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ความสัมพันธ์ระหว่างคุณภาพน้ำและการกระจายของตัวอ่อนแมลงเกาะหินในพื้นที่ซึ่งไม่ถูกรบกวนของอุทยานแห่งชาติห้วยน้ำดัง ประเทศไทย

Relationship between Water Quality and Distribution of Stonefly Larvae in Pristine Areas at Huai Nam Dung National Park, Thailand

Ratitorn Jaihao[1] *and Chitchol Phalaraksh*[2*]

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาความสัมพันธ์ของการกระจายของตัวอ่อนแมลงเกาะหินกับคุณภาพน้ำในอุทยานแห่งชาติห้วยน้ำดัง โดยเลือกลำน้ำ 3 แห่งจากพื้นที่ซึ่งไม่ถูกรบกวนของอุทยานแห่งชาตินี้เป็นตัวแทนในการศึกษา ผลการศึกษาพบตัวอ่อนแมลงเกาะหินจำนวน 15 สกุล จาก 4 วงศ์ โดยพบจำนวนตัวมากที่สุดในสกุล *Cryptoperla* (476 ตัว, 37.9%) แม่จอกเป็นลำธารที่พบความหลากหลายของจำนวนสกุลและจำนวนตัวมากที่สุด (13 สกุล, 555 ตัว) การศึกษาสหสัมพันธ์พบว่ามีความสัมพันธ์ในเชิงบวกระหว่างจำนวนตัวของแมลงเกาะหินกับระดับความสูงของพื้นที่ ($r = 0.540$, $P < 0.01$) และมีความสัมพันธ์เชิงลบระหว่างจำนวนตัวกับปัจจัยบางประการของแหล่งน้ำโดยเฉพาะมีความสัมพันธ์มากที่สุดต่ออุณหภูมิน้ำ ($r = -0.481$, $P < 0.01$) การศึกษาคุณภาพทางเคมีของแหล่งน้ำ พบว่าคุณภาพน้ำของลำธารน้ำดังและแม่ปิงอยู่ในระดับที่สะอาด (อุณหภูมิน้ำ = 18.5, 19.1 °C, pH = 7.4, 6.9, conductivity = 37.65, 26.99 µS/cm, BOD_5 = 0.6, 0.5 mg/l, NO_3-N = 0.13, 0.08 mg/l, NH_4-N = 0.91, 0.86 mg/l, O-PO_4-P = 0.41, 0.28 mg/l) ในขณะที่คุณภาพน้ำของแม่จอกอยู่ในระดับค่อนข้างสะอาด (อุณหภูมิน้ำ = 20.2 °C, pH = 7.1, conductivity = 44.78 µS/cm, BOD_5 = 0.7 mg/l, NO_3-N = 0.19 mg/l, NH_4-N = 0.75 mg/l, O-PO_4-P = 0.56 mg/l) ผลจากการศึกษาครั้งนี้บ่งชี้ว่าในพื้นที่ซึ่งไม่ถูกรบกวนมีความหลากหลายและจำนวนของตัวอ่อนของแมลงเกาะหินสูง ซึ่งอาจเนื่องจากความเหมาะสมของปัจจัยของแหล่งน้ำ

