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CHIRONOMID ASSEMBLAGES IN TWO THAI WATERCOURSES IN RELATION TO WATER QUALITY

S.E. Mustow[1], *R.S. Wilson*[2] *and Gotchagorn Sannarm*[1]

ABSTRACT

Seasonal samples of chironomid pupal exuviae were collected from seven sites on the Ping River and its tributary, the Kha drainage canal, in Chiang Mai, north-western Thailand. Two sites on the Ping were above the canal inflow and two were below. Gross organic pollution of the Kha was indicated by low dissolved oxygen and high levels of nitrate nitrogen, orthophosphate and conductivity. The differences in water quality were reflected by dissimilarities in chironomid assemblages (Ping, 48 genera; Kha, 4 genera, *Chironomus* nr. *riparius* dominant). Analysis of exuvial data, using Sørensen's coefficients of similarity, showed sites above and below the outfall of the Kha to be similar, whereas the Menhinick diversity index decreased slightly downstream on the Ping.

INTRODUCTION

WILSON & MCGILL (1977) were the first to propose that collection of the pupal exuviae or skins of Chironomidae (Diptera, Insecta) could form a quick and ready method of examining the chironomid fauna in relation to water quality. Work in the U.K. has shown that assemblages of skins can be defined which are indicative of different levels of enrichment caused by organic effluent inflows (WILSON, 1992, 1994). This technique has been used elsewhere in Europe, for example on the River Rhine (WILSON & WILSON, 1983, 1985) and the River Meuse (FRANTZEN, 1992).

The aim of the present study was to assess the potential suitability of the technique for use in Thailand. It was foreseen that it might be particularly useful on deep rivers and canals, where other biological surveillance methods, such as "kick-sampling" for benthic macroinvertebrates, would be impossible. Collections of skins and some physico-chemical measurements of water quality were therefore made on the Ping River above and below the inflow of the organically polluted Kha Canal (Klong Mae Kha), and on the canal itself. In the Tropics, only a limited number of studies have been made of the chironomid fauna using exuvial collections (e.g. COFFMAN ET AL., 1992).

[1] Knighton Road, Sutton Coldfield, West Midlands, B74 4NY, United Kingdom
[2] Department of Zoology, University of Bristol, Bristol, BS8, 1UG, United Kingdom
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LOCALITY

The Ping River, a main tributary of the Chao Phraya, originates in NW Thailand. The Kha Canal enters the Ping 3 km south of Chiang Mai City and receives waste water from the western side of the city together with runoff from irrigated land. Seven study sites were selected around the inflow region, three (KC1–3) on the canal and four (PR1–4) on the Ping, two above and two below the inflow (Figure 1). At this point the altitude is 295 ± 5 m a.s.l. and the river has a shallow gradient of 0.6‰. The Ping sites were spaced at distances of approximately 250 m and the lowest (PR4) was 400 m downstream of the confluence. The flow at KC3 was made up of water from both the Kha and a separate irrigation drain.

From observations in April, submerged macrophytes were abundant at sites PR1p and PR1, where *Hydrilla verticillata* (L.) covered approximately 30% of the bed. People fishing were observed to make catches on both the Ping and Kha.

