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Diversity and Structure of Trichoptera Communities and Water Quality Variables in Streams, Northern Thailand

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***Abstract*—**The influence of physicochemical water quality parameters on the abundance and diversity of caddisfly larvae was studied in seven sampling stations in Mae Tao and Mae Ku watersheds, Mae Sot District, Tak Province, northern Thailand. The streams: MK2 and MK8 as reference site, and impacted streams (MT1-MT5) were sampled bi-monthly during July 2011 to May 2012. A total of 4,584 individual of caddisfly larvae belonging to 10 family and 17 genera were found. The larvae of family *Hydropsychidae* were the most abundance, followed by *Philopotamidae*, *Odontoceridae*, and *Leptoceridae*, respectively. The genus *Cheumatopsyche, Hydropsyche*, and *Chimarra* were the most abundance genera in this study. Results of CCA ordination showed the total dissolved solids, sulfate, water temperature, dissolved oxygen and pH were the most important physicochemical factors to affect distribution of caddisflies communities. Changes in the caddisfly fauna may indicate changes in physicochemical factors owing to agricultural pollution, urbanization, or other human activities. Results revealed that the order Trichoptera, identified to species or genus, can be potentially used to assess environmental water quality status in freshwater ecosystems.

***Keywords*—**Caddisfly larvae, environmental variables, diversity, streams.

I. INTRODUCTION

FRESHWATER benthic macroinvertebrates inhabit river and stream beds, lakes and reservoirs and are associated with various types of substrates such as mineral sediments, detritus, macrophytes and filamentous algae [1]. They are essential elements in lentic and lotic trophic webs, participating in the energy flow and nutrient cycling [2]. They are also important food resources for fish [3] and some insectivorous birds [4]. The distribution of aquatic organisms is the result of interactions among their ecological role, the physical conditions that characterize the habitat, and food availability [5]. Thus, the community structure of benthic macroinvertebrates depends on a number of factors, such as water quality, type of substrate, particle size of sediment, water flow, sediment organic matter availability, oxygen concentration as well as environmental conditions surrounding the watercourse [4], [6]. Because they reflect environmental changes, benthic macroinvertebrates are often used as indicators of the effects of human activity on water system and they provide information on habitat and water quality [7]. The organic enrichment of water caused by both domestic and industrial effluents is a common anthropogenic impact on urban watercourses. This kind of pollution changes physical and chemical characteristics of lotic systems, thus affecting the assemblage of benthic macroinvertebrates [4], [8].

Amongst the benthic macroinvertebrates, order Trichoptera (or caddisflies) are probably the most widely distributed and larvae are common in running water (8-13% of total abundance) [9] and they represent one of the relatively well studied orders of aquatic insects in South East Asia [10], [11]. The larvae of many species coexist in running waters and they are known to have specific habitat and environmental requirements [12]. Caddisflies have been described as the most ecologically diverse group of aquatic insects, with 13,574 described species [11]. As a numerically dominant group in rivers and streams, caddisflies are important to the functioning of freshwater ecosystems because of their ability to partition habitats and trophic resources [13]. Their response to perturbation and reliance on plant matter for food are reasons why caddisflies are widely used in several aspects of water quality monitoring [14]. Furthermore, their well-described biology and taxonomy facilitate interpretation of water quality assessments. The use of species level identification to monitors water quality pollution is much more precise than using family or generic level [15]. The aim of this study was to investigate the diversity and structure of caddisflies communities in relation to water quality variables in order to explore the bioindication potential of caddisflies larvae for assessing water quality deterioration in northern Thailand.

II. MATERIAL AND METHODS

A. Description of the Study Area

Mae Tao and Mae Ku watersheds are located in the lower part of Mae Sot district, Tak Province, northern Thailand. The main agricultural products in this area are rice, soybean, sugar cane and garlic. The main industries are zinc mines and textiles. The seven sampling sites were selected in this study (Fig. 1). Study sites in Mae Tao watershed included MT1, MT2, MT3, MT4 and MT5, which runs through the mine. Agricultural activities were found along the length of this stream. MK2 and MK8, which both are parallel flow with

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that stream, were located in Mae Ku watershed. The stream from Mae Tao and Mae Ku watersheds flows to the Moei River. This river is the borderline between Myanmar and Thailand. It is 327 km long, flowing towards the north unlike a river in general. Also, the stream from watershed in Phop Phra district, Tak Province flows to Mae Hong Son via Mae Sot, Mae Ramat, and Tha Song Yang, to merge into the Salween River in Myanmar before flowing into the Gulf of Martaban.

