CHAPTER V. RESULTS

A. PHYSICO-CHEMICAL PROPERTIES OF THE STREAMS

The physico-chemical properties of the two streams are presented in Table 1. Alkalinity and BOD_5 were only measured in the rainy season, hence values are missing during the dry season. Similarly, only stations 1 and 2 of Doi Chang Kian stream (DCK) and station 2 of Ban Nong Hoi stream (BNH) have complete data for the two seasons as other sites were not studied until July.

Water temperatures in the first two stations of DCK stream were similar and a bit colder than the third station. In BNH stream, water got warmer downstream and generally warmer than DCK stream.

pH ranged from near neutrality to basic in all stations of both sites while conductivity was very high in all stations in BNH stream and tended to decrease slightly downstream. By contrast, conductivity in DCK stream was very low (<100 μS/cm) although station 1 has 2 times higher conductivity than stations 2 and 3.

There was no marked difference in the dissolved oxygen concentrations in all stations, each having a well-oxygenated environment. The same was observed for the calculated percent oxygen saturation where all stations had values more than 90%.

Nitrate was relatively lower in the first two stations of DCK stream while stations 1 and 3 of BNH and DCK streams, respectively, had more or less the same nitrate contents

Table 1. Physico-chemical properties of Doi Chang Kian and Ban Nong Hoi streams in two seasons.

Parameters	DCK1		DCK2		DCK3	BNH1	BNH2		BNH3
	D	R	D	R	R	R	D	R	R
DO mg/l	7.80	7.80	7.50	7.60	8.00	7.80	7.70	7.80	7.60
% O Sat	96.5	98.4	92.8	95.9	99.6	101	97.6	98.9	96.7
pH	7.36	8.68	7.63	8.43	8.74	8.60	7.20	8.79	8.87
Cond µS/cm	98.0	73.8	34.2	32.7	33.0	358	669	349	317
WTem °C	18.0	19.5	18.0	19.5	20.0	21.0	21.0	21.5	23.0
NO_3^- mg/l	0.01	0.60	0.18	0.70	1.10	1.00	1.00	1.90	1.90
PO_4^{2} mg/l	0.07	0.13	0.10	0.09	0.04	0.20	0.02	0.42	0.09
Alka meq/l	-	1.04	-	1.02	1.02	3.52	-	3.48	3.36
BOD_5 mg/l	-	0.00	-	0.20	0.40	0.30	-	0.70	0.60

D – Dry Season R – Rainy Season

and were a bit higher than the first two stations. Notable were the nitrate concentrations detected in stations 2 and 3 of BNH stream which were two folds higher than the rest of the stations.

Phosphate contents on the other hand were very low except in station 2 of BNH stream which had 0.42 mg/l phosphate contents, relatively higher in comparison to the other stations.

Alkalinity in DCK stream was low and more or less uniform in all stations. BNH stream also had uniform alkalinity except that it was 3 times higher than DCK stream and showed a slight decrease downstream.

BOD_5 was very low except in station 2 and 3 of BNH stream which registered relative high BOD_5 values in comparison to the other stations.

Seasonal changes of the physico-chemical properties of the two streams were also evident. pH tended to increase in the rainy season. The same trend was observed for nitrate and phosphate which showed an increase in the rainy season. By contrast, conductivity was higher in the dry season and declined in the rainy season. The dissolved oxygen did not show any marked changes between dry and rainy seasons.

1. DAY-NIGHT FLUCTUATIONS IN SELECTED PHYSICAL PARAMETERS

Water temperature, dissolved oxygen, percent oxygen saturation and conductivity were registered on a 4-hourly basis for 24-hour period in the three selected stations, namely: stations 1 and 2 of DCK stream and station 2 of BNH stream, the same time invertebrate diel periodicity investigation was conducted.

Figure 11 shows that water temperatures were higher in the day time and decreased in the early evening, with the minimum temperatures recorded in the early morning. This was observed in all stations. Stations 1 and 2 of DCK stream registered the same temperatures at all times for the whole 24-hour investigation. Temperature in station 2 of BNH stream was generally higher.

The dissolved oxygen concentration was high in the midnight and lowest in the late afternoon (Figure 12). Nevertheless, there was no remarkable difference in DO concentrations for 24-hour period and the increase was very minimal. The percent oxygen saturation on one hand tended to decrease in the early morning, but again like DO, differences between stations were very minimal (Figure 13).

Conductivity by contrast did not show any clear pattern of changes during the

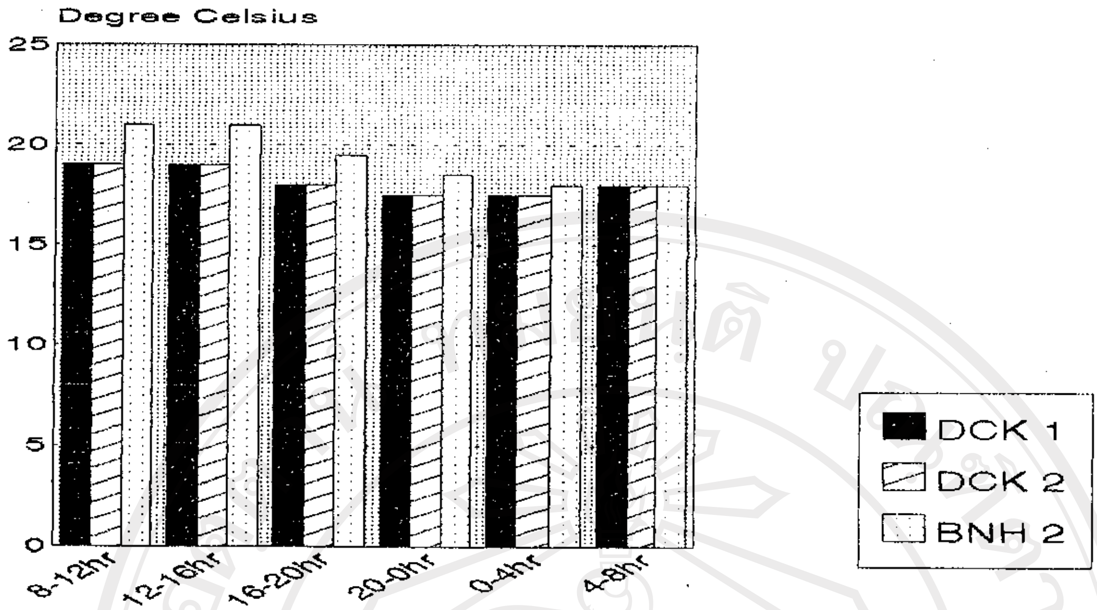


Fig. 11. Day-night changes in water temperature in stations 1 and 2 of Doi Chang Kian stream and station 2 of Ban Nong Hoi stream (March 10, 1993).

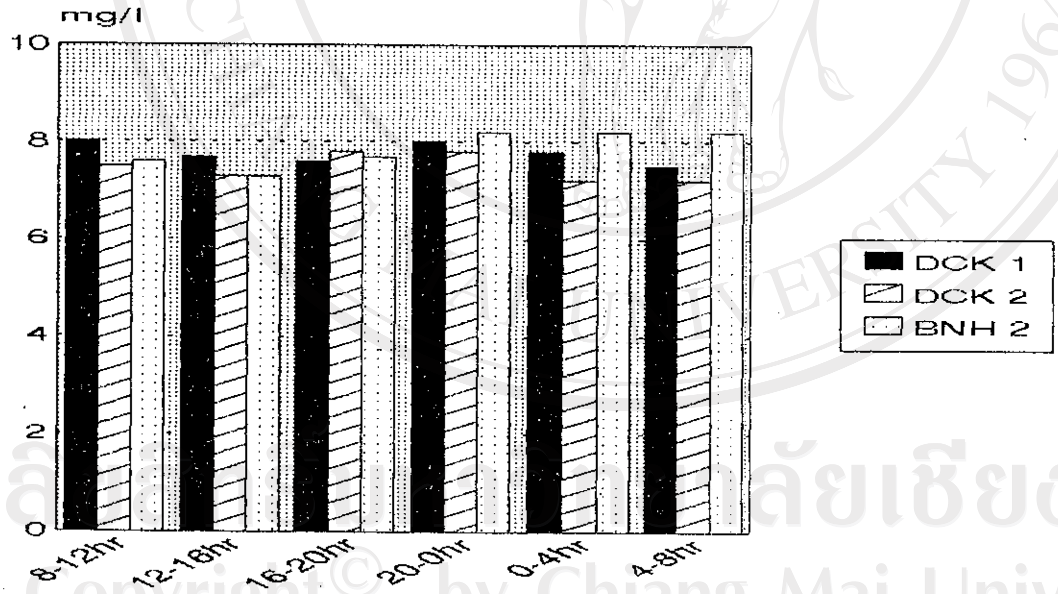


Fig. 12. Day-night changes in dissolved oxygen in stations 1 and 2 of Doi Chang Kian stream and station 2 of Ban Nong Hoi stream (March 10, 1993).

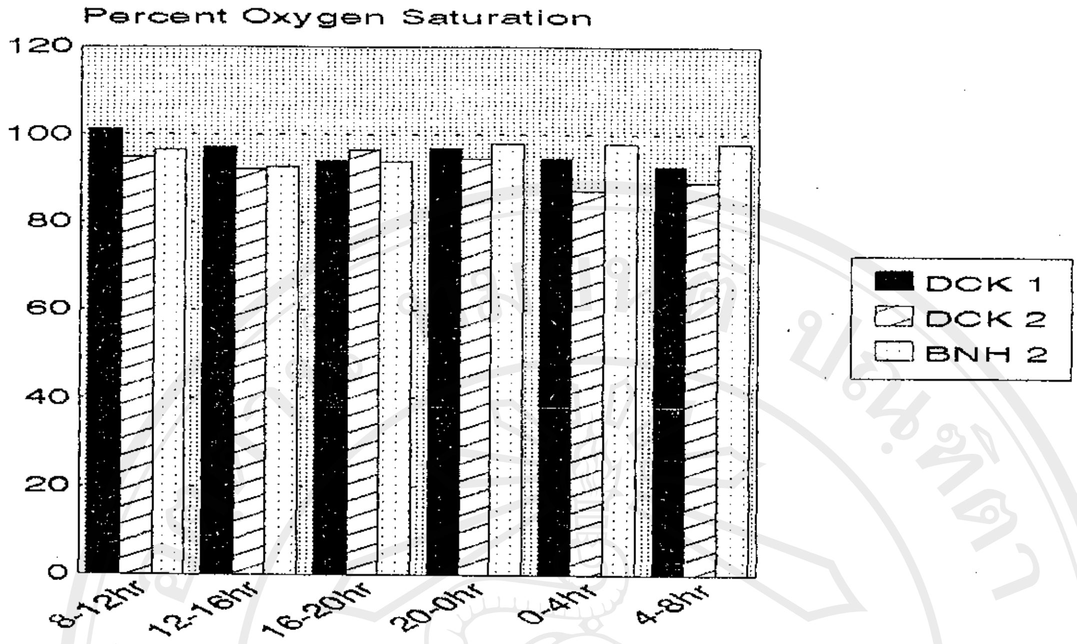


Fig. 13. Day-night changes in percent oxygen saturation in stations 1 and 2 of Doi Chang Kian stream and station 2 of Ban Nong Hoi stream (March 10, 1993).