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ABSTRACT

The aims of this study were to investigate how the distribution of stonefly larvae is related to the water quality of selected streams in Huai Nam Dung National Park, Thailand. Three streams were selected from pristine areas of the national park. Fifteen genera from four families were identified from this study. The highest total numbers of individual was found in genus *Cryptoperla* (476 individuals, 37.9%). The highest genera diversity was found from Mae Jok Stream (13 genera), and the highest total number of individuals specimens was also found from this stream (555 individuals). The Pearson's Correlation value indicated the positive correlation between stonefly abundance and the elevation ($r = 0.540$, $P < 0.01$), and the negative correlation between stonefly abundance and many physico-chemical parameters especially water temperature ($r = -0.481$, $P < 0.01$) which revealed the highest negative correlation in this study. In order to consider the water quality using the Chemical Index, it was found that Nam Dung and Mae Ping Stream were found to be clean streams (Water temperature = 18.5, 19.1 ℃, pH = 7.4, 6.9, Conductivity = 37.65, 26.99 µS/cm, BOD_5= 0.6, 0.5 mg/l, NO_3-N = 0.13, 0.08 mg/l, NH_4-N = 0.91, 0.86 mg/l, O-PO_4-P = 0.41, 0.28 mg/l), whereas the quality of Mae Jok Stream was in the fairly clean level (Water temperature = 20.2 ℃, pH = 7.1, Conductivity = 44.78 µS/cm, BOD_5 = 0.7 mg/l, NO_3-N = 0.19 mg/l, NH_4-N = 0.75 mg/l, O-PO_4-P = 0.56 mg/l). The results of this study indicate that the high abundance of stonefly larva could be found in the streams, which were located in the pristine areas that undisturbed by human activity, and the environment was suitable for stonefly larva.

คำสำคัญ: ตัวอ่อนแมลงเกาะหิน พื้นที่ไม่ถูกรบกวน ปัจจัยทางกายภาพ-เคมี การแพร่กระจาย อุทยานแห่งชาติห้วยน้ำดัง

Keywords: Stonefly larva, Pristine area, Physico-chemical parameters, Distribution, Huai Nam Dung National Park

Introduction

Stoneflies are distributed over all continents except Antarctica (Fochetti and Tierno de Figueroa, 2008), and stonefly diversity appears to increase from the equator toward to the poles (Zwick, 2000; Fochetti and Tierno de Figueroa, 2008 and Palma and Figueroa, 2008). In the oriental region, the lack of accumulated data related to the stonefly makes it difficult to estimate the real diversity and the exact number of species present (Fochetti and Tierno de Figueroa, 2008).

Stonefly larvae are often restricted to clean, cool and well-oxygenated running water, and they live mainly on stony or gravelly substrate (Hynes, 1976; Daly et al., 1978; McCafferty, 1998; Che et al., 2001; Gullan and Cranston, 2005; Fochetti and Tierno de Figueroa, 2008). Generally, they are intolerant of organic and thermal pollution.

The ecological factors, such as temperature, velocity, elevation, type of substrate, stream order, dissolved oxygen, and nutrients, as well as other, are related to distribution and diversity. The previous studies have revealed that stoneflies are correlated with the upper mountainous section of the stream systems (Palma and Figueroa, 2008), and the richness decreased dramatically from the head water to the mouth of the river (Miserendino, 2006). Furthermore, a loss of stonefly larvae occurs as water temperature increases (Gullan and Cranston, 2005), while the distribution of stonefly larvae is influenced by the mean column current velocity under conditions of low levels of dissolved oxygen (Genkai-Kato et al., 2005). Their ecological necessity greatly limits the dispersal, and they tend to remain at the higher altitudes and upper reaches of stream and river.

In Thailand, the stonefly has been studied in just a few areas, such as Doi Inthanon National Park (Promkatkaew, 1992), Nam Nao National Park (Chaisamsaeng, 2003), Thong Pha Phoom Forest, Kanjanaburi Province (Janpaisaeng, 2002), and Khao Yai National Park (Damrak, 2006). The pristine area at Huai Nam Dung National Park, which has had no previous research conducted on stoneflies was chosen to be the sampling area for this study.

The aims of this study were to investigate the distribution of stonefly larvae in pristine areas at Huai Nam Dung National Park, Thailand and to examine the physico-chemical factors of water quality related to the distribution of stonefly larva.

Materials and methods

Study area

Huai Nam Dung National Park extends into four districts: Mae Taeng, Chiang Dao, and Wiang Haeng in Chiang Mai Province, and Pai District in Mae Hong Son Province (Figure 1), and cover an area of approximately 1,247 square kilometers. It is the vital source of important waterfalls and streams that flow into the Pai River, Ping River, and Taeng River. The average year-round temperature is 20 °C, dropping to 8 °C from October to February and soaring to 12-28 °C from March to April. The wet months are from May to September (Ministry of Natural Resources and Environment, 2012).