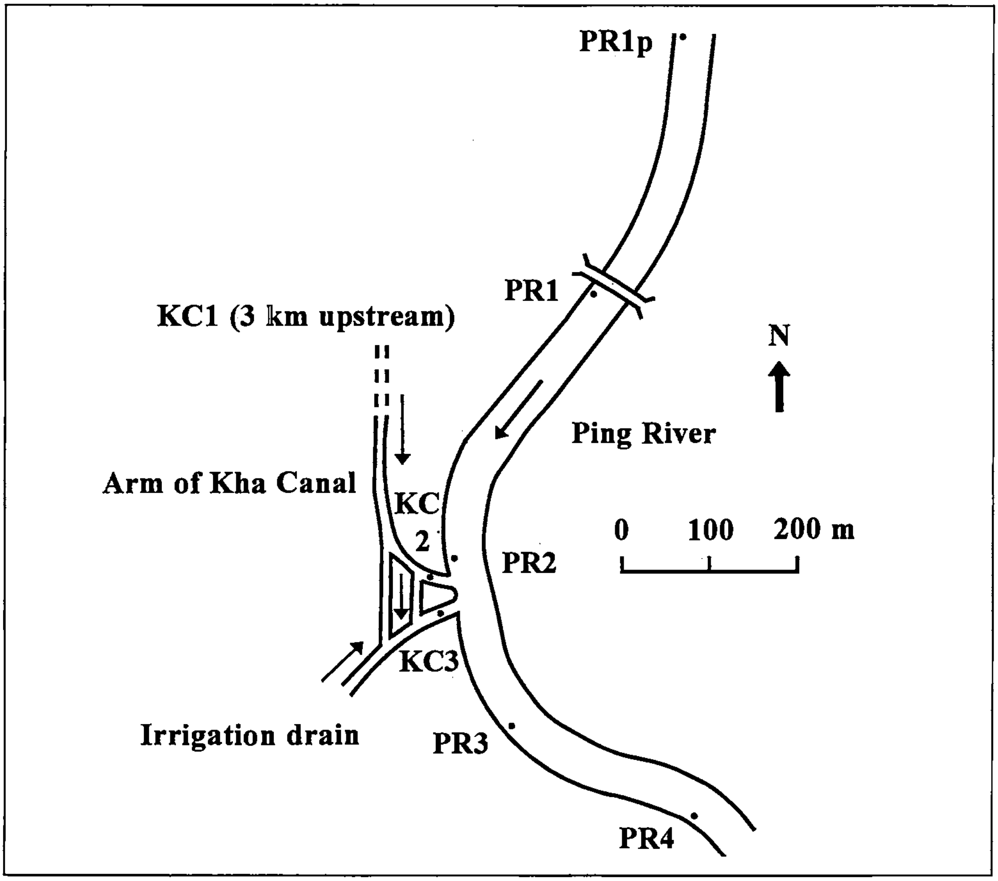

Figure 1. Map of the study area, at the Kha Canal and Ping River confluence (18° 44' 20"N, 98° 59' 00" E).

METHODS

Widths, depths and current velocities were measured or estimated and used to calculate discharges on the Kha. Discharge data for the Ping was accessed from the Royal Irrigation Department. Near-surface measurements of temperature, conductivity, dissolved oxygen (DO) and pH were made using a thermometer, and Walden Precision Apparatus and Ciba-Corning (M90) multi-probe kits. Orthophosphate and nitrate nitrogen were analysed once from samples taken in September 1993, using a Hach DR/2000 spectrophotometer and prepackaged reagents.

Chironomid exuvial samples were taken from sites in early August 1992, mid-December 1992 and mid-April 1993. Techniques were based on those described by WILSON (1994) and WILSON & MCGILL (1977, 1979). From the bank, a long-handled net (mesh size c. 250 μm) was swept across the water surface, in places where flotsam was seen to accumulate. When possible this procedure was continued along about 60 m of the bank. The exuvial types were identified to genus using WILSON & MCGILL (1982), LANGTON (1984, 1991) and WIEDERHOLM (1986).

In order to investigate differences between the chironomid assemblages above and below the outfall on the Ping River, and between Ping and Kha sites, the raw generic level data for each site were combined to reduce seasonal bias and to produce samples of greater size. Due to low numbers of exuviae in several Kha Canal samples, data from all points on the Kha were combined to give a single amalgamated sample (KC). Diversities were calculated using the Shannon (SHANNON & WEAVER, 1949) and Menhinick (MENHINICK, 1964) indices. The relevance of these diversity indices to aquatic ecosystems has been discussed in detail by WASHINGTON (1984). Following percentage transformation, a bar-chart of the relative percentages of individuals in particular taxa was drawn (WILSON, 1994), and average-linkage cluster analysis was applied to the sites as categorized by their coefficients of similarity (GAUCH, 1982; MANLY, 1986; DIGBY & KEMPTON, 1987). The similarity indices were calculated using Sørensen's qualitative and quantitative indices (SØRENSEN, 1948) for presence/absence and relative abundances of genera, respectively. Similarity indices provide a measure of the similarity of the structure of two communities, and are of particular use when water pollution is expected from a point source, and upper and lower communities can be compared (WASHINGTON, 1984; MAGURRAN, 1988).

Strong seasonal differences in exuviae were apparent on the Ping River. These were investigated, using Canonical Community Ordination (TER BRAAK, 1988), with a biological data set comprising non-combined generic level percentages and an environmental data set in which two of the three sampling months were used as dummy environmental variables. To display faunal differences between seasons, canonical correspondence analysis (CCA) was applied. To test whether the observed differences could be accounted for by pure chance, the Monte Carlo permutation test was employed, with the first eigenvalue as test statistic (TER BRAAK, 1988).

