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## Diversity of chironomid larvae in relation to water quality in the Phong River, Thailand


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**Abstract**. The diversity of chironomid larvae in relation to water quality in the Phong River, Thailand was investigated. Water samples and chironomid larvae were collected in July, December 2011 and March-April 2012. Water temperature, pH, turbidity, suspended solids and chlorophyll-a were not significantly different among sampling sites. The mean values of electrical conductivity, total dissolved solids, dissolved oxygen and orthophosphate were significantly different between sampling sites ($p<0.05$). A total of 4,028 individuals, 49 taxa, 35 genera and 3 subfamilies (Chironominae, Tanypodinae and Orthocladiinae) of chironomid larvae were found. The chironomid larvae of the Phong River mainly consisted of Chironominae, comprising 90.3% abundance (41 taxa, 28 genera) of the total chironomid larvae. This was followed by Tanypodinae and Orthocladiinae comprising 9.5% (5 taxa, 5 genera) and 0.2% abundance (3 taxa, 2 genera), respectively. The present study showed that *Polypedilum nubifer*, *Cladotanytarsus mancus* and *Skusella* sp. were the most abundant species within the chironomid assemblage, contributing 25.40%, 16.31% and 15.07% of total abundance, in order. *Cryptochironomus* sp., *Polypedilum nodosum* and *Skusella* sp. were present in all the study sites. *Cryptochironomus* sp., *Skusella* sp., *P. nodosum*, *Chironomus* sp., *Harnischia* sp., *Cryptotendipes* sp., *Endochironomus* sp. and *Paramerina* sp. had significant positive relationships to electrical conductivity, total dissolved solids, turbidity, suspended solids and orthophosphate, while *Rheotanytarsus* sp., *Tanytarsus* sp., *Polypedilum* sp.1, *Polypedilum* sp.4, *Polypedilum leei*, *P. nubifer*, *Polypedilum sordens*, *Stenochironomus* sp., *Stictochironomus* sp.1, *Cladopelma* sp., *Microtendipes pedellus*, *Parachironomus* sp., *Kiefferulus* sp., *Xylochironomus* sp., *Nanocladius* sp. and unknown 2 had significant positive relationships with pH and dissolved oxygen. Tolerance values of chironomid larvae ranged from 0.94 to 6.67. They were divided into 2 groups including (1) tolerant group had more occurrences with 70.3% of the total chironomid larvae and had tolerance values ranging from 0.94-4.35 and (2) very tolerant group had 29.7% of the total chironomid larvae with high ranges of tolerance values from 4.36-6.67. The very tolerant group showed high toleration and included *Cricotopus* sp.1, *Chironomus* sp., *Axarus* sp., *Harnischia* sp., *Polypedilum griseoguttatum*, *Polypedilum* (*Tripedilum*) sp., *Cryptochironomus* sp., *Skusella* sp., *P. nodosum* and *Microchironomus* sp., which were found at sites P7-P10 which had high values of suspended solids, turbidity, electrical conductivity, total dissolved solids and orthophosphate.



**Key Words**: Nematoceran, bloodworms, water pollution, tolerance values.


**Introduction**. Chironomid (Order Diptera, Family Chironomidae) has worldwide distribution and is an ecologically important group of aquatic insects, which often occurs in high densities and diversity. Approximately 5,000 species are described worldwide but estimates of actual species range up to 20,000 (Ferrington et al 2008). Some chironomid larvae (*e.g. Chironomus* and *Polypedilum*) are commonly called bloodworms because they have red blood pigment, haemoglobin, in their bodies, but not all chironomid larvae are red. The presence of haemoglobin enables the larvae to extract oxygen from extremely low oxygen environments resulting from organic pollution (Cranston 2004). Certain species of chironomids show adaptations in ecosystems at different trophic levels, to extreme environmental situations related to high temperature, pH, organic matter content in the sediment and low dissolved oxygen in the water-sediment interface. Chironomids are used as an indicator of biological water sources because they can tolerate a wider environment and resist many types and levels of pollution (Armitage et al 1995). This family has been distinguished into 11 subfamilies and only 4 subfamilies are commonly reported in the Oriental region, but a total of at least 3,000 species has been reported (Ahmad et al 2014; Dudgeon 1999). Surprisingly, in the Catalog of the Diptera of the Oriental Region (CDO) (Sublette & Sublette 1973) there are no chironomid species recorded from Thailand, but after 1973, Hashimoto recorded the phytophagous chironomid, *Polypedilum anticum,* from Thailand (Papp et al 2006). Hashimito et al (1981) gave a brief description of the adult morphology of 32 species of chironomids inhabiting rice fields. Cranston (2007) has reported the presence of 29 species, 15 genera of chironomid larvae associated with the Tsunami-impacted southwestern Thailand. In Thailand, knowledge about the diversity of chironomids is scarce and limited; most of them have been reported only as a subfamily. Therefore, this study aimed to determine the diversity of chironomids larvae along the Phong River and the relationship between chironomid larvae and environmental variables.

## Material and Method

***Study area***. The study was conducted from 10 sampling sites along the Phong River, Khon Kaen Province, northeastern Thailand (Figure 1). Table 1 presents latitude and longtitude of each sampling site.

