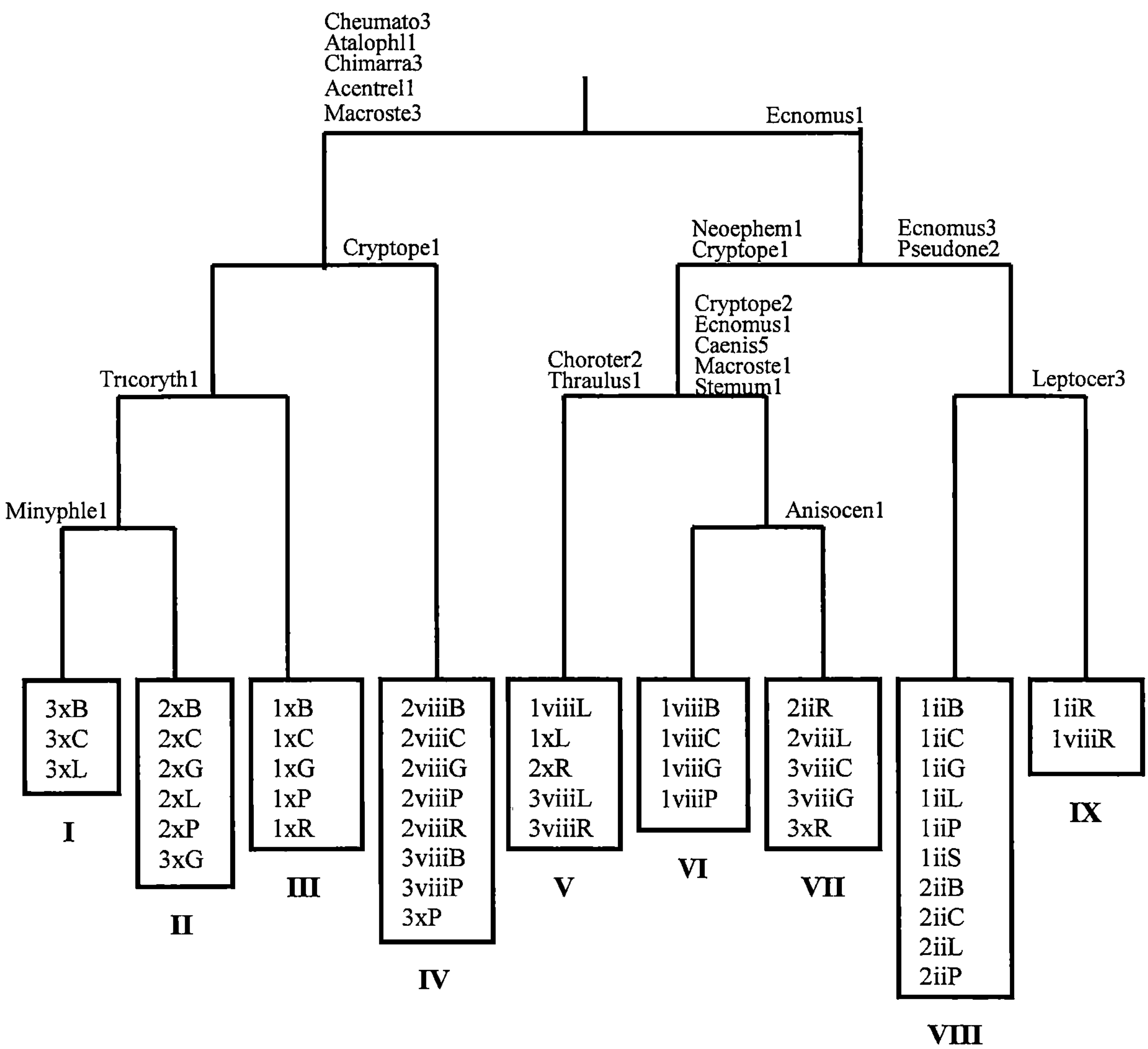


Table 3.25 Variables within each TWINSPAN group. Values followed by the same letter are not different at P = 0.05).

Variable	TWINSPAN Group								
	I	II	III	IV	V	VI	VII	VIII	IX
total SR	44	69	54	122	62	52	76	162	33
Mean SR	15a	12a	11a	15a	12a	13a	15a	16a	17a
Air Temp. (° C)	19.0a	20.7a	23.0b	26.4b	26.4b	28.0b	25.7b	20.6a	23.5b
Water Temp. (°C)	19.5a	19.8a	20.2a	22.9b	22.1b	24.4b	21.5b	17.9a	21.1b
Flow rate (ms^{-1})	0.3a	0.3a	0.3a	0.2b	0.2b	0.2b	0.2b	0.1b	0.2b
EC (μScm^{-1})	255.2ac	257.5a	260.7a	223.4a	232.4ac	222.8ac	252.9ac	372.7b	299.9bc
DO (mgL^{-1})	9.3a	9.1a	9.3a	8.5a	7.5a	6.4b	7.0b	6.4b	6.3b
TDS (mgL^{-1})	170.1ac	171.3ac	173.0ac	148.8a	154.6ac	148.6ac	168.4ac	248.5b	200.0bc
Mean pH	6.37ac	6.70ac	6.42a	6.29a	6.48ac	6.57ac	6.58ac	7.69b	7.13bc

Indicator species

Five different taxa acted as indicators for the left hand level 1 split. These were *Cheumatopsyche*, *Atalophlebioiodes*, *Chimarra*, *Acentrella* and *Macrostemum*.
The caddis *Ecnomus* is a strong indicator for the first level split high levels of this species also unite most of the February samples.
The leptocerid caddis *Leptocerus* was an indicator for group VIII which contains site 1 root samples.

Season as a factor
Month of the year was very influential in determining the number of species present in the samples (One Way ANOVA $F_{2,45} = 6.50$, P = 0.0033). February had the highest species richness and October the lowest (Table 3.26).

Table 3.26 Mean species richness + se of samples for each month. Means followed by the same letter are not different at P = 0.05.

Month	n	Mean SR	SE	sig.
February	12	16.6	1.2	a
August	18	14.1	0.8	b
October	18	12.3	0.6	b

Site as a factor
Sites did not differ in their mean species richness (Table 3.27, One Way ANOVA $F_{2,45} = 1.78$, P = 0.181).

Table 3.27 Mean species richness + se of samples for each site. Means followed by the same letter are not different at P = 0.05.

Site	n	Mean SR	SE	Sig.
HL1	19	13.7	0.9	a
HL2	17	13.3	0.8	a
HL3	12	15.7	0.5	a

Substrate as a factor

Substrates did not differ in their mean species richness (Table 3.28, One Way ANOVA $F_{5,41} = 0.391$, $P = 0.852$).

Table 3.28 Mean species richness + se of samples for each substrate. Means followed by the same letter are not different at P = 0.05.

Substrate	n	Mean	SE	Sig.
Boulder	8	13.9	1.51	a
Cobbles	8	14.6	1.40	a
Gravel	7	12.7	1.19	a
Leaf pack	8	13.5	1.24	a
Pebbles	8	14.0	1.18	a
Roots	8	15.1	1.37	a
Sand	1	16.0	0.00	a

Environmental variables as factors

pH

There was a significant difference in the mean pH value of the TWINSPAN groups (One Way ANOVA $F_{8,39} = 23.49$, $P < 0.001$). Group VIII, which consist of samples in February, had the highest pH value and group IV the lowest.

TDS

TDS was significantly different between the TWINSPAN groups (One Way ANOVA $F_{8,39} = 21.01$, $P < 0.001$). Group VIII had the highest TDS and group IV the lowest.

Dissolved Oxygen

DO was significantly different between the TWINSPAN groups (One Way ANOVA $F_{8,39} = 10.39$, $P < 0.001$). Groups I and III had the highest dissolved oxygen and group IX the lowest.

Electric Conductivity

EC was significantly different between the TWINSPAN groups (One Way ANOVA $F_{8,39} = 20.97$, $P < 0.001$). Group VIII had the highest EC and group VI the lowest.

Water Temperature

Water temperature was significantly different between the TWINSPAN groups (One Way ANOVA $F_{8,39} = 12.54$, $P < 0.001$). Group VI had the highest water temperarure and group VIII the lowest.

Air Temperature

Air temperature was significantly different between the TWINSPAN groups (One Way ANOVA $F_{8,39} = 6.21$, $P < 0.001$). Group VI had the highest air temperature and group I the lowest.

Flow Rate

Flow rate was significantly differences between the TWINSPAN groups (One Way ANOVA $F_{8,39} = 20.33$, $P < 0.001$). Group I, II and III had the highest flow rate and group VIII the lowest.

The above summary shows that Group VIII exhibited the most unique aquatic environment of all the groups.

3.2.3.2 Ordination of Samples

The output of the multidimensional scaling analysis using count and binary data is shown in Figures 3.39 - 3.40.

The species vectors indicate that 5 taxa (*Macrostemum*, Tricorythidae, *Chimarra*, *Cheumatopsyche* and *Atalophlebia*) are strongly associated with the October samples.
Taken overall, the pebble and boulder fauna is scattered over much of the ordination space.
However, within seasons, the fauna of pebbles and boulders at a site are very similar and they plotted closely together in the ordination.

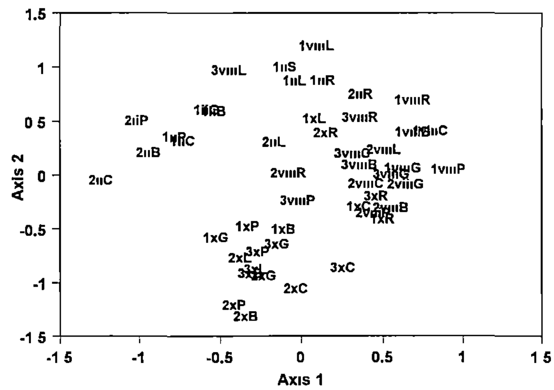
There is also evidence of seasonality in the dataset, with August and October samples plotting together, but February communities more broadly distributed over the ordination, especially at sites Hin Lat 1 and Hin Lat 2.

The following taxa were significantly correlated with the ordinations at $P < 0.01$ for both the binary and count data sets:
Anisocentropus, Centroptilum, Cheumatopsyche, Chimarra, Cryptopenella, Ecnomus, Ephemera,Helicopsyche, Hydropsychidae sp.1, *Nixe, Thraulus,*and *Tricorythodes* suggesting these may be the most informative taxa to survey in future.

The following taxa were significantly correlated with the ordinations at $P < 0.01$ for both the binary and count data sets:
Anisocentropus, Centroptilum, Cheumatopsyche, Chimarra, Cryptopenella, Ecnomus, Ephemera,Helicopsyche, Hydropsychidae sp.1, *Nixe, Thraulus,*and *Tricorythodes* suggesting these may be the most informative taxa to survey in future.

Figure 3.39 Ordination of Hin Lat stream samples, using count EPT data set at genus level, 3 dimensional solution, stress = 0.168. February samples in star symbols; August samples in triangle symbols and October samples in circle symbols. Significantly (p < 0.01) correlated taxa fitted in the same ordination space

All sites



Hin Lat Stream (Vector)

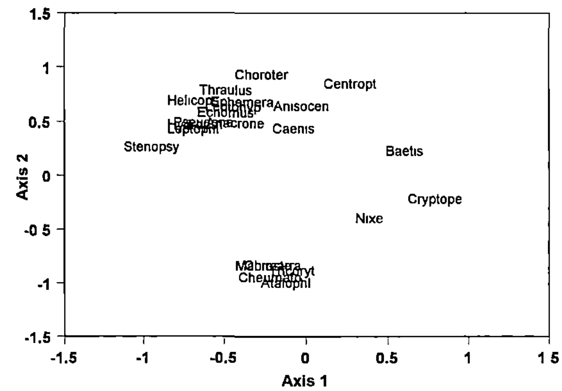
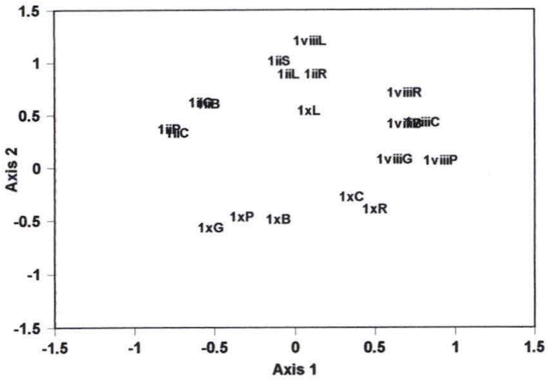
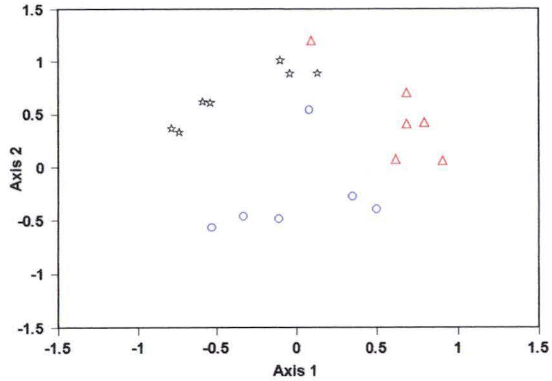


Figure 3.39 (continued) Ordination of Hin Lat stream samples, using count EPT data set at genus level, 3 dimensional solution, stress = 0.168. February samples in star symbols; August samples in triangle symbols and October samples in circle symbols. Significantly ($p < 0.01$) correlated taxa fitted in the same ordination space

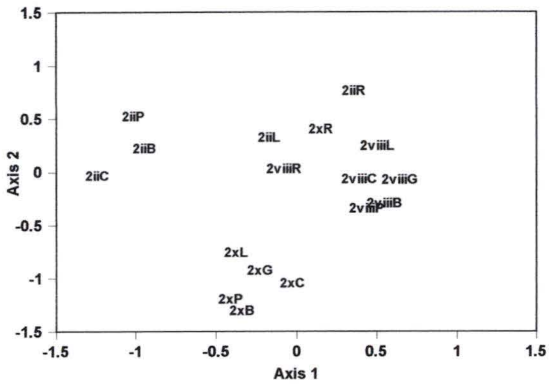
Site Hin Lat 1



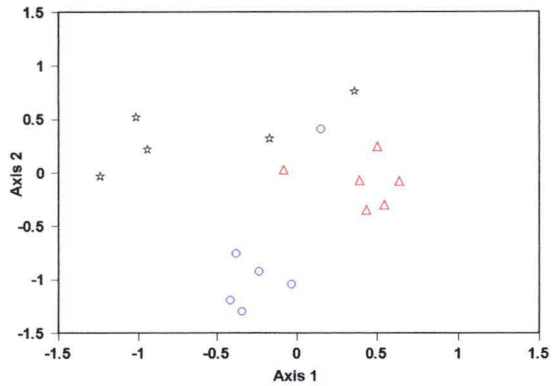
Site Hin Lat 1 (Feb=Black, Aug=Red, Oct=Blue)



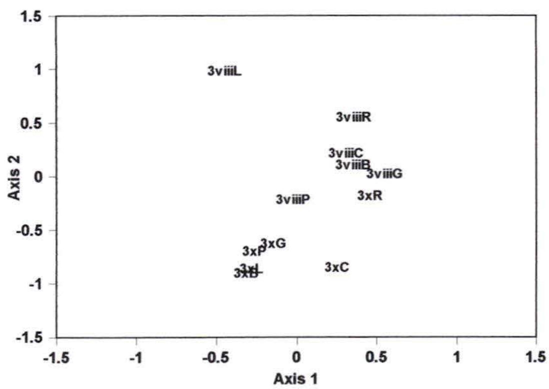
Site Hin Lat 2



Site Hin Lat 2 (Feb=Black, Aug=Red, Oct=Blue)



Site Hin Lat 3



Site Hin Lat 3 (Feb=Black, Aug=Red, Oct=Blue)

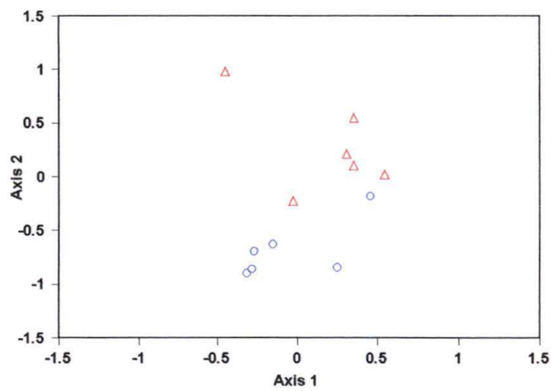


Figure 3.39 (continued) Ordination of Hin Lat stream samples, using count EPT data set at genus level, 3 dimensional solution, stress = 0.168. February samples in star symbols; August samples in triangle symbols and October samples in circle symbols. Significantly ($p < 0.01$) correlated taxa fitted in the same ordination space

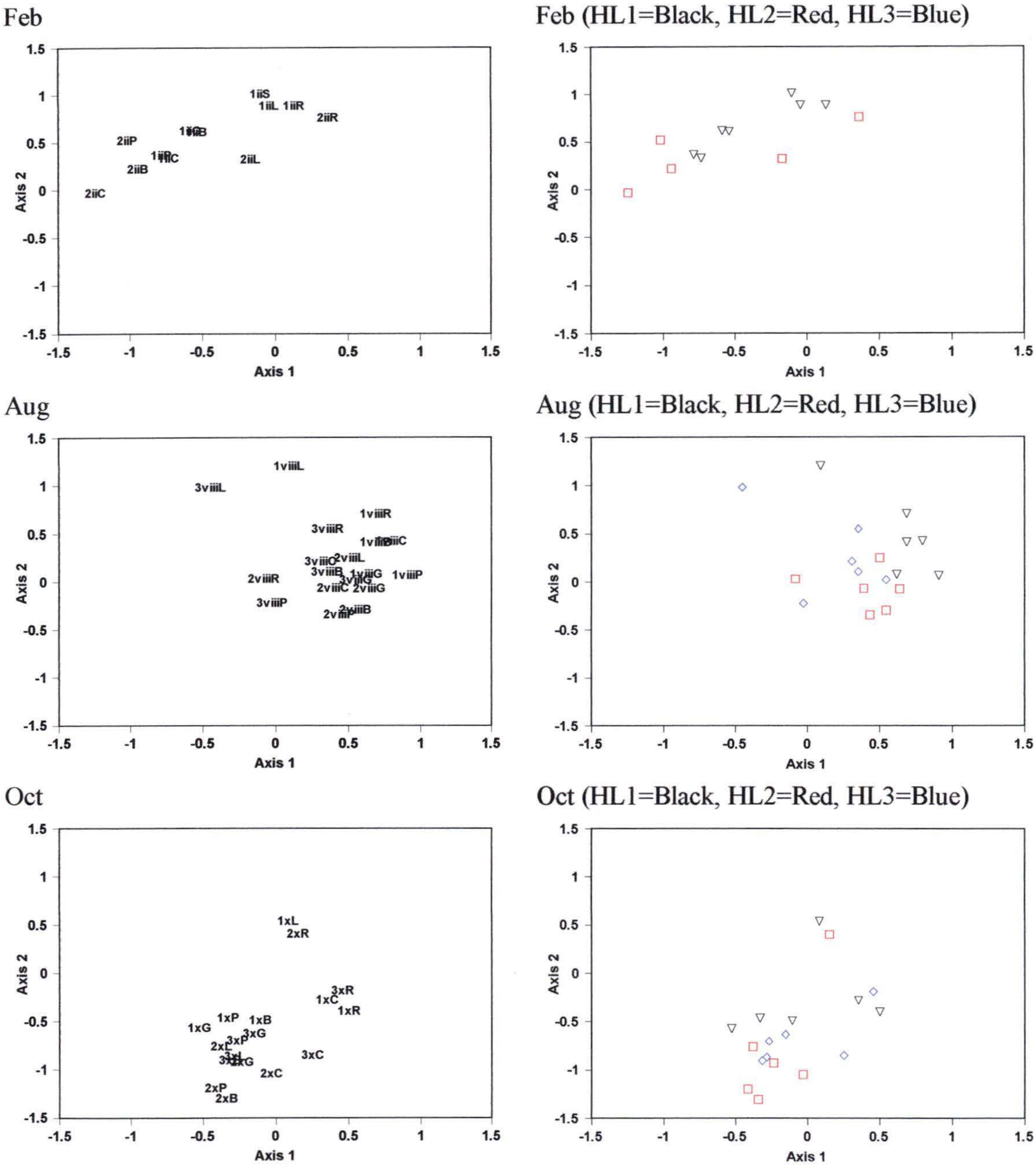


Figure 3.40 Ordination of Hin Lat stream samples, using binary EPT data set at genus level, 3 dimensional solution, stress = 0.184. February samples in star symbols; August samples in triangle symbols and October samples in circle symbols. Significantly ($p < 0.01$) correlated taxa fitted in the same ordination space.