RESULTS

Physical and Chemical Data

A summary of the physico-chemical data is given in Table 1. Ping River sites were considerably deeper and wider than Kha Canal sites. With one exception, water temperatures at all sites on all occasions were similar, with the lowest values in December. Electrical conductivity on the Ping, with mean values ranging from 179–203 μS, was considerably lower than on the Kha, 436–538 μS. There was a significant difference between Ping sites at the 5% level (two-way anova; df 3, 6), with lowest values above the outfall.

Mean pH values ranged from 7.0–7.3, with lowest values in August 1992. Dissolved oxygen levels on the Ping were all higher than those from the Kha, with values occupying the ranges 4.8–9.4 mg $l^{-1}$and 0.0–3.9 mg l^{-1}, respectively. On the Kha DO levels were highest at KC3, but at all points, on occasion, DO fell below 1.0 mg l^{-1}. Mean values on the Ping above the outfall were slightly higher than those obtained below, but there was no significant difference between sites at the 5% level (two-way anova; df 3, 6).

Orthophosphate and nitrate nitrogen levels were considerably higher on the Kha than on the Ping. Mean values of each, for Ping sites above and below the outfall, show a small increase downstream.

Discharge on the Kha, averaged over the three main sampling occasions, was estimated to be 6 million cubic metres (MCM) per month at KC1 and 5 MCM per month at the inflow to the River Ping (KC2 and KC3 flows combined). Flows on the Ping at Nawarat Bridge, approximately 7 km upstream of Site PR1, were 111 MCM in August 1992, 90 MCM in December 1992 and 43 MCM in April 1993. Current velocity was notably higher at PR1p. Canal substrates were characterised by thick black organic deposits, while on the Ping, mud and sand were predominant.

Exuvial Data

A total of 49 chironomid genera, from which 71 species could be separated, were recorded and are shown in Table 2. Forty-eight genera in total were collected from the Ping River with 39, 26, 23 and 37 at PR1, PR2, PR3 and PR4, respectively. Four genera, *Chironomus, Nilodorum, Tanytarsus* and an unknown genus of the tribe Chironomini, were found in the Kha Canal, the last two at KC3 only.

On the Kha Canal in particular, it proved difficult to obtain samples of 200 or more exuviae, the number recommended by WILSON & MCGILL (1979) as suitable for analysis. This problem was overcome by combining all the canal samples, producing an amalgamated sample of 237 exuviae.

On the Ping, Menhinick diversity value fell slightly below the Kha inflow, while Shannon diversity value showed little change (Figure 2). Values of both indices were considerably lower on the canal.

Chironomus nr. *riparius* made up over 70% of the Kha sample, but only appeared on the Ping below the inflow, making up 1.82% and 1.02% of the samples from PR3 and PR4, respectively (Figure 3). Other differences between points above and below the inflow were less marked, although there was a drop in the percentage dominance of the Chironomini

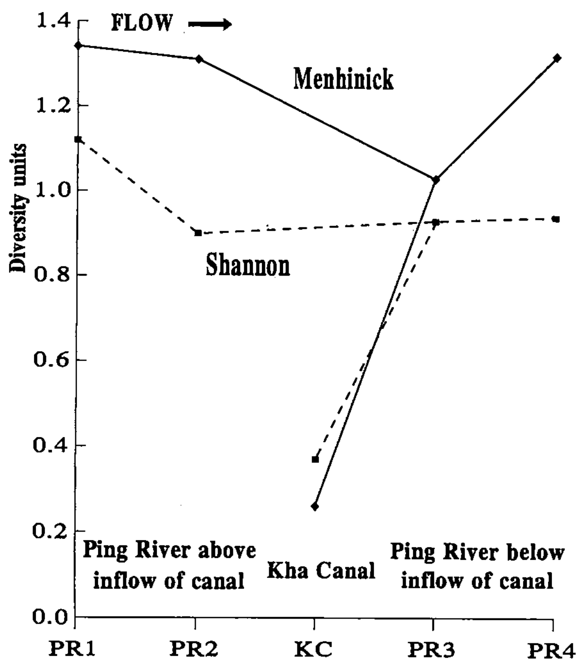

Figure 2. Diversity indices for combined chironomid exuvial samples (generic level data) from the Ping River and Kha Canal.