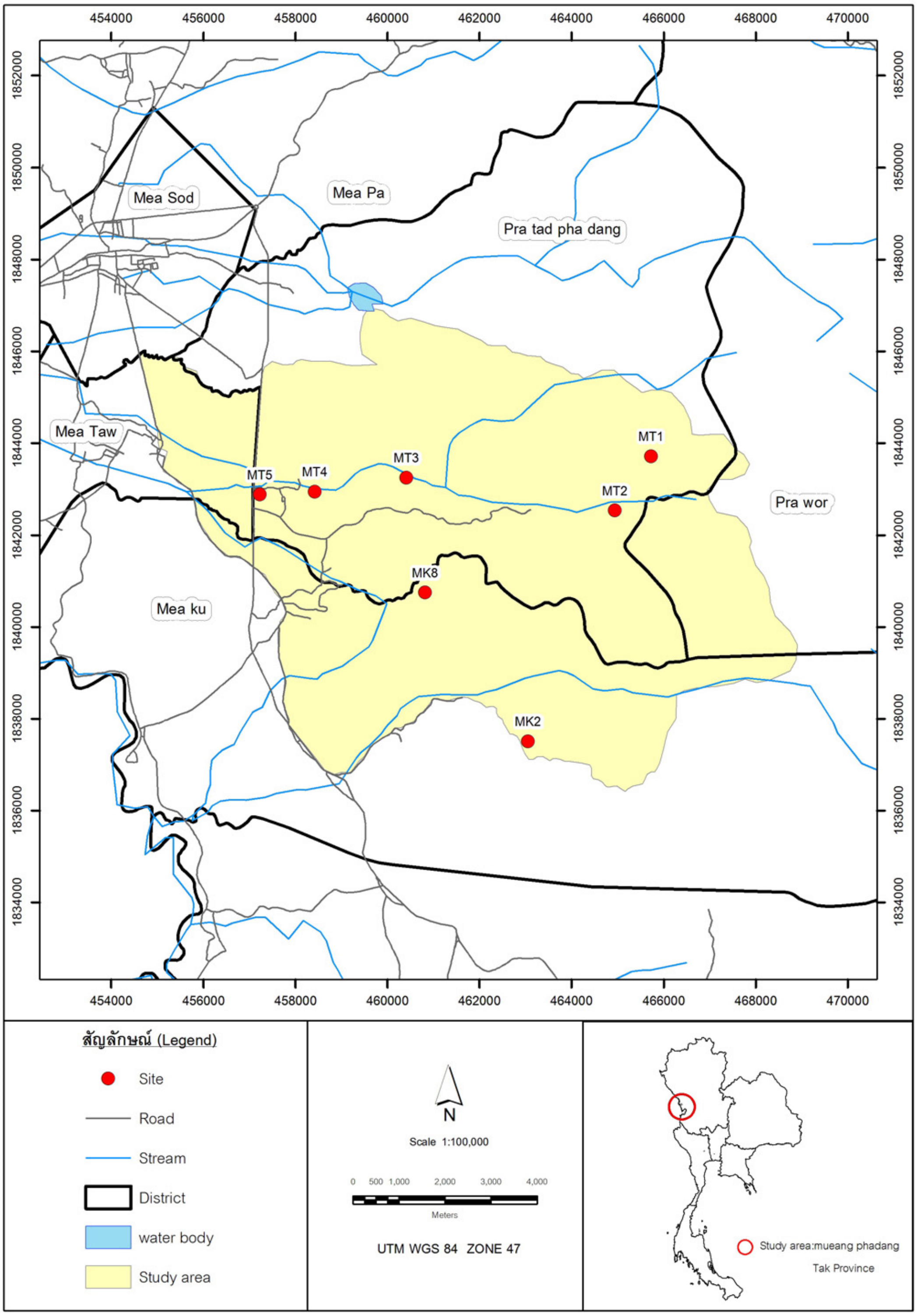

Fig. 1 The sampling sites in Mae Tao (MT1-MT5) and Mae Ku (MK2, MK8) watersheds, Mae Sot District, Tak Province, Northern Thailand