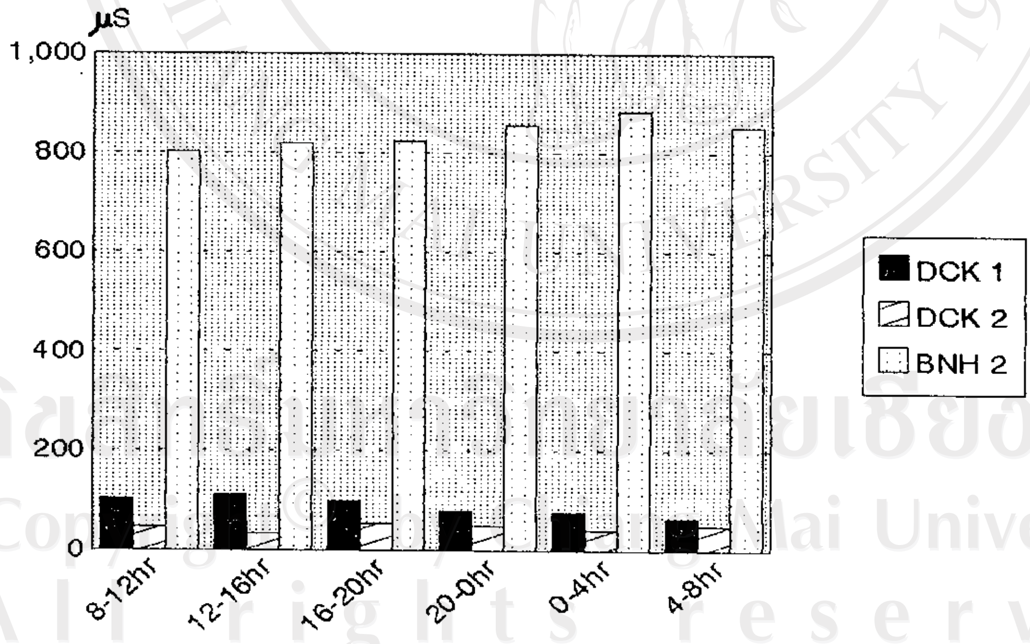
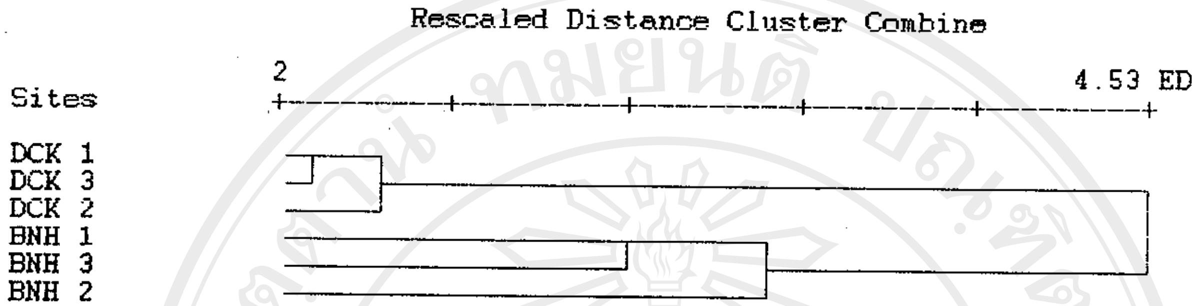


Fig. 14. Day-night changes in conductivity in stations 1 and 2 of Doi Chang Kian stream and station 2 of Ban Nong Hoi stream (March 10, 1993).

Fig. 15. Similarity of different stations in Doi Chang Kian and Ban Nong Hoi streams based on physico-chemical properties.



whole investigation. While conductivity in station 2 of BNH stream tended to increase in the midnight until in the early morning, the reverse was true for the two stations of DCK stream (Figure 14). As in DO, the fluctuation was also minimal.

2. SIMILARITY OF THE TWO STREAMS BASED ON PHYSICO-CHEMICAL PROPERTIES

A cluster analysis of the different stations in both sites based on their physico-chemical properties yielded two separate groups of streams (Figure 15). All stations in DCK stream were grouped together while the three stations in BNH stream were placed in a separate group.

B. BIOLOGICAL RESULTS

1. MACROINVERTEBRATES COLLECTED

A total of 57, 50 and 46 macroinvertebrate families were collected in the drift net in stations 1, 2 and 3 of DCK stream while 59, 62 and 26 families were recovered in the Surber sampler (Table 2). Drift net and Surber sampler in stations 1, 2 and 3 of BNH stream netted 46, 49 and 32 and 34, 35 and 21 macroinvertebrate families, respectively. Decapoda (Reptantia), Ostracoda, Hydracarina, Nematomorpha and Nematoda were identified higher than family level due to the difficulty in identification.

The species composition of the drift samples was very similar to that of benthos collected from Surber sampler. More families however, were collected in the drift net, except in stations 1 and 2 of DCK stream where slightly more families were recovered in the Surber sampler. Macroinvertebrates collected were composed of the phyla Annelida,

Table 2. Macroinvertebrate families collected by the Surber and drift net in Doi Chang Kian and Ban Nong Hoi streams.

	DCK 1		DCK 2		DCK 3		BNH 1		BNH 2		BNH 3	
Order/Family	DN	SS	DN	SS	DN	SS	DN	SS	DN	SS	DN	SS
Tricladida												
Planaridae (adult)	x	x	x	x		x	x	x				x
Temnocephalidea	x											
Nematoda	x	x	x	x	x	x			x	x		
Nematomorpha	x			x	x	x				x		x
Oligochaeta												
Lumbricidae	x	x	x	x			x	x	x	x		
Naididae	x	x	x	x	x	x		x	x	x	x	x
Tubificidae	x	x		x	x				x	x	x	x
Hirudinea												
Erpobdellidae								x				x
Hirudidae											x	
Gastropoda												
Lymnaeidae							x		x		x	x
Planorbidae											x	x
Thiaridae	x						x		x		x	x
Bivalvia												
Corbiculidae	x	x	x	x								
Hydracarina	x	x	x	x	x		x	x	x			
Ostracoda (adult)	x	x	x	x		x	x		x	x		
Decapoda-Reptantia	x	x	x	x			x	x				
Ephemeroptera												
Baetidae (larvae)	x	x	x	x	x	x	x	x	x	x	x	x
Caenidae (larvae)	x	x	x	x					x	x	x	x
Ephemeridae (larvae)	x	x		x	x							
Heptageniidae (larvae)	x	x	x	x	x	x	x	x	x	x	x	
Leptophlebiidae (larvae)	x	x	x	x	x	x	x	x	x		x	x
Tricorythidae (larvae)		x		x								
Odonata												
Aeshnidae (larvae)	x	x	x	x					x	x		
Calopterygidae (larvae)	x	x	x	x	x				x			
Coenagrionidae (larvae)			x									
Cordulegastridae (larvae)	x			x		x		x				
Corduliidae (larvae)				x					x	x		
Gomphidae (larvae)	x	x	x	x	x	x	x		x		x	x
Lestidae (larvae)		x					x					
Libellulidae (larvae)			x	x	x						x	
Protoneuridae (larvae)								x				
Plecoptera												
Capniidae (larvae)		x										
Leuctridae (larvae)	x	x	x	x			x					
Nemouridae (larvae)	x	x	x	x			x	x	x	x		
Peltoperlidae (larvae)	x	x	x	x	x		x	x				
Perlidae (larvae)	x	x	x	x	x	x	x	x	x	x	x	
Hemiptera												
Belastomatidae (adult)						x					x	
Gerridae (adult)	x	x	x	x	x	x	x		x	x		x
Hebridae (adult)				x								
Hydrometridae (adult)		x		x								
Mesoveliidae (adult)	x		x			x	x					
Naucoridae (adult)								x				

Notonectidae (adult)			x									
Pleidae (adult)	x				x							
Veliidae (adult)	x	x	x	x	x		x		x			
Megaloptera												
Corydalidae (larvae)		x	x	x	x			x	x		x	
Blattaria												
Epilampridae (adult)	x	x	x	x	x		x		x			
Coleoptera												
Chrysomelidae (larvae)	x	x		x			x		x		x	
Curculionidae (adult)	x				x		x		x			
Dytiscidae (adult & larvae)	x	x		x	x		x	x	x	x	x	
Dryopidae (adult & larvae)	x	x	x	x	x	x			x			
Elmidae (adult & larvae)	x	x	x	x	x	x	x	x	x	x	x	
Gyrinidae (adult & larvae)	x	x	x	x					x			
Haliplidae (larvae)					x				x			
Helodidae (larvae)	x	x	x	x	x	x	x	x	x	x	x	
Hydrophilidae (adult & larvae)	x	x	x	x	x	x	x	x	x	x	x	x
Lampyridae (larvae)							x		x		x	
Limnichidae (adult & larvae)					x							
Noteridae (larvae)					x		x					
Ptilodactylidae (larvae)		x		x				x				
Psephenidae (adult & larvae)		x	x	x			x	x				
Trichoptera												
Brachycentridae (larvae)	x	x		x			x					
Helicopsychidae (larvae)		x		x								
Hydropsychidae (larvae)	x	x	x	x	x	x	x	x	x	x	x	x
Lepidostomatidae (larvae)	x	x	x	x	x	x		x	x	x		
Leptoceridae (larvae)					x		x	x				
Limnephilidae (larvae)	x	x	x	x	x		x	x		x		
Odontoceridae (larvae)	x	x	x	x	x		x	x				
Philopotamidae (larvae)	x	x	x	x	x							
Polycentropodidae (larvae)	x	x	x	x			x	x				
Rhyacophilidae (larvae)		x		x		x		x				
Lepidoptera												
Noctuidae (larvae)									x			
Pyralidae (larvae)			x				x		x	x	x	
Diptera												
Athericidae (larvae)	x	x	x	x	x	x		x				
Blephariceridae (larvae)									x	x		
Chaoboridae (larvae)											x	
Chironomidae (larvae & pupae)	x	x	x	x	x	x	x	x	x	x	x	x
Ceratopogonidae (larvae)	x	x	x	x	x	x			x	x	x	
Culicidae (larvae)									x	x	x	
Dixidae (larvae)	x	x	x	x	x		x					
Empididae (larvae)	x	x	x	x	x		x	x	x	x		x
Ephydridae (larvae)	x	x	x	x	x		x		x	x	x	
Muscidae (larvae)	x	x	x	x	x		x		x	x	x	
Psychodidae (larvae)	x	x	x	x	x		x		x	x	x	x
Simuliidae (larvae & pupae)	x	x	x	x	x	x	x	x	x	x	x	x
Stratiomyidae (larvae)	x	x			x		x		x	x	x	
Syrphidae (larvae)	x				x					x		
Tabanidae (larvae)		x		x						x		
Thaumaleidae (larvae)												
Tipulidae (larvae)	x	x	x	x	x	x	x	x	x	x	x	x
Total	57	59	50	62	46	26	46	34	49	35	32	21

Legend:

DN = Drift Net

SS = Surber sampler

Nematoda, Platyhelminthes, Mollusca and Arthropoda. The phylum Annelida was represented by families Tubificidae, Naididae, Lumbricidae, Hirudinidae and Erpobdellidae. Planaridae represented phylum Platyhelminthes which was very abundant in stations 1 and 2 of DCK stream. For Mollusca, gastropods belonging to families Thiaridae, Planorbidae and Lymnaeidae were found in all stations in BNH stream and in a very small number in station 1 of DCK stream. By contrast, the bivalve of family Corbiculidae was only recorded in stations 1 and 2 of DCK stream. The phylum Arthropoda was composed of Insecta, Hydracarina and Crustacea. Ostracoda and Decapoda represented Crustacea with the former abounding in stations 1 and 2 of DCK stream. Insects were by far the most dominant macroinvertebrates collected in all stations in both sites. Ten insect orders were collected. Orders Ephemeroptera, Diptera, Trichoptera, Coleoptera and Plecoptera composed majority of the insects, while Odonata, Hemiptera, Megaloptera, Lepidoptera and Blattaria were randomly collected in very low number.