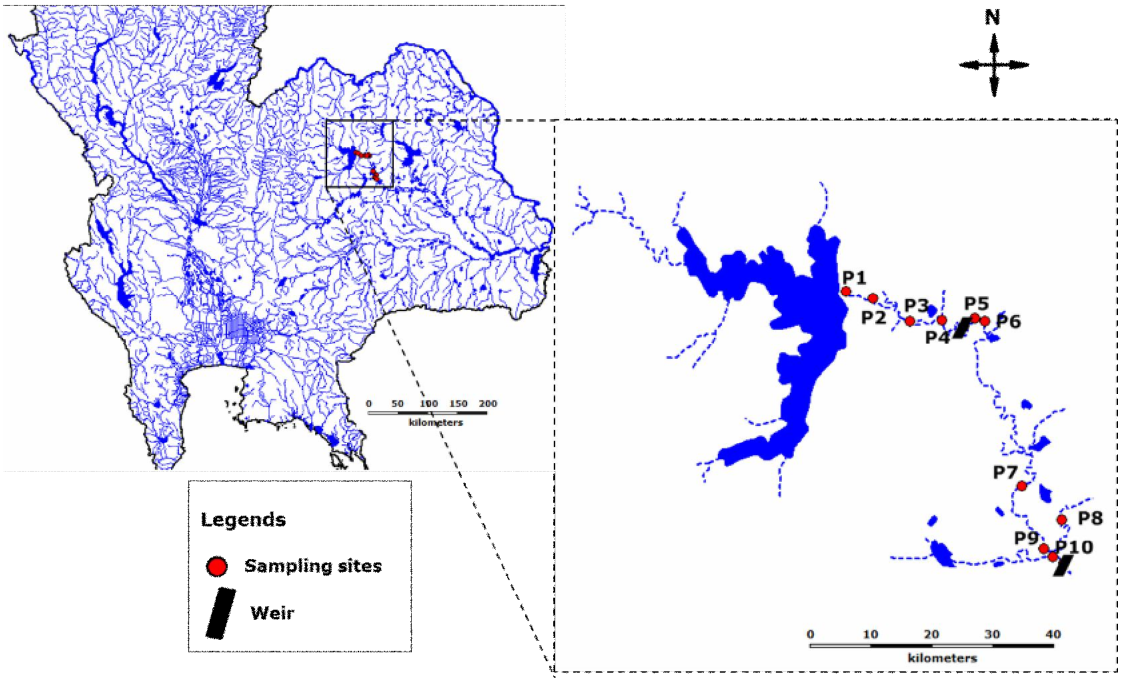


Figure 1. Map showing the position of sampling sites (P1-P10) along the Phong River, Thailand.

***Environmental variables***. Water temperature (°C), pH, electrical conductivity (EC, $\mu Scm^{-1}$) and total dissolved solids (TDS, $mgL^{-1}$) were measured with a pH/EC/TDS meter (Fisher Scientific model HI 98129) and dissolved oxygen (DO, $mgL^{-1}$) was evaluated with an Oxygen meter (YSI model 550A) at each sampling site. Turbidity (FAU), suspended solids (SS, $mgL^{-1}$) and orthophosphate ($PO_4^{-3}$, $mgL^{-1}$) were measured using a Hach DR/2010 spectrophotometer. Chlorophyll-a ($\mu gL^{-1}$) was measured using a methanol extraction method (APHA 1998). Three replicates of each parameter were measured.

Table 1

Location of sampling sites in the Phong River

| *Site code* | *Site* | *Latitude* | *Longitude* | *Elevation (m.a.s.l.)* |
|---|---|---|---|---|
| P1 | Ban Huay sai | 16º46'30.16"N | 102º37'42.39"E | 181 |
| P2 | Ban Nong tae | 16º45'49.36"N | 102º40'04.14"E | 171 |
| P3 | Ban Kum bon | 16º43'45.52"N | 102º43'22.08"E | 167 |
| P4 | Ban Non kham pae | 16º43'52.30"N | 102º46'16.55"E | 159 |
| P5 | Ban Kud nam sai noi | 16º43'45.75"N | 102º50'07.64"E | 144 |
| P6 | Ban Nong or noi | 16º44'01.41"N | 102º49'09.97"E | 159 |
| P7 | Ban Nong hin | 16º29'01.94"N | 102º53'24.85"E | 146 |
| P8 | Ban Ta hin | 16º26'00.59"N | 102º56'55.76"E | 147 |
| P9 | Ban Huay pra kruea | 16º23'28.74"N | 102º55'20.67"E | 147 |
| P10 | Makasarakram weir | 16º22'44.28"N | 102º56'10.99"E | 149 |

***Chironomid larval sampling***. Benthic samples were collected by Ekman grab (16 x 16 cm) from 10 sites along the Phong River in July, December 2011 and March-April 2012 with eight replicates at each site. Samples were preserved in 95% ethanol and transported to the laboratory. The benthic samples were washed with tap water through a sieve (500 μm mesh size). The chironomid larvae were sorted and preserved in 70% ethanol. Permanent slides of chironomid larvae were prepared, which was modified from Epler (2001). The permanent slides of larvae were identified to genus using appropriate taxonomic keys cited in Cranston (2007) and Epler (2001).