B. Sample Collection

At each site, the sample was collected bi-monthly during July 2011 to May 2012. The physicochemical water quality parameters were measured at all sampling stations between 09 a.m and 5 p.m prior to aquatic insect sampling. Three replicates of the physicochemical water quality parameters were recorded directly at each sampling site and included pH, measured by a pH-meter Waterproof Model Testr30, water temperature (WT) was measured by a hand-held thermometer, and dissolved oxygen (DO), which was measured by a HACH® Model sensION 6 DO meter cyberScan Model DO110, total dissolved solid (TDS) was measured by a EURECH CyberScan CON110 conductivity/TDS meter. Water samples from each collecting period were stored in polyethylene bottles (500 mL). The sulfate (SO_4^{2-}) and nitrate-nitrogen (NO_3-N) were determined in accordance with the standard method procedures [16].

At each sampling period, semi-quantitative samples of caddisflies larvae from the different microhabitats (riffles, depositional zones, different types of vegetation), were collected. A D-frame [5] aquatic hand net (mesh sieve 250 µm) was used. Lotic habitats with stony substrates were sampled during about 15 minutes along an approximately 100 m reach by hand-picking. Other habitats (fine sediments, roots, submerged and aquatic vegetation) were sampled at least in three different zones along the same reach. The contents of the aquatic hand net were poured into white trays. Living caddisflies were sorted and transferred into properly labelled plastic containers, preserved in 80% ethanol and taken back to the laboratory for analysis. In the laboratory, caddisflies larvae were sorted on a petri dish and identified to the genus and species level using taxonomic keys by several authors [13], [17]-[19]. All the sorted samples were kept in properly labelled vials containing 80% ethanol.

C. Data Analysis

The one-way ANOVA ($P < 0.05$) was used to test the difference in means of caddisfly larval abundance among various sampling occasions and among the sampling sites. Pearson's correlation was used to assess the influence of physicochemical variables on the abundance of the caddisfly larvae using the SPSS (Statistical Package for Social Science), Version 13.0. Canonical correspondence analysis (CCA) of PC-ORD Version 4.0 [20] investigate the contribution of the environmental stressors on the distribution and abundance of transformed caddisflies species data (log(x+1)). The Monte-Carlo test was applied to test the significance of the produced canonical axes with 998 permutations at $P < 0.05$. The biplot ordination diagram was produced using CanoDraw for Windows 10. In the CCA, taxa constituting more than 0.1% of the total abundance were selected, and in totals, 14 taxa were used in the analyses.

III. RESULTS

A. Physicochemical Water Quality Parameters

Table I summarized the means, standard deviations of measured physicochemical water quality parameters at the sampling sites taken during the six sampling periods. Dissolved oxygen was not varied significantly during the time of measured (P>0.05), whereas water temperature, pH, total dissolved solids, sulfate and nitrate-nitrogen were varied significantly during the time of measured (P<0.05). Temperature varied from 24.11 (MK2) to 27.22Cº (MK8). The lowest mean value of dissolved oxygen (4.32 mg l^{-1}) was found in the downstream station (MT4 and MT5), and the highest values were observed in upper stream station (≥4.35 mg l^{-1}). Regarding the pH, the water of Mae Tao and Mae Ku watersheds were slightly alkaline with low variation of pH ((8.06 (MT 1) -8.78 (MK2)). The highest mean value of total dissolved solids (294.04 mg l^{-1}) was observed at MK8 and lowest was observed at MT1 (158.12 mg l^{-1}). The mean nitrate-nitrogen concentrations varied from 1.91 (MT1 and MT2) to 3.05 mg l^{-1} (MK8). The mean sulfate value concentration varied from 16.14 (MT1) to 36.85 mg l^{-1} (MT5).