Insect families such as Baetidae, Hydropsychidae, Tipulidae, Chironomidae, Simuliidae and Hydrophilidae were collected in all sites for both methods employed. Tricorythidae, Helicopsychidae, Rhyacophilidae, Tabanidae, Ptilodactylidae, Protoneuridae and Erpobdellidae were only recovered in the Surber. By contrast, Noteridae, Haliplidae, Limnichidae and Notonectidae were only collected in the drift net. In all cases, these families which were recovered only in one method were rare in all stations, except for Tabanidae which was abundant in stations 1 and 2 of DCK stream.

Twelve macroinvertebrate families were only recovered in DCK stream while 11 were only collected in BNH stream in both methods. Of the 12 taxa collected in DCK stream, Capniidae was only found in station 1, Notonectidae, Hebridae and Coenagrionidae in station 2 and Limnichidae only in station 3. Families Tricorythidae, Helicopsychidae, Hydrometridae and the bivalve Corbiculidae were only recovered in the first two stations of DCK stream. By contrast, Philopotamidae and Pleidae were only collected in stations 1 and 3 while Ephemeridae was common in all stations.

Of the 11 taxa only recovered in BNH stream, Naucoridae and Protoneuridae were only collected in station 1, Blephariceridae and Noctuidae in station 2 and Chaoboridae, Hirudinidae and Planorbidae only in station 3. Culicidae was collected in stations 2 and 3 while the Erpobdellidae and aquatic Asian Lampyridae were only netted in stations 1 and 3. The only common taxon in all stations was the gastropod, Lymnaeidae.

Sixteen taxa common in DCK stream and can only be found in station 1 of BNH stream but not in the two downstream stations were recovered. These included the Trichopteran families Odontoceridae, Brachycentridae, Leptoceridae, Polycentropodidae and Rhyacophilidae, the Dipteran Athericidae, the Plecopteran Peltoperlidae and Leuctridae, Psephenidae, Noteridae and Ptilodactylidae in the Coleopteran order, Mesoveliidae and Naucoridae of the order Hemiptera, the Odonatan Lestidae and Cordulegastridae and the Decapoda represented by crab (Reptantia).

2. DAY-NIGHT FLUCTUATIONS IN DRIFT

This observation was done only in three selected sites in March 10. The selection of sites was based primarily on the accessibility and easiness in walking and collecting the drift net during the night time and their representation from both disturbed and relatively pristine streams. That is, Stations 1 and 2 of DCK stream were selected as they are separate streams and station 2 of BNH stream to represent the disturbed site.

Figure 16 shows the day-night fluctuations in drift expressed in N/m^3 per 4-hour sample in three selected sites for the whole 24-hour period. Drift index was used in showing the diel periodicity instead of the total number of drifting organisms, as drift is affected by the volume of water flowing through the drift net during the whole duration of the observation. It can be seen that all sites registered drift maxima during the early hours of the night or soon after dusk. Darkness was approximately from 18hr to 6hr during the sampling. The remarkable increase in drift was very much evident in station 1 of DCK stream, where a very high drift was recorded at 20hr. Station 2 of BNH stream also showed the same trend although the increase was of lower magnitude. On the other hand, station 2 of DCK stream with a very much reduced flow at the time of sampling, exhibited a continuous fluctuation of drift for the whole 24-hour sampling period, although there was also a slight increase in drift at 20hr. A decline in drift in the morning was observed in all stations except in station 2 of DCK stream which had a second peak at 4 hr due to Chironomidae after which it also declined. Table 3 illustrates that drift sizes and indices were generally higher in the night time (from 16hr-4hr) than during the day time (4hr-16hr) except in station 2 of DCK stream which had the same number of drift and indices during the day and night time.

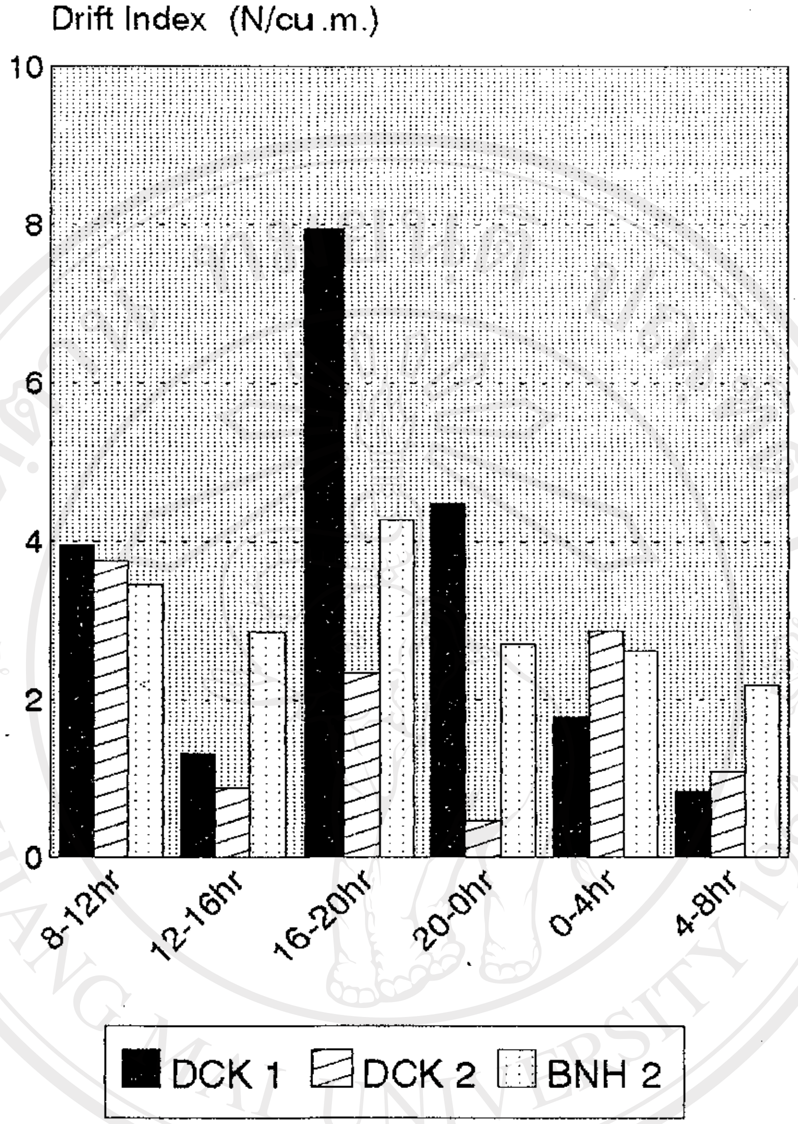


Fig. 16. Day-night changes in natural drift in stations 1 and 2 of Doi Chang Kian stream and station 2 of Ban Nong Hoi stream (March 10, 1993).

Table 3. Total, percentages and drift indices[1] of drifting invertebrates during the night and day time in Doi Chang Kian and Ban Nong Hoi streams.

Site	Night	Day
DCK 1	566 (75%) [3.33] {59%}	188 (25%) [2.36] {41%}
DCK 2	109 (50%) [1.89] {50%}	110 (50%) [1.91] {50%}
BNH 2	312 (53%) [3.20] {53%}	276 (47%) [2.83] {47%}

[1] Figures in bracket

Table 4. Day-night drift of selected invertebrate families[1].

Family	Night	Day
Baetidae	167 (61%) [1.54] {53%}	106 (39%) [1.36] {47%}
Lepidostomatidae	106 (69%) [0.98] {62%}	48 (31%) [0.61] {38%}
Hydropsychidae	85 (75%) [0.78] {68%}	29 (25%) [0.37] {32%}
Chironomidae	211 (67%) [1.95] {59%}	105 (33%) [1.34] {41%}
Simuliidae	98 (38%) [0.90] {30%}	162 (62%) [2.07] {70%}

[1] Taken from the total number of individuals for each family in the selected sites per night or day netting .

Figures in bracket are percentages and drift indices.

Night time was from 16-20hr + 20-0hr + 0-4hr

Day time was from 4-8hr + 8-12hr + 12-16hr

The bulk of the drift was dominated by Baetidae, Lepidostomatidae and Chironomidae which comprised 22, 17 and 17% of the total drift, respectively in station 1 of DCK stream, and 32, 10 and 15% in station 2. By contrast, Simuliidae and Chironomidae dominated the drift in station 2 of BNH stream, comprising 42 and 27%, respectively of the total drift. Baetidae, Lepidostomatidae, Hydropsychidae and Chironomidae exhibited high drift numbers and indices in the night with the highest numbers recorded between 20hr to 0hr. Simuliidae on one hand, recorded high drift numbers and indices during day time (Table 4). Interestingly, more number of families was collected in the evening except in station 2 of DCK stream which did not show an increase.

3. MONTHLY VARIATION IN THE DRIFT

Six sets of samples were collected in stations 1 and 2 of DCK and station 2 of BNH stream and the rest had only 5 as they were added later in July. Sampling was carried out at 3-week intervals starting in July to October 1993.

Figure 17 shows the monthly variation in drift in BNH stream in N/m^3. Drift index was very high in March as observed in station 2 and lowest in September 5 in station 1 at the onset of the heavy rain for the month of September when the flow regime started to increase, and in October 2 in stations 2 and 3 at the peak of the rainy season, respectively when the current flow and water discharge were at their peaks (Figure 18). The high drift index in March was dominated by Chironomidae and Simuliidae. It should be emphasized here that it was already raining, days before the September 5 sampling while the last week of September was the peak of the rainy season. Nevertheless, an increasing trend of the drift index was observed in the early winter (October 22) in stations 1 and 2. This increase in station 1 was due mainly to Baetidae while that of station 2 was accounted to Chironomidae which comprised 81% of the total drift at this time.

DCK stream also registered a very high drift index in March as in BNH 2, it then declined in July when the second sampling was done (Figure 19). This remarkable high drift in March was attributed to Baetidae, Lepidostomatidae and Chironomidae. Stations 1 and 3 reflected the same trend in drift index which tended to decline towards the rainy season except on September 3 sampling where an increase of the drift index was observed, which coincided with the coming of the first rain causing a slight increase in flow regime. The increase in station 1 was due to Chironomidae and Ostracoda while that of station 3

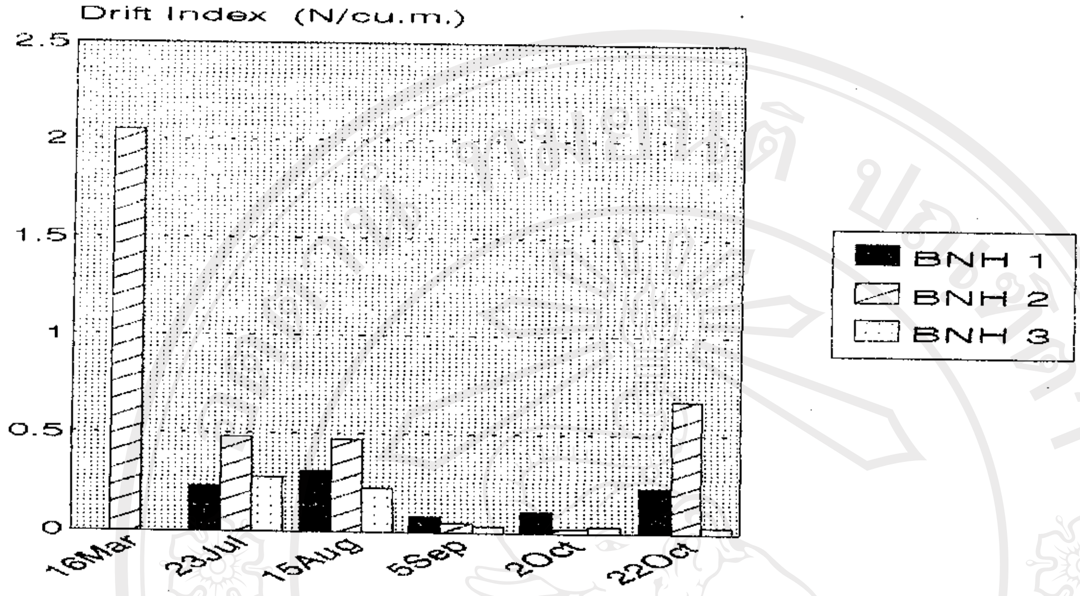


Fig. 17. Monthly drift indices in Ban Nong Hoi stream.