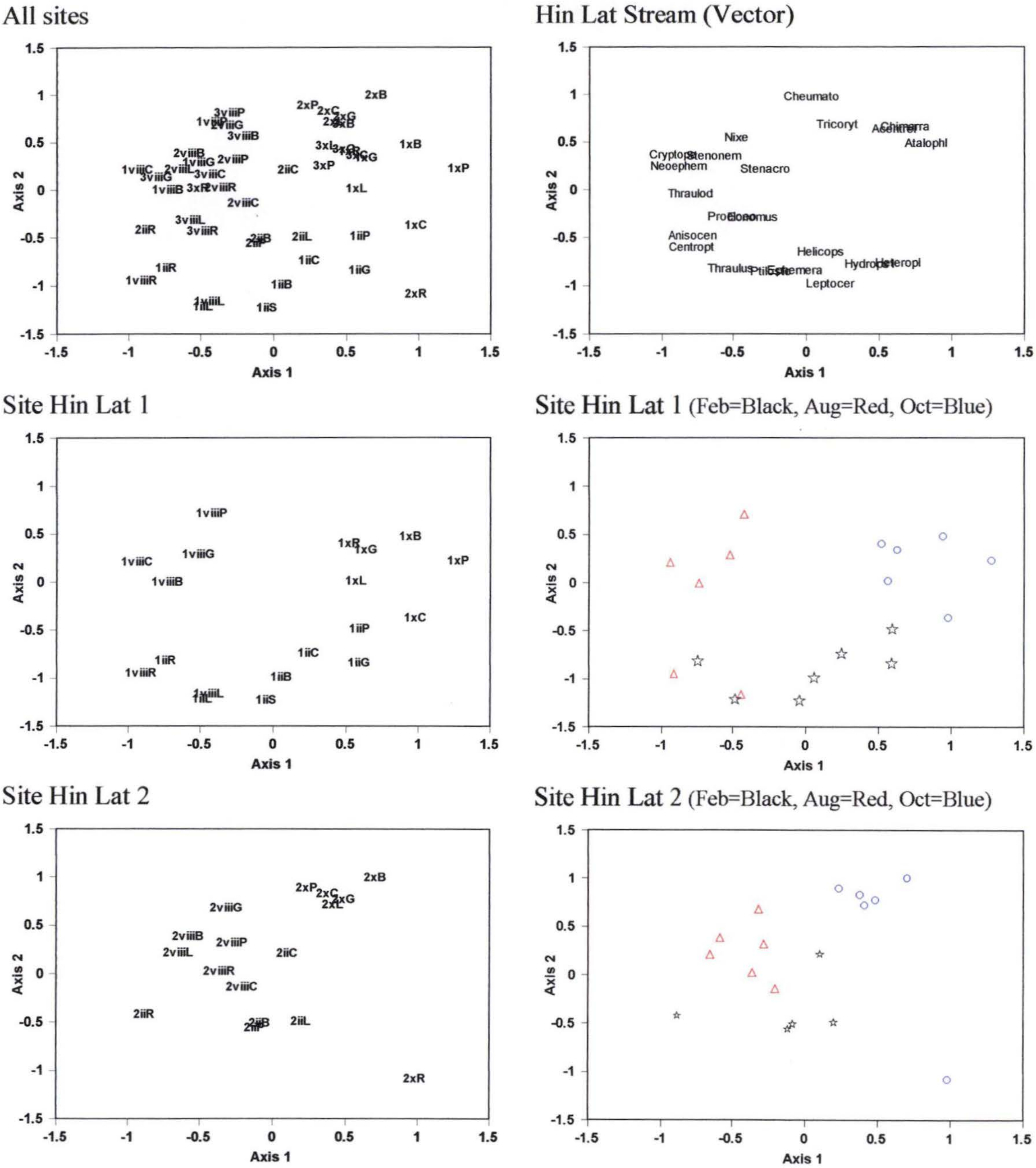
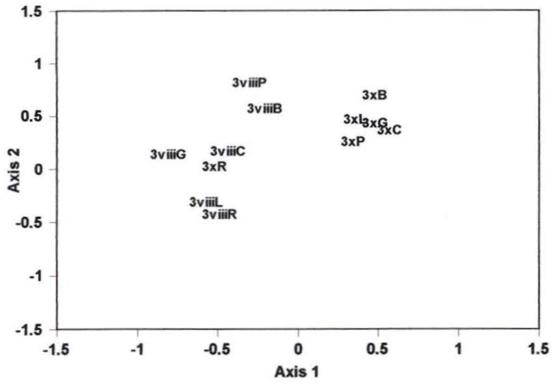
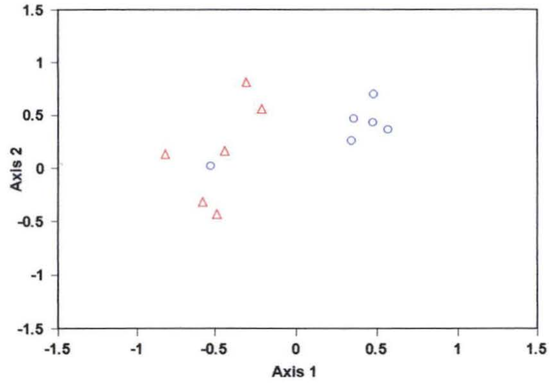


Figure 3.40 (continued) Ordination of Hin Lat stream samples, using binary EPT data set at genus level, 3 dimensional solution, stress = 0.184. February samples in star symbols; August samples in triangle symbols and October samples in circle symbols. Significantly ($p < 0.01$) correlated taxa fitted in the same ordination space.

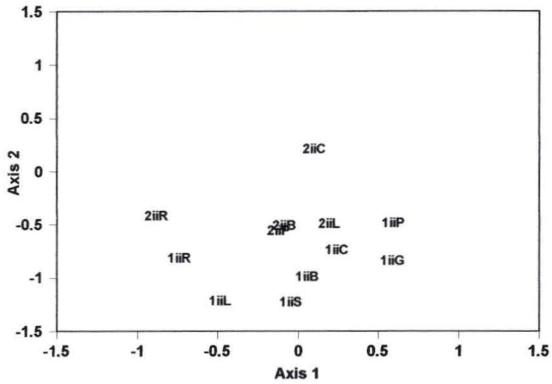
Site Hin Lat 3



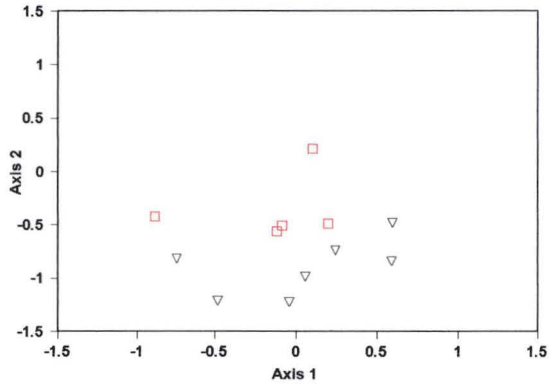
Site Hin Lat 3 (Feb=Black, Aug=Red, Oct=Blue)



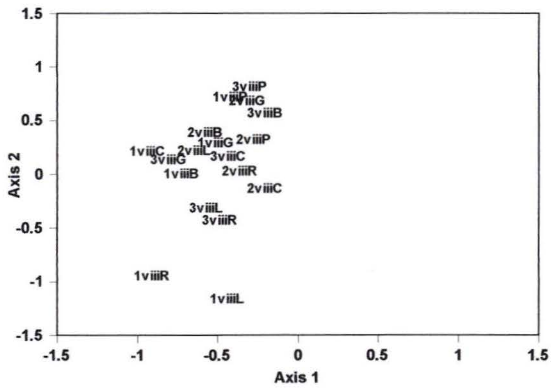
Feb



Feb (HL1=Black, HL2=Red, HL3=Blue)



Aug



Aug (HL1=Black, HL2=Red, HL3=Blue)

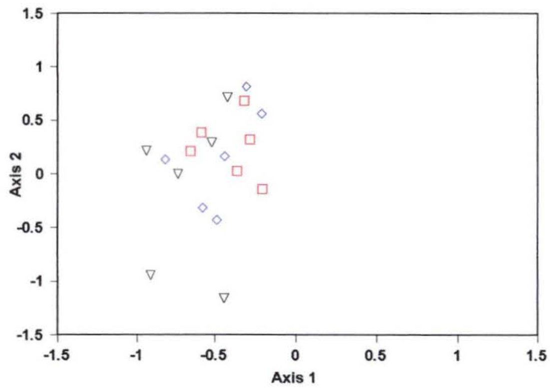
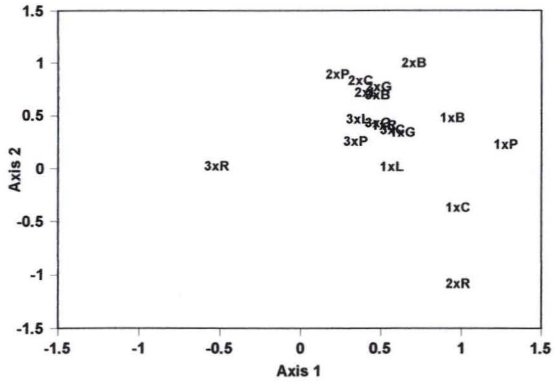
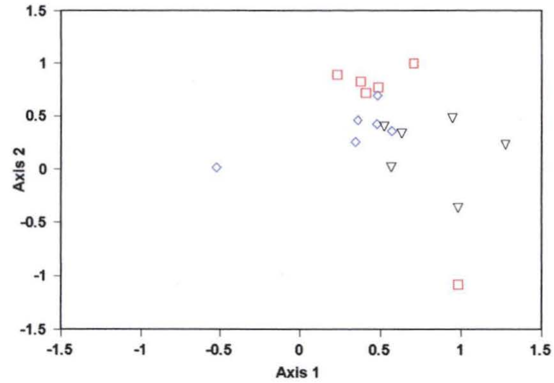


Figure 3.40 (continued) Ordination of Hin Lat stream samples, using binary EPT data set at genus level, 3 dimensional solution, stress = 0.184. February samples in star symbols; August samples in triangle symbols and October samples in circle symbols. Significantly (p < 0.01) correlated taxa fitted in the same ordination space.

Oct



Oct (HL1=Black, HL2=Red, HL3=Blue)



3.3 QUESTION 2: Does EPT richness and abundance differ in relation to parts of the stream system, i.e. pool, riffle and run?

3.3.1 Overview of the data set

A total of 3,345 individuals representing 22 families and 39 genera of EPT taxa was collected for this study. Of this total, 2,998 individuals, representing 22 families and 36 genera were collected bimonthly from Yakraue stream over a complete year in 1998; and 347 individuals, representing 14 families and 20 genera were from Hin Lat stream in August 1998 only.

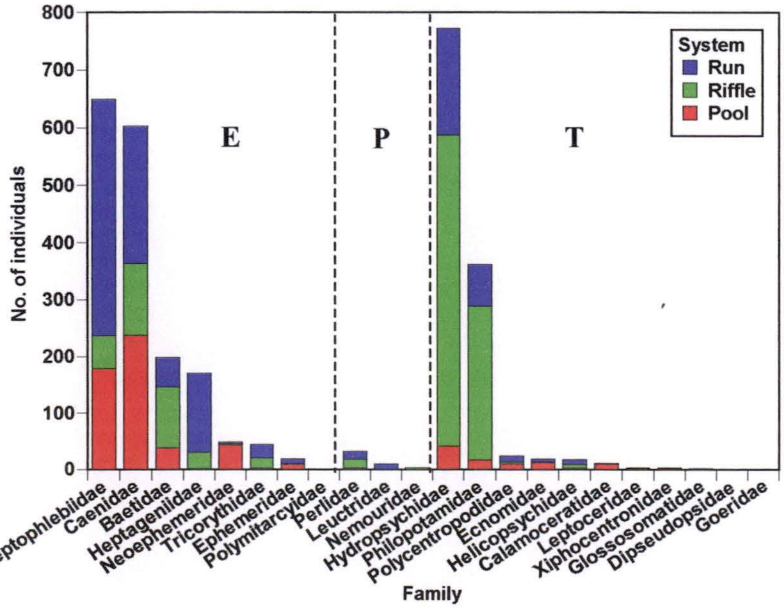
Table 3.29 summaries the total numbers of individuals and families collected from each stream and each part of the stream system. Ephemeroptera was collected most abundantly from sections of stream run, whereas Trichoptera was mostly collected from riffle. Plecoptera was very rare at both streams.

Table 3.29 Numbers of genera and individuals collected from Hin Lat and Yakraue streams, Nam Nao National Park, Thailand, 1998.

Stream	No. of genus/No. individual			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Hin Lat stream				
Pool	3/12	0/0	0/0	3/12
Riffle	7/42	0/0	7/220	14/262
Run	7/61	1/1	5/11	13/73
Total	10/115	1/1	9/231	20/347
Yakraue stream				
Pool	11/509	1/2	11/97	23/608
Riffle	11/342	2/19	8/832	21/1,193
Run	12/884	2/24	12/289	26/1,197
Total	16/1,735	3/45	17/1,218	36/2,998

Figure 3.41 displays the number of individuals collected bimonthly from each stream system from Yakraue stream in 1998. Heptageniidae, Baetidae, Tricorythidae, Perlidae, Leuctridae, Hydropsychidae, Philopotamidae and Helicopsychidae were mostly collected from riffle and run, whereas Neoephemeridae and Calamoceratidae were mostly collected from pools. Ephemeridae, Polycentropodidae and Ecnomidae were found commonly in both pool and run sections of the stream.

Figure 3.41 Sorted number of individuals of each family bimonthly collected from each stream system at Yakraue stream, Nam Nao National Park, Thailand 1998.



3.3.2 Comparing EPT taxa richness and density between stream systems (Yakraue data set)

Table 3.30 summaries the mean genus richness and density of individuals of Ephemeroptera, Plecoptera, Trichoptera and all EPT taxa together. Ephemeroptera, Trichoptera and all EPT taxa collectively, did not showed any significant difference in mean genus richness between stream system (pool, riffle and run). Only the order Plecoptera demonstrated a significant difference in genus richness, which was higher in riffle and run than in pool (One Way ANOVA on ranks $H_2 = 8.622$, $P = 0.013$).

Plecoptera and Trichoptera at order level showed significant differences in mean density of individuals between pool, riffle and run. Both orders were present at their highest density in riffles and lowest in pools (One Way ANOVA on ranks, $H_2 = 9.953$, $P = 0.007$ and $H_2 = 9.940$, $P = 0.007$ respectively).

Table 3.30 Genus richness (mean ± S.E.) and density (mean ± S.E.) of the EPT taxa bimonthly collected from Yakraue stream, Nam Nao National Park, Thailand 1998.

Stream system	Genus richness/Density (individuals/sample)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Pool	6.2 ± 1.1 : 19.8 ± 3.2	0.2 ± 0.2 : 0.2 ± 0.2	4.7 ± 0.5 : 4.2 ± 1.0	11.0 ± 1.5 : 23.7 ± 4.0
Riffle	6.5 ± 0.2 : 17.7 ± 5.7	1.3 ± 0.2 : 1.8 ± 0.2	4.8 ± 0.5 : 30.0 ± 6.9	12.7 ± 0.8 : 47.6 ± 7.9
Run	7.8 ± 0.6 : 32.4 ± 5.1	1.3 ± 0.3 : 1.5 ± 0.3	4.7 ± 0.8 : 9.7 ± 4.6	13.8 ± 1.6 : 42.0 ± 9.5

At family level, 9 from the 22 families recorded demonstrated significant differences in their preference for parts of the stream system (Table 3.31). Neoephemeridae and Calamoceratidae demonstrated a preference for pools and avoided both riffles and runs. Heptageniidae, Leptophlebiidae, Tricorythidae, and Leuctridae preferred runs, whereas Perlidae, Hydropsychidae and Philopotamidae were more common in riffles.

At genus level, about one quarter of the genera (10 from 39 genera found) demonstrated significant differences in stream system preferences (Table 3.31). Most of these genera reflected the preferences apparent at family level i.e. *Neoephemera* and *Heteroplectron* demonstrated a preference for pools; *Nixe*, *Cryptopenella*, *Tricorythodes* and *Paraleuctra* preferred runs; and *Macrostemum* and *Chimarra* were most common in riffles. Only *Accentrella* (Baetidae), which demonstrated a preference for riffles, departed from the preference showed at its family level overall.

Table 3.31 Summary of responses of aquatic taxa to stream system at Yakraue (combined data), Nam Nao N.P., Thailand, 1998. Values are mean density per Surber sample ± se. F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference is the stream system which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	Sig.	n	Pool	Riffle	Run	Significance value	Preference
Order							
Ephemeroptera	ns	6	19.8 ± 3.2	17.7 ± 5.7	32.4 ± 5.1	$F_{2,15}$ = 2.687, P = 0.101	
Plecoptera	s	6	0.2 ± 0.2b	1.8 ± 0.2a	1.5 ± 0.3ab	H_2 = 9.953, P = 0.007	Riffle
Trichoptera	s	6	4.2 ± 1.0b	30.0 ± 6.9a	9.7 ± 4.6ab	H_2 = 9.940, P = 0.007	Riffle
Family	s						
Heptageniidae	s	6	0.2 ± 0.2b	3.9 ± 1.2ab	9.1 ± 2.1a	H_2 = 12.089, P = 0.002	Run
Leptophlebiidae	s	6	7.8 ± 1.5ab	5.1 ± 1.9b	16.1 ± 4.3a	H_2 = 6.279, P = 0.043	Run
Neoephemeridae	s	6	4.7 ± 1.9a	0.3 ± 0.2b	0.5 ± 0.5b	H_2 = 10.363, P = 0.006	Pool
Tricorythidae	s	6	0.2 ± 0.2b	1.1 ± 0.3ab	3.0 ± 0.7a	H_2 = 12.610, P = 0.002	Run
Leuctridae	s	6	0.0 ± 0.0b	0.0 ± 0.0b	1.1 ± 0.4a	H_2 = 9.544, P = 0.008	Run
Perlidae	s	6	0.2 ± 0.2b	1.9 ± 0.3a	1.0 ± 0.3b	$F_{2,15}$ = 11.463, P = <0.001	Riffle
Calamoceratidae	s	6	1.4 ± 0.3a	0.0 ± 0.0b	0.2 ± 0.2b	H_2 = 10.748, P = 0.005	Pool
Hydropsychidae	s	6	2.1 ± 1.0b	24.7 ± 5.4a	6.7 ± 4.1ab	H_2 = 8.980, P = 0.011	Riffle
Philopotamidae	s	6	1.0 ± 0.4b	11.7 ± 2.5a	3.3 ± 1.7b	$F_{2,15}$ = 10.371, P = 0.001	Riffle
Genus							
Acentrella	s	6	0.0 ± 0.0b	2.0 ± 0.6a	1.0 ± 0.3ab	H_2 = 9.791, P = 0.007	Riffle
Nixe	s	6	0.2 ± 0.2b	3.9 ± 1.2b	8.6 ± 1.6a	$F_{2,15}$ = 12.859, P = <0.001	Run
Cryptopenella	s	6	2.3 ± 1.3b	3.8 ± 2.5b	19.5 ± 6.5a	H_2 = 8.985, P = 0.011	Run
Neoephemera	s	6	4.7 ± 1.9a	0.3 ± 0.2b	0.5 ± 0.5b	H_2 = 10.363, P = 0.006	Pool
Tricorythodes	s	6	0.2 ± 0.2b	1.1 ± 0.3ab	3.0 ± 0.7a	H_2 = 13.095, P = 0.001	Run
Paraleuctra	s	6	0.0 ± 0.0b	0.0 ± 0.0b	1.1 ± 0.4a	H_2 = 9.544, P = 0.008	Run
Anacroneuria	s	6	0.2 ± 0.2b	1.9 ± 0.3a	1.0 ± 0.3b	$F_{2,15}$ = 11.463, P = <0.001	Riffle
Heteroplectron	s	6	1.1 ± 0.4a	0.0 ± 0.0b	0.0 ± 0.0b	H_2 = 9.544, P = 0.008	Pool
Macrostemum	s	6	0.8 ± 0.7b	8.4 ± 3.2a	2.0 ± 0.6ab	H_2 = 9.427, P = 0.009	Riffle
Chimarra	s	6	1.0 ± 0.4b	11.7 ± 2.5a	3.3 ± 1.6b	$F_{2,15}$ = 10.516, P = 0.001	Riffle

3.3.3 Comparing EPT taxa density between stream systems in each month and stream

At the order level, Trichoptera clearly demonstrated a preference for riffles in the rainy season months of June, August and October and at the beginning of the cold season month of December; but did not show significant differences in the cold-dry season month of February and the hot dry season month of April (Table 3.32 and Table 3.33)

Ephemeroptera and Plecoptera demonstrated a significant preference for runs in the rainy season month of August at Yakraue stream only.