Three sampling sites were selected from pristine areas at Huai Nam Dung National

Park. The first site was the Nam Dung Stream (S-ND), which is located at N 19° 19.370', E 98° 37.224' and is 1,163 m above sea level. The Nam Dung Stream is the headwater of Nam Dung Waterfall. The second site was the Mae Ping Stream (S-MP), which is located at N 19° 18.422', E 98° 35.627' and is 1,397 m above sea level. The Mae Ping Stream is the headwater of the Mae Ping River, which is one of the important rivers in Pai District, Mae Hong Son Province. And the third site was the Mae Jok Stream (S-MJ), which is located at N 19° 16.827', E 98° 37.024' and is 1,210 m above sea level. Mae Jok Stream is the one of tributaries of the Mae Taeng River (Figure 2). All of the sampling sites are the headwaters that have been untouched from human activity.

Field methods

The sampling sites were sampled in February, April, June, August, October, and December in the year 2011. Stonefly larvae were collected by kick and pick sampling techniques, and samples were preserved in 4% formaldehyde solution. Insect specimens were sorted and stored in 70% ethanol, and identified using available keys (Morse et al., 1994 and Sangpradub and Boonsoong, 2006). At the same time, aquatic properties were examined in terms of a variety of parameters: velocity using a velocity meter, turbidity using a turbidity meter air and water temperature was measured by thermometer, conductivity, pH and Total Dissolved Solid (TDS) using the multiparameter analyser, Suspended Solid (SS) using the HACH DR2400 spectrophotometer, alkalinity using the Phenopthalene Methyl Orange Indicator Method (Greenberg et al., 1992), dissolved oxygen (DO) and biochemical oxygen demand (BOD_5) using the Azide Modification Method (Greenberg et al., 1992). Orthophosphate Phosphorus was determined by the Ascorbic Acid Method using Phos Ver 3 reagent and was detected by HACH DR2400 spectro-photometer. Nitrate nitrogen was determined by the Cadmium Reduction Method using Nitra Ver 5 Nitrate reagent and was measured by HACH DR2400 spectrophotometer. Ammonium nitrate was determined by the Nesslerrization technique, using Nessler reagent, Mineral stabilizer and Polyvinyl alcohol and was detected by HACH DR2400 spectro-photometer.

Data analysis

One-way ANOVA was used to compare mean values of the total number and physico-chemical factors in each site. Pearson Correlation was performed to assess the relationships between stonefly assemblages and environmental variables. Chemical Index (CI) was used to examine the water quality (Jurgen et al., 20002).

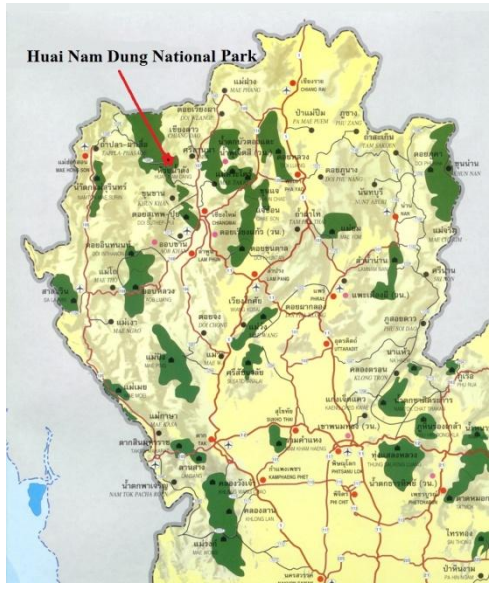

Figure 1. Huai Nam Dung National Park, Thailand (Ministry of Natural Resources and Environment, 2012)