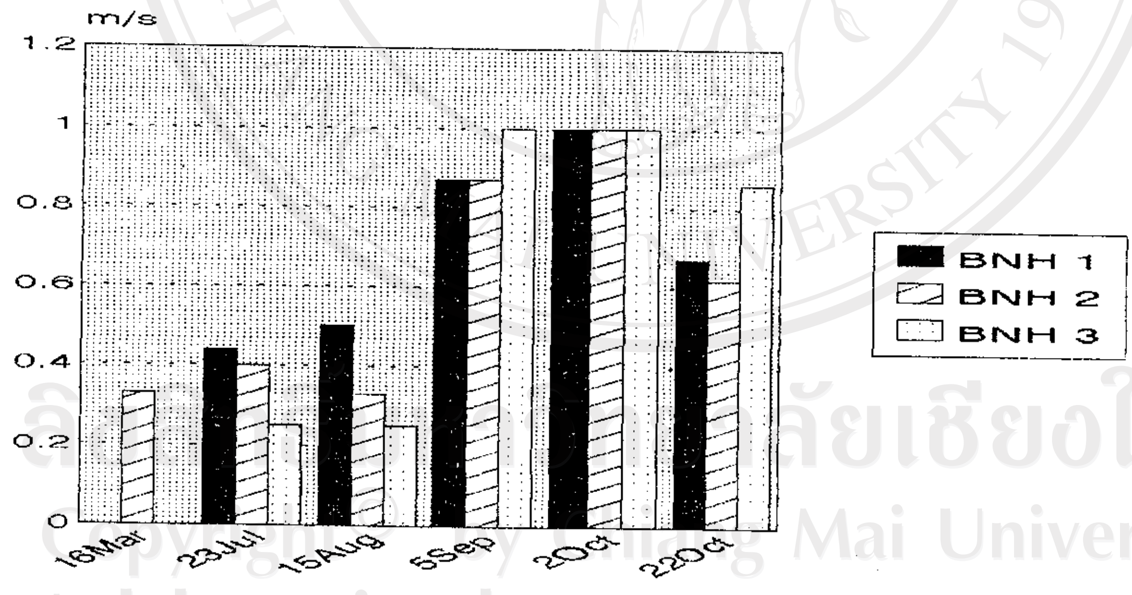


Fig. 18. Monthly flow velocity in Ban Nong Hoi stream.

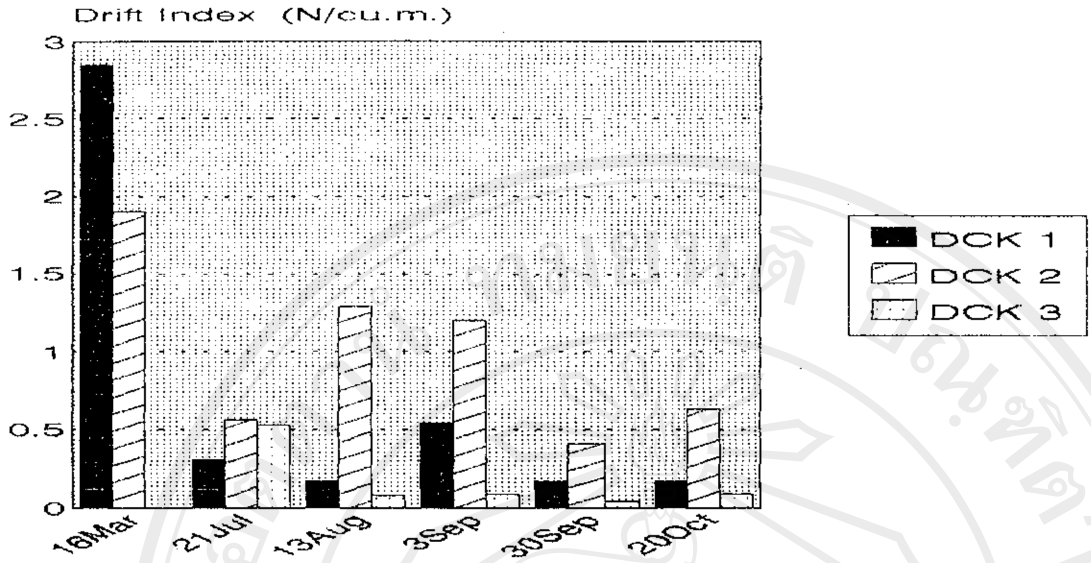


Fig. 19. Monthly drift indices in Doi Chang Kian stream.

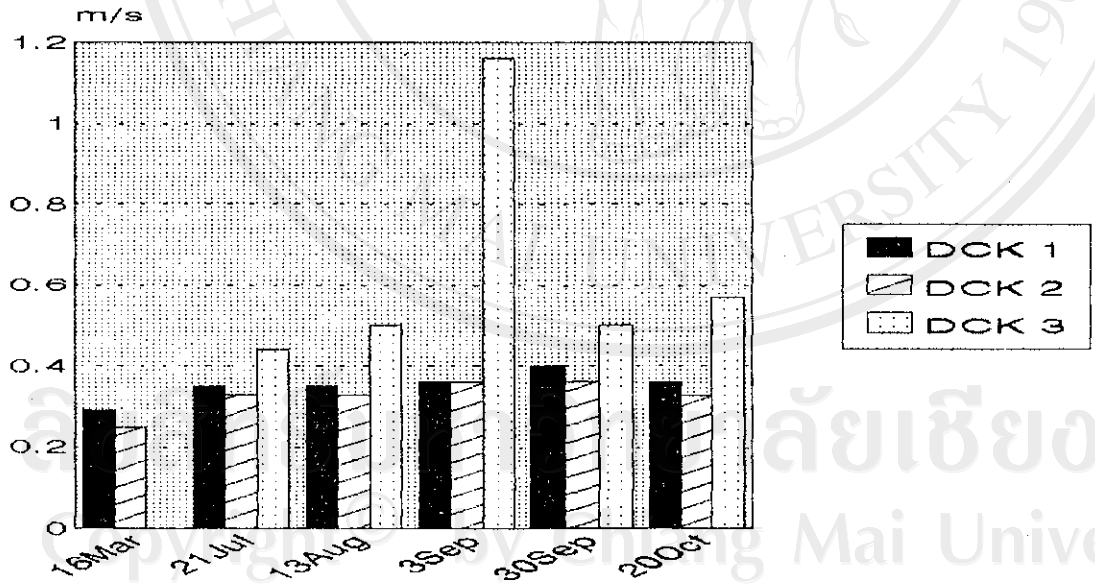


Fig. 20. Monthly flow velocity in Doi Chang Kian stream.

was due to Tubificidae which comprised 37% of the total drift. By contrast, station 2 showed an increase in August 13 and then declined at the onset of the rain for the month of September, with the lowest drift recorded at the peak of the rainy season as in the other stations when the water discharge was very high (Figure 20). Nevertheless, all stations exhibited a drift increase in the early winter as what was earlier observed in BNH stream. The increase in early winter was accounted mainly to Baetidae.

Ephemeroptera, particularly Baetidae was the most dominant drifting organisms in all stations of DCK stream and station 1 of BNH stream while Diptera, particularly Chironomidae and Simuliidae composed much of the drift in stations 2 and 3 of BNH stream. It is worthy to mention here that station 2 of DCK stream had always had a remarkable high drift index for the whole duration of the study in comparison to the other stations of both sites.

4. PESTICIDE-INDUCED DRIFT

Drift is a characteristic feature of invertebrate reactions to a wide range of chemicals and has been reported from several pesticide-contaminated streams.

This part of the observation was carried out in station 2 of BNH stream where extensive cultivation has been practiced for quite sometime now and application of pesticides is done regularly. Because of the difficulty in contacting the people in the area, pesticide-induced drift study was only undertaken twice. That was in March 17 when Malathion was applied to cabbage field and the second much wider scale spraying operation in July 5 of eggplant, cabbage and garlic fields by a mixture of Malathion, Ecomax, Cupravit (a.i.: copper oxychloride) , stickers and growth hormones. The spraying operation started at 8.30hr and lasted until 10hr.

The effect of spraying operation in the neighboring fields to invertebrate drift is presented in Figure 21. A small increase in drift index was observed in the post-spray collection (March 17) compared to the pre-spray collection in March 16. The small increase can not be accounted with certainty to pesticide as the increase was very small and there was only one pre-spray data for comparison. Nevertheless, during the second observation in July 5, a 3-day pre-spray data were available. As can be seen, a 38-fold increase in drift index was observed in the post-spray collection, from $0.38/m^3$, which was the average drift index of the 3-day pre-spray collection, to $14.45/m^3$ in the post-spray netting.

The 4-hourly drift index in the post-spray collection is shown in Figure 22. The first 4-hour of collection (8-12hr) recorded the highest drift index of 47.12. It then declined by a factor of 2 every four hours until the drift went back to normal 24 hours later.

Figure 23 shows the percentage increase in drift induced by pesticide for each insect order for the whole 24-hr drift. Plecoptera increased by 188 folds followed by Diptera (50 folds), Ephemeroptera (30 folds), Trichoptera (23 folds), Odonata (19 folds) and Coleoptera (12 folds).

The drift was dominated by Diptera comprising 91% of the total drift, followed by Trichoptera (3.42%), Ephemeroptera (1.7%), Coleoptera (1.5%), Plecoptera (1.04%),

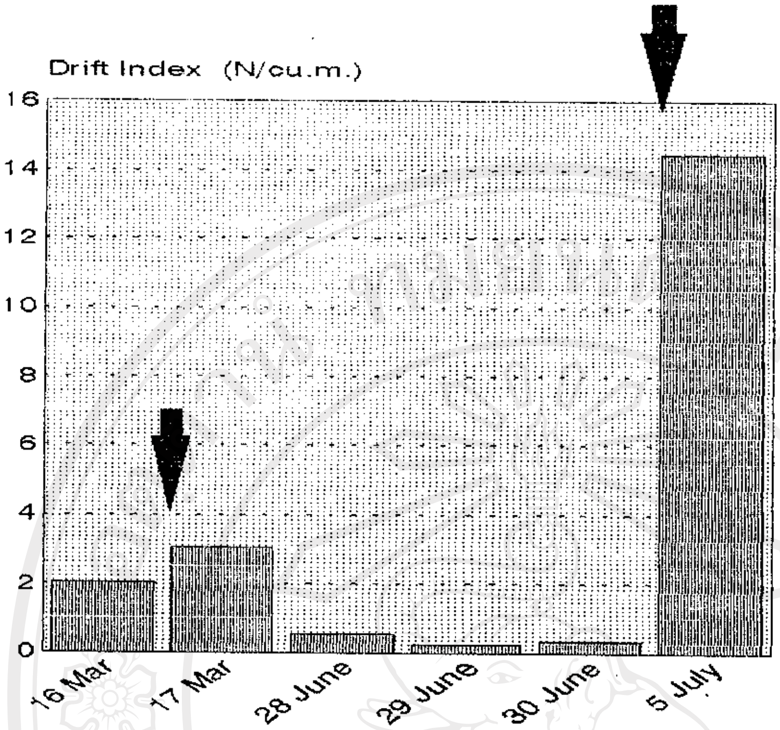


Fig. 21. Pesticide-induced drift in station 2 of Ban Nong Hoi stream (March 17 and July 5, 1993) (Arrows indicate dates of pesticide application)..

