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Leaf litter Decomposition in Headwater Streams, Nam Nao National Park, Thailand

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Abstract

Objectives of this research are to investigate long-term responses of leaf litter decomposition rates involved some abiotic factors and colonized macroinvertebrates in leaf litter bags at headwater streams, Nam Nao National Park by comparing data between 2002 and 2014. Three grams dry weight of Bambusa arundinacea Willd. was put in an individual nylon bag and they were placed in riffles and pools at 2 streams. These litter bags from each stream were retrieved every 2 weeks of immersion. Results showed that leaf breakdown rates were more rapidly in riffle than in pool and the rate was faster at Phromlaeng stream than those of Yakruae stream in both years. Increasing of water velocity was considered to increase leaf decay. Macroinvertebrates colonizing in the leaf litter bags was similar in 2002 and 2014. In both years, Dipteran and Ephemeropteran larvae were the most abundant (more than 50%) in the litter bags throughout the study, which were primarily collector-gatherers in the leaf litter bags. Shredders directly consumed leaves and other coarse particle organic matters were low abundance. Collector-filters were more abundant in riffle. Scrappers and predators did not feed on detritus, but they utilized the litter bag for shelter. In conclusion, decomposition rate was more rapidly caused by increasing water velocity. Increase in water velocity was a consequence of increase in precipitation which was directly related to climate change.

Keywords: allochthonous matter; Bambusa arundinacea; colonization; leaf litter breakdown

1. Introduction

Two main sources included autochthonous source from photosynthesis by algae, mosses and higher aquatic plants in stream and allochthonous source by imported organic matters from streamside vegetation included leaves and other parts of vegetation are energy sources for streams ecosystem. In small heavily shaded streams, there is normally insufficient light to support substantial in stream photosynthesis, thus energy pathways are supported largely by imported organic matter (Benfield, 2006). Leaves from trees that enter streams are an important nutritional resource for stream-dwelling organisms. Microbes such as bacteria and fungi and benthic macroinvertebrates included insect larvae feed on the leaves and in the process, help break them down and recycle the plant nutrients (Woodward, 2012). According to Benfield et al. (2001), leaf breakdown has been used to investigate long-term responses of stream on disturbance by watershed logging, it can be proposed as a useful process for assessing functional integrity of stream (Gessner and Chauvet, 2002) and also can be used to evaluate water quality and environmental health (Fenoglio et al., 2006). Currently, there are more studies in tropical streams such as comparison of leaf-litter decomposition between forested and urban sites in Ampang River, Kuala Lumpur, Malaysia (Yule et al., 2015), effect of urbanization on leaf-litter breakdown in streams at Central Amazonia, Brazil (Martins et al., 2015) and aquatic fungi associated with leaf litter processing rates (Rincon and Santelloco, 2009). In Thailand, Parnrong et al. (2002) reported no significant difference on processing rates of six plant species between the forested and agricultural sections of three streams in southern Thailand. David and Boonsoong (2014) studied colonization of *Bambusa bambos* and *Lagerstroemia floribunda* in a headwater stream at the Phachi River, western Thailand. They found that process of leaf breakdown was faster in riffle than in pool and collector-gatherer macroinvertebrates were dominant in litter bags.

Nam Nao National Park is a conservation area and it is a long-term research site on benthic macroinvvertebrates since 1998 (Sangpradub and Naknan, 1998). Leaf litter decomposition was studied in 2002 by the author (NS). Due to no study on long-term change of abiotic and biotic factors on leaf litter decomposition was investigated in Thailand. It is a good opportunity to conduct the study in order to compare rate of decomposition involve abiotic factors and colonization of macroinvertebrates between 2002 and 2014.

2. Materials and Methods

2.1 Study sites

The study was carried out from Yakruae stream (YK- altitude: 827 m, latitude 16°44’19.7”N, longitude 101°34’26.4”E) and Phromlaeng stream (PL- altitude: 740 m, latitude 16°38’24.2”N, longitude 101°34'52.9"E), located in Nam Nao National Park, Phetchabun and Chaiyaphum Provinces, Thailand (Figure 1).