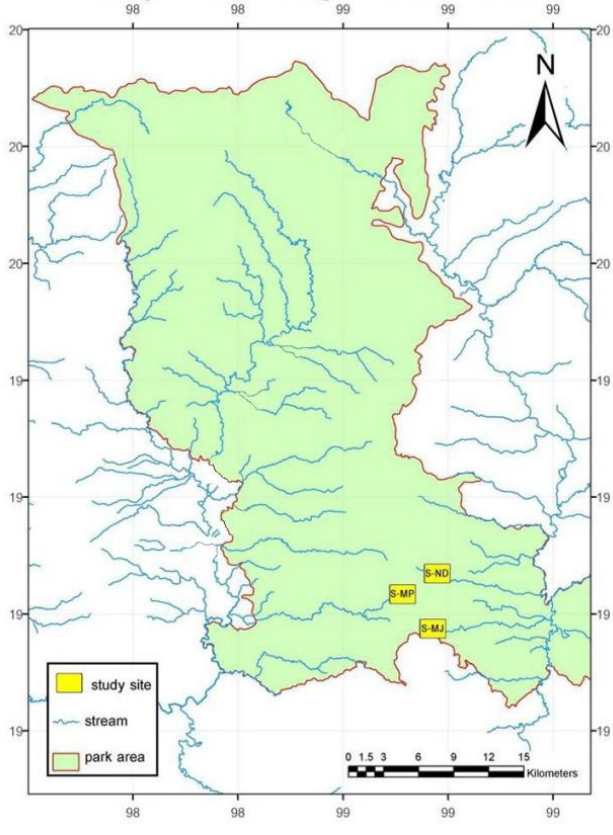

Figure 2. The sampling sites at Huai Nam Dung National Park

Results

Fifteen genera of four Plecopteran families were recorded in this study. Ten genera of the family Perlidae were identified including *Neoperla*, *Etrocorema*, *Togoperla, Agnetena, Tetropina*, *Caroperla, Phanoperla, Calineuria, Kamimuria,* and *Paragnetena,* whereas, the genus *Cryptoperla,* Family Peltoperlidae was also identified. The three genera of family Nemouridae, including *Indonemoura, Amphinemura* and *Sphaeronemoura*, and the genus *Rhopalopsole* of the family Leuctridae, were recorded.

The highest genera diversity was found from the Mae Jok Stream (13 genera), and the same numbers of genera (11 genera) were found from the Nam Dung and Mae Ping Streams (Table 1).

The highest total numbers of individuals (555 individuals) were found in the Mae Jok Stream, but they were not significantly different ($F = 1.334$, $P < 0.05$) compared with the other streams. *Cryptoperla* was the dominant genus (476 individuals, 37.9%), followed by *Etrocorema* (448 individuals, 35.6%) and *Indonemoura* (87 individuals, 6.9%). The percentages of the total numbers of individuals is shown in Figure 3.

The percentages of the total numbers of individuals and the differences of the community composition in each stream are shown in Figure 4. *Neoperla*, *Etrocorema*, *Togoperla, Phanoperla, Calineuria, Cryptoperla*, *Indonemoura*, and *Amphinemura* were found at all sampling sites. Alternatively, *Agnetena* and *Paragnetena* were found only in the Mae Jok Stream, but *Kamimuria* was not found in the Mae Jok Stream. *Tetropina* and *Sphaeronemoura* were not found in the Nam Dung Stream, and *Caroperla* was not found in the Mae Ping Stream. Besides, *Rhopalopsole* was found only in the Nam Dung Stream.

In terms of each sampling site, 279 individuals (50.3%) of *Cryptoperla* were collected from the Mae Jok Stream. Whilst, 188 individuals (45.7%) and 134 individuals (46.0%) of *Etrocorema* were collected from Nam Dung and Mae Ping Streams, respectively (Table 1 and Figure 4).