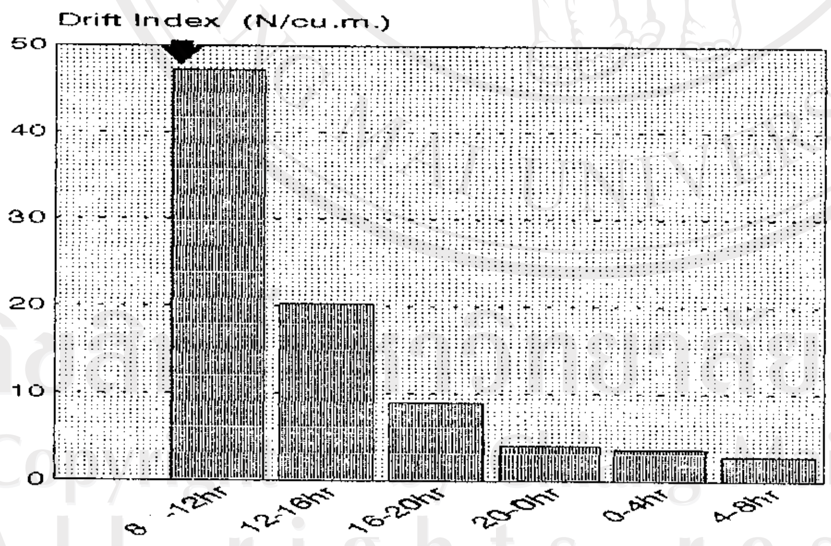


Fig. 22. Pesticide-induced drift at different hours in station 2 of Ban Nong Hoi stream (July 5, 1993) (Arrow indicates dates of pesticide application)..

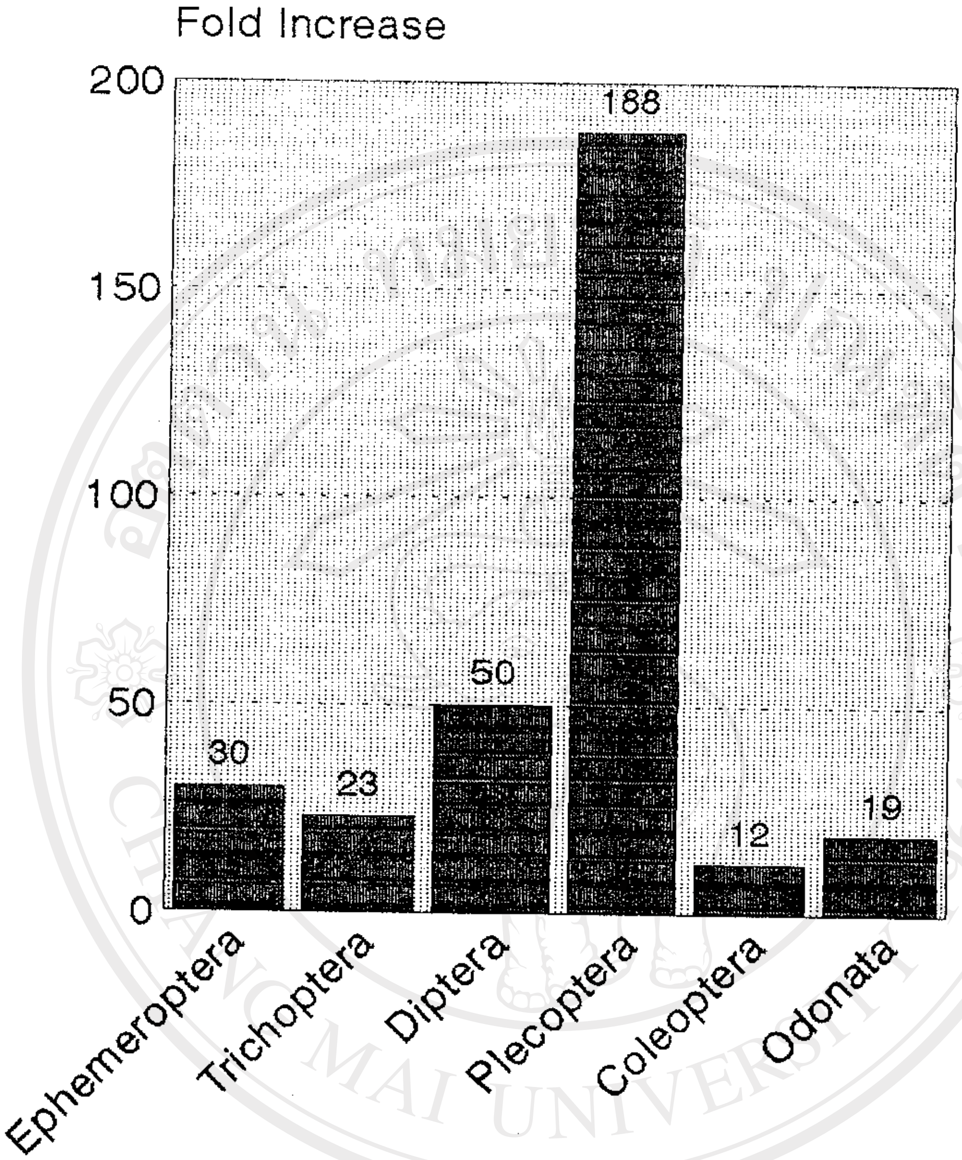


Fig. 23. Increase in drift in the post-spray collection in station 2 of Ban Nong Hoi stream using the 24-hour post spray data. (July 5, 1993).

Odonata (0.7%) and other macroinvertebrates which recorded a very low drift in the pre-spray investigation (Figure 24).

Among the Dipterans, Chironomidae and Simuliidae accounted 55 and 36% of the total Dipteran drift and 50 and 33% of the total invertebrate drift. Tipulidae and Ceratopogonidae also registered more than 1% of the total drift while the rest of the Dipteran families registered less than 1% of the total drift (Figure 25). Other macroinvertebrate families which registered high drift after the spraying but not in the pre-spray collection included Hydropsychidae (3%), Tipulidae (3.5%) and Nemouridae (1%), while the rest of the families registered less than 1% of the total drift.

More number of invertebrate families (44) was recorded during the post-spray collection compared to any of the pre-spray drift samplings which only generated a combined number of 27 families. The highest number of taxa recorded was in the first four hours of netting (36), but in the next four hours, the number of taxa netted went back to the pre-spray number (27) (Figure 26). Some families were only collected at this instance and were not found in any other pre-spray or natural drift samplings. These included families Ephemeridae, Odontoceridae, Limnephilidae, Polycentropodidae, Dixidae, Athericidae, Blephariceridae and Calopterygidae.

Although very high drifts were observed for Chironomidae and Simuliidae, an observation of their recovery rates revealed that 70% or more of these two drifting families recovered from the effect of pesticides. Observation was done by placing the collected invertebrates in a clean buckett with uncontaminated water and their recovery were then investigated for about an hour. That is, if they move, they are considered to have

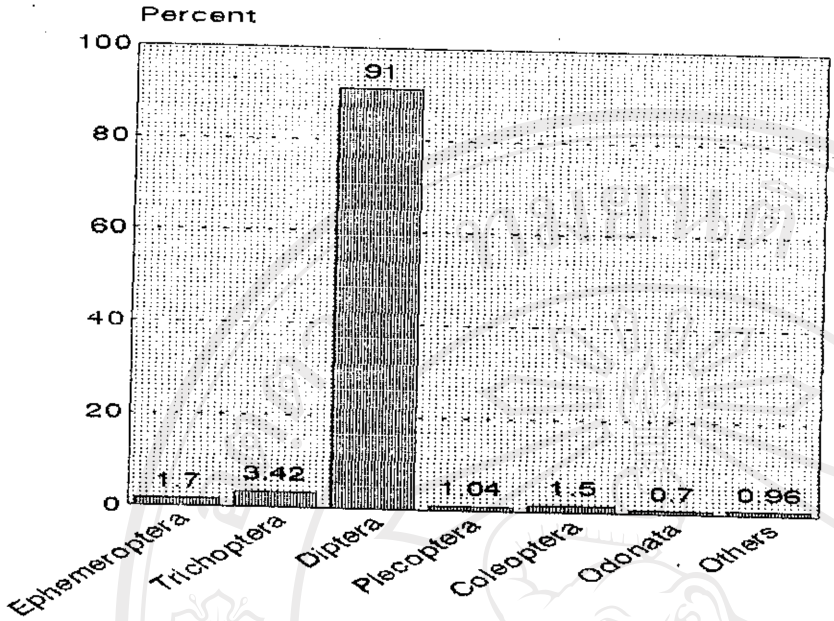


Fig. 24. Percent composition in drift induced by pesticide using the absolute number of individuals netted.

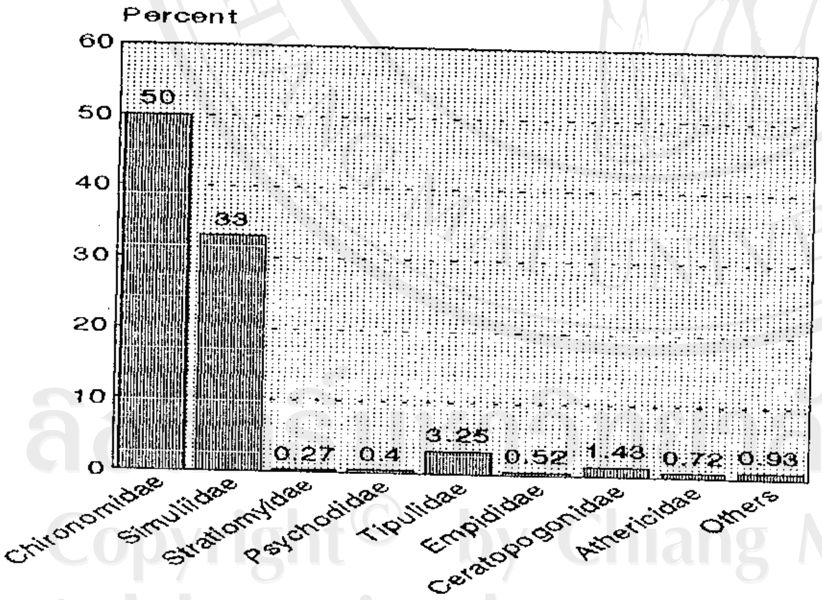


Fig. 25. Percent composition of the Dipteran drift induced by pesticides.