At both family and genus levels, and in both streams, most of the EPT taxa demonstrated significant preferences for riffles and runs during the rainy season and at the beginning of the cold season months (June – December). In contrast, during the cold dry and dry season months (February and April), little preference was apparent amongst most taxa, with the exceptions of the families Leptophlebiidae and Caenidae and the genus *Choroterpes* which showed a preference for pools.

Table 3.32. Summary of responses of aquatic taxa to stream system in various months at Yakraue and Hin Lat streams, Nam Nao N.P., Thailand, 1998. Values are mean density per Surber sample ± se. F values relate to ANOVA on raw data; H values relate to ANOVA on ranks; Preference is the stream system which supports significantly (P<0.05) higher densities of the taxon as determined by a Tukey Multiple Comparison Test following ANOVA on raw data, or a Dunn's multiple Comparison Test following ANOVA on ranks.

Taxa	month	n	Pool	Riffle	Run	Significance value	Preference
YAKRAUE							
Order							
Trichoptera	Jun	3	3.7 ± 2.2b	45.0 ± 4 6a	8 7 ± 3.0b	$F_{2,6}$ = 44.183, P = <0.001	Riffle
Ephemeroptera	Aug	6	6.5 ± 1 8b	18 7 ± 10.2b	44.5 ± 12 6a	$F_{2,15}$ = 9.837, P = 0.002	Run
Plecoptera	Aug	6	0.0 ± 0 0b	0.5 ± 0 3ab	1 3 ± 0 3a	H_2 = 8 122, P = 0.017	Run
Trichoptera	Aug	6	3.3 ± 1.7b	11 5 ± 2.3a	2.0 ± 0.5b	$F_{2,15}$ = 9 492, P = 0 002	Riffle
Trichoptera	Oct	6	4.8 ± 3 3b	22.5 ± 5 5a	4 7 ± 1 7b	$F_{2,15}$ = 7 088, P = 0 007	Riffle
Trichoptera	Dec	3	2 3 ± 1.3b	32 3 ± 4 7a	11.0 ± 6.5b	$F_{2,6}$ = 10 853, P = 0.010	Riffle
Family							
Leptophlebiidae	Feb	4	15.3 ± 2.7a	2.8 ± 1 7b	11.5 ± 3.9ab	H_2 = 7 612, P = 0 011	Pool
Caenidae	Apr	3	14.7 ± 1.5a	0.3 ± 0.3b	15 7 ± 3 8a	$F_{2,6}$ = 52 136, P = <0.001	Run, Pool
Leptophlebiidae	Jun	3	0.7 ± 0.3b	1 0 ± 1 0b	16 0 ± 2 7a	$F_{2,6}$ = 28 370, P = <0.001	Run
Baetidae	Aug	6	0.0 ± 0 0b	5.0 ± 1 7a	1 2 ± 0 4ab	H_2 = 12.666, P = 0 002	Riffle
Heptageniidae	Aug	6	0.2 ± 0.2b	0 0 ± 0.0b	10.8 ± 3.6a	H_2 = 14.481, P = <0.001	Run
Leptophlebiidae	Aug	6	2.7 ± 0 7b	2.5 ± 1 7b	21 3 ± 5.5a	H_2 = 11.165, P = 0 004	Run
Heptageniidae	Oct	6	0.0 ± 0.0b	3.8 ± 1 3a	0 5 ± 0.5b	H_2 = 10.037, P = 0 007	Riffle
Hydropsychidae	Oct	6	3 2 ± 2.2b	19 2 ± 5.0a	2.0 ± 1 8b	$F_{2,15}$ = 9 437, P = 0 002	Riffle
Tricorythidae	Oct	6	0.2 ± 0.2b	0.2 ± 0.2b	3 3 ± 0 7a	H_2 = 13 805, P = 0.001	Run
Heptageniidae	Dec	3	0 0 ± 0.0b	0 7 ± 0 7ab	4 3 ± 0.9a	H_2 = 6.720, P = 0 050	Run
Hydropsychidae	Dec	3	1 0 ± 0.6b	27 3 ± 4.1a	8 7 ± 4.7a	$F_{2,6}$ = 17 263, P = 0.003	Riffle, Run
Genus							
Choroterpes	Feb	4	15.0 ± 2.4a	2.8 ± 1.7b	11.3 ± 3 6ab	$F_{2,9}$ = 5 424, P = 0.028	Pool
Choroterpes	Jun	3	0.7 ± 0 3b	1 0 ± 1 0b	16.0 ± 2 6a	$F_{2,6}$ = 28 370, P = <0.001	Run
Acentrella	Aug	6	0.0 ± 0 0b	1 3 ± 0 5a	0 3 ± 0.2ab	H_2 = 6.469, P = 0 039	Riffle
Baetis	Aug	6	0.0 ± 0.0b	3.7 ± 1.5a	0.8 ± 0.3ab	H_2 = 12.006, P = 0.002	Riffle
Nixe	Aug	6	0 2 ± 0.2b	0 0 ± 0 0b	10 8 ± 3.6a	H_2 = 14.481, P = <0 001	Run
Cryptopenella	Aug	6	0.3 ± 0.2b	1 7 ± 1 7b	21.3 ± 5.5a	H_2 = 12.309, P = 0 002	Run
Nixe	Oct	6	0 0 ± 0 0b	3.8 ± 1.2a	0 5 ± 0 5b	H_2 = 10.037, P = 0 007	Riffle
Tricorythodes	Oct	6	0 2 ± 0.2b	0 2 ± 0 2b	3.3 ± 0.7a	H_2 = 13 805, P = 0.001	Run
Cheumatopsyche	Oct	6	2 2 ± 1.2ab	9 0 ± 2 4a	0 8 ± 0.8b	H_2 = 9 488, P = 0.009	Riffle
Macrostemum	Oct	6	1 0 ± 1 0b	10.2 ± 3 0a	1 2 ± 1 0b	H_2 = 10 348, P = 0.006	Riffle
Acentrella	Dec	3	0.0 ± 0 0b	2.3 ± 0.7a	0 3 ± 0.3b	$F_{2,6}$ = 8 600, P = 0.017	Riffle
Nixe	Dec	3	0.0 ± 0 0bb	0 7 ± 0 7ab	4.3 ± 0 9a	H_2 = 6 720, P = 0 050	Run
HIN LAT							
Order							
Trichoptera	Aug	6	0.0 ± 0.0b	36.7 ± 20.0a	1.8 ± 0 9ab	H_2 = 13.056, P = 0.001	Riffle
Family							
Baetidae	Aug	6	0.0 ± 0.0b	4 8 ± 1 3a	0.7 ± 0.5b	H_2 = 12 977, P = 0.002	Riffle
Caenidae	Aug	6	0.5 ± 0.3b	1 5 ± 0 7ab	5.3 ± 1 4a	H_2 = 6 776, P = 0 034	Run
Hydropsychidae	Aug	6	0.0 ± 0.0b	24 5 ± 20 5a	0 7 ± 0 7b	H_2 = 13 027, P = 0.001	Riffle
Philopotamidae	Aug	6	0 0 ± 0.0b	11 7 ± 6.8a	0 5 ± 0.3ab	H_2 = 8 686, P = 0.013	Riffle
Genus							
Acentrella	Aug	6	0.0 ± 0.0b	2 2 ± 0 9a	0.0 ± 0.0b	H_2 = 9.544, P = 0.008	Riffle
Baetis	Aug	6	0.0 ± 0 0b	1 8 ± 0 5a	0 7 ± 0.5ab	H_2 = 8.035, P = 0 018	Riffle
Caenis	Aug	6	0.5 ± 0 3b	1.5 ± 0.7ab	5.3 ± 1 4a	H_2 = 6 776, P = 0 034	Run
Amphisyche	Aug	6	0 0 ± 0.0b	22 7 ± 20.9a	0.2 ± 0.2b	H_2 = 10.701, P = 0.005	Riffle
Chimarra	Aug	6	0 0 ± 0.0b	11 7 ± 6.8a	0.5 ± 0.3ab	H_2 = 8.686, P = 0 013	Riffle

Table 3.33 Summary of preferential stream components of each EPT taxa in each month at Yakraue and Hin Lat streams

Taxa	Preferential stream component					
	Feb	Apr	Jun	Aug	Oct	Dec
Yakraue						
Order						
Ephemeroptera	ns	ns	ns	Run	ns	ns
Plecoptera	ns	ns	ns	Run	ns	ns
Trichoptera	ns	ns	Riffle	Riffle	Riffle	Riffle
Family						
Leptophlebiidae	Pool	ns	Run	Run	ns	ns
Caenidae	ns	Run, Pool	ns	ns	ns	ns
Baetidae	ns	ns	ns	Riffle	ns	ns
Heptageniidae	ns	ns	ns	Run	Riffle	Run
Hydropsychidae	ns	ns	ns	ns	Riffle	Riffle, Run
Tricorythidae	ns	ns	ns	ns	Run	ns
Genus						
Choroterpes	Pool	ns	Run	ns	ns	ns
Acentrella	ns	ns	ns	Riffle	ns	Riffle
Baetis	ns	ns	ns	Riffle	ns	ns
Nixe	ns	ns	ns	Run	Riffle	Run
Cryptopenella	ns	ns	ns	Run	ns	ns
Tricorythodes	ns	ns	ns	ns	Run	ns
Cheumatopsyche	ns	ns	ns	ns	Riffle	ns
Macrostemum	ns	ns	ns	ns	Riffle	ns
HIN LAT						
Order						
Trichoptera	ns	ns	ns	Riffle	ns	ns
Family						
Baetidae	ns	ns	ns	Riffle	ns	ns
Caenidae	ns	ns	ns	Run	ns	ns
Hydropsychidae	ns	ns	ns	Riffle	ns	ns
Philopotamidae	ns	ns	ns	Riffle	ns	ns
Genus						
Acentrella	ns	ns	ns	Riffle	ns	ns
Baetis	ns	ns	ns	Riffle	ns	ns
Caenis	ns	ns	ns	Run	ns	ns
Amphisyche	ns	ns	ns	Riffle	ns	ns
Chimarra	ns	ns	ns	Riffle	ns	ns

3.4 QUESTION 3: Is there any difference in the fauna upstream and downstream of a small tourist facility? A pre-existing small restaurant situated on a small stream discharges liquid waste to the water and may have a previously unmeasured effect on the biota. Is the natural variation in the stream fauna likely to make judgements on the effect of the facility impossible to determine?

3.4.1 Overview of the Data Set

A total of 13,037 individuals represented 24 families and 48 genera were collected from Yakraue stream, Nam Nao National Park, Thailand during a year of this study (Table 3.34).

Table 3.34 Number of families and individuals of EPT taxa collected from Yakraue stream during February and December 1998.

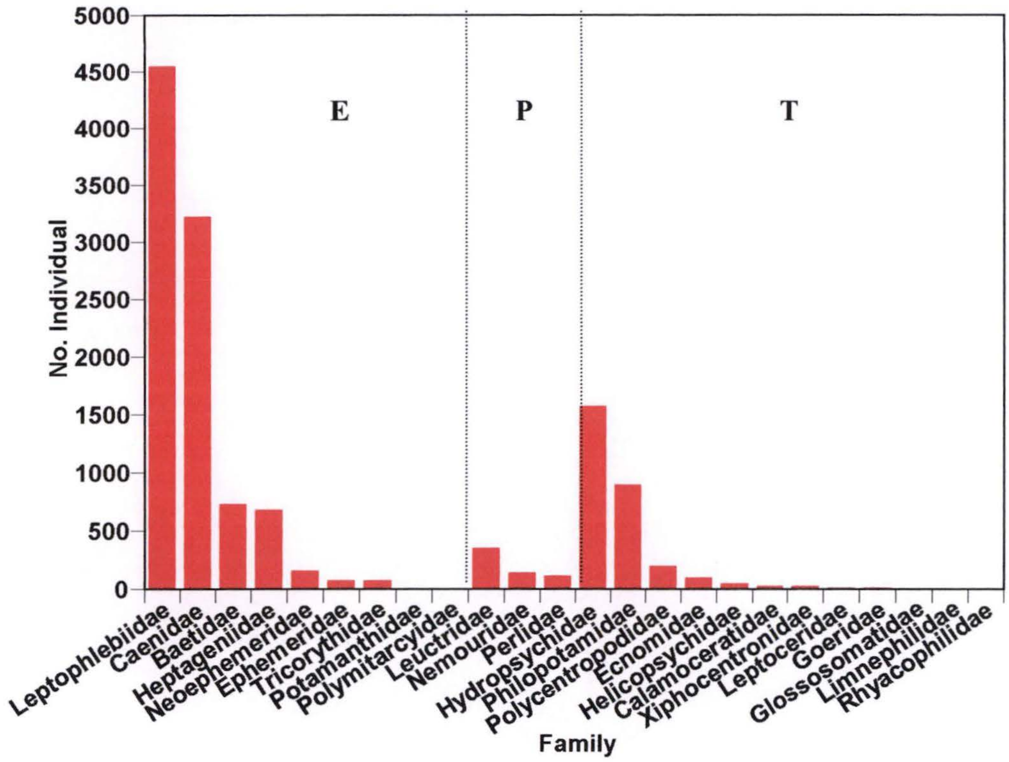
Order	Family Richness	No. Individuals
Ephemeroptera	9	9,509
Plecoptera	3	617
Trichoptera	12	2,911
Total EPT	24	13,037

Ephemeroptera was the most abundant order with a total of 9,509 individuals, and accounted for 73 % of the total number of the EPT individuals collected. Trichoptera was the second most abundant with a total of 2,911 individuals, and accounted for 22 %. Among the EPT group, Plecoptera was the rarest group with only 617 individuals, and accounted for 5 % of the total number of the EPT individuals.

In term of family richness, Trichoptera was the most diverse order with 12 families, and accounted for more than half (52 %) of the total EPT families collected. Ephemeroptera was the second most diverse group with 9 families and Plecoptera was the rarest group with only 3 families represented.

The two most common families of Ephemeroptera were Leptophlebiidae and Caenidae with 4,550 and 3,223 individuals; and accounted for 35 % and 25 % respectively of the total EPT individuals collected (Figure 3.42). Whereas, Potamanthidae and Polymitarcyidae were the two rarest families of Ephemeroptera order with only 2 and 1 individuals respectively. Leuctridae was the most common family of Plecoptera with 356 individuals, and accounted for 3 % of the total EPT individuals collected. Hydropsychidae and Philopotamidae were the two most common families of Trichoptera with 1,580 and 899 individuals; and accounted for 12 % and 7 % of the total EPT individuals collected respectively. The two rarest families of Trichoptera were Limnephilidae and Rhyacophilidae with only one individual of each collected.

Figure 3.42 Sorted abundance of each EPT family bimonthly collected between February and December 1998 at Yakraue stream, Nam Nao National Park, Thailand.



3.4.2 Comparing EPT Richness and Density between Sites

Table 3.35 summarizes EPT family richness and density of each site. Total EPT family richness was significantly different between sites (One Way ANOVA $F_{8, 45} = 12.770$, $P < 0.001$). The mean EPT family richness was highest at site Y8 with 14.8 ± 0.7 families and lowest at site Y1 with 6.5 ± 0.4 families. Family richness of each EPT group; Ephemeroptera, Plecoptera and Trichoptera; was also significantly different between sites (One Way ANOVA $H_8 = 37.806$, $P = <0.001$; $H_8 = 27.669$, $P = <0.001$ and $F_{8, 45} = 7.710$, $P < 0.001$ respectively). Both Ephemeroptera and Trichoptera family richness had the same trend as the total EPT family richness. It was highest at site Y8 with 7.2 ± 0.2 and 6.0 ± 0.5 families respectively; and lowest at site Y1 with 4.2 ± 0.2 and 1.7 ± 0.2 families respectively. Both the mayfly and caddis density tended to increase downstream. In contrast, the stonefly family richness was highest at site Y4 and Y5 with 2.7 ± 0.2 families each and lowest at site Y1 and Y3 with 0.7 ± 0.3 families each. The stonefly families richness tended to decrease at the impacted upstream sites (Y1 and Y3) and downstream sites (Y7 and Y8) and increase at the upstream sites of Y4, Y5 and Y6.

There were also significantly difference between sites in term of EPT taxa mean density (One Way ANOVA $F_{8, 45} = 11.392$, $P = <0.001$; $F_{8, 45} = 5.968$, $P = <0.001$; $H_8 = 30.006$, $P = <0.001$; and $H_8 = 41.122$, $P = <0.001$ for total EPT, Ephemeroptera, Plecoptera and Trichoptera density respectively). The total EPT mean density was lowest at site Y1 with 14.9 ± 3.7 individuals per sample and highest at site Y9 with 77.4 ± 6.8 individuals per sample. Ephemeroptera had quite low mean density with 13.8 ± 3.4, 24.0 ± 2.5 and 15.9 ± 3.0 individuals per sample at site Y1, Y2 and Y3 in the upper part of the stream respectively. At these sites, water current was not consistent all year round, with almost no flow from December to April (dry season). In addition, site Y3 received wastewater from the Nam Nao National Park's cafeteria. Sites Y4, Y5 and Y6, also located in the upper part of the stream, had quite high Ephemeroptera mean density with 41.8 ± 9.8, 35.3 ± 5.7 and 37.4 ± 4.3 individuals per sample respectively.

Site Y 7 had relatively low Ephemeroptera mean density with 32.6 ± 5.8 individuals per sample when compared with the other downstream sites. Site Y8 had the highest Ephemeroptera density with 55.0 ± 6.5 individuals per sample.

Plecoptera density was very high at site Y4 and Y5 located in the headwater area of the pine forest community with 7.5 ± 1.6 and 8.8 ± 1.8 individuals per sample respectively. Site Y3 had the lowest Plecoptera density (0.7 ± 0.3 individual per sample). The density was also quite low at the down stream sites.

Trichoptera density was highest at site Y9 with 35.3 ± 5.3 individuals per sample. The upstream sites of Y4 also had quite high Trichoptera density with 21.5 ± 1.8 individuals per sample, whereas, the upstream sites of Y1, Y2 and Y3 had relatively low density within the range of 1.8 ± 0.3 and 3.4 ± 1.3 individuals per sample.

Table 3.35 Family richness and density of the EPT groups of all sampling sites at Yakraue stream, Nam Nao National Park, Thailand found during February and December 1998.