***Statistical analysis***. Mean values and standard deviations of each environmental variable at the 10 sampling sites were calculated. One-way ANOVA was used to determine significant differences of environmental variables between sampling site (Zar 2010). Chironomid larvae relative abundance data were calculated according to the proportion (%) of each species found at each site. In order to study relationships between environmental variables and the distribution of the chironomids taxa, Canonical Correspondence Analysis (CCA) was performed based on the data matrix of taxa abundance. The CCA were performed using the program PC-ORD Version 5.1 (McCune & Mefford 2006). Chironomid tolerance score was calculated using a mathematical approach for tolerance values of macroinvertebrates in the Mekong River (MRC 2010). In this study, we used an average water quality classification score of the sites instead of site disturbance score. Water quality is a representative of integration of physical and chemical parameters of water. Each chironomid taxon is assigned a score related to its resistance to pollution as shown in equation 1.  Only resistant taxa could survive under the severely disturbed conditions.

$$Tc_a = [(\sum_{i=1}^{n} (w_i n_{ai})/\Sigma n_{ai}) - 2]\, 5 \quad \text{...............(1)}$$

where $Tc_a$ - Tolerance score of chironomid taxon $a^{th}$
$w_i$ - average water quality score at site i
$n_a$ - number of samples for taxon $a^{th}$ in site i

**Results and Discussion**

***Environmental variables of water quality***. Means, standard deviations and ranges of measured environmental variables at 10 sampling sites as well as p-values for only variables showing significant differences between sampling sites are shown in Table 2. Analysis of environmental variables (one-way ANOVA) showed that mean values of water temperature, pH, turbidity, SS and chlorophyll-a were not significantly different among sampling sites. The mean values of EC, TDS, DO and $PO_4^{-3}$ were significantly different between sampling sites ($p<0.05$).

Table 2

Mean, standard deviations, ranges of measured environmental variable (n=3) and p-values are shown only for variables that showed significant differences between sampling sites

| *Parameter* | *Site* | | | | | | | | | | *p-value* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *P1* | *P2* | *P3* | *P4* | *P5* | *P6* | *P7* | *P8* | *P9* | *P10* | |
| Water temp (˚C) | 26.68±3.12 (22.50-29.60) | 27.07±2.98 (22.90-29.60) | 26.79±2.75 (23.20-29.60) | 26.79±2.92 (22.80-29.20) | 27.31±2.87 (23.50-29.90) | 27.84±3.37 (23.30-30.50) | 27.43±2.66 (23.80-29.60) | 27.73±2.56 (24.20-30.10) | 27.59±2.51 (24.40-30.20) | 27.28±3.20 (22.90-29.80) | 0.716 |
| pH | 7.79±0.23 (7.51-8.22) | 7.66±0.24 (7.20-7.94) | 7.51±0.24 (7.11-7.85) | 7.46±0.27 (7.04-7.84) | 7.66±0.26 (7.35-8.15) | 7.52±0.16 (7.33-7.79) | 7.45±0.21 (7.13-7.75) | 7.10±0.12 (6.94-7.30) | 6.96±0.23 (6.76-7.29) | 7.13±0.27 (6.85-7.66) | 0.574 |
| EC ($\mu Scm^{-1}$) | 152.33±10.21 (137.00-167.00) | 154.44±7.18 (143.00-162.00) | 153.00±6.50 (141.00-160.00) | 164.00±4.09 (158.00-168.00) | 176.33±10.83 (168.00-192.00) | 166.78±5.56 (159.00-173.00) | 184.22±20.16 (168.00-212.00) | 190.33±22.31 (171.00-222.00) | 337.89±34.10 (304.00-384.00) | 195.33±21.02 (175.00-223.00) | 0.001 |
| TDS ($mgL^{-1}$) | 76.67±4.77 (69.00-83.00) | 77.22±3.90 (71.00-81.00) | 75.67±3.32 (70.00-80.00) | 82.00±2.18 (78.00-84.00) | 87.67±5.57 (83.00-96.00) | 83.22±2.77 (80.00-87.00) | 91.89±10.12 (84.00-106.00) | 94.00±10.81 (83.00-110.00) | 168.89±16.66 (153.00-191.00) | 97.67±10.50 (87.00-111.00) | 0.001 |
| DO ($mgL^{-1}$) | 6.22±1.37 (4.16-7.42) | 6.09±1.37 (4.20-7.65) | 5.99±1.29 (4.25-7.52) | 5.10±1.89 (3.38-7.62) | 6.35±1.16 (5.13-7.90) | 5.93±0.81 (4.75-6.86) | 5.93±0.95 (4.68-6.85) | 5.01±0.63 (4.41-5.90) | 2.98±0.56 (2.18-3.54) | 5.65±0.65 (4.70-6.55) | 0.018 |
| Turbidity (FAU) | 5.00±4.33 (1.00-10.00) | 9.44±5.17 (4.00-21.00) | 9.11±7.17 (2.00-25.00) | 8.11±4.76 (1.00-15.00) | 13.89±6.33 (6.00-21.00) | 6.67±3.16 (4.00-14.00) | 22.67±10.00 (6.00-39.00) | 14.33±3.24 (8.00-20.00) | 40.00±14.53 (23.00-59.00) | 20.11±6.88 (10.00-31.00) | 0.157 |
| SS ($mgL^{-1}$) | 2.11±2.32 (0.00-6.00) | 2.89±1.62 (1.00-6.00) | 5.44±3.78 (1.00-14.00) | 3.22±1.56 (1.00-5.00) | 8.56±3.13 (4.00-12.00) | 5.33±4.50 (2.00-17.00) | 13.89±4.51 (8.00-23.00) | 9.22±2.17 (7.00-13.00) | 25.56±11.50 (13.00-41.00) | 11.89±3.02 (8.00-17.00) | 0.075 |
| $PO_4^{-3}$ ($mgL^{-1}$) | 0.01±0.01 (0.00-0.02) | 0.04±0.04 (0.00-0.12) | 0.04±0.04 (0.01-0.10) | 0.07±0.06 (0.01-0.15) | 0.08±0.05 (0.01-0.14) | 0.03±0.03 (0.01-0.10) | 0.11±0.08 (0.01-0.23) | 0.11±0.09 (0.01-0.26) | 0.36±0.21 (0.16-0.71) | 0.13±0.10 (0.04-0.35) | 0.019 |
| Chlorophyll-a ($\mu gL^{-1}$) | 2.36±1.55 (0.42-4.48) | 1.74±1.60 (0.52-4.17) | 1.30±0.71 (0.21-2.09) | 1.00±0.83 (0.42-3.13) | 4.42±6.00 (0.31-15.64) | 0.97±0.86 (0.31-3.02) | 1.44±0.69 (0.42-2.61) | 1.37±0.72 (0.10-2.29) | 5.35±2.06 (2.40-8.65) | 1.82±1.43 (0.42-4.27) | 0.336 |