YK stream is the second order stream of the Cheun River. It is an approximately 200 m east from the Visitors' Center. The study site was approximately 250 m along the stream and the main substrates of stream bed consisted of gravels (60%), mix of boulders and cobbles (30%), bed rock (10%) and an accumulation of woody debris and leaf litters were also found. The study site was heavily shaded and only 20% sun light penetrated to the stream.

PL stream is the third order stream of the Phom River. It is approximately 10 km from the Visitors' Center and there was no disturbed by anthropogenic activity. The dominant stream substrates consisted of bed rock (85%) followed by boulders (5%) and the remaining substrates (10%) were mixtures of cobbles, pebbles, gravels and sand. This site had more open canopies, approximate 75% of sunlight penetrated to the stream. The accumulation of organic matter and leaf litters were also found along pools and riffles.

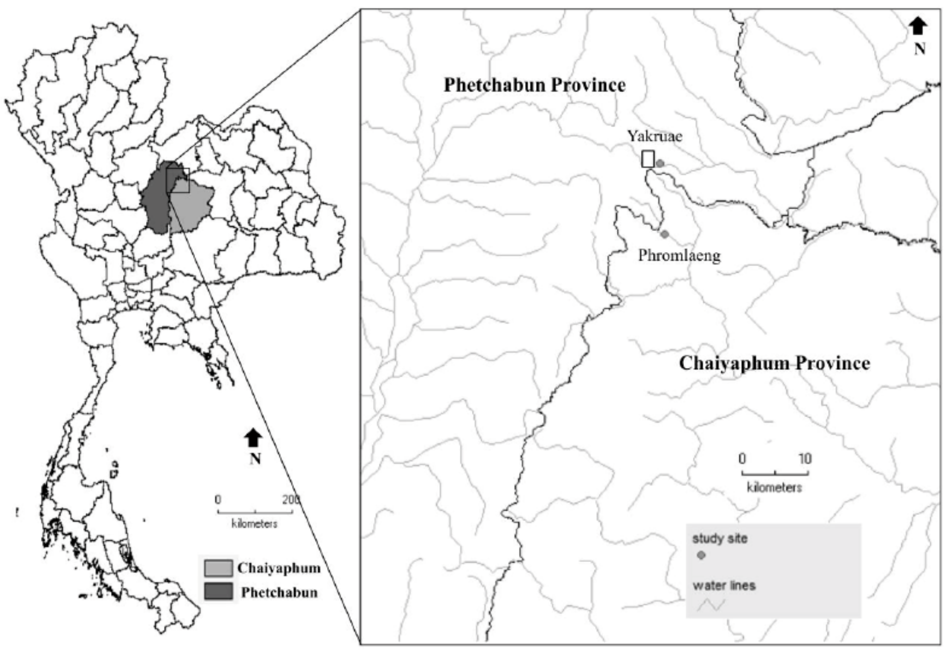

Figure 1. Locations of two sampling sites (•) in the Nam Nao National Park (□ = Visitors' Center)

2.2 Environmental variables

Three replicates of environmental variables were measured at each sampling site consisted of stream depth (cm) by measuring ruler, water velocity (m/s) by flow meter (Model 625, Gurley Precision Instruments, USA), pH, water temperature (°C) and electrical conductivity (EC, μS/cm) by pH/Conductivity/TDS and Temperature Tester (Hanna HI 98129, Mauritius) and dissolved oxygen (DO, mg/l) by Dissolved Oxygen meter and Temperature Tester (YSI 550A, USA). Total precipitation and mean temperature at Lom Sak Meteorological and Hydrographic Station located close to Nam Nao National Park were obtained in 2002 and 2014. Total precipitation and minimum temperature in 2014 was higher than that in 2002, while mean temperature was equal in both years (Table 1).