Sites	Family richness (mean ± S.E.)/Density (mean ± S.E. individuals per sample)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Y1	4.2 ± 0.2/13.8 ± 3.4	0.7 ± 0.3/1.8 ± 0.9	1.7 ± 0.2/1.8 ± 0.3	6.5 ± 0.4/14.9 ± 3.7
Y2	6.3 ± 0.2/24.0 ± 2.5	2.0 ± 0.4/2.5 ± 0.4	4.0 ± 0.4/3.4 ± 1.3	12.3 ± 0.4/26.6 ± 2.7
Y3	5.7 ± 0.4/15.9 ± 3.0	0.7 ± 0.3/0.7 ± 0.3	3.7 ± 0.4/3.2 ± 0.7	10.0 ± 1.0/17.4 ± 3.1
Y4	4.5 ± 0.2/41.8 ± 9.8	2.7 ± 0.2/7.5 ± 1.6	4.5 ± 0.3/21.5 ± 1.8	11.7 ±0.4 /69.3 ± 11.0
Y5	5.0 ± 0.3/35.3 ± 5.7	2.7 ± 0.2/8.8 ± 1.8	4.7 ± 0.4/9.5 ± 1.8	12.3 ± 0.7/51.5 ± 7.7
Y6	4.5 ± 0.3/37.4 ± 4.3	2.3 ± 0.3/2.6 ± 1.0	4.8 ± 0.7/5.2 ± 1.5	11.7 ± 0.8/43.7 ± 6.1
Y7	6.7 ± 0.2/32.6 ± 5.8	1.8 ± 0.2/1.9 ± 0.3	5.3 ± 0.2/8.0 ± 1.4	13.8 ± 0.4/41.0 ± 6.3
Y8	7.2 ± 0.2/55.0 ± 6.5	1.7 ± 0.3/2.9 ± 1.4	6.0 ± 0.5/8.5 ± 2.2	14.8 ± 0.7/63.5 ± 8.28
Y9	5.8 ± 0.4/41.7 ± 3.8	2.3 ± 0.2/2.6 ± 0.3	5.2 ±0.6/35.3 ± 5.3	13.3 ± 0.9/77.4 ± 6.8

The most common families at Yakraue stream were Leptophlebiidae and Caenidae (Table 3.36) which also constituted the two predominant families at all of the sampling sites. The third most common families at the upstream sites were Baetidae (site Y1 and Y3), Neoephemeridae (site Y2), Philopotamidae (site Y4), Leuctridae (site Y5) and Heptageniidae (site Y6). Hydropsychidae was the third most common families at all the downstream sites (site Y7, Y8 and Y9).

Baetidae was not significantly different between sites in term of mean density, however, it occurred at high density in most of the upstream sites (Y2, Y3, Y4, Y5 and Y6) within the range of 4.0 ± 1.2 - 6.0 ± 1.8 individuals per sample. Baetid density was quite low at all of the downstream sites (Y7, Y8 and Y9) with 3.0 ± 0.7 - 3.6 ± 0.7 individuals per sample. However, site Y1 at the upstream had the lowest density with 2.1 ± 0.5 individuals per sample which may reflect the inconsistency of water flow

The mean density of Caenidae was significantly different between site Y8, and site Y1 and Y3. Site Y8 had the highest mean density with 24.9 ± 2.8 individuals per sample, whereas, site Y1 and Y3 had the lowest with 6.5 ± 1.6 and 7.1 ± 2.6 individuals per sample respectively.

Ephemeridae occurred at the highest density at the downstream site of Y7 with 3.2 ± 1.7 individuals per sample, whereas, it was absent at the upstream sites of Y4 and Y6.

Heptageniidae occurred at the highest density at site Y8 and Y9 with 6.4 ± 1.3 and 9.0 ± 1.6 individuals per sample respectively. Sites Y1 and Y3 had the lowest density with 1.1 ± 0.3 and 1.3 ± 0.3 respectively. The density tended to increase downstream.

Leptophlebiidae density was highest at Site Y8 with 25.5 ± 4.8 individuals per sample and site Y4, Y5 and Y6 had relatively high density within 20.9 ± 3.2 - 24.8 ± 5.6 individuals per sample. Site Y1 had the lowest density with 8.7 ± 3.0 individuals per sample. Leptophlebiidae tended to show that the sites most distant from tourist camps had the higher density.

Neoephemeridae was present at high density at site Y2 and Y8 with 6.7 ± 1.9 and 3.0 ± 0.5 individuals per sample respectively and in moderate density at sites Y3, Y7 and Y9. This family was absent at most of the upstream sites (Y1, Y4, Y5 and Y6).

Polymitarcyidae was a very rare family at Yakraue stream. It was present only at site Y8 with a mean density of 0.2 ± 0.2 individual per sample. Potamanthidae was also very rare and present at only 2 sites (Y3 and Y6) with 0.2 ± 0.2 individuals per sample.

Tricorythidae was represented over all sites with quite low mean density between 0.2 ± 0.2 and 1.6 ± 0.3 individuals per sample.

Leuctridae was present at high density at the upstream sites of Y4 and Y5 with 5.8 ± 1.1 and 7.1 ± 1.7 individuals per sample. It was present at low density at the upstream sites of Y3 with 0.2 ± 0.2 individuals per sample and totally disappeared at site Y1. At site Y2 and Y6 (upstream sites); and site Y7, Y8 and Y9 (downstream sites), it was present in moderate numbers between the range of 1.1 ± 0.4 and 2 5 ± 1 5 individuals per sample.

Nemouridae was present at high density at sites Y4 and Y5 with 3.6 ± 1.0 and 3.4 ± 0.7 individuals per sample respectively and at low density at site Y3 with 0.2 ± 0.2 individuals per sample. It was absent from site Y7. The upstream sites of Y1, Y2 and Y3 had relatively low mean density compared to the upstream sites of Y4, Y5 and Y6.

Perlidae had the highest mean density at site Y2 and Y9 with 3.4 ± 1.3 and 2.4 ± 0.4 respectively, whereas site Y3 had the lowest density with 0.3 ± 0.2 individuals per sample. It was also well present at low density at the other sites (0.8 ± 0.3 –1.5 ± 0.2 individuals per sample).

Calamoceratidae was present at highest density at site Y5 with 2.0 ± 0.7 individuals per sample but disappeared at Y1 and Y9. It occurred at very low density at the other sites within the range 0.2 ± 0.2 – 0.6 ± 0.3 individuals per sample.

Ecnomidae occurred at the highest density at site Y7 with 2.3 ± 0.6 individuals per sample and at the lowest density at site Y1 and Y5 with 0.2 ± 0.2 individuals per sample. It also appeared at the other sites with low density within the range between 0.5 ± 0.2 and 1.9 ± 0.4 individuals per sample.

Goeridae was mostly present at the downstream sites (Y6, Y7, Y8 and Y9) with low density within the range between 0.2 ± 0.2 and 0.5 ± 0.3 individuals per sample. It was absent at the upstream sites (Y1, Y2, Y3, Y4 and Y5).

Helicopsychidae was present at very low density at most of the sampling sites within the range between 0.3 ± 0.3 and 1.9 ± 0.5 individuals per sample. It was absent at site Y1.

Hydropsychidae was present at the highest density at site Y9 with 23.7 ± 4.1 individuals per sample. The density was very low at the upstream sites of Y1, Y2 and Y3 with mean density range between 0.5 ± 0.3 and 3.1 ± 2.0 individuals per sample. It was present in moderate density within the range between 3.8 ± 1.2 and 10.5 ± 2.9 individuals per sample at the upstream sites of Y4, Y5 and Y6. Most of downstream sites (Y7 and Y8 and Y9) had higher mean density of the Hydropsychid caddis than the upstream sites (Y1, Y2, Y3, Y5 and Y6).

Leptoceridae was only present at the upstream sites included site Y1, Y2, Y3, Y5 and Y6 with very low density within the range between 0.2 ± 0.2 and 0.5 ± 0.2 individuals per sample. It was absent at all of the downstream sites.

Limnephilidae was very rare and was only present at site Y6 where 1 individual was found in April.

Philopotamidae was present at high density at site Y4, Y5 and Y9 with 12.4 ± 3.5, 10.5 ± 2.7 and 14.3 ± 2.6 individuals per sample respectively and at low density at site Y1, Y2 and Y7 with 1.3 ± 0.4, 1.2 ± 0.7 and 2.1 ± 1.2 individuals per sample respectively.

Polycentropodidae was well present at all sites within the mean density range between 0.3 ± 0.3 and 3.4 ± 0.8 individuals per sample. Site Y7 and Y4 had significantly highest mean density and site Y1 had the lowest mean density.

Rhyacophilidae was very rare, with only a single individual collected at site Y3 in June.

Xiphocentroniidae was mostly present at the downstream sites (Y7, Y8 and Y9) with low mean density within the range between 0.2 ± 0.2 and 1.3 ± 0.4 individuals per sample. Site Y2 was the only one of the upstream sites which Xiphocentroniidae was found with 0.3 ± 0.2 individuals per sample.

At genus level, there were 24 from 48 genera collected, which demonstrated significant differences in mean density between sites (Appendix 6).

Table 3.36 Mean ± S.E density (individuals per sample) of each EPT family found at each site at Yakraue stream, Nam Nao National Park, Thailand in 1998, Followed with the same letter was not significantly different *(p*=0.05).

Family	Density (imean ± S.E of individuals per sample)									Sig.	Stat. value
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9		
Baetidae	2.1 ± 0.5	4.9 ± 1.4	4.6 ± 1.7	4.2 ± 0.3	6.0 ± 1.8	4.0 ± 1.2	3.0 ± 0.7	3.3 ± 0.4	3.6 ± 0.7	ns	H_8 = 9.150, P = 0.330
Caenidae	6.5 ± 1.6b	10.1 ± 2.2ab	7.1 ± 2.6b	13.9 ± 4.6ab	9.4 ± 1.9ab	11.8 ± 2.7ab	15.7 ± 3.5ab	24.9 ± 2.8a	15.8 ± 1.8ab	s	H_8 = 24.314, P = 0.002
Ephemeridae	0.2 ± 0.2ab	0.8 ± 0.4ab	1.5 ± 0.6ab	0.0 ± 0.0b	0.8 ± 0.4ab	0.0 ± 0.0b	3.2 ± 1.7a	1.8 ± 0.4a	0.8 ± 0.4ab	s	H_8 = 25.353, P = 0.001
Heptageniidae	1.1 ± 0.3b	2.3 ± 0.3ab	1.3 ± 0.3b	3.3 ± 0.5ab	3.5 ± 0.9ab	4.0 ± 1.6ab	3.8 ± 0.7ab	6.4 ± 1.3a	9.0 ± 1.6a	s	H_8 = 34.591, P = <0.001
Leptophlebiidae	8.7 ± 3.0b	11.4 ± 2.0ab	10.3 ± 2.5ab	24.8 ± 5.6a	20.9 ± 3.2ab	21.9 ± 2.5ab	11.4 ± 1.7ab	25.5 ± 4.8a	22.3 ± 3.3ab	s	$F_{8,45}$ = 4.070, P = 0.001
Neoephemeridae	0.0 ± 0.0b	6.7 ± 1.9a	1.1 ± 0.5ab	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	2.4 ± 0.6ab	3.0 ± 0.5a	0.6 ± 0.4ab	s	H_8 = 43.018, P = <0.001
Polymitarcyidae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	ns	H_8 = 8.000, P = 0.433
Potamanthidae	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	H_8 = 7.135, P = 0.522
Tricorythidae	0.2 ± 0.2	1.1 ± 0.3	0.7 ± 0.3	0.5 ± 0.2	0.5 ± 0.2	0.3 ± 0.2	1.3 ± 0.5	1.4 ± 0.3	1.6 ± 0.3	ns	H_8 = 19.415, P = 0.013
Leuctridae	0.0 ± 0.0b	1.1 ± 0.4ab	0.2 ± 0.2b	5.8 ± 1.1a	7.1 ± 1.7a	2.4 ± 1.3ab	1.7 ± 0.5ab	2.5 ± 1.5ab	1.5 ± 0.2ab	s	H_8 = 35.400, P = <0.001
Nemouridae	1.0 ± 1.0ab	0.3 ± 0.2ab	0.2 ± 0.2b	3.6 ± 1.0a	3.4 ± 0.7a	1.3 ± 0.4ab	0.0 ± 0.0b	0.5 ± 0.5ab	0.3 ± 0.2ab	s	H_8 = 32.537, P = <0.001
Perlidae	1.3 ± 0.7ab	3.4 ± 1.3a	0.3 ± 0.2b	0.9 ± 0.3ab	0.9 ± 0.3ab	0.9 ± 0.3ab	1.5 ± 0.2ab	0.8 ± 0.3ab	2.4 ± 0.4a	s	H_8 = 21.986, P = 0.005
Calamoceratidae	0.0 ± 0.0b	0.3 ± 0.2ab	0.2 ± 0.2ab	0.3 ± 0.2ab	2.0 ± 0.7a	0.5 ± 0.2ab	0.2 ± 0.2ab	0.6 ± 0.3ab	0.0 ± 0.0b	s	H_8 = 18.538, P = 0.018
Ecnomidae	0.2 ± 0.2b	0.7 ± 0.3ab	0.5 ± 0.2ab	0.7 ± 0.2ab	0.2 ± 0.2b	0.7 ± 0.7ab	2.3 ± 0.6a	1.9 ± 0.4ab	1.0 ± 0.4ab	s	H_8 = 24.235, P = 0.002
Glossosomatidae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.3	ns	H_8 = 8.000, P = 0.433
Goeridae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.5 ± 0.3	0.5 ± 0.3	0.3 ± 0.2	ns	H_8 = 11.037, P = 0.200
Helicopsychidae	0.0 ± 0.0	0.9 ± 0.5	0.5 ± 0.3	1.7 ± 1.1	0.5 ± 0.2	1.3 ± 0.8	0.3 ± 0.3	0.3 ± 0.2	1.9 ± 0.5	ns	H_8 = 12.740, P = 0.121
Hydropsychidae	0.5 ± 0.3b	3.1 ± 2.0bc	2.0 ± 0.6bc	10.5 ± 2.9ac	3.8 ± 0.8ab	3.8 ± 1.2ab	6.9 ± 0.8ab	11.1 ± 3.7ab	23.7 ± 4.1a	s	H_8 = 34.865, P = <0.001
Leptoceridae	0.2 ± 0.2	0.4 ± 0.3	0.2 ± 0.2	0.0 ± 0.0	0.2 ± 0.2	0.5 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	H_8 = 11.511, P = 0.174
Limnephilidae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	H_8 = 8.000, P = 0.433
Philopotamidae	1.3 ± 0.4bc	1.2 ± 0.7b	2.8 ± 0.9ab	12.4 ± 3.5ac	10.5 ± 2.7ab	2.4 ± 1.1ab	2.1 ± 1.2bc	1.9 ± 0.4ab	14.3 ± 2.6a	s	H_8 = 32.988, P = <0.001
Polycentropodidae	0.3 ± 0.3b	1.2 ± 0.4ab	0.5 ± 0.3ab	2.9 ± 0.8a	2.2 ± 0.5ab	1.6 ± 0.2ab	3.4 ± 0.8a	1.5 ± 0.4ab	2.5 ± 0.7ab	s	H_8 = 24.126, P = 0.002
Rhyacophilidae	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	H_8 = 8.000, P = 0.433
Xiphocentronidae	0.0 ± 0.0b	0.3 ± 0.2ab	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	1.3 ± 0.4a	1.3 ± 0.2a	0.2 ± 0.2b	s	H_8 = 38.288, P = <0.001

3.4.3 Seasonal variability of EPT family richness and density

Total EPT family richness was significantly different between months (Table 3.37, One Way ANOVA, $F_{5, 30} = 12.646$, $P < 0.001$). In the hot dry season month of April had the highest EPT family richness with the average of 16.3 ± 0.7 families. The richness was lowest in the cold dry season month of February with 10.0 ± 0.3 families. Mayfly family richness was highest in the hot dry (April) and wet (August and October) season months with the range of 6.5 ± 0.3 and 6.5 ± 0.4; and lowest in the cold dry season months of February and December with 5.0 ± 0.4 and 5.0 ± 0.3 respectively (One Way ANOVA, $F_{5, 30} = 5.138$, $P = 0.002$). Plecoptera richness was highest in April and December with 2.8 ± 0.2 families each; and lowest in February with 1.0 ± 0.4 families (One Way ANOVA on ranks, $H_5 = 21.323$, $P = < 0.001$). Trichoptera family richness was significantly high in the hot dry season (April) and the wet season (June) with 7.0 ± 0.6 and 6.5 ± 0.4 families respectively and lowest in the cold dry season (February) with 4.0 ± 0.3 families (One Way ANOVA, $F_{5, 30} = 7.543$, $P = < 0.001$).

In the cold dry season month of April had the highest mean EPT families richness, whereas, in the hot dry season month of February had the lowest. However, each order demonstrated that it had many months of high family richness e.g. Ephemeroptera in April, August and October; Plecoptera in April, August and December; and Trichoptera in April and June. Every EPT order had the lowest family richness in the same month (February).

Table 3.37 Family richness and density of the EPT groups in each sampling month at Yakraue stream, Nam Nao National Park, Thailand found during February and December 1998.

Month	Family richness (mean ± S.E.)/Density (mean ± S.E. individuals per sample)			
	Ephemeroptera	Plecoptera	Trichoptera	All EPT
Feb	5.0 ± 0.4/45 0 ± 2.6	1.0 ± 0.4/1.9 ± 0.8	4.0 ± 0.3/18.8 ± 6.7	10.0 ± 0.3/54.8 ± 3.5
Apr	6.5 ± 0.3/43.7 ± 4.2	2.8 ± 0.2/7.6 ± 2.7	7.0 ± 0.6/19.4 ± 4.9	16.3 ± 0.7/61.4 ± 5.5
Jun	6.2 ± 0.2/35.2 ± 4.6	1.7 ± 0.2/2.9 ± 0.7	6.5 ± 0.4/9.1 ± 1.7	14.3 ± 0.2/43.7 ± 3.9
Aug	6.5 ± 0.3/42.5 ± 4.8	2.7 ± 0.2/7.7 ± 1.7	5.7 ± 0.4/13.9 ± 1.5	14.8 ± 0.9/57.6 ± 5.4
Oct	6.5 ± 0.4/20.2 ± 2.0	2.3 ± 0.2/2.1 ± 0.3	4.2 ± 0.3/8.6 ± 1.9	13.0 ± 0.6/28.4 ± 3.0
Dec	5.0 ± 0.3/18.9 ± 2.2	2.8 ± 0.2/3.3 ± 0.4	5.7 ± 0.6/11.3 ± 1.7	13.5 ± 0.6/30.9 ± 3.7

Density of the EPT taxa was also significantly different between months (One Way ANOVA, $F_{5, 30} = 10.867$, $P = <0.001$). Table 3.37 summarizes monthly variability of the EPT density. Total EPT taxa density was highest in April with the average of 61.4 ± 5.5 individuals per sample and lowest in October with 28.4 ± 3.0 individuals per sample respectively.

Only mayflies and stoneflies which demonstrated significant differences in mean density between months (One Way ANOVA, $H_5 = 24.513$, $P = <0.001$ and $H_5 = 15.259$, $P = 0.009$). Mayflies had significantly higher density in February, April and August with the range of 42.5 ± 4.8 and 45.0 ± 2.6 individuals per sample; and lower density in October and December with the range of 18.9 ± 2.2 and 20.2 ± 2.0 individuals per sample. The mean density of stoneflies was highest in August with 7.7 ± 1.7 individuals per sample and lowest in February and October with 1.9 ± 0.8 and 2.1 ± 0.3 individuals per sample respectively.

There were 6 from 23 families collected, which significantly demonstrated differences in density between months (Table 3.38). Caenidae, Neoephemeridae and Polycentropodidae had their highest density in the dry season months of February and April; and lowest density during the end of the wet and the beginning of the dry season months of October and December.

Leptophlebiidae was present at the highest density in the wet season month of August and lowest in the cold season month of December.