It was found that the mean values of EC and TDS were the highest at site P9 (337.89 μScm$^{-1}$, 168.89 mgL$^{-1}$) and the lowest at site P1 (152.33 μScm$^{-1}$, 76.67 mgL$^{-1}$). The highest mean value of DO was at site P5 (6.35 mgL$^{-1}$) and the lowest at site P9 (2.98 mgL$^{-1}$). In addition, the highest mean value of $PO_4^{-3}$ was at site P9 (0.36 mgL$^{-1}$) and the lowest was at site P1 (0.00 mgL$^{-1}$). Water quality of site P9 was poor with high EC, TDS, $PO_4^{-3}$ and low DO, as previously mentioned, due to this site receiving untreated sewage water from Khon Kaen municipality. Based on the standard surface water quality of Thailand (Pollution Control Department, PCD 2000), sites P1, P2 and P3 were classified into water quality class 2 (good quality) used for consumption but requiring ordinary water treatment process before use, conservation of aquatic organisms, fisheries and recreation while sites P4-P8 and P10 were in class 3 (fair quality) used for consumption by passing through an ordinary treatment process before use and agriculture and site P9 was in class 4 (poor quality) used for consumption, but requiring a special treatment process and industry.

***Diversity of chironomid larvae****.* Table 3 shows percentage of total number count, percentage relative abundance, number of taxa and total number of chironomids sampled at each sampling site. A total of 4,028 individuals, 49 taxa, 35 genera and 3 subfamilies (Chironominae, Tanypodinae and Orthocladiinae) of chironomid larvae were found. The chironomid larvae of the Phong River mainly consisted of Chironominae comprising 90.3% abundance (41 taxa, 28 genera) of the total chironomid larvae. This was followed by Tanypodinae and Orthocladiinae comprising 9.5% (5 taxa, 5 genera) and 0.2% abundance (3 taxa, 2 genera), respectively. The present study showed that *Polypedilum nubifer*, *Cladotanytarsus mancus* and *Skusella* sp. were the most abundant species within the chironomid assemblage, contributing 25.40%, 16.31% and 15.07% of total abundance, in order. *Cryptochironomus* sp., *Polypedilum nodosum* and *Skusella* sp. were present in all the study sites. The highest diversity of taxa richness (29 taxa) was found at site P1 followed by sites P2, P4, P3, P5, P6, P8, P10 and P7, in order and the lowest richness (4 taxa) occurred at site P9. From the previous studies by Mustow et al (2002), Cranston (2007) and Utayopas (2011), three subfamilies and 48 genera of chironomid larvae were reported from Thailand. *Larsia*, *Conochironomus*, *Einfeldia*, *Fittkauimyia, Micropsectra*, *Tanypus*, *Tribelos*, *Orthocladius*, *Demicryptochironomus*, *Kloosia*, *Nilodorum*, *Robackia*, *Xenochironomus*, *Pseudochironomus*, *Sublettea*, *Cardiocladius*, *Corynoneura*, *Eukiefferiella*, *Parakiefferiella*, *Rheocricotopus*, *Thienemanniella*, *Coelotanypus*, *Nilotanypus* and *Monopelopia* were not found in this study. From the present study, *Axarus*, *Endochironomus*, *Microtendipes*, *Neozavrelia*, *Paratendipes*, *Skusella*, *Stenochironomus*, *Xylochironomus* and *Nilodosis* were the first reports from Thailand. It is found that five genera reported by Mustow et al (2002), Cranston (2007) and Utayopas (2011) were also found in the present study, namely *Chironomus*, *Clinotanypus*, *Parachironomus*, *Polypedilum* and *Tanytarsus*. This may be due to *Chironomus*, *Parachironomus* and *Tanytarsus* having worldwide distribution, whereas *Polypedilum* is very common in the tropical region (Cranston 2007).