In each month, differences of genera composition and total number of individuals were found. The highest total individual numbers of stonefly collected from Nam Dung and Mae Ping Streams were found in December (153, 106 individuals, respectively), but the highest total individual number collected from the Mae Jok Stream was found in April (199 individuals) (Table 1).

Table 1. Plecopteran genera found in three streams of Huai Nam Dung National Park, Thailand

Site	Family	Genera	The Total Individuals						
			February	April	June	August	October	December	Total
S-ND	Perlidae	*Neoperla*		14	15	2	4		**38**
		Etrocorema	9	31	22	12	10	104	**188**
		Togoperla	1	4			1	5	**11**
		Kamimuria	4			3		1	**5**
		Phanoperla		7				2	**9**
		Calineuria	3						**3**
		Caroperla		2					**2**
	Peltoperlidae	*Cryptoperla*	6	30	12	33	21	31	**133**
	Nemouridae	*Indonemoura*		2	1	2	1	9	**15**
		Amphinemura		1	3		1	1	**6**
	Leuctridae	*Rhopalopsole*		1					**1**
	Total		**23**	**92**	**53**	**52**	**38**	**153**	**411**
S-MP	Perlidae	*Neoperla*	1	2		2		1	**6**
		Etrocorema	6	18	21	5	31	53	**134**
		Togoperla	2	2		3		2	**9**
		Kamimuria	2						**2**
		Tetropina				1			**1**
		Phanoperla		4			1	1	**6**
		Calineuria		3					**3**
	Peltoperlidae	*Cryptoperla*	2	35	9	7	8	3	**64**
	Nemouridae	*Indonemoura*				3	10	35	**48**
		Amphinemura		3		1	2	11	**17**
		Sphaeronemoura				1			**1**
	Total		**13**	**67**	**30**	**23**	**52**	**106**	**291**
S-MJ	Perlidae	*Neoperla*	3	4	13				**20**
		Etrocorema	12	29	18	13	13	41	**126**
		Togoperla	2	8			2	4	**16**
		Agnetena		1					**1**
		Tetropina		7					**7**
		Paragnetena	1						**1**
		Phanoperla	2	10	6	24		10	**52**
		Calineuria					1		**1**
		Caroperla		3					**3**
	Peltoperlidae	*Cryptoperla*	18	124	47	19	51	20	**279**
	Nemouridae	*Indonemoura*		4			12	8	**24**
		Amphinemura		8	3		3	6	**20**
		Sphaeronemoura		1				4	**5**
	Total		**38**	**199**	**87**	**56**	**82**	**93**	**555**

Note: S-ND= Nam Dung Stream, S-MP= Mae Ping Stream, S-MJ= Mae Jok Stream

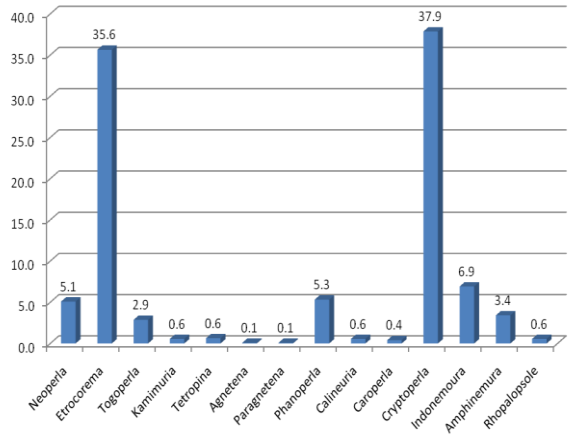

Figure 3. Percentage of Plecopteran genera of three streams at Huai Nam Dung National Park, Thailand

Table 2. Minimum and maximum values of physic-chemical parameters of three streams from Huai Nam Dung National Park