The other two families, Leuctridae and Nemouridae, were present at their highest density in the wet season (August) and at the beginning of cold dry season (December) respectively. Both of them had the lowest density in the cold dry season (February)

At the genus level, there were 18 from 48 genera collected, which demonstrated significant differences in density between months at Yakraue stream (Appendix 7)

Table 3.38 Mean ± S.E. density (individuals per sample) of each family in each month at Yakrau stream, Nam Nao National Park, Thailand, 1998.

Family	Mean Density (individuals per sample) ± S.E.						Sig.	
	February	April	June	August	October	December		
Baetidae	4.9 ± 0.8	2.9 ± 0.5	4.2 ± 1.1	5.0 ± 1.1	3.4 ± 1.0	3.8 ± 0.8	ns	$H_5 = 5.439, P = 0.365$
Caenidae	22.8 ± 1.8a	20.1 ± 0.8ac	15.2 ± 3.5ab	12.7 ± 1.4ab	5.8 ± 0.9b	8.6 ± 2.3bc	s	$H_5 = 23.288, P = <0.001$
Ephemeridae	1.1 ± 0.6	1.5 ± 0.4	4.8 ± 3.3	0.6 ± 0.3	1.0 ± 0.5	0.2 ± 0.2	ns	$H_5 = 9.522, P = 0.090$
Heptageniidae	6.7 ± 0.6	4.7 ± 1.4	5.7 ± 2.9	4.7 ± 0.9	4.8 ± 1.1	4.0 ± 0.8	ns	$H_5 = 6.103, P = 0.296$
Leptophlebiidae	24.3 ± 4.6ac	22.9 ± 3.3ac	17.3 ± 0.5ab	25.5 ± 2.9a	9.5 ± 0.8bc	8.5 ± 0.8b	s	$H_5 = 24.949, P = <0.001$
Neoephemeridae	0.2 ± 0.2ab	2.9 ± 0.6a	2.8 ± 1.4ab	2.5 ± 0.8ab	5.3 ± 2.6ab	0.0 ± 0.0b	s	$H_5 = 17.273, P = 0.004$
Polymitarcyidae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	ns	$H_5 = 5.000, P = 0.416$
Potamanthidae	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.2 ± 0.2	0.0 ± 0.0	ns	$H_5 = 4.118, P = 0.533$
Tricorythidae	0.5 ± 0.3	0.8 ± 0.3	1.0 ± 0.4	1.4 ± 0.4	1.3 ± 0.2	1.2 ± 0.3	ns	$H_5 = 5.752, P = 0.331$
Leuctridae	0.7 ± 0.3b	6.2 ± 2.4ac	1.7 ± 1.2bc	6.5 ± 1.2a	1.8 ± 0.3ab	2.4 ± 0.5ab	s	$H_5 = 20.673, P = <0.001$
Nemouridae	0.0 ± 0.0b	2.9 ± 0.7ab	2.4 ± 1.2ab	2.6 ± 1.2ab	0.3 ± 0.2ab	3.4 ± 0.6a	s	$H_5 = 16.611, P = 0.005$
Perlidae	1.5 ± 0.8	1.2 ± 0.3	1.3 ± 0.3	2.3 ± 0.4	1.7 ± 0.3	1.0 ± 0.2	ns	$F_{5, 30} = 1.318, P = 0.283$
Calamoceratidae	0.0 ± 0.0	1.0 ± 0.4	1.3 ± 0.6	0.2 ± 0.2	0.0 ± 0.0	0.3 ± 0.2	ns	$H_5 = 13.462, P = 0.019$
Ecnomidae	1.7 ± 0.5	3.3 ± 1.6	1.4 ± 0.3	1.6 ± 0.4	0.7 ± 0.2	0.8 ± 0.3	ns	$H_5 = 10.607, P = 0.060$
Glossosomatidae	0.0 ± 0.0	0.3 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	$H_5 = 5.000, P = 0.416$
Goeridae	0.0 ± 0.0	0.3 ± 0.2	0.3 ± 0.3	0.3 ± 0.2	0.0 ± 0.0	0.3 ± 0.2	ns	$H_5 = 4.667, P = 0.458$
Helicopsychidae	0.2 ± 0.2	1.7 ± 0.6	1.8 ± 1.1	1.0 ± 0.5	0.2 ± 0.2	0.3 ± 0.2	ns	$H_5 = 10.834, P = 0.055$
Hydropsychidae	13.0 ± 3.6	25.6 ± 9.3	3.1 ± 1.1	9.9 ± 2.7	9.3 ± 2.6	9.2 ± 1.9	ns	$H_5 = 9.818, P = 0.081$
Leptoceridae	0.0 ± 0.0	0.5 ± 0.2	0.0 ± 0.0	0.2 ± 0.2	0.7 ± 0.3	0.3 ± 0.2	ns	$H_5 = 8.366, P = 0.137$
Limnephilidae	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	$H_5 = 5.000, P = 0.416$
Philopotamidae	9.5 ± 3.9	8.4 ± 3.3	22.9 ± 9.0	9.7 ± 4.3	2.7 ± 0.6	5.8 ± 2.1	ns	$H_5 = 8.371, P = 0.137$
Polycentropodidae	2.4 ± 1.1ab	3.1 ± 0.6a	2.1 ± 0.5ab	2.2 ± 0.7ab	0.5 ± 0.2b	1.5 ± 0.3ab	s	$H_5 = 12.515, P = 0.028$
Rhyacophilidae	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	ns	$H_5 = 5.000, P = 0.416$
Xiphocentronidae	0.3 ± 0.2	0.3 ± 0.2	1.3 ± 0.4	0.5 ± 0.2	0.3 ± 0.2	1.2 ± 0.5	ns	$H_5 = 7.709, P = 0.173$

3.4.4 Community patterns

3.4.4.1 TWINSPAN groups

There were 49 combinations of site x month which were classified on the basis of their EPT communities. Binary (presence/absence) data was used for simplicity.

Nine groups of samples were recognised by TWINSPAN based upon the binary data set (Figure 4.43). Membership per group ranged from 3 to 12 samples, and mean species richness per group ranged almost three-fold, from 6.8 ± 1.4 to 20.0 ± 0.6 species.

There was not a simple separation of sites, however, samples from the upstream sites Y4, Y5 and Y6; and the down stream site of Y9 were allocated to the left-hand side only.

In contrast, samples of the upstream sites of Y1, Y2 and Y3; and the down stream sites of Y7 and Y8 were present on both left and right hand sides after the first division, however, only the samples taken in the dry season (February and April) and in the early wet season months (June and August) were present on the right hand side. Hence there is some organisation on the basis of season.

Table 3.39 summarizes biological and environmental variables within each TWINSPAN group at Yakraue stream.

Figure 3.43 TWINSPAN groups of Yakraue stream based on binary data.

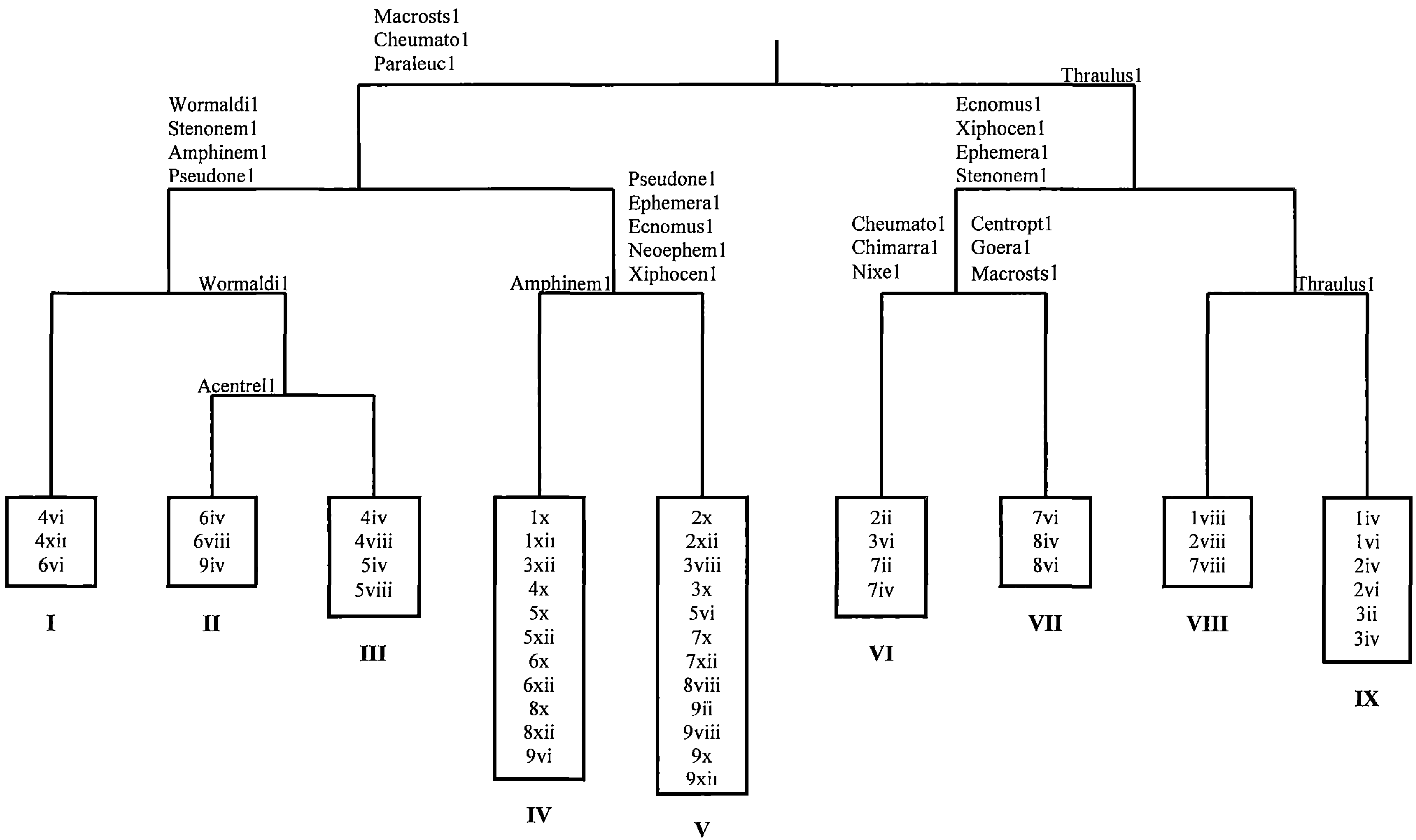


Table 3.39 Variables within each TWINSPAN group of Yakraue stream. Values followed by the same letter are not different at P = 0.05).

Variable	TWINSPAN Group								
	I	II	III	IV	V	VI	VII	VIII	IX
total SR	45	60	67	124	189	57	44	33	41
Mean SR	15.0 ± 1.5ab	20.0 ± 0.6a	16.8 ± 1.1ac	11.3 ± 0.7ab	15.8 ± 1.0ab	14.3 ± 0.9ab	14.7 ± 1.2ab	11.0 ± 2.6bc	6.8 ± 1.4b
Air Temp. (° C)	26.3 ± 0.2ab	26.5 ± 0.5ab	26.1 ± 0.3ab	22.5 ± 0.2b	22.5 ± 0.5b	27.1 ± 0.9ab	27.7 ± 0.2a	24.7 ± 0.1b	28.3 ± 0.3a
Water Temp. (°C)	20.8 ± 0.5b	23.3 ± 0.4ac	22.8 ± 0.1b	19.2 ± 0.2b	20.4 ± 0.3b	21.0 ± 0.7bc	25.3 ± 0.2a	23.0 ± 0.1ab	22.8 ± 0.3ab
Flow rate (ms^{-1})	0.1 ± 0.0b	0.1 ± 0.0b	0.1 ± 0.0b	0.2 ± 0.1ab	0.2 ± 0.0a	0.1 ± 0.0b	0.1 ± 0.0b	0.1 ± 0.0b	0.0 ± 0.0b
Depth (cm)	5.2 ± 0.8ab	4.2 ± 0.6b	3.2 ± 0.4b	4.2 ± 0.3b	6.5 ± 0.5ab	10.1 ± 1.1a	9.7 ± 0.9a	7.7 ± 1.1ab	10.0 ± 1.1ab
EC (μScm^{-1})	573.8 ± 5.1a	328.5 ± 8.6b	419.1 ± 2.5b	404.4 ± 20.4b	490.4 ± 11.3ab	535.0 ± 40 9ac	430.3 ± 39.2ab	397.1 ± 47.2bc	393.3 ± 36.1b
DO (mgL^{-1})	4.7 ± 0.4b	4.6 ± 0.4b	3.7 ± 0.3b	6.8 ± 0.2a	6.6 ± 0.2ab	5.4 ± 0.4ab	7.1 ± 0.4a	4.9 ± 0.3b	3.5 ± 0.2b
TDS (mgL^{-1})	380.1 ± 4.6a	219.2 ± 5.7b	279.5 ± 1.7b	270.9 ± 13.5b	326.7 ± 7.5ab	356.7 ± 27.2a	286.6 ± 26.0ab	264.6 ± 31.4b	264.9 ± 24.7b
Mean pH	9.1 ± 0.2a	7.4 ± 0.1b	7.7 ± 0.1bc	7.9 ± 0.1bc	7.9 ± 0.1bc	8.0 ± 0.1bc	8.0 ± 0.0c	7.4 ± 0.0b	7.8 ± 0.1bc

Indicator taxa

Indicator taxa are those which most strongly influence division at particular levels in the analysis. Four different taxa acted as indicators for the level 1 split. *Macrostemum similior*, *Cheumatopsyche malaysiensis,* and *Paraleuctra* spp. were indicators for left hand level 1 split, whereas, *Thraulus* was an indicator for right hand level 1 split.

Season as a factor

Month of the year was very influential in determining the number of species present in the samples (One Way ANOVA on ranks H = 29.172, P = <0.001. August had the highest species richness and February the lowest (Table 3.40).

Table 3.40 Mean species richness + se of samples for each month. Means followed by the same letter are not different at P = 0.05.

Month	n	Mean SR	SE	sig.
February	6	11.5	0.2	b
April	6	23.7	1.0	ac
June	6	21.3	0.3	ac
August	6	24.7	1.1	a
October	6	16.2	0.9	bc
December	6	19.2	0.8	ab

Site as a factor

Sites differed strongly in their mean species richness (One Way ANOVA on ranks H_8 = 37.721, P = <0.001. Sites Y7 and Y8 had the highest mean species richness and site Y1 and Y3 had the lowest (Table 3.41).

Table 3.41 Mean species richness + se of samples for each site. Means followed by the same letter are not different at P = 0.05.

Site	n	Mean SR	SE	Sig.
Y1	6	9.3	0.6	b
Y2	6	15.8	0.6	ab
Y3	6	13.7	1.0	b
Y4	6	17.3	0.3	ab
Y5	6	17.2	1.0	ab
Y6	6	15.8	1.3	ab
Y7	6	20.7	0.7	a
Y8	6	20.7	0.7	a
Y9	6	18.8	1.0	ab

Species richness (SR) as factors

The mean species richness of the TWINSPAN groups was significantly different (One Way ANOVA $F_{8,40}$ = 8.792, <0.001). It was high in group II and III which mainly consisted of the upstream sites of Y4, Y5 and Y6; and low in group VIII and IX which mainly consisted of the upstream sites of Y1, Y2 and Y3.

Environmental variables as factors
All of the environmental variables differed between the TWINSPAN groups as follows:

pH
There was a significant difference in the mean pH value of the TWINSPAN groups (One Way ANOVA on ranks H_8 = 71.798, P = <0.001). Group I had a conspicuously high pH value and all of the other groups had lower readings. The catchment has considerable amounts of limestone geology.

TDS
TDS was significantly different between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 51.583, P = <0.001). Group I had the highest TDS; and group II, III, IV, VIII and IX had relatively low values.

Dissolved Oxygen
DO was significantly different between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 127.607, P = <0.001). Groups IV and VII had relatively high dissolved oxygen and group I, II, III, VIII and IX had relatively low values.

Electric Conductivity
EC was significantly different between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 53.030, P = <0.001). Group I had the highest EC and group II, III, IV, VIII and IX had relatively low values.

Water Temperature
Water temperature was significantly different between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 119.333, P = <0.001). Group II and VII had relatively high water temperature and group I, III, IV, V and VI had relatively low values.

Air Temperature
Air temperature was significantly different between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 141.637, P = <0.001). Group VII and IX had relatively high air temperature and group IV, V and VIII had relatively low values.

Flow Rate
Flow rate was significantly different between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 69.690, P = <0.001). Group V had the highest flow rate and group I, II, III, VI, VII, VIII and IX had relatively low values.

Water depth
Water depth also differed between the TWINSPAN groups (One Way ANOVA on ranks H_8 = 72.854, P = <0.001). The mean water depth was high in groups VI and VII; and relatively low in groups II and III.

The above summary shows that the community patterns of the EPT taxa in Yakraue stream may be influenced by many factors included sites, month of the year and environmental factors.

3.4.4.2 Ordination of samples

Ordination allows for a better appreciation of the continuous variation in the data set. Both raw count data and binary transformed data (presence/absence) were used. Appendices 10-11 show the mds plots within each month for clarity. The output of the multidimensional scaling (mds) ordination is shown in Figure 3.44 and 3.45.

Site Y3 in February, April, and December; and site Y1 in June, were strongly separated from the other sites in the ordination space suggesting the EPT community at these sites might be affected by some unique combination of factors. The known factors affecting site Y3 is wastewater from the Nam Nao restaurants and that affecting site Y1 is the inconsistency in water flow, with effectively no water in the dry season.

The vectors of the significantly correlated taxa show that 6 genera (*Ecnomus*, *Neoephemera*, *Stenonema*, *Pseudoneureclipsis*, *Caenis* and *Goera*) are strongly associated with site Y7, Y8 and Y9 in April and June; the other 6 taxa (*Macrostemum*, *Choroterpes*, *Nixe*, *Amphinemura*, *Chimarra* and *Anocroneuria*) are strongly associated with site Y4, Y5 and Y9 in June and December.

Figure 3.44 Ordination of Yakraue stream sites based on EPT count data set. 3 dimensional solution, stress = 0.144. Significantly correlated ($p < 0.05$) taxa are fitted in the same ordination space.