Table 3

Percentage of total number count is shown for taxa, percentage relative abundance, number of taxa and total number of chironomids sampled at each of the sampling sites along the Phong River

| *Taxa* | *Percent of total number* | *Site* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *P1* | *P2* | *P3* | *P4* | *P5* | *P6* | *P7* | *P8* | *P9* | *P10* |
| **Chironominae** | | | | | | | | | | | |
| *Tribe Chironomini* | | | | | | | | | | | |
| 1 *Axarus* sp. | 1.24 | 1.03 | | | 0.85 | 10.11 | 5.56 | | | | 22.58 |
| 2 *Chironomus* sp. | 0.99 | 0.62 | | | 1.69 | 0.56 | 0.46 | | | 77.42 | 6.45 |
| 3 *Cladopelma* sp. | 0.02 | 0.10 | | | | | | | | | |
| 4 *Cladopelma edwardsi* | 0.05 | | | | 0.56 | | | | | | |
| 5 *Cryptochironomus* sp. | 4.52 | 9.31 | 2.41 | 3.44 | 4.79 | 2.25 | 5.56 | 1.11 | 1.39 | 6.45 | 16.13 |
| 6 *Cryptotendipes* sp. | 0.02 | | | | | | | | 0.35 | | |
| 7 *Dicrotendipes* sp. | 6.80 | 7.96 | 13.35 | 1.91 | 10.70 | | 1.39 | | 0.35 | | 3.23 |
| 8 *Endochironomus* sp. | 0.02 | | | | | | | | 0.35 | | |
| 9 *Glyptotendipes* sp. | 0.02 | | | | | 0.56 | | | | | |
| 10 *Harnischia* sp. | 0.55 | | 0.09 | 1.53 | 1.41 | 0.56 | | 0.28 | 0.70 | | 12.90 |
| 11 *Kiefferulus* sp. | 0.02 | | 0.09 | | | | | | | | |
| 12 *Microchironomus* sp. | 0.55 | | 0.19 | 0.96 | 1.13 | | | | 3.48 | | 3.23 |
| 13 *Microtendipes pedellus* | 0.02 | 0.10 | | | | | | | | | |
| 14 *Nilodosis* sp. | 0.22 | 0.10 | | 1.34 | | | | | 0.35 | | |
| 15 *Parachironomus* sp. | 0.12 | 0.41 | 0.09 | | | | | | | | |
| 16 *Paratendipes nudisquma* | 0.12 | | | | | 2.81 | | | | | |
| 17 *Polypedilum* (*Tripedilum*) sp. | 0.52 | | 0.19 | | 5.07 | | 0.46 | | | | |
| 18 *Polypedilum* (*Tripodura*) sp. | 0.22 | 0.21 | | | 1.97 | | | | | | |
| 19 *Polypedilum griseoguttatum* | 3.03 | 0.10 | 1.11 | 1.34 | 0.85 | 22.47 | 12.96 | 6.93 | 2.09 | | |
| 20 *Polypedilum leei* | 0.10 | | 0.37 | | | | | | | | |
| 21 *Polypedilum nodosum* | 2.73 | 1.03 | 2.59 | 4.21 | 3.38 | 4.49 | 3.70 | 1.94 | 3.14 | 12.90 | 6.45 |
| 22 *Polypedilum nubifer* | 25.40 | 42.50 | 31.60 | 39.20 | 10.99 | 4.49 | 7.87 | | 0.70 | | |

| *Taxa* | *Percent of total number* | | | | | *Site* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 *Polypedilum pedestre* | 0.22 | | | 0.38 | 1.97 | | | | | | |
| 24 *Polypedilum sordens* | 3.08 | 10.03 | 1.48 | 1.53 | | | 0.46 | | 0.70 | | |
| 25 *Polypedilum* sp.1 | 0.55 | 1.03 | 0.09 | 0.19 | | 5.62 | | | | | |
| 26 *Polypedilum* sp.2 | 0.07 | | | | 0.85 | | | | | | |
| 27 *Polypedilum* sp.3 | 0.50 | 0.62 | | | | 6.74 | 0.93 | | | | |
| 28 *Polypedilum* sp.4 | 1.29 | 0.52 | 1.67 | 0.38 | 1.69 | 7.87 | 2.78 | 0.28 | | | |
| 29 *Saetheria* sp. | 0.02 | | | 0.19 | | | | | | | |
| 30 *Skusella* sp. | 15.07 | 1.76 | 1.95 | 1.34 | 17.46 | 6.74 | 10.65 | 88.37 | 48.78 | 3.23 | 16.13 |
| 31 *Stenochironomus* sp. | 0.02 | 0.10 | | | | | | | | | |
| 32 *Stictochironomus* sp.1 | 0.12 | 0.41 | 0.09 | | | | | | | | |
| 33 *Stictochironomus* sp.2 | 0.10 | | 0.19 | | | 0.56 | | | 0.35 | | |
| 34 unknown 1 | 0.05 | | 0.09 | | 0.28 | | | | | | |
| 35 *Xylochironomus* sp. | 0.25 | 0.21 | 0.56 | 0.19 | 0.28 | | | | | | |
| 36 *Zavreliella* sp. | 0.05 | 0.10 | | | 0.28 | | | | | | |
| *Tribe Tanytarsini* | | | | | | | | | | | |
| 37 *Cladotanytarsus mancus* | 16.31 | 8.48 | 18.63 | 19.69 | 13.80 | 16.29 | 40.28 | 1.11 | 34.15 | | 12.90 |
| 38 *Neozavrelia* sp. | 0.12 | | | | | | 2.31 | | | | |
| 39 *Paratanytarsus* sp. | 0.05 | | | | | 1.12 | | | | | |
| 40 *Rheotanytarsus* sp. | 0.25 | 0.52 | 0.09 | | | 1.12 | 0.93 | | | | |
| 41 *Tanytarsus* sp. | 4.92 | 2.48 | 9.64 | 5.93 | 5.92 | 4.49 | 2.78 | | 1.39 | | |
| **Orthocladiinae** | | | | | | | | | | | |
| 1 *Cricotopus* sp.1 | 0.07 | 0.10 | 0.09 | | 0.28 | | | | | | |
| 2 *Cricotopus trianulatus* | 0.07 | | | | 0.28 | 0.56 | 0.46 | | | | |
| 3 *Nanocladius* sp. | 0.02 | | 0.09 | | | | | | | | |
| **Tanypodinae** | | | | | | | | | | | |
| 1 *Ablabesmyia* sp. | 1.84 | 3.41 | 1.67 | 1.34 | 4.51 | | | | | | |
| 2 *Clinotanypus* sp. | 5.93 | 4.65 | 9.82 | 12.05 | 5.92 | | 0.46 | | 1.05 | | |
| 3 *Paramerina* sp. | 0.02 | | | | | | | | 0.35 | | |