TABLE I

MEAN ± SD SELECTED PHYSICOCHEMICAL WATER QUALITY PARAMETER MEASURED BI-MONTHLY IN MAE TAO AND MAE KU WATERSHEDS DURING JULY 2011 TO MAY 2012

Site/ parameter	WT (ºC)	DO (mg l^{-1})	pH	TDS (mg l^{-1})	NO_3-N (mgl^{-1})	SO_4^{2-} (mg l^{-1})
MT1	$26.24±2.04^{ab}$	$4.35±1.00^{a}$	$8.06±0.19^{a}$	$158.12±31.96^{a}$	$1.91±0.63^{a}$	$16.14±2.85^{a}$
MT2	$25.35±1.68^{ab}$	$5.30±1.12^{a}$	$8.58±0.11^{bc}$	$231.04±21.24^{bc}$	$1.91±0.49^{a}$	$23.85±5.46^{ab}$
MT3	$25.54±1.98^{ab}$	$5.26±0.78^{a}$	$8.66±0.13^{cd}$	$228.71±52.61^{bc}$	$2.07±0.49^{a}$	$33.28±5.46^{c}$
MT4	$25.02±2.31^{ab}$	$4.32±1.07^{a}$	$8.62±0.19^{bcd}$	$211.28±50.20^{ab}$	$2.55±1.19^{ab}$	$34.42±5.79^{c}$
MT5	$25.50±2.29^{ab}$	$4.32±1.81^{a}$	$8.43±0.27^{b}$	$245.86±48.68^{bc}$	$2.18±0.71^{a}$	$36.85±7.01^{c}$
MK2	$24.11±1.85^{a}$	$5.38±1.03^{a}$	$8.78±0.09^{d}$	$244.33±62.18^{bc}$	$3.01±0.62^{b}$	$20.66±5.31^{ab}$
MK8	$27.22±2.45^{b}$	$5.04±0.85^{a}$	$8.50±0.08^{bc}$	$294.04±107.75^{c}$	$3.06±0.33^{b}$	$25.42±12.08^{b}$

Values with different letters indicate significant mean difference following Turkey post hoc tests (P<0.05)

B. Caddisfly Larvae Abundance and Distribution

The relative abundance and distribution of caddisflies larvae recorded at each of sampling sites during each of sampling periods are presented in Table II. Eighteen genera in ten families, with a total of 4 584 larvae, were collected (Table II). At MT1 and MT3, 599 and 213 specimens in 12 genera were identified, and *Marilia sumatrana* and *Cheumatopsyche* *lucida* were the most abundant. MT2 and MT5 had the largest abundance larvae, 883 and 1 887 specimens in 10 genera, of which *Cheunatopsyche lucida* were the most frequent. MT4 had the highest genera, 454 specimens in 14 genera were collected, with *Cheunatopsyche lucida* were the most frequent. MK2 and MK8 had the lowest abundance, 178 and 370 specimens in 7 and 8 genera, respectively.

As shown in Table III, the abundance of caddisflies taxa (*Agapetus halong*, *Cheumatopsyche lucida* and *Lepidostoma doligung*) recorded from Mae Tao and Mae Ku watersheds shows significant difference among sampling dates (ANOVA, F = 1.578, 2.158, and 2.400, respectively). *Agapetus halong*, *Chimarra* spp., *Helicopsyche* spp., *Cheumatopsyche* spp., *Diplectrona* spp., *Ceraclea* spp., *Setodes* spp., *Marilia sumatrana*, *Anisocentropus erichthonios*, *Ganonema* spp., *Goera* spp. abundance differed significantly (P<0.05) among the investigated sites (ANOVA, F = 1.926, 1.648, 2.500, 3.939, 2.363, 2.250, 2.500, 2.339, 2.500, 3.235, and 2.500, respectively).

Table IV shows the correlation coefficients (Spearman's correlation test at P<0.05) between the physicochemical parameters and caddisflies taxa abundance. *Hydropsyche* spp. and *Macrostemum fenestratum* abundance were negatively correlated with water temperature (P<0.05). *Chimarra* spp. (P<0.05), *Cheumatopsyche* spp. (P<0.01) and *Diplectrona* spp. (P<0.01) showed negative correlation with dissolved oxygen. The abundance of *Agapetus halong* (P<0.05), *Diplectrona* spp. (P<0.01), *Anisocentropus erichthonios* (P<0.01), and *Ganonema* spp. (P<0.01) were negatively correlated with pH, indicating their preference for acidity habitat. The abundance of *Chimarra* spp. were negatively correlated with nitrate-nitrogen (P<0.01). The abundance of *Cheumatopsyche* spp., *Oecetis* spp., and *Lepidostoma doligung* were positively correlated with sulfate (P<0.05).