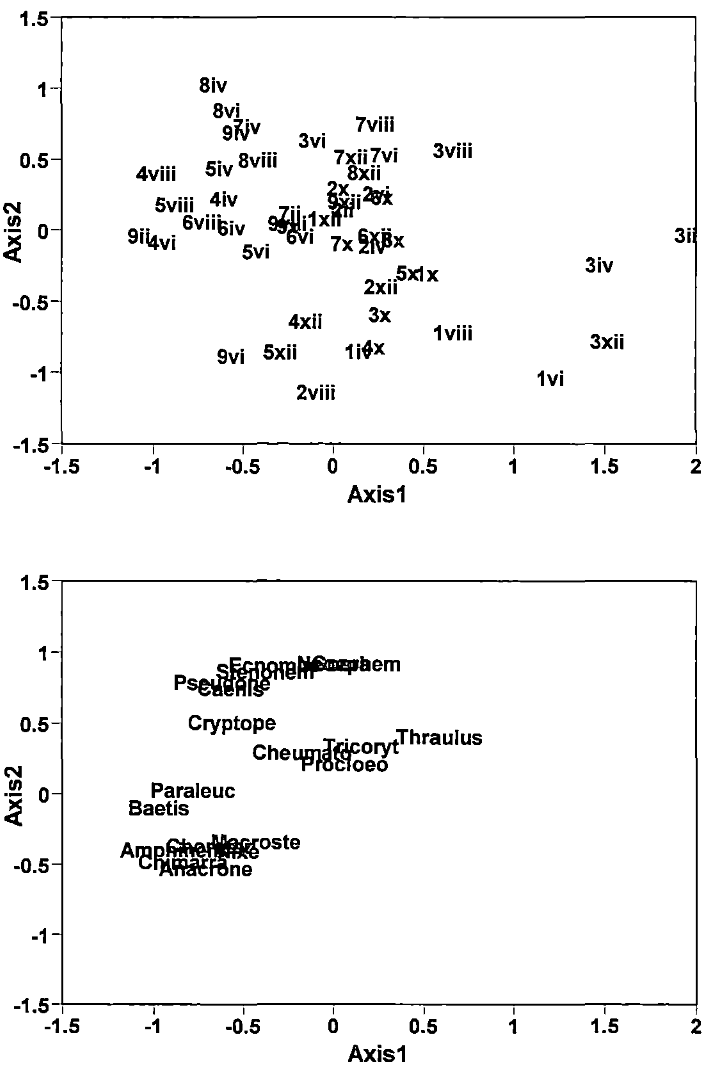
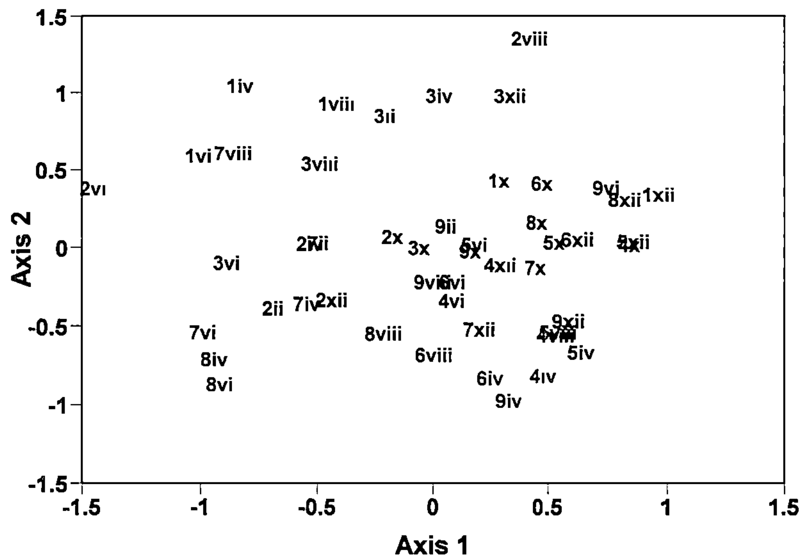
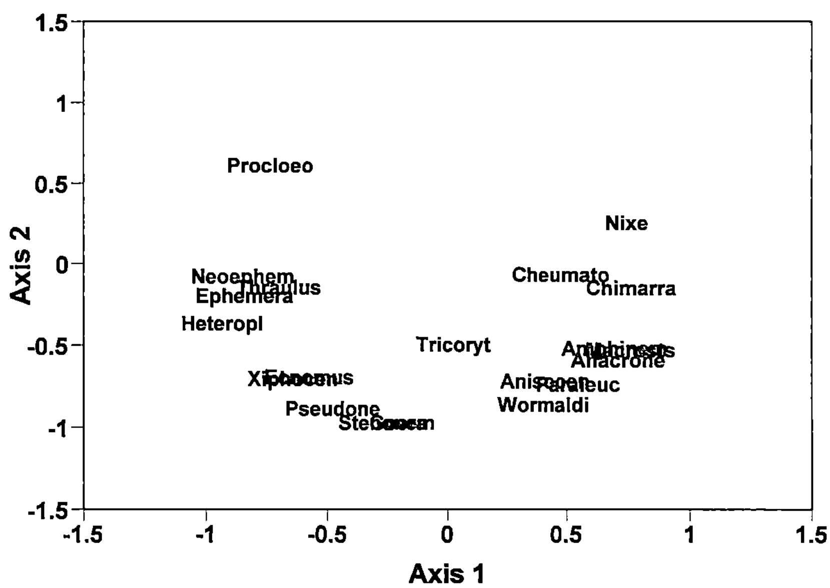


Figure 3.45 Ordination of Yakraue stream based on binary EPT data set. 3 dimensional solution, stress = 0.18. Significant ($p < 0.01$) correlated taxa fitted in the same ordination space.





4. DISCUSSION

Overview of the fauna

The few studies published on tropical stream systems indicate that their macroinvertebrate communities can be very rich in taxa (Bishop 1973, Dudgeon 1996b, 1997), especially those in forested catchment (Brewin *et al.* 1995), and my study of 2 streams in Nam Nao National Park supports this finding.

The highly uneven family abundance of the EPT fauna in Nam Nao National Park is typical of family profiles reported from other locations in Thailand. For example, Chantaramongkol *et al.* (1999) found that in a fauna of 68 Trichoptera species from a 12 month survey near Chiang Mai, 26 species were represented by a single specimen and only 19 species contributed more than one percent of the total. The numerical domination of Ephemeroptera reflects that reported in other tropical areas in Asia and the Americas (Brewin *et al.* 1995, Ramirez & Pringle 1998), however Baetidae rather than Caenidae appear to be dominant in streams in Nepal (Brewin *et al.* 1995). The low proportional representation of Plecoptera in my streams is consistent with their scarcity in other tropical streams (Wuillot 1994) and is a common contrast with streams in the temperate zone. Collector-gatherers were the dominant functional-feeding group and very few shredders were found in a tropical stream in Costa Rica (Ramirez & Pringle 1998). Riffles supported the highest abundance and biomass of benthic insects. Benthic abundance increased with the number of days since the last large rainstorm (>50 mm/24 h) and habitat-weighted abundance was negatively correlated with stream discharge.

There are too few published studies from tropical Asian streams to generalise safely about large scale patterns in the aquatic fauna but a few trends are evident and invite comparison with the present study. Oriental caddisfly faunas are claimed to be dominated by case-building leptocerids and net-spinning hydropsychids (Dudgeon 1990) but leptocerids were uncommon in my study. Nevertheless, two hydropsychid genera common in my sites were also dominant in a Hong Kong stream investigated by Dudgeon (1997). Two *Cheumatopsyche* species were the most abundant hydropsychids, followed by a *Macrostemum* which made up 42% of total hydropsychid biomass and there was little inter-year variation in total hydropsychid standing stocks. Dudgeon found *Macrostemum* was most numerous following recruitment during the wet season. *Cheumatopsyche* spp. had bivoltine life histories while *Macrostemum* was univoltine; the latter grew rapidly to the final instar and then spent several months increasing in weight before emergence.

The environmental variables in Nam Nao streams need further investigation. The high pH value in streams is usually conducive to high biodiversity and the high density of gastropods observed and the presence of *Heptagenia* can be indicative of high pH. Inputs of litter and detritus to these streams is largely determined by the nature of the riparian vegetation and the input of allochthonous organic material and its relative retention between seasons is likely to be important to the fauna. The sites in my study were heavily forested and inputs of leafy material were especially high in the cold dry season. Spate events in the wet season can locally deplete this resource.

My study has also shown that adequate taxonomic resolution is critical in understanding how EPT taxa respond to different substrates within streams. Although responses at family and genus level were often consistent between sites and between seasons, this was not always the case. Evidence from elsewhere shows that even different species in the same genus may prefer either pools or riffles, e.g. *Atalonella* spp in tropical Australia so generalizations should be treated with caution.

Question 1: Do EPT taxa colonize different substrate types preferentially in space and time?

The data indicate that substrate distribution has a major role in determining the distribution of many macroinvertebrates, however, fluctuations in the abundance of some species may be a response to variations in stream discharge. Seasonal concentration of populations can occur in the dry season due to decreasing flows. Apart from physical displacement of invertebrates, wet season spates may also make conditions unsuitable because they flush detritus from the system and rapidly change abiotic factors such as TDS. There was exceptionally high rainfall in August 1998 during this study and discharge was extremely high.

Life cycles of many stream dwelling invertebrates in tropical Asia have probably evolved in response to the timing of monsoonal rain (Dudgeon 1992, 1995). Dramatic declines in numbers of various species coinciding with the start of the wet season have been recorded in Hong Kong (Dudgeon 1999) and tropical Australia (Nolen & Pearson 1992), and was also apparent at site Hin Lat 1. Some species may have adult stages active most of the year in Thailand (e.g. some Trichoptera, Chantaramongkol *et al.* 1999) and have rapidly growing immature stages which allow populations to recover quickly after temporary depletion of their numbers in the wet season (Dudgeon, 1994). This may result in extended opportunities for recruitment, which may benefit species living in seasonally disturbed environments (Mackay 1992). Alternatively, other species may adjust the timing of their life cycle in response to seasonally predictable, spate-induced mortality. Clearly, flexibility in life cycles is an advantage in this climate.

Despite the physical stresses of wet season streams, numerous taxa were able to maintain substantial populations at this time, notably mayflies associated with boulders. Smaller particle sized substrates are probably very unstable under spate conditions and would be expected to support fewer animals. Root and leaf packs had their most diverse fauna in February when water flow is at a minimum, input of leaf material is high, and at this time of year pools represent the most reliable part of the stream environment.

All hydropsychids in the Hong Kong stream studied by Dudgeon (1997) were significantly more abundant in midstream microhabitats than close to the stream banks. Hydropsychid microdistribution was influenced by sediment grain-size characteristics, although algae or detritus also had some influence on most species (Dudgeon 1999). Microdistribution of most heptageniids was influenced significantly by sediment grain-size characteristics rather than by algae or detritus, but the proportion of variation in the abundance of each heptageniid species accounted for by sediment characteristics was low. In Hong Kong streams, the mayfly *Ephemera spilosa* was patchily distributed and more common in microhabitats close to the stream banks where sediments were relatively fine grained (Dudgeon 1996a). Enhanced sediment deposition is known to alter macroinvertebrate assemblages (Hubert *et al.* 1996). Sources of this may be roading, increased fire frequency and deforestation in the catchment. Increased fire frequency is a risk in Nam Nao National Park due to increasing visitor pressure and long term climate warming and could therefore affect aquatic communities.

The question of whether leaf packs represent a food source or a living space for stream fauna has been addressed for an Asian stream by Dudgeon & Wu (1999). Although they found that leaf type was influential, the density of *Baetis* mayflies was affected by the amounts of algae that developed on leaf surfaces. They concluded that greater densities of macroinvertebrates (mainly collectors) on palatable leaves reflected their importance as a food source rather than a substrate. The meso-habitat distribution of Limnephilidae is known to be related to the quality of detritus, which is their principal food source (Suren 1991).
There is generally a scarcity of shredders in tropical Asian streams (Dudgeon 1995) perhaps due to the higher levels of bacterial decomposition in the tropics. One of the few shredders recognised in my study was *Anisocentropus*, a leaf-case bearer which lives among the accumulations of leaf litter on which it feeds (Nolen & Pearson 1992, Dudgeon 1994). Hence an association with leaf packs in Hin Lat stream is consistent with its known ecology.

Question 2: Does EPT taxa richness differ in relation to parts of the stream system, i.e. pool, riffle and run?
The results clearly showed that EPT taxa differ strongly in their associations with parts of the stream system. Aquatic fauna can have one of several possible responses to the flow-related components of the stream system. They may be relatively insensitive to it, they may exhibit a preference in some but not all seasons, or they may preferentially occupy a section of the stream all the time.

Preferences for different components of the stream system were apparent between the EPT orders and between seasons of the year at Yakraue, but discrimination by all of the orders was most pronounced in the wet season. Trichoptera were consistently more abundant in riffle sections of the stream than in pools or runs, during both wet and dry seasons. In contrast, Ephemeroptera were approximately twice as abundant in runs as in riffles and pools. Plecoptera were not detected in pools in the wet season but were present in low densities in riffles and runs.

At the family level, Leptophlebiidae seemed most responsive to the stream component. In the dry season, high numbers were found in pools probably due to low water levels in the riffle sections of the streams. However, by June with the restoration of water levels, individuals had become uncommon in pools and high numbers were present in runs. Heptageniidae (*Nixe*) avoided pools. Hydropsychidae had a strong preference for riffles. About half the family level taxa exhibited preferences for either riffles or stream margins in the Nepalese study of Brewin *et al.* (1995). Forest streams were characterized by rich macroinvertebrate assemblages, including several taxa whose abundance was positively correlated with cover by detritus. Substratum composition, which has been shown to influence patterns of macroinvertebrate distribution (Wright *et al.* 1984), was important in correlation with the abundance of some macroinvertebrate taxa (Brewin *et al.* 1995).

At the genus level, differences were also most pronounced in the wet season. However, the temporary dominance of *Choroterpes* in pools in February may relate to the relative permanence of water in these sites, and contrasted with its preference for riffles and runs in the wet season. The influence of the wet season in reinforcing preferences between stream sections was supported by results from the Hin Lat stream in August. Trichoptera larvae were dominant in riffles, most notably the genera *Amphipsyche* and *Chimarra*. Caenidae (*Caenis*) were strongly associated with the run section of Hin Lat stream at this time.

There were also strong differences in the diversity of the fauna between stream sections in the total dataset, which combined all the bimonthly samples at Yakraue. The taxa diversity for Ephemeroptera was remarkably similar for pools, riffles and runs, but there was a more than two-fold difference in individuals with runs having twice the annual number of mayflies as riffles. Mean generic richness in Trichoptera was also similar between stream components, but there were very large differences (up to 7-fold) between them in terms of the density of individual animals. Plecoptera totaled only 3 species and strongly avoided pools.

Question 3: Is there any difference in the fauna upstream and downstream of a tourism facility which may result in increasing impacts on the stream in future?

Extended sampling of the densely forested YaKruae stream system reinforced many of the conclusions drawn from the faunistic study in the Hin Lat stream system in the south of the National Park. Ephemeroptera were about three times more abundant than Trichoptera, while Plecoptera were scarce. Despite the relatively short length of stream over which these sites were distributed, there was considerable difference in EPT richness and density between the sites. There was a clear trend to higher numbers of taxa and individuals downstream, except for Plecoptera, which peaked in numbers in the higher reaches of one tributary. The two similar scale tributaries, which have their confluence below the restaurant, were different in some aspects of their fauna. The "restaurant" stream (Y1-Y3) supported less diversity, especially of Ephemeroptera, than its adjacent tributary (Y4-Y6).
It is noteworthy that Plecoptera were at their lowest density at sample point Y3 which receives untreated grey-water from the restaurant; however the discharged volume is relatively small although this changes with visitor numbers, which peak in April coinciding with minimum water flow.

There is clear evidence of rapid change in EPT diversity through the year. Remarkably, family level diversity peaked in the hot dry season (April, n = 16), shortly after the annual minimum diversity recorded in the cold dry month of February (n = 10). It was noted that many Trichoptera pupae were present in mid-March, but these had all emerged by April. About one quarter of the families recorded (6 of 24) differed in density between months. Animal densities peaked in April also, but the annual minimum was in October when rainfall is declining but water flow is still high. August 1998 experienced an extreme spate (with rainfall double the previous August total) and may have been an influence on this outcome.

Although TWINSPAN successfully detected a number of groupings of site x month samples, there was considerable overlap of sites and months within groups. This is most probably a reflection of the presence of widespread taxa which are relatively insensitive to season and site, at least on the scale measured here. However, the use of binary data in the analysis ignores the contribution by various abundances of taxa to the resulting classification. There is indirect evidence that environmental variables may play a role in this grouping, since the groups differed in the mean values of these variables, but more work is needed to explore their relative contributions to faunal patterns.
Multidimensional scaling was successful in separating the site x month samples in the ordination space, and highlighted the impacted site Y3 in December, February and April as an outlier. It is tempting to speculate that the impacts of the kitchen discharge may thus be detectable in the fauna, at least in seasons of low water flows. It was noted too that chironomid larvae were very common at this site from February to June. However, better proof of impacts is lacking and a more comprehensive study is needed.
Results showed that either count data or binary data were satisfactory in separating EPT fauna samples in the ordination space. However, major differences are apparent in which taxa were most significantly correlated with the two ordinations. Based on the count dataset, Ephemeroptera genera ranked highly as significant taxa, and most Trichoptera were not influential. However, with the derived binary data, the most highly correlated genera are drawn from all the orders. In conclusion, it is clear that binary data would be satisfactory to recommend in future surveys of this stream system, resulting in significant savings in costs.

When studying the impact of an existing point source of pollution entering a stream, it is very difficult to avoid a confounded experimental design (Downes et al. 1993). Differences in the community between upstream control sites and downstream impacted sites (treatments) may be a simple consequence of differences between locations. However, if a lower level of certainty in the results is acceptable then this design may suffice, especially if it can be replicated in other stream systems nearby.

Finally to revisit the original question: Is there any difference in the fauna upstream and downstream of a tourism facility which may result in increasing impacts on the stream in future? It is apparent that the fauna within Yakraue stream is quite heterogeneous on the scale measured here, both in time and space. This creates some difficulties in recognizing any impacts, although preliminary data does suggest some response in the aquatic fauna near the existing point pollution source. The downstream changes in EPT communities documented here almost certainly reflect natural variation and it is not possible to ascribe these to existing impacts with any confidence. Nevertheless, the effluent from the tourism facilities should be treated rather than let it flow directly into the stream and re-assessment of the benthic macroinvertebrate fauna should be made at suitable intervals. In addition, further monitoring should be undertaken if any expansion is planned in the tourism facilities in the catchment of the Yakraue stream system. If this expansion occurs, then the data gathered for this thesis will form an important basis for comparisons needed to detect future impacts.

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Appendix 1 Selected Ephemeroptera found at Yakraue and Hin Lat streams, Nam Nao National Park, Thailand 1998.

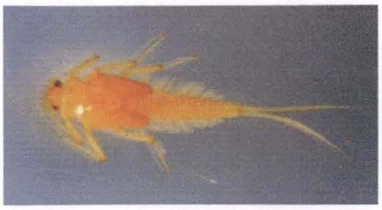


Plate 1 *Acentrella,* F. Baetidae

Plate 2 *Baetis*, F. Baetidae

Plate 3 *Baetis,* F. Baetidae

Plate 4 Cloeon, F. Baetidae

Plate 5 F. Heptageniidae

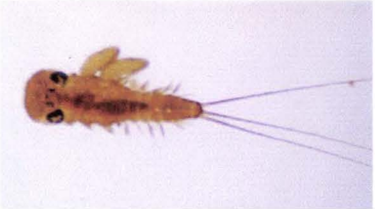


Plate 6 F. Heptageniidae

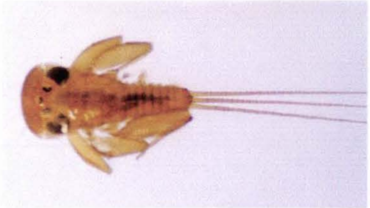


Plate 7 F. Heptageniidae

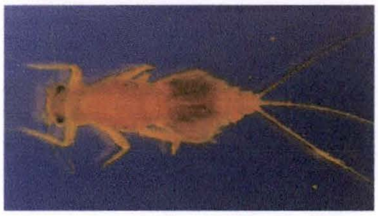


Plate 8 *Caenis*, F. Caenidae

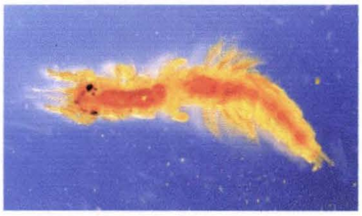


Plate 9 *Ephemera*, F. Ephemeridae

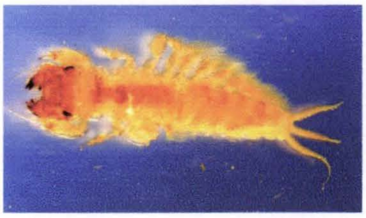


Plate 10 F. Pothamanthidae

Plate 11 *Neoephemera*, F. Neoephemeridae

Plate 12 *Choroterpes*, F. Leptophlebiidae

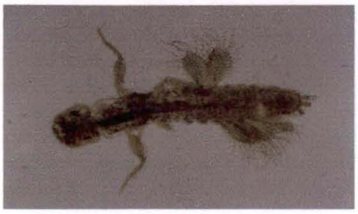


Plate 13 *Thraulus*, F. Leptophlebiidae

Plate 14 Tricorythodes, F. Tricorythidae

Appendix 2 Selected Plecoptera found at Yakraue and Hin Lat streams, Nam Nao National Park, Thailand 1998.