| *Taxa* | *Percent of total number* | *Site* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 *Procladius* sp. | 1.02 | 1.03 | 0.83 | 2.87 | 1.97 | | | | | | |
| 5 unknown 2 | 0.65 | 1.03 | 0.93 | | 1.13 | 0.56 | | | 0.35 | | |
| Number of taxa | 49 | 29 | 28 | 20 | 27 | 20 | 18 | 7 | 18 | 4 | 9 |
| Total number of chironomids | 4,028 | 967 | 1079 | 523 | 355 | 178 | 216 | 361 | 287 | 31 | 31 |

***Chironomid larvae and environmental variables***. The effect of the environmental parameters on the distribution of chironomid larvae was investigated using CCA. The CCA first axis explained 27.2% and the second axis 17.8% of the variance and a Monte Carlo permutation test was significant ($p<0.001$). The results of CCA showed that chironomid assemblage composition at sites P7, P8, P9 and P10 were affected by a heavy pollution gradient (Figure 2).

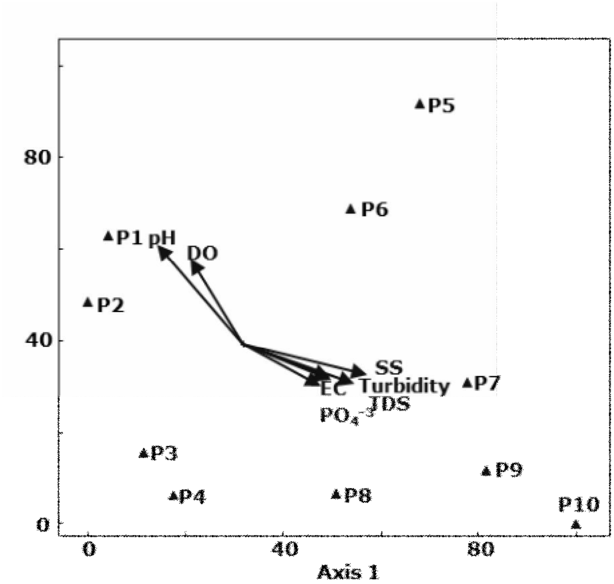


Figure 2. Ordination canonical correspondence analysis (CCA) biplot for sampling site and environmental variables on the axes 1 and 2.

*Cryptochironomus* sp., *P. nodosum*, *Skusella* sp., *Chironomus* sp., *Harnischia* sp., *Microchironomus* sp., *Paramerina* sp., *Cryptotendipes* sp. and *Endochironomus* sp. had significantly positive relationships to high EC, TDS, Turbidity, SS and $PO_4^{-3}$ (Figure 3). Sites P7-P10 were classified as water quality class 3 (fair) to class 4 (poor), since SS, turbidity, EC and $PO_4^{-3}$ were parameters indicating pollution (PCD 2000). It was clear that sites P7-P10 had more pollution gradient than those of sites P1 and P2. The calculated chironomid tolerance value ranged from 0.94 to 6.67. They were divided based on the $65^{th}$ percentile of value to 2 groups including (1) tolerant group with score range from 0.94-4.43 and (2) very tolerant group with score from 4.44-6.67. The tolerant group were composed of *C. mancus*, *Stictochironomus* sp.2, *Polypedilum* sp.3, *Polypedilum* sp.4, *P. nubifer, Tanytarsus* sp., unknown 2, *Rheotanytarsus* sp., *Polypedilum sordens*, *Dicrotendipes* sp., *Cricotopus trianulatus*, *Nilodosis* sp., *Clinotanypus* sp., *Procladius* sp., *Xylochironomus* sp., *Polypedilum* sp.1 and *Ablabesmyia* sp., whereas the very tolerant group consisted of *Cricotopus* sp.1, *Chironomus* sp., *Axarus* sp., *Harnischia* sp., *Polypedilum griseoguttatum*, *Polypedilum* (*Tripedilum*) sp., *Cryptochironomus* sp., *Skusella* sp., *P. nodosum* and *Microchironomus* sp. (Table 4). The results of CCA agreed with the results of chironomid tolerance score, by which *Cryptochironomus* sp*., P. nodosum, Skusella* sp*., Chironomus* sp*., Harnischia* sp. *and Microchironomus* sp. were classified as very tolerant chironomid taxa and they occurred in a high pollution gradient. Mousavi et al (2003) and Salma et al (2010) mentioned that *Chironomus* was very tolerant and *Polypedilum* was tolerant, since chironomid larvae can be found elsewhere ranging from less impact to heavily polluted rivers (Barton et al 1994; Hardwick et al 1994). Moreover, Cranston (2007) found chironomid larvae in both un-impacted and impacted water sources after the Tsunami disaster in Thailand. Chironomid tolerance score may aid to determine the impact in a water body. In addition, we also found chironomid larvae with different mouth part deformities in the chironomid tolerant group from various water qualities (unpublished data). From this point of view, chironomid tolerance score and/or chironomid mouth part deformity may help to assess the impact on freshwater habitats.