TABLE II
LIST OF CADDISFLIES LARVAE AND % RELATIVE ABUNDANCE (RA) IN MAE TAO AND MAE KU WATERSHEDS, TAK PROVINCE, NORTHERN THAILAND DURING JULY 2011 TO MAY 2012

Taxa	Abbr.	MT1	MT2	MT3	MT4	MT5	MK2	MK8	%RA
Hydroptilidae									
Orthrotrichia spp.	Orthro			1				1	0.04
Glososomatidae									
Agapetus halong	Agahal	99	33	8	2	24	1		3.64
Philopotamidae									
Chimarra spp.	Chimar	21	187	35	63	134	42	1	10.50
Helicopsychidae									
Helicopsyche spp.	Helico			2					0.04
Hydropsychidae									
Cheumatopsyche lucida	Cheluc	112	392	82	173	848	38	277	41.9
Cheumatopsyche spp.	Che pp.	45	52	34	98	680	1	59	21.1
Diplectrona spp.	Diplec	84	45	2	4	122	13		5.89
Hydropsyche spp.	Hydrop	36	161	1	24	35	80	3	7.42
Macrostemum fenestratum	Macfen		3		2				0.11
Potamyia spp.	Potamy		3		2	32			0.81
Leptoceridae									
Ceraclea spp.	Ceracl	36		3	1			2	0.92
Oecetis spp.	Oeceti	17	4	7	24	1		1	1.19
Setodes spp.	Setode				1				0.02
Odontoceridae									
Marilia sumatrana	Marsum	117	3	37	56	7	3	26	5.43
Lepidostomatidae									
Lepidostoma doligung	Lepdol	6		1		4			0.24
Calamoceratidae									
Anisocentropus erichthonios	Anieri	20							0.44
Ganonema spp.	Ganone	6			2				0.17
Goeridae									
Goera spp.	Goera				2				0.04
Total number of individual		599	883	213	454	1 887	178	370	
Total number of genera		12	10	12	14	10	7	8	

CCA was utilized to investigate the effect of the environmental parameters on the distribution of caddisflies larvae. The CCA biplot is shown in Fig. 2. The first axis explained 46.6% and the second axis 34.3% of the variances and the Monte Carlo permutation test (998 permutations) was significant at $P < 0.05$ (Table IV). Total dissolved solids and sulfate showed the highest positive correlation with axis 1. Axis 1 was interpreted as an environmental gradient of increasing total dissolved solids and sulfate (Table V, Fig. 2). Taxa with high positive scores on the first CCA axis included *Cheumatopsyche lucida* and *Potamyia* spp. Taxa with high negative scores on axis 1 included *Agapetus halong*, *Diplectrona* spp. *Ceraclea* spp., *Marilia sumatrana*, *Oecetis* spp., *Lepidostoma doligung*, *Aniscocentropus erichthonios*, and *Ganoneema* spp. (Fig. 2). Axis 2 explained 34.3% of the variance in taxa–environment relations (Table IV). Water temperature positively correlated while dissolved oxygen and pH negatively correlated with axis 2, so this axis was interpreted as a gradient of increasing values of water temperature and decreasing dissolved oxygen and pH parameter. Taxa with high negative scores on axis 2 included *Chimarra* spp., *Hydropsyche* spp., *Macrostemum fenestratum*. Few taxa (*Cheumatopsyche* spp.) had high positive scores with axis 2 (Fig. 2).