Site		S-ND (Nam Dung Stream)	S-MP (Mae Ping Stream)	S-MJ (Mae Jok Stream)
Elevation (m)		1163.00	1397.00	1210.00
Temperature (°C)	Air	11.5-21.0	13.5-22.5	18.0-23.5
	Water	12.8-20.5	13.0-20.5	15.0-21.5
Velocity (m/s)		0.305-1.078	0.203-1.191	0.365-1.384
Conductivity (µS/cm)		30.2-46.1	20.3-33.1	38.1-36.5
pH		7.0-7.9	6.40-7.31	6.80-7.68
DO (mg/l)		7.4-9.0	7.2-8.4	6.8-8.8
BOD_5 (mg/l)		0.07-1.50	0.27-0.87	0.27-1.80
TDS (mg/l)		16.4-25.4	10.5-17.6	20.0-29.5
Turbidity (NTU)		5.53-52.0	3.36-33.16	11.26-37.32
Alkalinity (mg/l)		19-36	15-58	21-40
SS (mg/l)		6-46	11-31	12-178
NO_3-N (Ammonium nitrate) (mg/l)		0.03-0.28	0.02-0.19	0.02-0.66
NH_4-N (Nitrate nitrogen) (mg/l)		0.4-1.5	0.5-1.3	0.1-1.3
O-PO_4-P (Orthophosphate phosphorus) (mg/l)		0.17-0.74	0.12-0.63	0.14-1.26

The minimum and maximum values of the physico-chemical properties are shown in Table 2. The Mae Ping Stream had the highest elevation in this study. The mean comparison of the three streams revealed that there was no significant difference in many parameters, such as air-water temperature, dissolved oxygen, biochemical oxygen demand, alkalinity, and nitrate nitrogen. The significant term of ANOVA indicated that the Mae Ping Stream has slowest velocity, while Nam Dung Stream was the fastest flowing

stream (F = 3.526, P < 0.05). In this study, it was found that conductivity, TDS, SS, ammonium nitrate, and orthophosphate phosphorus were significantly high in the Nam Dung Stream (F = 0.001, 0.001, 0.027, 0.026, 0.010, P < 0.05) compared with the other streams. In addition, pH and turbidity were significantly high in the Nam Dung Stream (F = 0.001, 0.002, P < 0.05) compared with the other streams (Table 4).