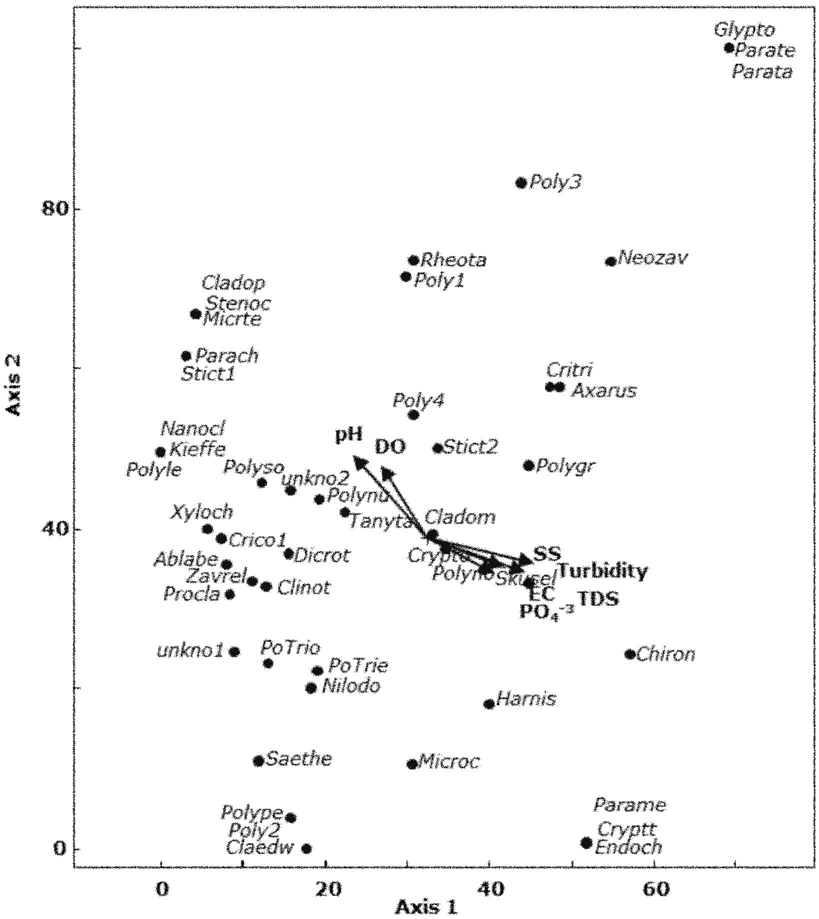


Figure 3. Ordination canonical correspondence analysis (CCA) biplot for chironomids taxa and environmental variables on the axes 1 and 2 (*Ablabe* = *Ablabesmyia* sp., *Axarus* = *Axarus* sp., *Chiron* = *Chironomus* sp., *Cladom* = *Cladotanytarsus mancus*, *Claedw* = *Cladopelma edwardsi*, *Cladop* = *Cladopelma* sp., *Clinot* = *Clinotanypus* sp., *Crico1* = *Cricotopus* sp.1, *Critri* = *Cricotopus trianulatus, Crypto* = *Cryptochironomus* sp., *Cryptt* = *Cryptotendipes* sp., *Dicrot* = *Dicrotendipes* sp., *Endoch* = *Endochironomus* sp., *Glypto* = *Glyptotendipes* sp., *Harnis* = *Harnischia* sp., *Kieffe* = *Kiefferulus* sp., *Microc* = *Microchironomus* sp., *Micrte* = *Microtendipes pedellus*, *Nanocl* = *Nanocladius* sp., *Neozav* = *Neozavrelia* sp., *Nilodo* = *Nilodosis* sp., *Parach* = *Parachironomus* sp., *Parame* = *Paramerina* sp., *Parata* = *Paratanytarsus* sp., *Parate* = *Paratendipes nudisquma*, *Poly1* = *Polypedilum* sp.1, *Poly2* = *Polypedilum* sp.2, *Poly3* = *Polypedilum* sp.3, *Poly4* = *Polypedilum* sp.4, *Polygr* = *Polypedilum griseoguttatum*, *Polyle* = *Polypedilum leei, Polyno* = *Polypedilum nodosum*, *Polynu* = *Polypedilum nubifer*, *Polype* = *Polypedilum pedestre*, *Polyso* = *Polypedilum sordens*, *PoTrie* = *Polypedilum (Tripedilum)* sp., *PoTrio* = *Polypedilum* (*Tripodura*) sp., *Procla* = *Procladius* sp., *Rheota* = *Rheotanytarsus* sp., *Saethe* = *Saetheria* sp., *Stenoc* = *Stenochironomus* sp., *Skusel* = *Skusella* sp., *Stict1* = *Stictochironomus* sp.1, *Stict2* = *Stictochironomus* sp.2, *Tanyta* = *Tanytarsus* sp., unkno1 = unknown 1, unkno2= unknown 2, *Xyloch* = *Xylochironomus* sp., *Zavrel* = *Zavreliella* sp.).