TABLE III
RESULTS OF THE ONE-WAY ANOVA ON BI-MONTHLY VARIATION OF THE CADDISFLIES LARVAE ABUNDANCE FROM JULY 2011 TO MAY 2012

Taxa	ANOVA (factor month, *df*= 5)		ANOVA (factor site, *df* = 6)	
	F	Significance	*F*	Significance
Orthrotrichia spp.	0.800	0.557	0.833	0.522
Agapetus halong	**1.578***	0.191	**1.926***	0.104
Chimarra spp.	1.756	0.148	**1.648***	0.163
Helicopsyche spp.	0.800	0.557	**2.500***	0.410
Cheumatopsyche lucida	**2.158***	0.081	1.292	0.286
Cheumatopsyche spp	1.170	0.343	**3.939***	0.004
Diplectrona spp.	1.400	0.247	**2.363***	0.051
Hydropsyche spp.	1.455	0.229	1. 790	0.130
Macrostemum fenestratum	1.272	0.297	1. 341	0.265
Potamyia spp.	1.395	0.250	0.947	0.475
Cereclea spp.	1.422	0.240	**2. 250***	0.061
Oecetis spp.	0.667	0.651	1.190	0.334
Setosdes spp.	0.800	0.557	**2.500***	0.041
Marilia sumatrana	2.194	0.076	**3.339***	0.053
Lepidostoma doligung	**2.400***	0.560	0.833	0.552
Anisocentropus erichthonios	0.800	0.557	**2.500***	0.041
Ganonema spp.	1.338	0.270	**3. 235***	0.120
Goera spp.	0.800	0.557	**2.500***	0.041

TABLE IV
NON-PARAMETRIC CORRELATION (CORRELATION COEFFICIENT VALUES) BETWEEN CADDISFLIES SPECIES LARVAE AND WATER PARAMETERS

Taxa/parameters	Water temperature	Dissolved oxygen	pH	Total dissolved solids	Nitrate-nitrogen	Sulfate
Orthrotrichia spp.	-0.114	0.048	0.107	0.064	0.088	0.288
Agapetus halong	-0.173	-0.142	**-0.335***	-0.297	-0.297	-0.229
Chimarra spp.	0.014	**-0.378***	-0.173	0.031	**-0.439***	0.200
Helicopsyche spp.	0.186	-0.046	0.137	0.182	-0.132	0.254
Cheumatopsyche lucida	-0.116	-0.062	-0.014	0.288	-0.169	0.186
Cheumatopsyche spp.	-0.042	**-0.421***	-0.207	0.162	-0.289	0.319
Diplectrona spp.	0.247	**-0.556***	**-0.461****	0.057	-0.283	0.093
Hydropsyche spp.	**-0.373***	0.218	0.243	-0.158	-0.057	-0.280
Macrostemum fenestratum	**-0.334***	0.017	0.137	-0.076	-0.232	0.008
Potamyia spp.	-0.148	-0.170	-0.027	0.007	-0.191	0.144
Cereclea spp.	0.208	-0.101	0.121	0.195	-0.156	**0.319***
Oecetis spp.	-0.035	-0.095	0.065	0.027	-0.169	0.078
Setosdes spp.	0.087	-0.175	-0.035	0.062	-0.090	0.231
Marilia sumatrana	0.100	-0.235	-0.021	0.169	-0.210	**0.356***
Lepidostoma doligung	-0.136	0.010	-0.121	-0.157	-0.200	-0.120
Anisocentropus erichthonios	0.226	-0.293	**-0.570****	-0.148	-0.132	-0.301
Ganonema spp.	0.112	-0.301	**-0.395****	-0.039	-0.149	0.049
Goera spp.	0.087	-0.175	-0.035	0.062	-0.090	0.231