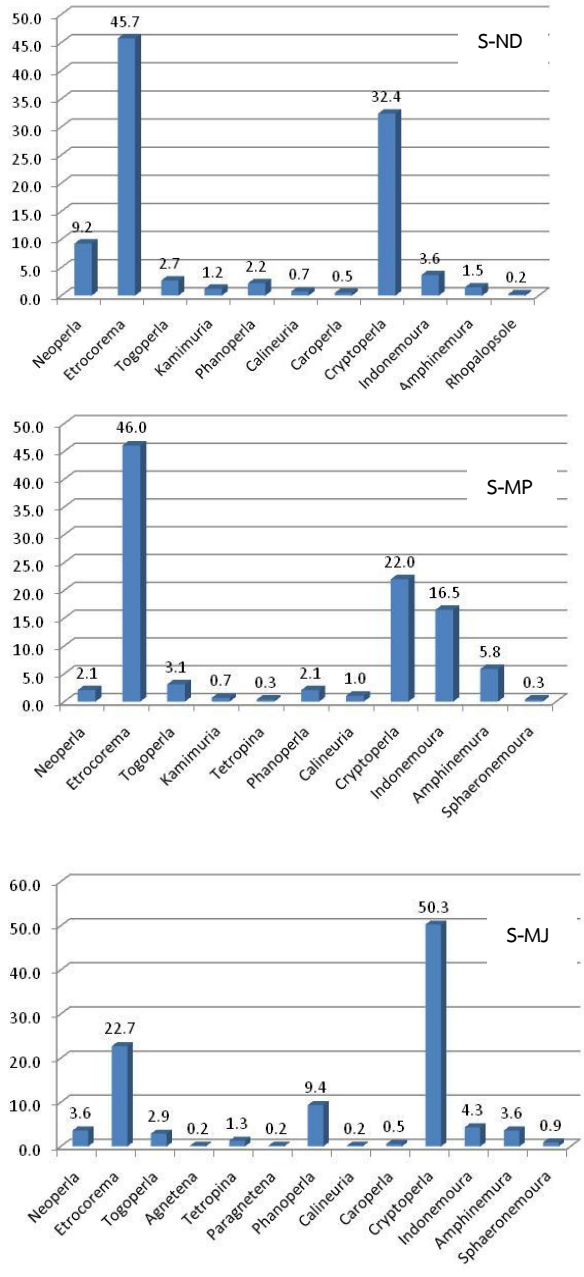

Figure 4. The ratio of total numbers of each genus collected from each stream.

Table 3. Correlation values between Plecopteran abundance and physico-chemical parameter.

	Plecopteran abundance		
	Pearson Correlation	**Sig. (2-tailed)**	**N**
Elevation	.540**	.000	54
Air temperature	-.270**	.000	54
Water temperature	-.481**	.000	54
Velocity	-.268**	.000	54
Conductivity	-.468**	.000	54
pH	-.443**	.000	54
TDS	-.430**	.000	54
Turbidity	-.338**	.000	54
Alkalinity	-.393**	.000	54
SS	-.310**	.000	54
NO_3-N	-2.72**	.000	54
NH_4-N	-.156*	.036	54
O-PO_4-P	-.282**	.000	54

Table 4. Mean comparison of physico-chemical parameter in three streams using One-Way ANOVA.

Physico-Chemical Parameter		Nam Dung Stream	Mae Ping Stream	Mae Jok Stream	F	P-Value
Velocity	Mean	0.71	0.48	0.66	3.526	0.037
	SD	0.223	0.217	0.277		
Conductivity	Mean	37.65	26.99	44.78	46.696	0.001
	SD	5.557	4.606	6.347		
pH	Mean	7.4	6.9	7.1	12.958	0.001
	SD	0.280	0.281	0.258		
TDS	Mean	20.00	14.26	23.80	47.917	0.001
	SD	3.067	2.492	3.256		
Turbidity	Mean	30.72	17.31	21.43	7.297	0.002
	SD	14.344	8.513	8.420		
SS	Mean	26.50	16.88	49.22	3.890	0.027
	SD	13.294	9.993	59.585		
NO_3-N	Mean	0.13	0.08	0.19	3.917	0.026
	SD	0.058	0.046	0.189		
O-PO_4-P	Mean	0.41	0.28	0.56	5.022	0.010
	SD	0.194	0.156	0.380		

Table 5 Water quality calculated from Chemical Index.

Parameters	Nam Dung Stream		Mae Ping Stream		Mae Jok Stream	
	Measured value	Value from conversion table	Measured value	Value from conversion table	Measured value	Value from conversion table
Water temperature	17.334	1.437	17.333	1.437	18.111	1.430
pH	7.363	1.584	6.929	1.579	7.069	1.585
Conductivity	37.656	1.371	26.994	1.368	44.788	1.373
Saturate O_2	102.519	2.512	102.101	2.512	100.205	2.512
BOD_5	0.638	2.510	0.595	2.510	0.700	2.509
NO_3-N	0.131	1.984	0.080	1.995	0.190	1.938
NH_4-N	0.916	1.565	0.866	1.565	0.755	1.567
O-PO_4-P	0.412	1.249	0.289	1.348	0.566	1.783
Site classification	clean		clean		fairly clean	

In order to consider the water quality using the Chemical Index, it was found that the Nam Dung and Mae Ping Streams were clean streams, but the quality of the Mae Jok Stream was at the fairly clean level (Table 5).

The Pearson's Correlation value indicated a positive correlation only between abundance of stonefly lava and elevation ($r = 0.540$, $P < 0.01$), whereas the other parameters showed a negative correlation (Table 3).