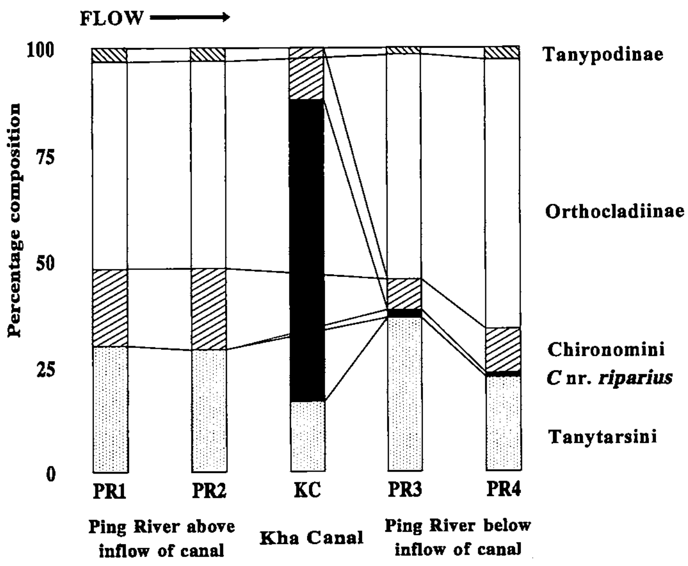

Figure 3. Bar chart showing percentage of *Chironomus* nr. *riparius*, and of subfamilies and tribes, for combined chironomid exuvial samples from the Ping River and Kha Canal. Pseudochironomini, which occurred at very low relative abundances, has not been included.

Table 1. Summary of physical and chemical water quality measurements taken between August 1992 and September 1993, on the Ping River and Kha Canal

	Ping River, upstream		Kha Canal			Ping River, downstream	
	PR1p	PR2	KC1	KC2	KC3	PR3	PR4
Metres upstream of the Kha Canal and Ping River junction*	700	30	3000	30	80	-150	-400
Maximum depth/m†	0.9–2.6	1.1–2.0	0.4–1.0	0.5–1.0	0.3–1.0	1.4–1.9	
Water velocity/m s^{-1}	0.7–1.0	0.2–0.5	0.1–0.3	0.5–0.6	0.0–0.5	0.2–0.3	0.3–0.4
Width/m	40–50	40–50	20–25	3–5	2–6	40–50	40–50
Water temperature/°c‡	26 (3.1)	27 (2.5)	26 (2.6)	26 (2.6)	29 (5.5)	26 (2.8)	26 (2.9)
Conductivity/µS (at 25°c)‡	184 (9)	179 (16)	538 (62)	507 (40)	436 (216)	201 (18)	203 (26)
Dissolved oxygen/mg l^{-1}‡	7.4 (0.7)	7.9 (2.0)	0.6 (0.7)	1.6 (1.6)	2.3 (1.6)	6.1 (1.2)	5.8 (1.3)
pH‡	7.3 (0.5)	7.2 (0.3)	7.0 (0.2)	7.0 (0.2)	7.0 (0.4)	7.1 (0.3)	7.2 (0.4)
Orthophosphate/mg l^{-1} PO_4^{3-}§	0.92	0.48	2.88	6.48	4.04	1.06	0.76
Nitrate nitrogen/mg l^{-1} NO_3^- - N§	4.6	3.8	9.5	7.9	10.9	4.8	5.2

*PR1 was 400 m upstream.
† maximum depth could not be measured at PR4, as the bank was sloping.
‡ means of 3 measurements, standard deviations in parentheses.
§ samples taken on 18/9/93.

downstream. No representatives of the Orthocladiinae and Tanypodinae were collected from the canal.

Average linkage clustering applied to the sample set, using Sørensen's coefficients of similarity for presence/absence and relative abundances of genera, showed the combined Kha sample to have less than 15% similarity to the Ping samples. Ping samples from above and below the inflow were all linked at ≥ 60% and did not form separate clusters.

An ordination diagram (Figure 4) was produced by applying CCA to the unamalgamated exuvial data. The generic scores (of genera making up at least 10% of any one sample),

sample scores and centroids of the environmental variables are on axes 1 and 2. The first axis (eigenvalue = 0.62) clearly separates August samples from those of December and April, while the second axis (eigenvalue = 0.48), clearly separates April samples from those of other months. Genera displayed near to a month's centroid, occur mainly in samples from that month. The 99 random data sets generated by Monte Carlo random permutation of samples all yielded eigenvalues lower than the first eigenvalue (the test statistic). It was therefore concluded that there were significant differences in chironomid assemblages between the seasons ($p \leq 0.01$).