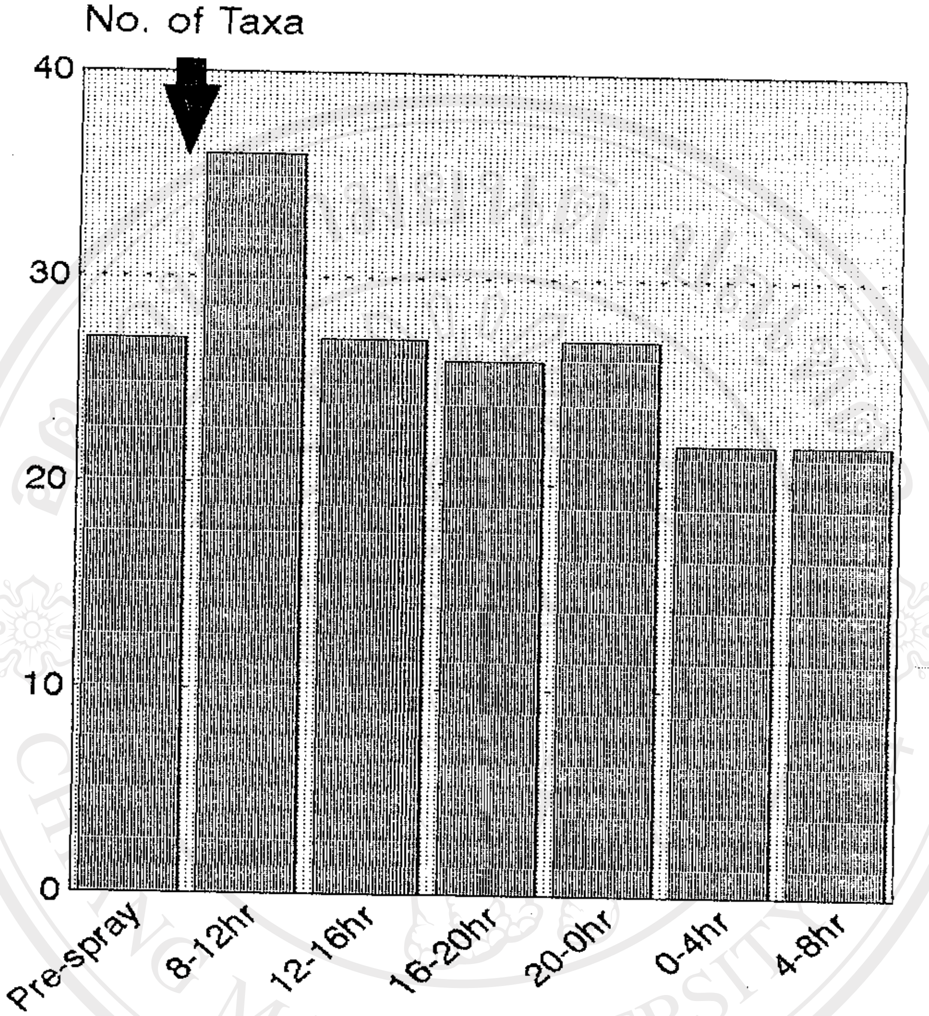


Fig. 26. Number of taxa netted in station 2 of Ban Nong Hoi stream (Pre-spray collection from June 28, 29, 30, 1993 and post-spray collection, July 5, 1993).

recovered. By contrast, Coleoptera of families Dytiscidae, Hydrophilidae, Helodidae and Dryopidae were all found to be dead. The same was true for Ephemeroptera particularly Ephemeridae, Caenidae and Heptageniidae. Some rare Trichoptera families in this station such as Odontoceridae, Limnephilidae, Lepidostomatidae and Polycentropodidae were also netted albeit in very low number. Similarly, Gomphidae and Corduliidae were also collected despite of their poor presence of the drift in the pre-spray collection. The list of sensitive taxa to the applied pesticides is presented in Table 5. The sensitivities were based on the taxa which exhibited catastrophic drifts in the post-spray collection with very low recovery rates or those which were netted only in the post-spray collection but never in any natural or pre-spray collection. But it should be taken into consideration that due to previous and continuous pesticide application in this stream, the benthic community might already represent a selection of the more tolerant taxa.

Table 5. List of sensitive macroinvertebrate families to the applied pesticides[1].

Ephemeroptera	Hydrophilidae (larvae & adult)
Caenidae	Helodidae (larvae)
Ephemeridae	Dryopidae (larvae)
Heptageniidae	**Diptera**
Trichoptera	Tipulidae
Hydropsychidae	Athericidae
Odontoceridae	Psychodidae
Limnephilidae	**Plecoptera**
Polycentropodidae	Nemouridae
Lepidostomatidae	**Odonata**
Coleoptera	Corduliidae
Dytiscidae (larvae)	Gomphidae

[1] Taxa which exhibited catastrophic drift with very low recovery rates or those which were collected only in the post-spray netting but not in any pre-spray or natural drift sampling.

5. NATURAL MONTHLY DRIFT DIVERSITY

The calculation for this is based on the total number of organisms netted in each month and their distribution and not based on the drift index although the later can also be used to calculate drift diversity.

The monthly drift diversity in BNH stream is reflected in Figure 27. By contrast to the drift index which was low during the rainy season, drift diversity in all stations was at its peak at the start of the heavy rain in the first week of September after which it declined towards the early winter, in contrast to the drift index which tended to increase. The diversity in station 1 of BNH stream was always high compared to the other two stations in all samplings.

Interestingly, DCK stream exhibited a different diversity trend with diversity tending to increase in the early winter. The lowest diversity was registered at the peak of the rainy season except in station 2 which has the highest diversity on September 30 after which it decreased in the early winter (Figure 28). The diversity of station 3 was always low in comparison to the other stations.

6. PESTICIDE-INDUCED DRIFT DIVERSITY

A separate diversity values were computed from the drift induced by pesticide (Figure 29). The diversity in March 16 and 17 was more or less the same and it then declined in June 28 and started to increase a little bit in June 29 and 30. Diversity of July 5 sampling which is our post-spray data was low compared to the average diversity of the

Fig. 27. Monthly drift diversity in Ban Nong Hoi stream.

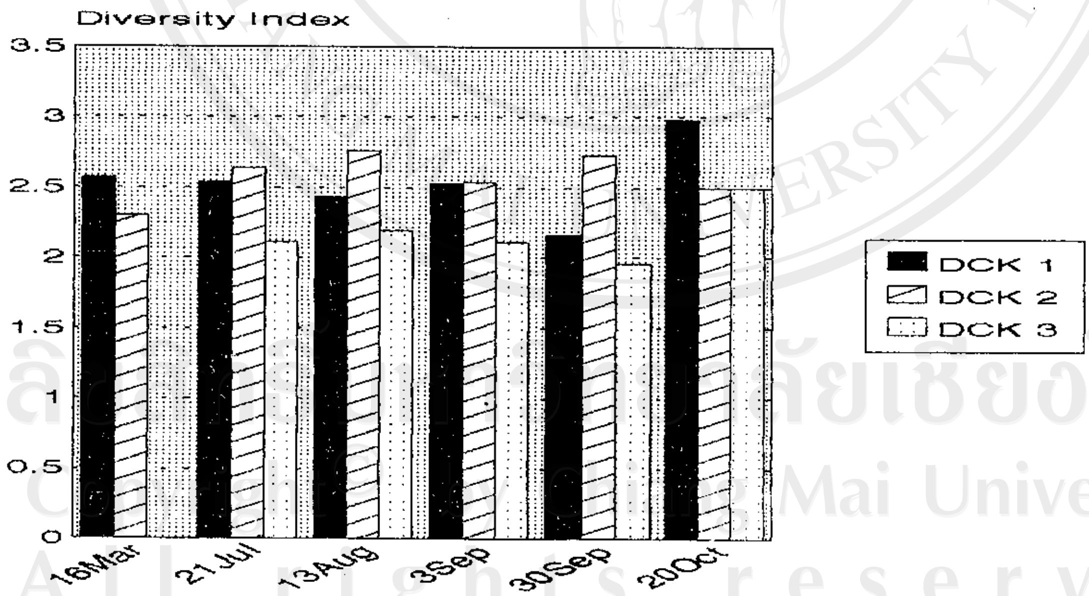


Fig. 28. Monthly drift diversity in Doi Chang Kian stream.

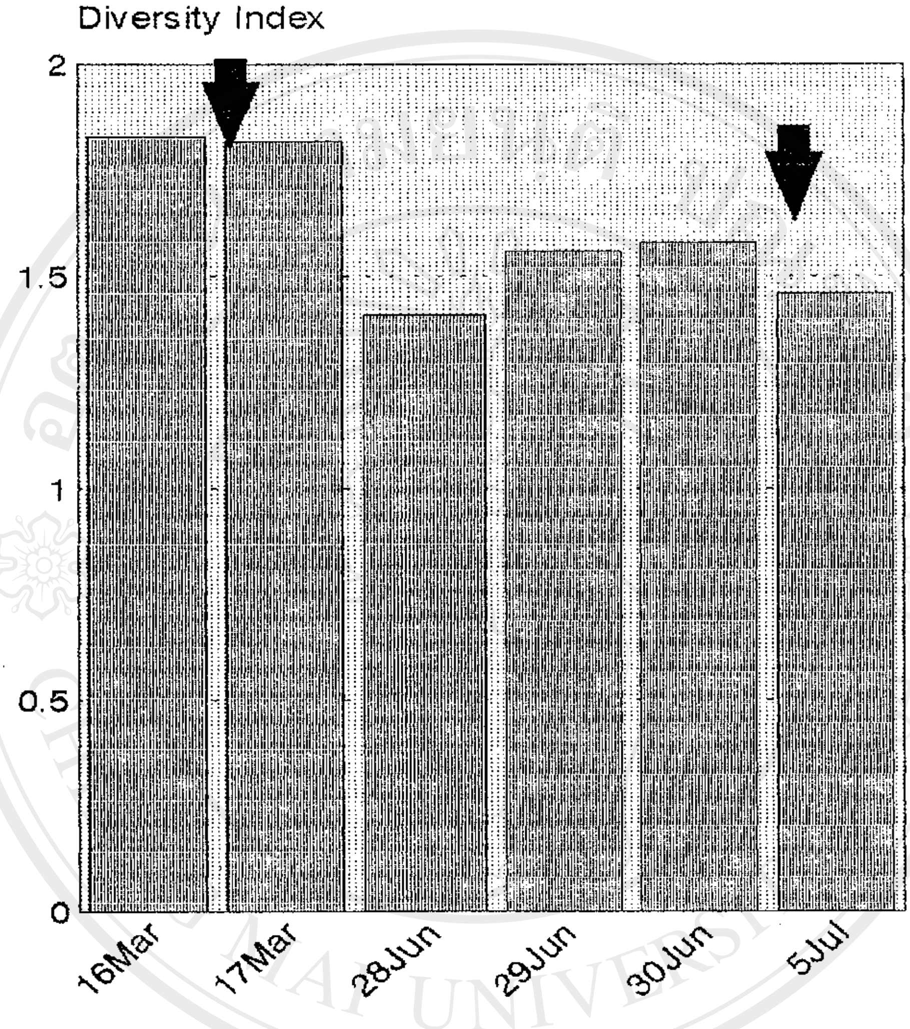


Fig. 28. Pesticide-induced drift diversity in station 2 of Ban Nong Hoi stream (arrows indicate dates of pesticide application).

pre-spray data.