Plate 1 *Paraleuctra*, F. Leuctridae

Plate 2 F. Nemouridae

Plate 3 F.Nemouridae

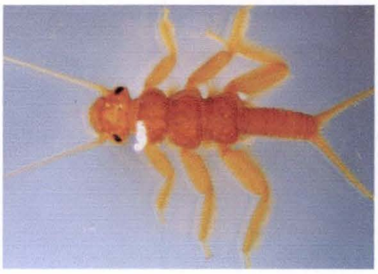


Plate 4 F. Perlidae

Plate 5 F. Perlidae

Appendix 3 Selected Trichoptera found at Yakraue and Hin Lat streams, Nam Nao national Park, Thailand 1998.

Plate 1 F. Calamoceratidae

Plate 2 *Chimarra,* F. Philopotamidae

Plate 3 *Ecnomus*, F. Ecnomidae

Plate 4 *Xiphocentron*, F. Xiphocentronidae

Plate 5 *Leptocerus*, F. Leptoceridae

Plate 6 F. Helicopsychidae (case)

Plate 7 *Macrostemum* F. Hydropsychidae (pupa)

Plate 11 *Macrostemum* F. Hydropsychidae

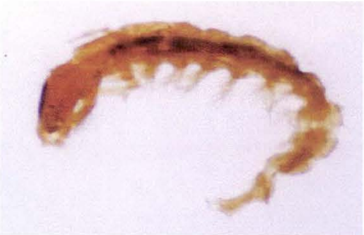


Plate 12 F. Hydropsychidae

Plate 13 *Stenopsyche*, F. Stenopsychidae

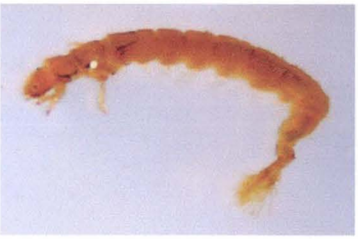


Plate 14 *Hydropsyche*, F. Hydropsychidae

Plate 15 *Cheumatopsyche*, F. Hydropsychidae

Appendix 4 Correlation coefficients and their significance value from ordination using count PT data set at genus level, Hin Lat stream. * P = 0.05, ** P = 0.01, ns = not significant.

Order	Family	Genus	Correlation coefficient	Significance value
Trichoptera	Hydropsychidae	*Cheumatopsyche*	0.833	**
Ephemeroptera	Caenidae	*Caenis*	0.822	**
Trichoptera	Philopotamidae	*Chimarra*	0.732	**
Ephemeroptera	Leptophlebiidae	*Atalophlebioides*	0.705	**
Trichoptera	Stenopsychidae	*Stenopsyche*	0.677	**
Ephemeroptera	Ephemeridae	*Ephemera*	0.660	**
Ephemeroptera	Tricorythidae	*Tricorythodes*	0.645	**
Trichoptera	Polycentropodidae	*Pseudoneureclipsis*	0.630	**
Trichoptera	Hydropsychidae	*Macrostemum*	0.617	**
Trichoptera	Ecnomidae	*Ecnomus*	0.602	**
Plecoptera	Perlidae	*Anacroneuria*	0.599	**
Ephemeroptera	Leptophlebiidae	*Leptophlebia*	0.572	**
Ephemeroptera	Heptageniidae	*Nixe*	0.565	**
Ephemeroptera	Baetidae	*Baetis*	0.538	**
Ephemeroptera	Leptophlebiidae	*Thraulus*	0.535	**
Ephemeroptera	Leptophlebiidae	*Choroterpes*	0.527	**
Ephemeroptera	Leptophlebiidae	*Cryptopenella*	0.517	**
Ephemeroptera	Tricorythidae	*Leptohyphes*	0.517	**
Trichoptera	Calamoceratidae	*Anisocentropus*	0.514	**
Trichoptera	Hydropsychidae	*Hydropsychidae* sp.1	0.514	**
Trichoptera	Helicopsychidae	*Helicopsyche*	0.513	**
Ephemeroptera	Baetidae	*Centroptilum*	0.482	**
Trichoptera	Xiphocentronidae	*Xiphocentron*	0.476	*
Ephemeroptera	Heptageniidae	*Stenonema*	0.458	*
Trichoptera	Goeridae	*Goera*	0.416	*
Ephemeroptera	Leptophlebiidae	*Minyphlebia*	0.390	ns
Trichoptera	Dipseudopsidae	*Dipseudopsis*	0.369	ns
Trichoptera	Leptoceridae	*Triaenodes*	0.367	ns
Ephemeroptera	Neoephemeridae	*Neoephemera*	0.365	ns
Plecoptera	Nemouridae	*Amphinemura*	0.357	ns
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	0.353	ns
Trichoptera	Leptoceridae	*Nectopsyche*	0.350	ns
Trichoptera	Polycentropodidae	*Polycentropus*	0.341	ns
Trichoptera	Philopotamidae	*Wormaldia*	0.341	ns
Trichoptera	Leptoceridae	*Leptocerus*	0.339	ns
Ephemeroptera	Baetidae	*Procloeon*	0.339	ns
Trichoptera	Calamoceratidae	*Heteroplectron*	0.338	ns
Trichoptera	Psychomyiidae	*Tinodes*	0.329	ns
Trichoptera	Phryganeidae	*Ptilostomis*	0.321	ns
Trichoptera	Phryganeidae	*Agrypnia*	0.319	ns
Ephemeroptera	Heptageniidae	*Cinygma*	0.319	ns
Trichoptera	Hydropsychidae	*Diplectrona*	0.317	ns
Trichoptera	Polycentropodidae	*Neureclipsis*	0.310	ns
Ephemeroptera	Leptophlebiidae	*Thraulodes*	0.306	ns

Appendix 4 (continued) Correlation coefficients and their significance value from ordination using count EPT data set at genus level, Hin Lat stream. * P = 0.05, ** P = 0.01, ns = not significant.

Order	Family	Genus	Correlation coefficient	Significance value
Trichoptera	Limnephilidae	*Apatania*	0.304	ns
Trichoptera	Odontoceridae	*Nerophilus*	0.303	ns
Trichoptera	Leptoceridae	*Oecetis*	0.299	ns
Ephemeroptera	Baetidae	*Callibaetis*	0.292	ns
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	0.279	ns
Trichoptera	Polycentropodidae	*Cernotina*	0.263	ns
Plecoptera	Perlidae	*Paragnetina*	0.263	ns
Plecoptera	Nemouridae	*Prostoia*	0.247	ns
Plecoptera	Perlidae	*Perlinella*	0.239	ns
Plecoptera	Capniidae	*Eucapnopsis*	0.237	ns
Trichoptera	Hydropsychidae	*Hydropsyche*	0.234	ns
Trichoptera	Odontoceridae	*Namamyia*	0.219	ns
Plecoptera	Nemouridae	*Zapada*	0.219	ns
Plecoptera	Perlidae	*Agnetina*	0.210	ns
Ephemeroptera	Heptageniidae	*Stenacron*	0.200	ns
Plecoptera	Leuctridae	*Paraleuctra*	0.199	ns
Trichoptera	Philopotamidae	*Dolophilodes*	0.179	ns
Ephemeroptera	Baetidae	*Acentrella*	0.148	ns
Trichoptera	Calamoceratidae	*Ganonema*	0.146	ns

Appendix 5 Correlation coefficients and their significance value from ordination using binary EPT data set at genus level, Hin Lat stream. * P = 0.05, ** P = 0.01, ns = not significant.

Order	Family	Genus	Correlation coefficient	Significance value
Ephemeroptera	Baetidae	*Acentrella*	0.693	**
Trichoptera	Calamoceratidae	*Anisocentropus*	0.609	**
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	0.829	**
Ephemeroptera	Baetidae	*Centroptilum*	0.617	**
Trichoptera	Hydropsychidae	*Cheumatopsyche*	0.649	**
Trichoptera	Philopotamidae	*Chimarra*	0.625	**
Ephemeroptera	Leptophlebiidae	*Cryptopenella*	0.766	**
Trichoptera	Ecnomidae	*Ecnomus*	0.859	**
Ephemeroptera	Ephemeridae	*Ephemera*	0.624	**
Trichoptera	Helicopsychidae	*Helicopsyche*	0.573	**
Trichoptera	Calamoceratidae	*Heteroplectron*	0 609	**
Trichoptera	Hydropsychidae	Hydropsychidae sp.1	0.52	**
Trichoptera	Leptoceridae	*Leptocerus*	0.571	**
Ephemeroptera	Neoephemeridae	*Neoephemera*	0.681	**
Ephemeroptera	Heptageniidae	*Nixe*	0.69	**
Ephemeroptera	Baetidae	*Procloeon*	0.607	**
Trichoptera	Phryganeidae	*Ptilostomis*	0.495	**
Ephemeroptera	Heptageniidae	*Stenacron*	0.554	**
Ephemeroptera	Heptageniidae	*Stenonema*	0.613	**
Ephemeroptera	Leptophlebiidae	*Thraulodes*	0.497	**
Ephemeroptera	Leptophlebiidae	*Thraulus*	0.566	**
Ephemeroptera	Tricorythidae	*Tricorythodes*	0.664	**
Ephemeroptera	Leptophlebiidae	*Atalophlebioides*	0.427	*
Ephemeroptera	Baetidae	*Baetis*	0.485	*
Ephemeroptera	Leptophlebiidae	*Choroterpes*	0.56	*
Trichoptera	Hydropsychidae	*Macrostemum*	0.52	*
Ephemeroptera	Leptophlebiidae	*Minyphlebia*	0.466	*
Trichoptera	Odontoceridae	*Namamyia*	0.411	*
Plecoptera	Leuctridae	*Paraleuctra*	0.441	*
Trichoptera	Philopotamidae	*Wormaldia*	0.482	*
Plecoptera	Perlidae	*Agnetina*	0.074	ns
Trichoptera	Phryganeidae	*Agrypnia*	0.203	ns
Plecoptera	Nemouridae	*Amphinemura*	0.098	ns
Plecoptera	Perlidae	*Anacroneuria*	0.364	ns
Trichoptera	Limnephilidae	*Apatania*	0.289	ns
Ephemeroptera	Caenidae	*Caenis*	0.193	ns
Ephemeroptera	Baetidae	*Callibaetis*	0.247	ns
Trichoptera	Polycentropodidae	*Cernotina*	0.324	ns
Ephemeroptera	Heptageniidae	*Cinygma*	0.203	ns
Trichoptera	Hydropsychidae	*Diplectrona*	0.24	ns
Trichoptera	Dipseudopsidae	*Dipseudopsis*	0.379	ns
Trichoptera	Philopotamidae	*Dolophilodes*	0.137	ns
Plecoptera	Capniidae	*Eucapnopsis*	0.168	ns
Trichoptera	Calamoceratidae	*Ganonema*	0.286	ns

Appendix 5 (continued) Correlation coefficients and their significance value from ordination using binary EPT data set at genus level, Hin Lat stream. * P = 0.05, ** P = 0.01, ns = not significant.

Order	Family	Genus	Correlation coefficient	Significance value
Trichoptera	Goeridae	*Goera*	0.296	ns
Trichoptera	Hydropsychidae	*Hydropsyche*	0.242	ns
Ephemeroptera	Tricorythidae	*Leptohyphes*	0.32	ns
Ephemeroptera	Leptophlebiidae	*Leptophlebia*	0.388	ns
Trichoptera	Leptoceridae	*Nectopsyche*	0.347	ns
Trichoptera	Odontoceridae	*Nerophilus*	0.379	ns
Trichoptera	Polycentropodidae	*Neureclipsis*	0.328	ns
Trichoptera	Leptoceridae	*Oecetis*	0.144	ns
Plecoptera	Perlidae	*Paragnetina*	0.385	ns
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	0.259	ns
Plecoptera	Perlidae	*Perlinella*	0.302	ns
Trichoptera	Polycentropodidae	*Polycentropus*	0.346	ns
Plecoptera	Nemouridae	*Prostoia*	0 267	ns
Trichoptera	Polycentropodidae	*Pseudoneureclipsis*	0 288	ns
Trichoptera	Stenopsychidae	*Stenopsyche*	0.322	ns
Trichoptera	Psychomyiidae	*Tinodes*	0.257	ns
Trichoptera	Leptoceridae	*Triaenodes*	0.344	ns
Trichoptera	Xiphocentronidae	*Xiphocentron*	0.365	ns
Plecoptera	Nemouridae	*Zapada*	0.411	ns

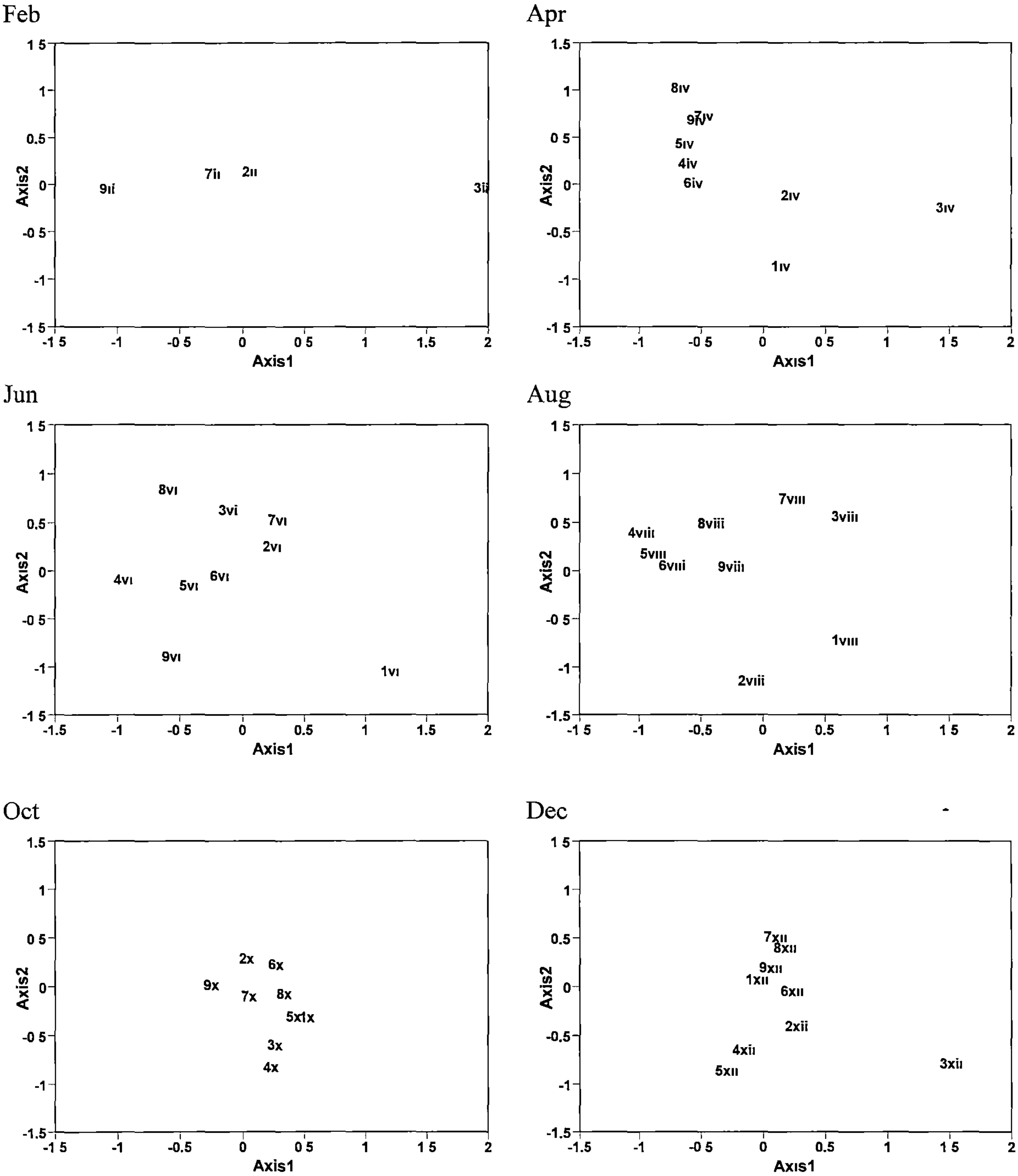
Appendix 6 Mean ± S.E density (individuals per sample) of each EPT genus found at each site at Yakraue stream, Nam Nao National Park, Thailand in 1998. Followed with the same letter was not significantly different (*p*=0.05).

Family	Density (imean ± S.E of individuals per sample)									Sig.	Significance value
	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9		
Centroptilum	0.7 ± 0.7ab	0.0 ± 0.0b	0.0 ± 0.0b	0.3 ± 0.3ab	0.2 ± 0.2ab	3.0 ± 3.0ab	1.2 ± 0.2a	1.8 ± 0.5a	0.3 ± 0.3ab	s	H_8 = 28.687, P = <0.001
Caenis	6.5 ± 1.6b	10.1 ± 2.2ab	7.1 ± 2.6b	13.9 ± 4.6ab	9.4 ± 1.9ab	11.8 ± 2.7ab	15.7 ± 3.5ab	24.9 ± 2.8a	15.8 ± 1.8ab	s	H_8 = 24.314, P = 0.002
Ephemera	0.2 ± 0.2ab	0.8 ± 0.4ab	1.5 ± 0.6ab	0.0 ± 0.0b	0.8 ± 0.4ab	0.0 ± 0.0b	3.2 ± 1.7a	1.8 ± 0.4a	0.8 ± 0.4ab	s	H_8 = 25.353, P = 0.001
Nixe	1.1 ± 0.3b	2.3 ± 0.3ab	1.5 ± 0.4bc	2.7 ± 0.7ab	2.4 ± 0.6ab	3.9 ± 1.6ab	4.8 ± 1.5ab	7.3 ± 1.6ac	8.7 ± 1.6a	s	H_8 = 28.628, P = <0.001
Stenonema	0.0 ± 0.0b	0.0 ± 0.0b	0.5 ± 0.3ab	2.3 ± 0.7ab	2.5 ± 1.1ab	0.3 ± 0.3ab	3.4 ± 0.8a	3.6 ± 1.9ab	5.8 ± 4.3ab	s	H_8 = 25.236, P = 0.001
Atalophlebia	0.0 ± 0.0b	4.9 ± 3.1ab	8.7 ± 3.6a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	9.2 ± 2.7a	0.0 ± 0.0b	0.0 ± 0.0b	s	H_8 = 38.763, P = <0.001
Choroterpes	8.8 ± 3.5ab	6.6 ± 2.2ab	3.2 ± 1.2b	29.3 ± 6.9a	15.4 ± 1.6ab	8.0 ± 3.2ab	5.7 ± 1.7ab	1.4 ± 0.5b	25.6 ± 2.9a	s	H_8 = 37.911, P = <0.001
Thraulus	2.2 ± 2 0ab	2.3 ± 0.6a	10.8 ± 8.5ab	0.3 ± 0.2ab	0.0 ± 0.0b	0.3 ± 0.2ab	2.3 ± 0.6ab	0.8 ± 0.5ab	0.0 ± 0.0b	s	H_8 = 23.039, P = 0.003
Neoephemera	0.0 ± 0 0b	6.7 ± 1.9a	1.1 ± 0.5ab	0.0 ± 0.0b	0.0 ± 0 0b	0.0 ± 0.0b	2.4 ± 0.6ab	3.0 ± 0.5a	0 6 ± 0.4ab	s	H_8 = 43.018, P = <0.001
Tricorythodes	0 0 ± 0.0b	1.1 ± 0.3ab	0.5 ± 0.2ab	0.3 ± 0.2ab	0.5 ± 0.2ab	0.2 ± 0.2ab	1.1 ± 0.4ab	1.3 ± 0.3ab	1.5 ± 0 2a	s	H_8 = 25.615, P = 0 001
Paraleuctra	0.0 ± 0.0b	1.1 ±0.4ab	0.2 ± 0.2b	5.8 ± 1.1a	7.1 ± 1.7a	2.4 ± 1.3ab	1.7 ± 0.5ab	2.5 ± 1.5ab	1 5 ± 0.2ab	s	H_8 = 35.400, P = <0.001
Amphinemura	1.0 ± 1.0ab	0.3 ± 0.2ab	0.0 ± 0.0b	3.6 ± 1.0a	3.4 ± 0.7a	1.3 ± 0.4ab	0.0 ± 0.0b	0.5 ± 0.5ab	0.3 ± 0.2ab	s	H_8 = 34.135, P = <0.001
Anacroneuria	1.3 ± 0.7ab	0.8 ± 0.4b	0.3 ± 0.2b	0.9 ± 0.3ab	0.9 ± 0.3ab	0.9 ± 0.3ab	1.5 ± 0.2ab	0.8 ± 0 3b	2.4 ± 0.4a	s	$F_{8,45}$ = 2.759, P = 0.014
Paragnetina	0.0 ± 0.0b	2.7 ± 1.5a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0 0b	0.0 ± 0.0b	0.2 ± 0.2ab	0.0 ± 0.0b	0.0 ± 0.0b	s	H_8 = 20.117, P = 0.010
Anisocentropus	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.2 ± 0.2ab	2.0 ± 0.7a	0.5 ± 0.2ab	0.2 ± 0.2ab	0.0 ± 0.0b	0.0 ± 0.0b	s	H_8 = 28.529, P = <0.001
Ecnomus	0.2 ± 0.2b	0.7 ± 0.3ab	0.5 ± 0.2ab	0.7 ± 0.2ab	0 2 ± 0.2b	0.7 ± 0.7ab	2.3 ± 0.6a	1.9 ± 0.4ab	1.0 ± 0.4ab	s	H_8 = 24.235, P = 0.002
Cheumatopsyche	0.2 ± 0.2a	2.4 ± 1.9ab	1.8 ± 0.5ab	1.9 ± 0.3ab	1.9 ± 1.0ab	1.8 ± 0.5ab	6.0 ± 0.8a	8.0 ± 2.9ab	12.3 ± 3.6a	s	H_8 = 30.504, P = <0.001
Hydropsyche	0.0 ± 0.0b	0.7 ± 0.7ab	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	1.3 ± 0.8ab	7.3 ± 5.8a	40.1 ± 26.3ab	s	H_8 = 24.396, P = 0.002
Macrostemum	0.3 ± 0.3b	0.5 ± 0.3b	0.7 ± 0.4bc	9.6 ± 2.8a	3.3 ± 0.8ab	3.2 ± 1.6ab	3.2 ± 1.3ab	1.3 ± 0.4ab	6.3 ± 1.3ac	s	H_8 = 31.311, P = <0.001
Chimarra	0.8 ± 0.7b	1.2 ± 0.7b	2.8 ± 0.9ab	5.5 ± 2.7ab	4.8 ± 1.6ab	1.8 ± 0.7ab	2.1 ± 1.2ab	1.9 ± 0.4ab	14.7 ± 2.9a	s	H_8 = 24.523, P = 0.002
Dolophilodes	0.8 ± 0 3ab	0.0 ± 0.0b	0.0 ± 0.0b	10.8 ± 5.2a	5.7 ± 2 9ab	2 5 ± 2.1ab	0.0 ± 0.0b	0.0 ± 0.0b	3.2 ± 1.3ab	s	H_8 = 31.356, P = <0.001
Wormaldia	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	8 4 ± 3.1a	4.7 ± 1.8ab	0.5 ± 0.2ab	0.0 ± 0.0b	0.0 ± 0.0b	0.2 ± 0.2b	s	H_8 = 40.083, P = <0.001
Pseudoneureclipsis	0.3 ± 0.3b	1.2 ± 0.4ab	0.5 ± 0.3ab	2.9 ± 0.8ab	2.1 ± 0.6ab	1.6 ± 0.2ab	3.4 ± 0.8a	1.5 ± 0.4ab	2.4 ± 0.6ab	s	H_8 = 22.900, P = 0.003
Xiphocentron	0.0 ± 0.0b	0.3 ± 0.2ab	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0 0 ± 0.0b	1.3 ± 0.4ac	1.3 ± 0.2a	0.2 ± 0.2bc	s	H_8 = 38.288, P = <0.001