* $P<0.05$, ** $P<0.01$

IV. DISCUSSION

A. Physicochemical Water Quality Parameters

Components of the mean physicochemical status obtained in this study are associated with variety of contaminating practices, such as agricultural activities and mining activities, and they are simple summaries for the pollution status of each sampling station. However, caution must be exercised when interpreting these results, since the impacts of pollution on benthic assemblage structure are potentially confounded by an assemblage's dependence on other environmental characteristics, such as riparian forest, periphyton assemblage and sediment characteristics or channel morphology [21]. In this study, dissolved oxygen was not varied significantly among sampling sites of measured (P>0.05). The lowest mean value of dissolved oxygen (4.32 mg l^{-1}) was found in the downstream station (MT4 and MT5), and the highest values were observed in upper stream station (≥4.35 mg l^{-1}). The low values of dissolved oxygen concentration recorded in downstream stations, is an indication of deterioration of the water quality as a result of various anthropogenic activities in these sites as observed. The plausible reason for high dissolved oxygen in upper station could be attributed to the high current velocity. Dissolved oxygen is considered one of the most important limnological variables, both for the characterization of aquatic ecosystems and for the maintenance of aquatic life. Many organisms, specially the indicators of good environmental quality require high concentrations of dissolved oxygen for their survival [22]. This situation was observed in this study, with a negative relationship between *Chimarra* spp., *Cheumatopsyche* spp., and *Diplectrona* spp. and oxygen concentration. The oxygen concentration of the water and the upper sediment of layer is of considerable important to benthic communities [23], [24]. Fluctuating oxygen levels are often observed in inland waters, as a result of complex diurnal and annual variations depending on both (a)biotic variables such as light intensity, current velocity or disintegration processes, as well as human activities like hydrological and geomorphological modifications or additional input of organic matter [25], [26]. Minimal content of oxygen is an important factor limiting the distribution of benthic organisms and the ecological recovery of aquatic ecosystems. For example, Becker [27] demonstrated that re-colonization of the caddisfly *Hydropsyche contubernalis* in the River Rhine coincided with increasing oxygen levels.

TABLE V
SUMMARY OF CCA RESULTS FOR THE ABUNDANCE OF CADDISFLIES LARVAE AND WATER QUALITY VARIABLES AXES 1 AND 2 WERE SIGNIFICANT FOLLOWING MONTE-CARLO PERMUTATION PROCEDURES (P<0.05)

	Axis 1	Axis 2	Axis 3	Total variance
				0.6240
Eigenvalue	0.291	0.214	0.067	
% of variance explained in taxa data	46.6	34.3	10.7	
Cumulative % variance explained	46.6	80.9	91.7	
Pearson Correlation, Spp-Envt*	1.000	1.000	1.000	

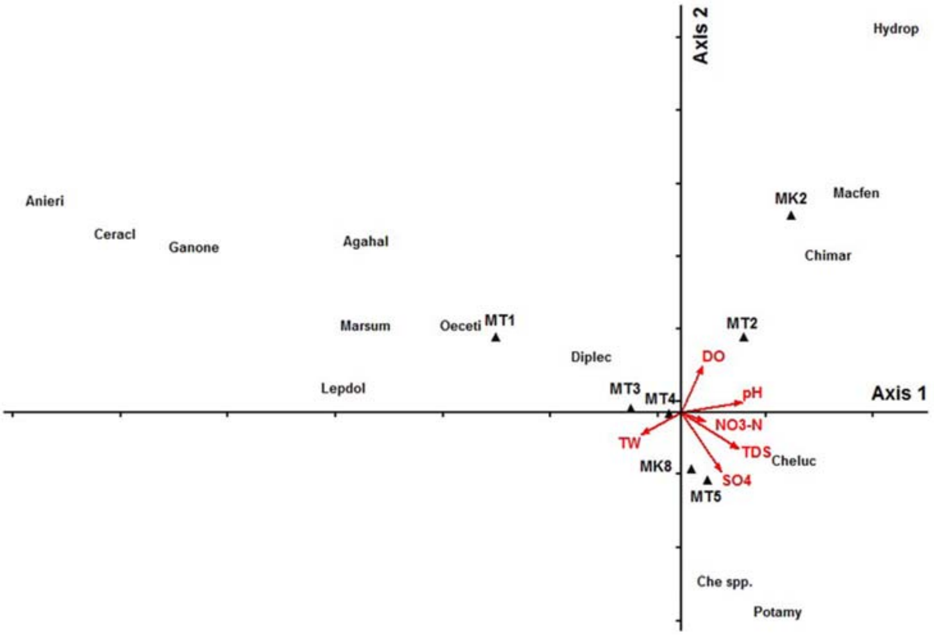

Fig. 2 Correlation between aquatic insect taxa and physicochemical variables, Abbreviations of taxonomic are shown in Table II

Temperature is an important water quality parameter and is relatively easy to measure water bodies will naturally show changes in temperature seasonally. Temperature values recorded during the sampling period ranged from 24.11 to 27.22ºC. This value falls within the optimal range for tropical freshwaters. The variation in temperature observed was because of low solar heat radiation across the stations. Inundation by run-off water into the stream also causes a reduction in temperature. This temperature reading indicates a great impact on the abundance and distribution of aquatic insects as more species were collected at relatively high temperature than when there was a drop in temperature. Analysis between caddisflies taxa abundance and water temperature showed *Hydropsyche* spp. and *Macrostemum fenestratum* correlated negatively with water temperature. Possibly, because some caddisflies species are temperature dependent, this favours their rate of feeding, metabolism and reproduction [28].