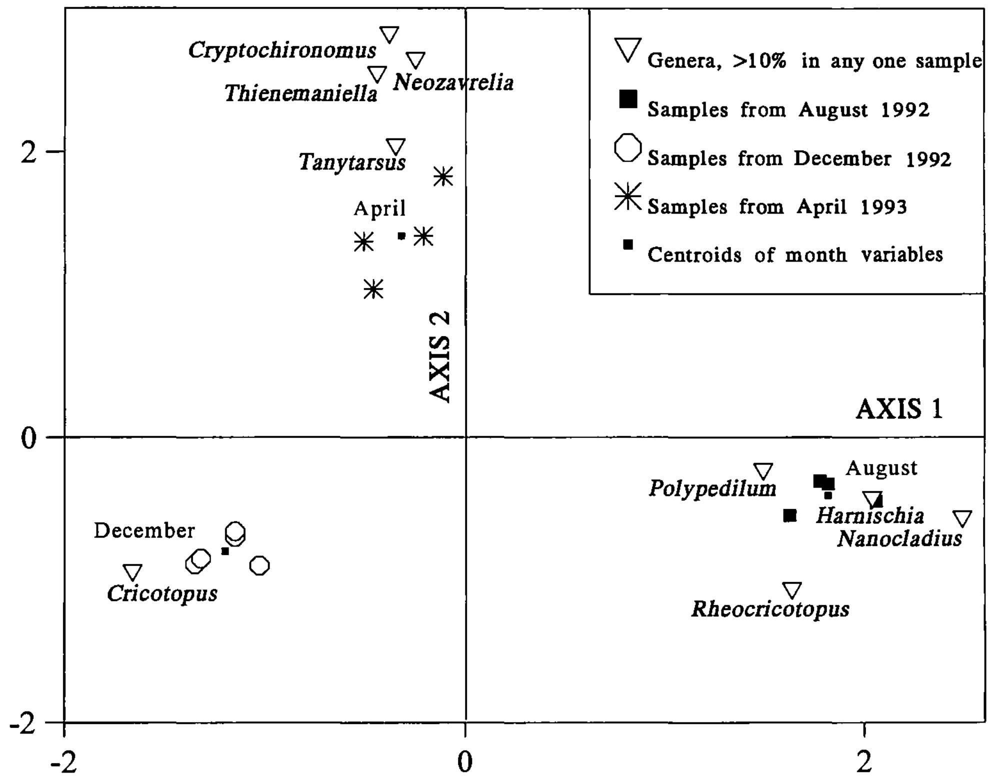

Figure 4. Biplots of Axes 1 and 2 of CCA ordination of exuvial genera, samples and nominal environmental variables representing month of sampling, using data from the Ping River only. Only genera making up more than 10% of any one sample are shown.

Table 2. Percentage composition of Chironomidae genera in combined samples from sites on the Ping River (PR) and Kha Canal (KC), 1992–1993. All figures are given to the nearest 1%; + = <0.5%, - = not recorded; codes in ( ) denote unknown genera

Genera / taxa	PR1	PR2	KC	PR3	PR4
TANYPODINAE					
Ablabesmyia	1	+	-	+	+
Clinotanypus	+	+	-	-	+
Coelotanypus	+	2	-	-	-
Nilotanypus	1	+	-	1	1
Paramerina	+	1	-	-	1
Procladius	+	-	-	-	-
Tanypus	+	-	-	-	-
(TP–31)	+	-	-	+	+
ORTHOCLADINAE					
Cardiocladius	1	1	-	1	-
Corynoneura	+	+	-	-	-
Cricotopus	24	39	-	34	23
Eukiefferiella	3	1	-	3	1
Nanocladius	12	4	-	8	36
Parakiefferiella	1	1	-	-	+
Rheocricotopus	4	1	-	1	2
Thienemanniella	3	2	-	6	+
(OO–A)	+	+	-	-	-
CHIRONOMINAE					
Chironomini					
Chironomini Genus C	1	-	-	-	+
Chironomini Genus F	1	-	-	-	+
Chironomus	-	-	71	2	1
Cryptochironomus	6	-	-	+	+
Cryptotendipes	-	+	-	-	+
Demicryptochironomus	1	1	-	2	1
Dicrotendipes	1	+	-	1	1
Glyptotendipes	+	-	-	-	+
Harnischia	3	9	-	2	1
Kloosia	-	+	-	-	+
Nilodorum	-	-	2	+	-
Parachironomus	+	-	-	-	+
Polypedilum	3	8	-	1	5
Robackia	-	+	-	-	-
Saetheria	+	-	-	-	+
Xenochironomus	+	-	-	-	+
(CC–26)	+	-	-	-	-

Table 2 (continued).