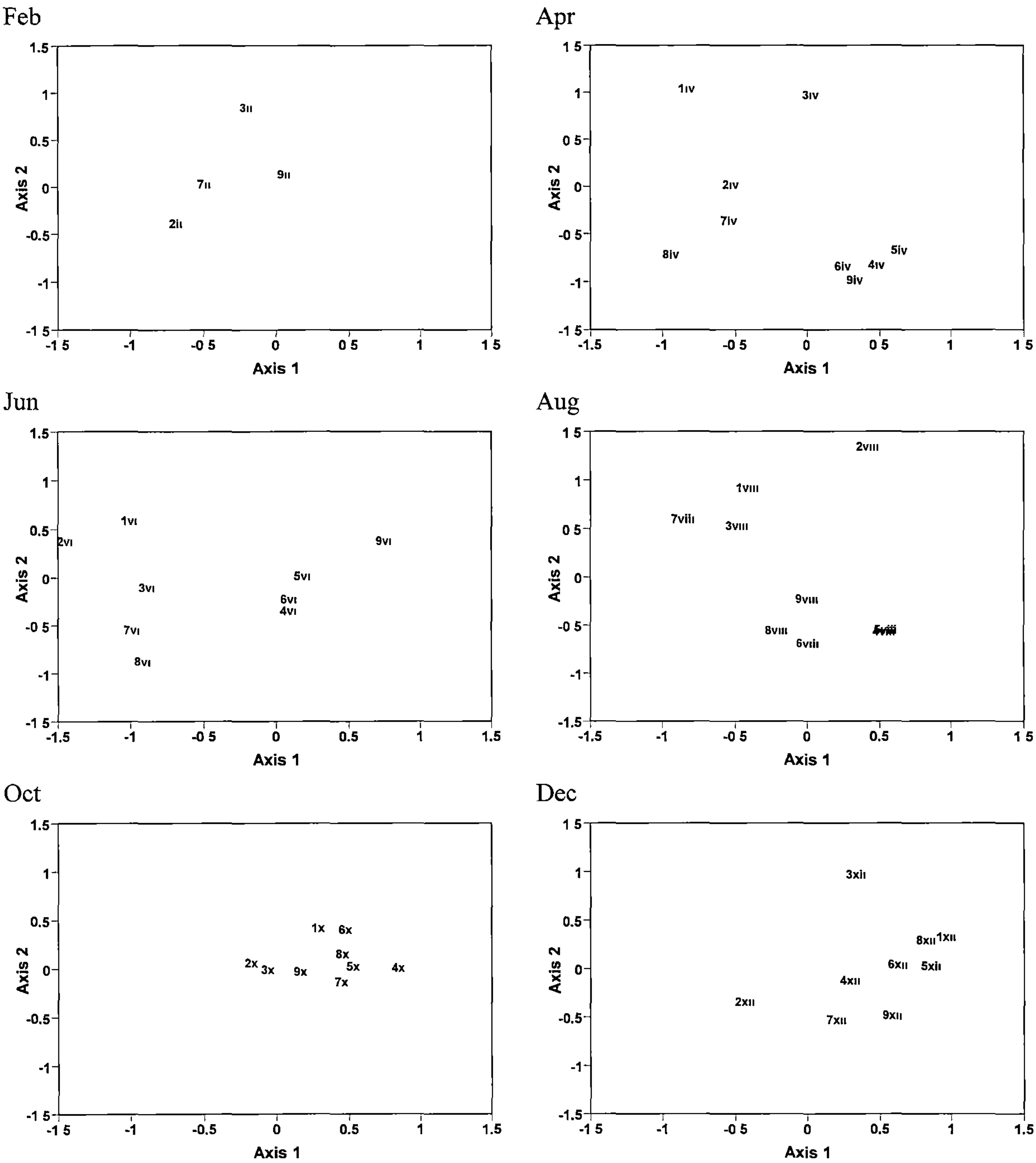
Appendix 7 Mean ± S.E. density (individuals per sample) of each genus in each month at Yakraue stream, Nam Nao National Park, Thailand, 1998. Followed with the same letter was not significantly different (*p*=0.05).

Genus	Mean Density (individuals per sample) ± S.E.						Sig.	Significance value
	February	April	June	August	October	December		
Centroptilum	0.0 ± 0.0b	0.0 ± 0.0b	1.2 ± 0.2ac	2.6 ± 1.0a	1.0 ± 0.7ab	0.2 ± 0.2bc	s	H_5 = 23.686, P = <0.001
Caenis	22.8 ± 1.8a	20.1 ± 0.8ac	15.2 ± 3.5ab	12.7 ± 1.4ab	5.8 ± 0.9b	8.6 ± 2.3bc	s	H_5 = 23.288, P = <0.001
Stenacron	0.0 ± 0.0b	0.0 ± 0.0b	3.3 ± 3.3ab	2.1 ± 0.8a	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 21.873, P = <0.001
Stenonema	0.0 ± 0.0b	5.6 ± 1.9a	1.3 ± 0.5ab	3.5 ± 0.7a	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 29.486, P = <0.001
Atalophlebia	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0 0b	11.8 ± 2.3a	0.0 ± 0.0b	0.2 ± 0.2b	s	H_5 = 31.140, P = <0.001
Choroterpes	22.3 ± 4.3a	8.0 ± 3.8ab	14.3 ± 2.8ac	6.6 ± 2.2ab	3.2 ± 0.6b	4.7 ± 1.1bc	s	H_5 = 20.827, P = <0.001
Cryptopenella	0.0 ± 0.0b	25.1 ± 3.9a	16.5 ± 5.4ab	32.0 ± 4.8a	8.9 ± 0.8ab	7.2 ± 1.1ab	s	H_5 = 26.362, P = <0 001
Thraulus	5.6 ± 3.0ab	3.7 ± 1.1a	1.9 ± 0 3ab	0.2 ± 0.2b	0.2 ± 0.2b	0.0 ± 0.0b	s	H_5 = 22.839, P = <0.001
Neoephemera	0.2 ± 0.2ab	2.9 ± 0.6a	2.8 ± 1.4ab	2.5 ± 0.8ab	5.3 ± 2.6ab	0.0 ± 0.0b	s	H_5 = 17.273, P = 0.004
Tricorythodes	0.0 ± 0.0b	0.8 ± 0.3ab	0.8 ± 0.3ab	0.9 ± 0.3ab	1.3 ± 0.2a	1.2 ± 0.3a	s	$F_{5,30}$ = 3.513, P = 0.013
Paraleuctra	0.7 ± 0.3b	6.2 ± 2.4ac	1.7 ± 1.2bc	6.5 ± 1.2a	1.8 ± 0.3ab	2.4 ± 0.5ab	s	H_5 = 20.673, P = <0.001
Amphinemura	0.0 ± 0.0b	2.9 ± 0 7ab	2.4 ± 1 2ab	2.6 ± 1.2ab	0.2 ± 0.2ab	3.4 ± 0.6a	s	H_5 = 17.372, P = 0.004
Paragnetina	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	2.8 ± 1.4a	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 21.780, P = <0.001
Macrostemum	2.7 ± 1.3ab	4.9 ± 1.4ab	1.4 ± 0.4b	11.6 ± 5.3a	6.5 ± 1.7ab	3.9 ± 0.7ab	s	H_5 = 14.105, P = 0.015
Dolophilodes	0.7 ± 0.7bc	0.0 ± 0.0b	15.3 ± 10.5ac	0.2 ± 0.2bc	0.0 ± 0.0b	5.2 ± 1.1a	s	H_5 = 25.614, P = <0.001
Dolophilus	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	0.5 ± 0.2a	0.0 ± 0.0b	0.0 ± 0.0b	s	H_5 = 15.909, P = 0.007
Wormaldia	0.0 ± 0.0b	3.9 ± 1.5ab	0.0 ± 0.0b	9.6 ± 5.1a	0.0 ± 0.0b	0.0 ± 0.0b		H_5 = 30.224, P = <0.001
Pseudoneureclipsis	2.4 ± 1.1ab	3.1 ± 0.6a	2.1 ± 0.5ab	2.2 ± 0.7ab	0.5 ± 0.2b	1.7 ± 0.5ab	s	H_5 = 12.169, P = 0.033

Appendix 8 Ordination of Yakraue sites based on EPT count data set for each month. 3 dimensional solution, stress = 0.144.



Appendix 9 Ordination of Yakraue sites based on binary EPT data set. 3 dimensional solution, stress = 0.144.



Appendix 10 Correlation coefficients and their significance value from ordination using count EPT data set of Yakraue stream, Nam Nao Nation Park, Thailand. ns not significant, * P<0.05, ** P<0.01.

Taxa			Correlation coefficient	Significance value
Order	Family	Genus		
Ephemeroptera	Caenidae	*Caenis*	0.789	**
Ephemeroptera	Heptageniidae	*Stenonema*	0.542	**
Ephemeroptera	Leptophlebiidae	*Choroterpes*	0.703	**
Ephemeroptera	Leptophlebiidae	*Cryptopenella*	0.72	**
Ephemeroptera	Leptophlebiidae	*Thraulus*	0.644	**
Ephemeroptera	Tricorythidae	*Tricorythodes*	0.536	**
Plecoptera	Nemouridae	*Amphinemura*	0.434	**
Trichoptera	Hydropsychidae	*Macrostemum*	0.556	**
Ephemeroptera	Baetidae	*Baetis*	0.416	*
Ephemeroptera	Baetidae	*Procloeon*	0.387	*
Ephemeroptera	Heptageniidae	*Nixe*	0.449	*
Ephemeroptera	Neoephemeridae	*Neoephemera*	0.408	*
Plecoptera	Leuctridae	*Paraleuctra*	0.473	*
Plecoptera	Perlidae	*Anacroneuria*	0.491	*
Trichoptera	Ecnomidae	*Ecnomus*	0.526	*
Trichoptera	Goeridae	*Goera*	0.405	*
Trichoptera	Hydropsychidae	*Cheumatopsyche*	0.474	*
Trichoptera	Philopotamidae	*Chimarra*	0.44	*
Trichoptera	Polycentropodidae	*Pseudoneureclipsis*	0.517	*
Ephemeroptera	Baetidae	*Acentrella*	0.281	ns
Ephemeroptera	Baetidae	*Centroptilum*	0.196	ns
Ephemeroptera	Baetidae	*Cloeon*	0.313	ns
Ephemeroptera	Ephemeridae	*Ephemera*	0.399	ns
Ephemeroptera	Heptageniidae	*Stenacron*	0.338	ns
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	0.29	ns
Ephemeroptera	Leptophlebiidae	*Choroterpides*	0.197	ns
Ephemeroptera	Leptophlebiidae	*Leptophlebia*	0.237	ns
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	0.098	ns
Ephemeroptera	Polymitarcyidae	*Povilla*	0.151	ns
Ephemeroptera	Potamanthidae	*Anthopotamus*	0.16	ns
Ephemeroptera	Tricorythidae	*Leptohyphes*	0.315	ns
Plecoptera	Nemouridae	*Zapada*	0.168	ns
Plecoptera	Perlidae	*Paragnetina*	0.397	ns
Trichoptera	Calamoceratidae	*Anisocentropus*	0.266	ns
Trichoptera	Calamoceratidae	*Heteroplectron*	0.373	ns
Trichoptera	Glossosomatidae	*Protoptila*	0.285	ns
Trichoptera	Helicopsychidae	*Helicopsyche*	0.355	ns
Trichoptera	Hydropsychidae	*Hydropsyche*	0.313	ns
Trichoptera	Leptoceridae	*Leptocerus*	0.053	ns
Trichoptera	Leptoceridae	*Triaenodes*	0.083	ns
Trichoptera	Limnephilidae	*Allomyia*	0.144	ns
Trichoptera	Philopotamidae	*Dolophilodes*	0.346	ns
Trichoptera	Philopotamidae	*Dolophilus*	0.291	ns
Trichoptera	Philopotamidae	*Wormaldia*	0.374	ns
Trichoptera	Polycentropodidae	*Neureclipsis*	0.171	ns
Trichoptera	Polycentropodidae	*Polycentropus*	0.255	ns
Trichoptera	Rhyacophilidae	*Rhyacophila*	0.212	ns
Trichoptera	Xiphocentronidae	*Xiphocentron*	0.394	ns

Appendix 11 Correlation coefficients and their significance value from ordination using binary EPT data set of Yakraue stream, Nam Nao Nation Park, Thailand. ns not significant, * P<0.05, ** P<0.01.

Taxa			Correlation coefficient	Significance value
Order	**Family**	**Genusd**		
Trichoptera	Hydropsychidae	*Cheumatopsyche*	0.782	**
Ephemeroptera	Neoephemeridae	*Neoephemera*	0.769	**
Ephemeroptera	Leptophlebiidae	*Thraulus*	0.736	**
Trichoptera	Hydropsychidae	*Macrostemum similior*	0.715	**
Plecoptera	Nemouridae	*Amphinemura*	0.704	**
Trichoptera	Polycentropodidae	*Pseudoneureclipsis*	0.659	**
Plecoptera	Leuctridae	*Paraleuctra*	0.653	**
Trichoptera	Ecnomidae	*Ecnomus*	0.647	**
Ephemeroptera	Ephemeridae	*Ephemera*	0.631	**
Trichoptera	Philopotamidae	*Chimarra*	0.625	**
Ephemeroptera	Tricorythidae	*Tricorythodes*	0.622	**
Trichoptera	Philopotamidae	*Wormaldia*	0.622	**
Ephemeroptera	Heptageniidae	*Stenonema*	0.620	**
Plecoptera	Perlidae	*Anacroneuria*	0.617	**
Ephemeroptera	Baetidae	*Procloeon*	0.587	**
Trichoptera	Xiphocentronidae	*Xiphocentron*	0.576	**
Ephemeroptera	Heptageniidae	*Nixe*	0.565	**
Trichoptera	Calamoceratidae	*Anisocentropus*	0.560	**
Trichoptera	Goeridae	*Goera*	0.505	**
Trichoptera	Calamoceratidae	*Heteroplectron*	0.497	**
Ephemeroptera	Baetidae	*Baetis*	0.460	*
Trichoptera	Helicopsychidae	*Helicopsyche*	0.447	*
Ephemeroptera	Leptophlebiidae	*Atalophlebia*	0.430	ns
Ephemeroptera	Leptophlebiidae	*Leptophlebia*	0.428	*
Ephemeroptera	Baetidae	*Cloeon*	0.417	ns
Ephemeroptera	Baetidae	*Acentrella*	0.408	*
Plecoptera	Perlidae	*Paragnetina*	0.397	*
Ephemeroptera	Leptophlebiidae	*Cryptopenella*	0.391	*
Ephemeroptera	Leptophlebiidae	*Paraleptophlebia*	0.359	ns
Ephemeroptera	Caenidae	*Caenis*	0.340	ns
Ephemeroptera	Leptophlebiidae	*Choroterpes*	0.335	ns
Trichoptera	Philopotamidae	*Dolophilodes*	0.330	ns
Trichoptera	Hydropsychidae	*Macrostemum fenestratum*	0.326	ns
Trichoptera	Limnephilidae	*Allomyia*	0.303	ns
Trichoptera	Philopotamidae	*Dolophilus*	0.290	ns
Trichoptera	Rhyacophilidae	*Rhyacophila*	0.283	ns
Ephemeroptera	Leptophlebiidae	*Choroterpides*	0.273	ns
Trichoptera	Polycentropodidae	*Polycentropus*	0.265	ns
Ephemeroptera	Caenidae	*Caenis*	0.261	ns
Trichoptera	Glossosomatidae	*Protoptila*	0.261	ns
Ephemeroptera	Baetidae	*Centroptilum*	0.257	ns
Trichoptera	Leptoceridae	*Triaenodes*	0.234	ns
Trichoptera	Polycentropodidae	*Neureclipsis*	0.233	ns
Trichoptera	Hydropsychidae	*Hydropsyche*	0.232	ns
Plecoptera	Nemouridae	*Zapada*	0.229	ns
Ephemeroptera	Tricorythidae	*Leptohyphes*	0.214	ns
Ephemeroptera	Potamanthidae	*Anthopotamus*	0.210	ns
Ephemeroptera	Heptageniidae	*Stenacron*	0.206	ns
Ephemeroptera	Polymitarcyidae	*Povilla*	0.205	ns
Trichoptera	Leptoceridae	*Leptocerus*	0.121	ns