Nitrate-nitrogen correlated negatively with caddisflies larvae. It is likely that input of nutrients in the stream enhanced secondary production. At MK8 recorded higher values in nutrients nitrate-nitrogen indicating significant input of organic discharges in this area. Zabbey and Hart [29] recorded similar trend in Woji creek in the Niger Delta where organic wastes are discharged constantly into the stream. Arimoro et al. [30] also recorded similar result in Ethiope River in Niger delta. Nitrate-nitrogen is also an important factor in the distribution and abundance of *Chimarra* spp. The uses of agricultural fertilizers are believed to increase the ammonia, nitrate and phosphate concentrations because the absence of freshwater plants might affect the increase in Nitrogen ion concentrations in the stream.

In natural waters, the pH scale runs from 0 to 14. A pH value of 7 is neutral; a pH less than 7 is acidic and greater than 7 represents base saturation or alkalinity. Generally, tropical waters tend to have low pH. Lower values in pH are indicative at high acidity, which can be caused by the deposition of acid forming substances in precipitation. A high organic content will tend to decrease the pH because of the carbonate chemistry. As microorganisms break down organic material, the by-product will be CO_2 that will dissolve and equilibrate with the water forming carbonic and (H_2CO_3). Most metals will become more soluble in water as the pH decreases. The excesses of dissolved metals in solution will negatively affect the health of the aquatic organisms. The pH value obtained from this study ranged from slightly alkaline (8.06-8.87). Most insect species such as *Agapetu halong*, *Diplectrona* spp., *Anisocentropus erichthonios* and *Ganonema* spp. are slightly affected by alkaline; whereas others are acid-sensitive. pH values recorded in the study is in agreement with the pH values reported for other fresh water systems [31].

Elevated levels of total dissolved solids (TDS) have been suggested as stressors to aquatic life in Central Appalachian streams influenced by coal mining [32], [33]. In coalfield streams, TDS is most often dominated by the dissolved ions SO_4^{2-} and HCO_3^-, with elevated concentrations (relative to reference) of Ca^{2+}, Mg^{2+}, Na^+, K^+, and Cl^- also common [33], [34]. At present here, *Ceraclea* spp. and *Marilia sumatrana* were correlated positively with sulfate. This suggests that while the number of taxa present may increase with increasing TDS, abundance of individuals within the remaining species, and perhaps overall species abundance, may remain less affected, at least within the range of TDS.

B. Caddisflies Communities and Diversity

The number of taxa (or taxa richness) is a synthetic measurement for biological structure. This structure depends on the quality and availability of habitats [35]; they reflect the impact of all investigated stressors independent of ecoregion boundaries. According to the result the highest diversity of caddisflies, species were observed in sampling site MT4 which may be due to presence of rich and undisturbed habitat structure in place, while the lowest values were observed in MK2 and MK8. Low taxa richness indicated of pollution or disturbances in environmental conditions of the streams.

The aim of this study was to investigate the diversity and structure of caddisflies communities in relation to water quality variables in order to explore the bioindication potential of caddisflies larvae for assessing water quality deterioration in northern Thailand. Surveys of this kind have been criticized for their inability to detect or interpret subtle environmental changes leading to changes in community composition and therefore to differentiate between natural changes and those caused by pollution [36]. Since, detailed site-specific information is not usually available in developing countries; therefore, baseline surveys of the kind conducted in this study are necessary to produce a general view of the biological communities present within a particular area. The differences observed in caddisflies assemblage structure and abundance reflected the differences in location of site and distance from sources of human activities and resulting impacts (e. g. agriculture and industrial effluents).

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