2.3 Leaf litter collection, litter bag preparation and litter bag exposure in the field

Bamboo (Bambusa arundinacea Willd.) leaves were chosen as an experimental plant because it is a common taxa and more abundant in the riparian zone at both YK and PL. Only senescent leaves ready to fall from trees were collected by hand. The collected leaves were dried in open-air at room temperature in the laboratory until weight was constant. Dried litter samples (3 ± 0.1 g) were weighed and filled in nylon net (12.5 x 12.5 cm) with 2.0 mm mesh size. The selected mesh size was based on results of head capsule width (HCW) of several aquatic insects from the area which HCW were smaller than 2.0 mm (Radomsuk, 1999; Chaiyapa, 2001; Phaphong, 2001). Therefore, this mesh size was big enough to allow macroinvertebrates moving into the bags and it could prevent a loss of large fragments of leaves before decomposition process.

The studies were conducted in year 2002 (January-June) and 2014 (February-July). In each year, 50 litter bags were randomly submersed in riffle and pool of each stream and three replicates of litter bags were randomly retrieved at an interval of 2 weeks for 5 months. Each litter bag was kept separately in an

Table 1. Mean air temperatures and precipitations from Lom Sak Meteorological and Hydrographic Station (Thai Meteorological Department, Ministry of Digital Economy and Society)

Studied period	Air temperature (°C) Mean (min-max)	Total precipitation (mm)
January 25, 2002 to June 7, 2002	28.98 (17.0-40.3)	171.8
February 17, 2014 to July 1, 2014	28.98 (18.1-40.0)	220.1

individual plastic bag and transported to laboratory for further investigation.

2.4 Laboratory methods

In the laboratory, the leaves from each bag were gently rinsed off from silt and debris over 250 µm sieve. Macroinvertebrates were sorted out and preserved in 70% ethanol. Remaining leaves were air dried, grounded and dried in a hot air oven (Memmert BM600, Schutzart DIN 40050-IP20, Germany) at 50 °C for 24 h. The samples were combusted in a muffle furnace at 550 °C for 40 min and put in the oven, dry again at 50 °C for 24 h. Ash-free dry mass (AFDM) was estimated according to Benfield (1996). At the initial time of the experiment, three sub-samples of leaves were combusted similarly to obtain initial AFDM. The negative exponential decay model was used to determine leaf litter decomposition rates (Abelho, 2001).

The sorted macroinvertebrates were identified to genus or species level with taxonomic keys of Morse et al. (1994) and Sangpradub and Boonsoong (2006). Unknown genera of Ephemeroptera and Trichoptera in 2002 were reindentified by using Sangpradub and Boonsoong (2006). Coleoptera, Odonata and Chironomidae were identified to family. In order to address what fauna are important in leaf litter decomposition process, taxa were also assigned to functional feeding group (FFG) according to Dudgeon (1999), Morse et al. (1994) and Ruangkit (2014).

2.5 Data analysis

Two-way ANOVA was applied to test spatial and temporal difference of each parameter. Data of environmental variables of each stream in both years were compared by independent t-test for groups that met required assumptions (normal distribution and equal variances) and Mann-Whitney U test (non-parametric test) for other groups (SPSS for Windows version 17.0) (Dytham, 2011). In addition, a principal component analysis (PCA) was also used to analyze all measured physico-chemical variables among treatment for determine the relative importance of the environmental parameters on leaf decomposition.

The exponential decay model to decomposition data was applied to leaf breakdown in both streams in order to obtain the breakdown coefficient k (Abelho, 2001) as follow:

$$M_t = M_i e^{-kt}$$

Where M_t is the mass remaining AFDM at time t,

M_i is initial AFDM,

$-k$ is the exponential decay coefficient expressed in mass loss per day or degree-day.

3. Results

3.1 Environmental variables of streams

Two-way ANOVA revealed that stream depth, water velocity, DO and EC were significantly difference in both spatial and temporal variations. The early 3 parameters were significantly higher in PL than those in YK, but EC was higher in YK. Water temperature and pH were significant difference between years as well as EC was significant difference between streams. Table 2 presents range and mean values of environmental variables at YK and PL during 2002 and 2014. At YK, means of stream depth and DO showed significantly lower (*t*-test, $p<0.01$) in 2014 than those in 2002, whereas means of water velocity, water temperature, pH and EC showed non-significant difference between years. At PL, means of water velocity, water temperature and pH showed significantly higher, whereas means of DO showed significantly lower (*t*-test, $p<0.05$) in 2014 than those in 2002. Stream depth in PL was lower in 2014 than that in 2002 with non- significant difference.