Table 4

Chironomid taxa, number of each chironomids' taxa and tolerance values of chironomid larvae at each sampling site along the Phong River

| *Taxa* | *Site* | | | | | | | | | | *Tolerance value* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *P1* | *P2* | *P3* | *P4* | *P5* | *P6* | *P7* | *P8* | *P9* | *P10* | |
| **Chironominae** | | | | | | | | | | | |
| *Tribe Chironomini* | | | | | | | | | | | |
| 1 *Axarus* sp. | 10 | | | 3 | 18 | 12 | | | | 7 | 5.71 |
| 2 *Chironomus* sp. | 6 | | | 6 | 1 | 1 | | | 24 | 2 | 6.43 |
| 3 *Cryptochironomus* sp. | 90 | 26 | 18 | 17 | 4 | 12 | 4 | 4 | 2 | 5 | 4.9 |
| 4 *Dicrotendipes* sp. | 77 | 144 | 10 | 38 | | 3 | | 1 | | 1 | 2.95 |
| 5 *Harnischia* sp. | | 1 | 8 | 5 | 1 | | 1 | 2 | | 4 | 5.25 |
| 6 *Microchironomus* sp. | | 2 | 5 | 4 | | | | 10 | | 1 | 4.44 |
| 7 *Nilodosis* sp. | 1 | | 7 | | | | | 1 | | | 2.5 |
| 8 *Polypedilum* (*Tripedilum*) sp. | | 2 | | 18 | | 1 | | | | | 5 |
| 9 *Polypedilum griseoguttatum* | 1 | 12 | 7 | 3 | 40 | 28 | 25 | 6 | | | 5.17 |
| 10 *Polypedilum nodosum* | 10 | 28 | 22 | 12 | 8 | 8 | 7 | 9 | 4 | 2 | 4.46 |
| 11 *Polypedilum nubifer* | 411 | 341 | 205 | 39 | 8 | 17 | | 2 | | | 3.55 |
| 12 *Polypedilum sordens* | 97 | 16 | 8 | | | 1 | | 2 | | | 3 |
| 13 *Polypedilum* sp.1 | 10 | 1 | 1 | | 10 | | | | | | 1.25 |
| 14 *Polypedilum* sp.3 | 6 | | | | 12 | 2 | | | | | 4.17 |
| 15 *Polypedilum* sp.4 | 5 | 18 | 2 | 6 | 14 | 6 | 1 | | | | 3.93 |
| 16 *Skusella* sp. | 17 | 21 | 7 | 62 | 12 | 23 | 319 | 140 | 1 | 5 | 4.58 |
| 17 *Stictochironomus* sp.2 | | 2 | | | 1 | | | 1 | | | 4.17 |
| 18 *Xylochironomus* sp. | 2 | 6 | 1 | 1 | | | | | | | 1.25 |
| *Tribe Tanytarsini* | | | | | | | | | | | |
| 19 *Cladotanytarsus mancus* | 82 | 201 | 103 | 49 | 29 | 87 | 4 | 98 | | 4 | 4.35 |
| 20 *Rheotanytarsus* sp. | 5 | 1 | | | 2 | 2 | | | | | 3.13 |
| 21 *Tanytarsus* sp. | 24 | 104 | 31 | 21 | 8 | 6 | | 4 | | | 3.47 |
| **Orthocladiinae** | | | | | | | | | | | |
| 1 *Cricotopus* sp.1 | | | | 1 | 1 | 1 | | | | | 6.67 |
| 2 *Cricotopus trianulatus* | 1 | 1 | | 1 | | | | | | | 2.5 |
| **Tanypodinae** | | | | | | | | | | | |
| 1 *Ablabesmyia* sp. | 33 | 18 | 7 | 16 | | | | | | | 0.94 |
| 2 *Clinotanypus* sp. | 45 | 106 | 63 | 21 | | 1 | | 3 | | | 2.31 |
| 3 *Procladius* sp. | 10 | 9 | 15 | 7 | | | | | | | 1.25 |
| 4 unknown 2 | 10 | 10 | | 4 | 1 | | | 1 | | | 3.18 |
| Number of taxa | 22 | 22 | 18 | 21 | 17 | 17 | 7 | 15 | 4 | 9 | |
| Total number of chironomids | 953 | 1070 | 520 | 334 | 170 | 211 | 361 | 284 | 31 | 31 | |

**Conclusions**. According to the present study 49 taxa, 35 genera and 3 subfamilies (Chironominae, Tanypodinae and Orthocladiinae) of chironomid larvae were found in the Phong River, Thailand. Chironominae was dominant with 90.3% abundance (41 taxa, 28 genera) and was followed by Tanypodinae and Orthocladiinae comprising 9.5% (5 taxa, 5 genera) and 0.2% abundance (3 taxa, 2 genera), respectively. *Polypedilum nubifer*, *Cladotanytarsus mancus* and *Skusella* sp. were the most abundant species within the chironomid assemblage. The chironomid larvae were divided into 2 groups based on their resistance to water pollution in the Phong River. Approximately 30% of the total chironomid larvae were very tolerant group, regarding water quality. The very tolerant group is composed of *Cricotopus* sp.1, *Chironomus* sp., *Axarus* sp., *Harnischia* sp., *Polypedilum griseoguttatum*, *Polypedilum* (*Tripedilum*) sp., *Cryptochironomus* sp., *Skusella* sp., *P. nodosum* and *Microchironomus* sp. which were found at sites of high values of suspended solids, turbidity, electrical conductivity, total dissolved solids and orthophosphate. The other 70% chironomid larvae were tolerant group inhabited in good to fair water quality.

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