7. BENTHOS AND BENTHOS DIVERSITY

Table 6 presents the population densities of benthos (N/m^2) collected from the Surber sampler. The benthos population was very high in the dry season, with the highest number registered in station 2 of DCK stream. It then declined in the rainy season. Nevertheless, the highest was still recorded in station 2 of DCK stream, followed by Station 1, while the lowest was registered in station 3 of BNH stream.

The composition of the benthos in all stations is shown in Table 7. Orders Diptera and Ephemeroptera were the dominant groups in the benthos in DCK stream. But also important components were Coleoptera, Trichoptera, Plecoptera and Platyhelminthes primarily the family Planaridae, while Hemiptera, Odonata, Annelida and Crustacea, mainly Ostracoda were only minor components. The population density of Diptera was very high in the dry season especially in station 2 of DCK stream where it comprised 62% of the total number of individuals. But it then declined in the rainy season. The same thing was observed for Trichoptera. By contrast, Plecoptera, Coleoptera, Platyhelminthes

Table 6. Population densities (N/m^2) of benthos collected by Surber sampler in Doi Chang Kian and Ban Nong Hoi streams in two seasons.

Sites	Dry Season	Rainy Season
DCK 1	4,128	1,156
DCK 2	6,515	1,260
DCK 3	-	566
BNH 1	-	824
BNH 2	3,462	928
BNH 3	-	192

Table 7. Percent (%) composition of each major group in the benthos in Doi Chang Kian and Ban Nong Hoi streams.

Order	DCK1		DCK2		DCK3	BNH1	BNH2		BNH3
	D	R	D	R	R	R	D	R	R
Ephe	33.4	26.8	12.3	15.6	29.1	13.0	8.6	5.2	21.7
Plec	2.0	5.7	1.1	7.1	3.7	27.6	1.1	0.0	0.0
Dipt	43.1	25.6	62.1	33.4	24.9	16.1	85.2	81.2	51.7
Cole	4.8	5.0	6.4	9.4	13.0	10.9	1.2	0.5	0.8
Tric	10.9	7.1	12.5	7.7	11.9	28.4	2.7	0.5	5.0
Hemi	0.8	2.1	0.5	1.3	6.2	0.2	0.1	0.0	2.5
Odon	1.0	1.2	0.4	3.7	0.9	1.0	0.1	0.2	0.8
Crus	1.8	11.3	0.5	1.1	0.3	0.6	0.4	0.2	0.0
Plat	1.8		3.3	13.5	1.1	1.6	0.0	0.0	0.8
Othe	0.4		0.9	7.1	9.0	1.0	0.7	12.1	15.8

Legend:

Ephe = Ephemeroptera
Plec = Plecoptera
Dipt = Diptera
Cole = Coleoptera
Tric = Trichoptera
Hemi = Hemiptera
Odon = Odonata
Crus = Crustacea
Plat = Platyhelminthes
Othe = Others
D = Dry season
R = Rainy season

and Crustacea exhibited an increase in the rainy season, with Platyhelminthes increasing dramatically. The increase in Crustacea especially in station 1 was attributed primarily to Ostracoda.

In BNH stream, station 1 had very different benthic community to that of its two downstream stations. Trichoptera and Plecoptera were the most dominant groups although Diptera, Ephemeroptera and Coleoptera were also significant components. By contrast, Diptera dominated the benthos in stations 2 and 3 comprising more than two thirds in station 2 and slightly more than 50% in station 3. Other orders were present in very smalll numbers, except for Ephemeroptera mainly Baetidae and Mollusca which were also major components in the benthos in station 3.

Figure 30 shows the diversity of benthic communities collected by Surber sampler in all stations during the rainy season. All stations in DCK stream had always had remarkable high diversity compared to BNH stream, with the highest diversity registered in station 2 and the lowest in station 3. In BNH stream, station 1 had the highest diversity while station 2 had the lowest.

Seasonal variations in benthos were also observed. DCK stream showed an increase in diversity during the rainy season while the opposite was observed in BNH stream (Figure 31).

8. SIMILARITY BETWEEN COMMUNITIES

Sorensen's equation is one of the measures in determining similarity between communities based on the notion of common species shared by the communities.

Tables 8 and 9 illustrate the similarity of different stations in both sites. The results show that stations 1 and 2 of DCK stream are very similar in community structure both for drift net and Surber sampler. Notable in our result is the least similarity of station 3 of BNH stream to all stations in both sites except in station 2 of BNH stream where similarity value obtained from drift net was high (0.70).

9. STATISTICAL PACKAGE FOR SOCIAL SCIENCES (SPSS) RESULTS

9.1. Factor Analysis

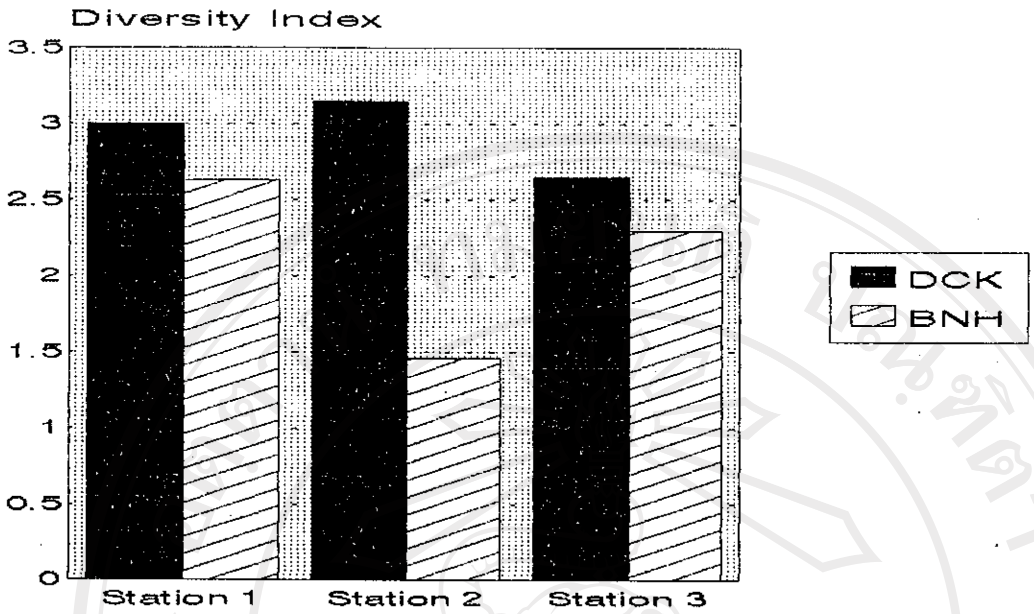


Fig. 30. Diversity of benthos collected by Surber sampler during the rainy season in Doi Chang Kian and Ban Nong Hoi streams.

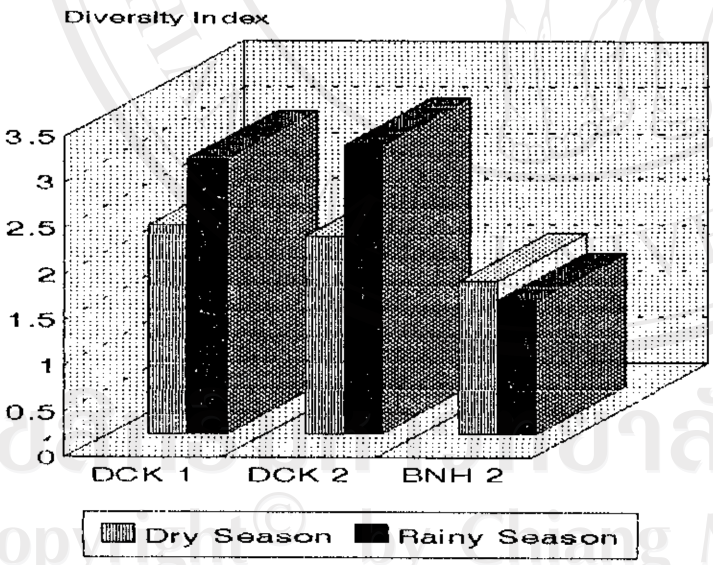


Fig. 31. Seasonal changes in benthos diversity in selected stations of Doi Chang Kian and Ban Nong Hoi streams.

Table 8. Similarity of different stations based on taxa collected by drift net using Sorensen's equation.

	DCK 1	DCK 2	DCK 3	BNH 1	BNH 2	BNH 3
DCK 1						
DCK 2	0,82					
DCK 3	0,78	0,71				
BNH 1	0,74	0,71	0,63			
BNH 2	0,72	0,69	0,68	0,68		
BNH 3	0,52	0,51	0,56	0,54	0,70	

Table 9. Similarity of different stations based on taxa collected by Surber sampler using Sorensen's equation.

	DCK 1	DCK 2	DCK 3	BNH 1	BNH 2	BNH 3
DCK 1						
DCK 2	0,93					
DCK 3	0,52	0,51				
BNH 1	0,62	0,63	0,57			
BNH 2	0,62	0,62	0,56	0,49		
BNH 3	0,38	0,39	0,55	0,40	0,46	

Legend :

80 – 100 % similar

40 – 60 % similar

60 – 80 % similar

< 40 % similar

Figure 32 shows the result of factor analysis of invertebrate families collected from the drift net. All families collected in all samplings were used. The result shows four distinct groups of macroinvertebrates which are composed of the following families:

Group 1 is composed of the following families: Ceratopogonidae, Chironomidae, Blephariceridae, Corduliidae, Dytiscidae, Empididae, Simuliidae, Tipulidae, Caenidae, Nemouridae, Thiaridae, Planorbidae, Lymnaeidae, Psychodidae, Hydropsychidae, Athericidae, Corydalidae and Chrysomelidae.

Group 2 is composed by the families Lepidostomatidae, Chaoboridae, Brachycentridae, Hirudinidae, Cordulegastridae, Coenagrionidae, Decapoda, Gerridae, Leptophlebiidae, Syrphidae, Leuctridae, Mesoveliidae, Naididae, Libellulidae, Thaumaleidae, Muscidae, Noctuidae, Philopotamidae, Notonectidae, Ostracoda, Psephenidae and Nematomorpha.

Group 3 is composed by Families Haliplidae, Noteridae and Perlidae.

Group 4 includes Pleidae, Elmidae and Limnichidae.

Groupings of benthic macroinvertebrate families collected from the Surber sampler are presented in Figure 33. Three groups are observable after the analysis.

Group 1 comprises the families Syrphidae, Culicidae, Pyralidae, Leptoceridae, Protoneuridae, Naucoridae, Lestidae, Capniidae, Planorbidae, Lymnaeidae, Thiaridae, Erpobdellidae, Mesoveliidae, Belastomatidae, Blephariceridae, Nemouridae and Caenidae.