Discussion and Conclusions

Fifteen genera of four Plecopteran families resulted in the highest diversity, when compared to the previous record of Thailand. Only one family (Perlidae) was found in Doi Inthanon National Park (Promkatkaew, 1992), and three families (Perlidae, Nemouridae, and Leuctridae) were found in Nam Nao National Park (Chaisamsaeng, 2003). Four families of stoneflies; namely Leuctridae, Nemouridae, Piltoperlidae and Perlidae, which cover eight genera and 16 species as follows: *Rhopalopsole* sp., *Amphinemura* sp., *Amphinemura* sp., *Amphinemura* sp., *Amphinemura* sp., *Indonemoura jacobsoni*, *Cryptoperla* sp., *Neoperla thai*, *Neoperla gordonae*, *Neoperla fallax*, *Neoperla* sp., *Chinoperla unidentata*, *Phanoperla* sp., *Phanoperla* sp., *Phanoperla* sp. and *Kamimuria* sp. were found in Khao Yai National Park (Damrak, 2006). Only one family (Perlidae) was found in the Mekong River, which passes through Thailand (Thani and Phalaraksh, 2008), and three families (Perlidae, Nemouridae, and Chloroperlidae) were found in the southern part of Thailand (Watanasit, 1999).

The Chemical Index showed that all streams were of good quality, and the

physico-chemical parameters revealed the suitable environmental conditions for stonefly larva, including a low level of temperature, BOD_5, nutrients, and high levels of dissolved oxygen. Another illustration of this was that all sampling sites were located in pristine areas that were undisturbed from human activity. So, it is the cause of the high abundance and diversity. The result of this study was supported by the study of Janpaisaeng (2002) in the Thong Pha Phoom Forest showed that the diversity of stonefly in the undisturbed streams was higher than the disturbed streams. Thani and Phalaraksh (2008) found that the stonefly larvae were found only in the upper site of the Mekong River tributaries, which showed less pollution (Thani and Phalaraksh, 2008). Baumann (1979) found that the stonefly were sensitize to concentration of dissolved oxygen, and Hynes (1976) explained that temperature was the one of controlling factors, which effected the growth, occurring in each season, and potentially damaging to the stonefly. Therefore, the pristine stream, which had the high level of dissolved oxygen and low level of pollutants, had the high abundance and diversity. Tierno de Figueroa *et al*. (2010) determined from these results that higher air temperatures lead to higher water temperatures, as well as environmental impacts of increased water temperatures, which may include reduced habitats for cold water aquatic species and oxygen depletion.

Furthermore, the results of a study of the relationships between stonefly assemblages and environmental variables by Pearson's Correlation showed that there was a positive correlation between stonefly abundance and elevation. Oppositely, the stonefly abundance and water temperature revealed the highest negative correlation in this study. This results were found to be similar to the study of Miserendino (2006), who studied study the seasonal and spatial distribution of stoneflies in the Chubut River, Argentina and found that conductivity, nutrient level, and TSS also showed strong and significant correlations with stonefly assemblages. These results support the fact that the high abundance and diversity of stonefly lava could be found in the upper sites or the lower stream order sites.

The physico-chemical factors affected the community composition of the stonefly. As stonefly larvae possess the high stenoecity, a minimum of environmental change may affect the existence in some areas. Moreover, the existence of some genera in some areas may be caused from the idea that the stonefly was the endemic species. Fochetti and Tierno de Figueroa (2008) revealed the determination that their ecological requirements greatly limit the dispersal

capacity of the larvae and, because adults have a reduced flight ability, stoneflies show a high percentage of endemism. In addition, Tierno de Figueroa *et al.* (2010) determined that most aquatic organisms have a specific range of temperatures that they can tolerate, which determines their local and regional spatial distribution.

The highest total number of individuals collected from each site was found in the dry season. This result was similar to the report by Watanasit (1999), which found that the greater total number of families was found in the dry season, when compare to the wet season. In addition, Krno (2000) found that the periods of highest discharge and increased erosion in the wet season resulted in a considerable decline in the abundance of stoneflies.

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