Genera / taxa	PR1	PR2	KC	PR3	PR4
(CC–31)	+	-	-	-	+
(CC–32)	-	-	-	+	-
(CC–33)	-	-	10	-	-
(CCX–2)	+	-	-	-	+
(CCX–3)	-	-	-	-	+
(CCX–6)	-	-	-	-	+
Pseudochironomini					
Pseudochironomus	+	-	-	+	1
Tanytarsini					
Cladotanytarsus	1	1	-	2	1
Micropsectra	+	-	-	-	-
Neozavrelia	21	11	-	24	9
Paratanytarsus	-	-	-	+	+
Rheotanytarsus	2	2	-	4	2
Sublettea	+	+	-	-	+
Tanytarsus	5	16	17	7	9
Zavreliella	1	-	-	-	+
Total genera: 49					
Total exuviae: 2763					

DISCUSSION

Organic pollution in the Kha Canal was indicated by low DO and high electrical conductivity levels. With DO sustained at levels < 3.5 mg l^{-1} the Kha may be regarded as severely polluted according to the broad categories of pollution suggested for a tropical stream in Australia (PEARSON & PENRIDGE, 1987). By contrast, the Ping River would be classified as clean or mildly polluted. Nutrient measurements, albeit from a single occasion, indicate the enriched state of the system and of the Kha in particular. Nitrate nitrogen levels on the Ping and Kha were comparable to those recorded by HASSAN (1981) on a tropical stream, downstream of a sewage treatment plant (> 2.4 mg l^{-1}). The high levels may have been due to runoff from intensively farmed land in the Chiang Mai Basin. Phosphate levels on the Ping and Kha were of similar magnitude to those recorded by HASSAN, upstream and downstream of the sewage treatment plant effluent, respectively.

The effect of the Kha inflow on the Ping appeared to be mild, due to the > 10–fold dilution ratio. Decomposition and mineralization of organic material in tropical waters proceeds very rapidly and efficiently (PAYNE, 1986).

The relative abundance of *C.* nr. *riparius* in skin samples shows a close relationship with the pollution status of sampling sites. This species made up over 70% of the combined Kha samples; however, it did not appear on the Ping above the outfall, but occurred at low relative abundances below it. A similar relationship has been observed in temperate regions (e.g. WILSON, 1994). PEARSON & PENRIDGE (1987) and REDDY & RAO (1991) have reported an increase in the relative abundance of the larvae of *Chironomus* species with increasing organic pollution, in tropical regions of Australia and India, respectively. It is not thought that the skins of *C. riparius* found on the Ping, had simply floated in from the canal, as they occurred in all but one of the downstream samples and were often scarce on the Kha.

Analyses of the data using the diversity indices and average-linkage cluster analysis of coefficients of similarity, also show a clear distinction between exuvial collections from the Kha and Ping. Additionally, if the genera collected from the Ping and Kha are awarded a pollution tolerance status based on studies of the British fauna (WILSON & MCGILL, 1982), 45% of individuals collected from the Ping would be classed as intolerant of pollution, compared to only 19% from the Kha.

KC3 had a more diverse fauna than the other Kha sites. A small difference between upstream and downstream sites on the Ping, was shown by examination of the relative percentages of individuals in particular taxa and by the Menhinick diversity index. Some of the dissimilarity between Ping and Kha sites in particular, could be due to environmental factors not related to water quality, such as flow and depth.

Seasonal changes in the exuvial collections mean that single samples cannot properly be compared with samples taken at different times of the year, for assessing water quality (MCGILL, 1981). Difficulties in obtaining exuviae were possibly due to fast decomposition rates and high turbulence during elevated river flows (least difficulty was experienced in obtaining skins during the lowest discharges in April 1993).

CONCLUSIONS

This study has demonstrated that river quality assessment techniques base on chironomid pupal exuviae have potential for use in Thailand. The results show that poor quality sites can be clearly distinguished and suggest that this might also be the case for moderately impacted sites. Taxonomic identification and the collection of adequately-sized samples was more difficult than is usually the case in Europe. However, the majority of exuviae could be identified to generic level with relative ease and extended collection times might solve the problem of low sample size. As with all water quality surveillance methods, the cost-effectiveness of the technique and its performance in relation to other methods, would need to be assessed before it was used in Thailand on a wide scale.

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