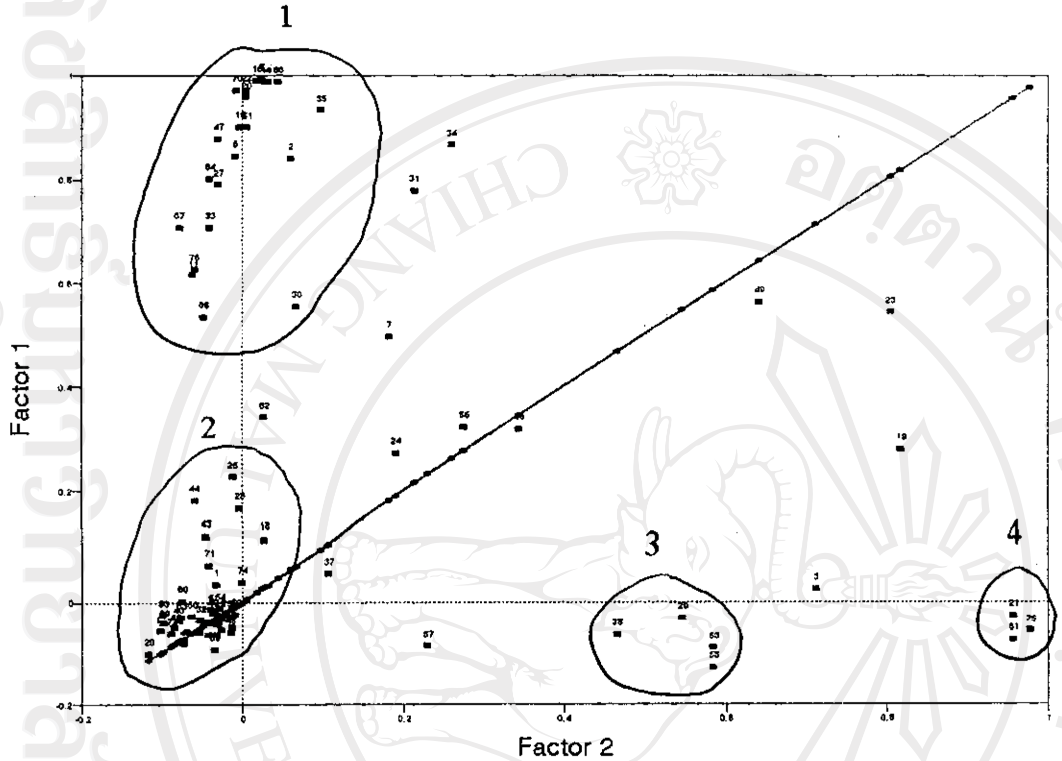


Fig. 32. Association of drifting macroinvertebrates in Doi Chang Kian and Ban Nong Hoi streams using rotated factor analysis.

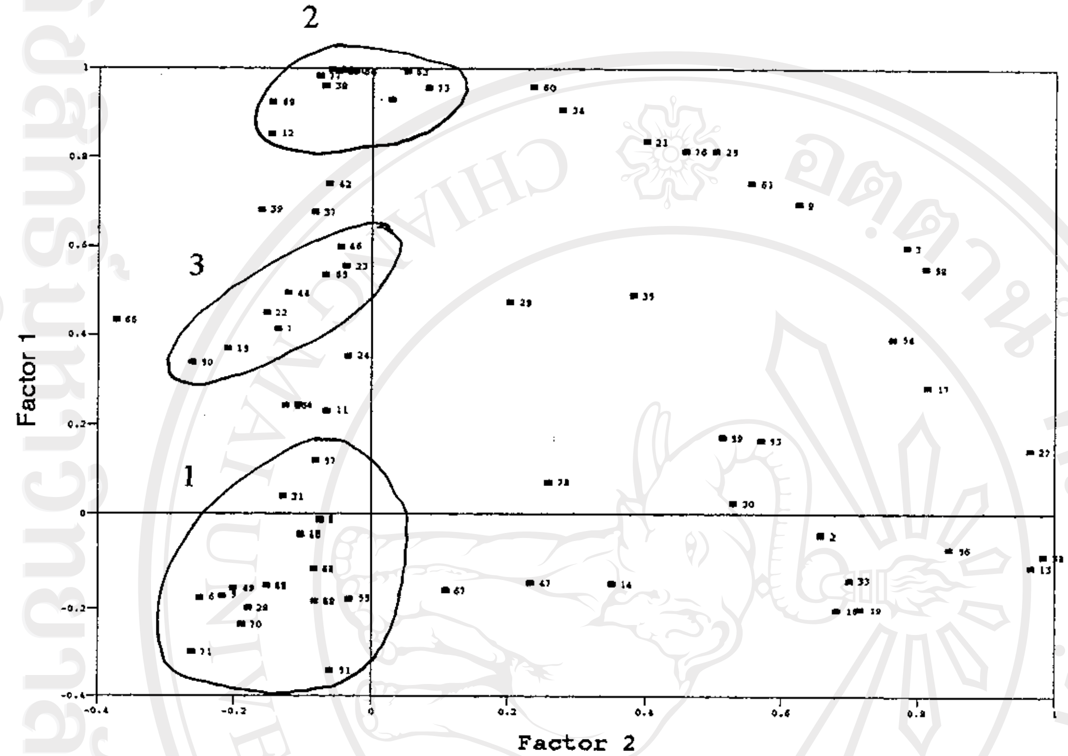


Fig. 32. Association of benthic communities Doi Chang Kian and Ban Nong Hoi streams using rotated factor analysis.

Group 2 includes Tricorythidae, Hydracarina, Hydrophilidae, Lepidostomatidae, Dixidae, Libellulidae, Rhyacophilidae, Tabanidae, Polycentropodidae and Veliidae.

Group 3 is composed by families Psephenidae, Elmidae and Limnephilidae, Leuctridae, Dytiscidae, Brachycentridae, Cordulegastridae and Muscidae.

9.2 Cluster Analysis

A cluster analysis of different samplings for invertebrate drifts in all stations using a dendrogram (a branching arrangement illustrating the relative similarity of samples) is presented in Figure 34. The monthly drift index was used in clustering.

The dendrogram shows three distinct groupings. The first group includes all samplings done starting July until October regardless of the station, but excluding the July 5 sampling. The second group is the March sampling when the density of benthos was high and the third group placed in the extreme end of our dendrogram, is the July 5 sampling, which is actually the post-spray collection.

The similarity of different stations in two seasons based on benthic macroinvertebrates recovered from the Surber sampler is shown in Figure 35. Two groups are very evident in our dendrogram.

Group 1 includes all stations where agricultural activities are going on. These include all stations in BNH stream and station 3 of DCK stream.

Fig. 34. Similarity of All Drift Net Samples Based on Drift Index

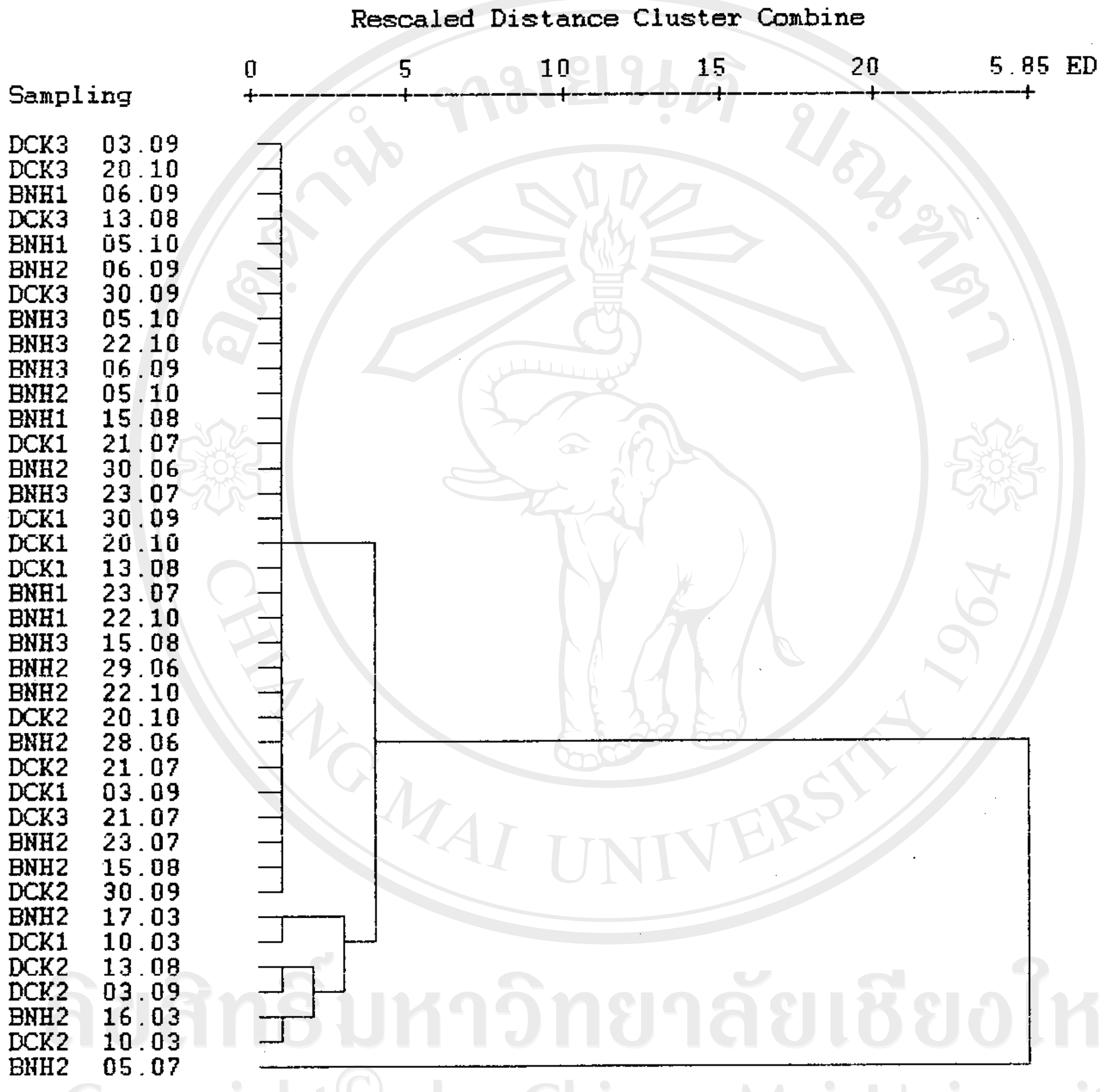
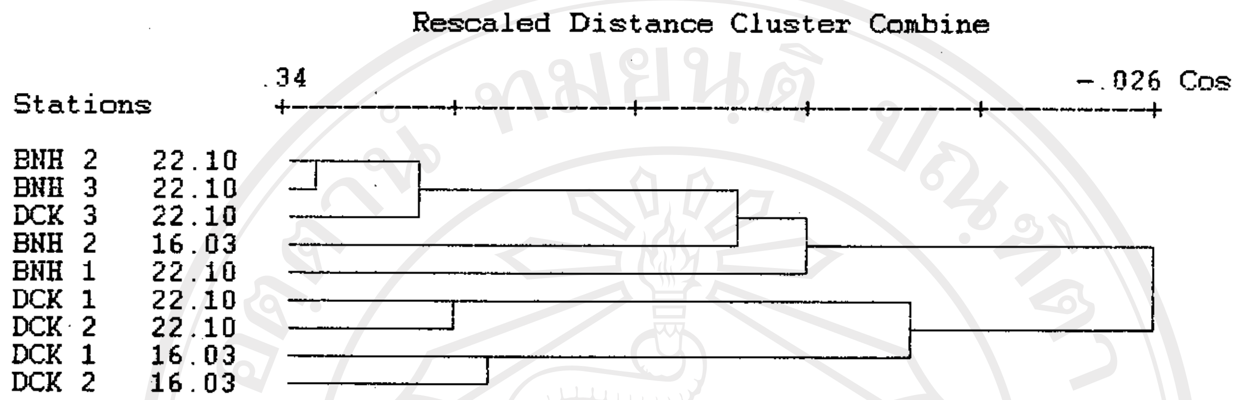


Fig. 35. Similarity of All Surber samples Based on Benthos Density.



The second group is formed by stations 1 and 2 of DCK stream regardless of season, which are actually the clean stations.