3.2 Leaf-litter decomposition

Leaf-litter breakdown rate (*k*-values) ranged from 0.015/day to 0.029/day in 2002 and from 0.018/day to 0.036/day in 2014 (Figure 2). The leaf breakdown rates in both streams in 2014 were more rapid than those in 2002, particularly in riffle were 1.57 and 1.24 folds faster at YK and PL, respectively. Results of breakdown rate were clearly faster in riffles than those of pools. It was also found that leaching was the fastest in the first day of immersion. Thereafter, dry mass decreased progressively to the end of experiment in 2002, whereas it was decreasing sharply during 15-60 d in 2014 (Figure 2).

3.3 Macroinvertebrate fauna and functional feeding groups (FFGs)

Four phyla, 16 orders, 67 families and 109 taxa of macroinvertebrates were found. They consisted of phylum Platyhelminthes, Annelida, Mollusca and Arthropoda. Taxa richness and density of benthic macroinvertebrates colonizing in the litter bags were higher at PL than those of YK in both years. Trichoptera was the most diverse group (17 families, 31 taxa) followed by Ephemeroptera (9 families, 27 taxa), and Diptera (9 families, 11 taxa), respectively. Whereas, Chironomids (*O. diptera*) was the most abundant in the litter bags (36.22-65.23%) followed by Caenis (*O. ephemeroptera*) (1.63-28.44%) and Macrostemum (*O. trichoptera*) (0.46-19.53%), respectively (Table 3). Density of macroinvertebrates to colonize in litter bags was varied throughout 134 days of experiment.

Of FFGs, 79.04% was collector-gatherers followed by collector-filterers (10.66%), predators (5.23%) scrapers and shredders (each 2.54%), respectively. Percentage of each FFG differed among collecting dates (Figure 3 A-B),

Table 2. Environmental variables with each sampling site

Year	Days after immersed	stream depth (cm)		water velocity (m/s)		water temperature (°C)		DO (mg/l)		pH		EC (µS/cm)	
		YK	PL	YK	PL	YK	PL	YK	PL	YK	PL	YK	PL
2002	1	12.83 ±4.96	17.00 ±1.26	0.05 ±0.06	0.12 ±5.27	15.00 ±0.00	17.45 ±0.17	6.77 ±0.46	7.72 ±0.13	7.95 ±0.03	7.78 ±0.01	578.67 ±5.35	357.50 ±1.18
	15	11.58 ±2.42	12.67 ±1.87	0.04 ±0.05	0.05 ±0.02	20.6 ± 0.5	17.00 ±0.00	7.43 ±0.21	8.00 ±0.04	8.06 ±0.06	7.89 ±0.01	580.67 ±40.03	380.50 ±1.09
	27	13.33 ±2.59	15.42 ±1.31	0.05 ±0.06	0.11 ±0.06	18.3 ±0.61	17.07 ±0.04	6.98 ±1.05	7.20 ±0.25	8.02 ±0.05	7.96 ±0.01	586.83 ±5.83	390.33 ±10.32
	43	15.50 ±7.15	13.33 ±1.82	0.06 ±0.06	0.11 ±0.05	19.08 ±0.2	18.00 ±0.00	6.82 ±0.59	7.43 ±0.08	7.91 ±0.13	7.80 ±0.01	529.00 ±18.91	417.50 ±0.92
	57	12.67 ±4.27	11.50 ±2.60	0.05 ±0.07	0.14 ±0.06	22.28 ± 0.13	22.85 ±0.08	5.97 ±0.20	7.97 ±0.10	7.99 ±0.01	7.82 ±0.02	508.50 ±3.51	422.83 ±2.34
	71	7.33 ±2.94	10.17 ±1.58	0.15 ±0.17	0.21±0.05	22.0 ± 0.85	22.53 ±0.16	5.92 ±0.36	6.83 ±0.04	7.42 ±0.06	7.88 ±0.06	471.00 ±17.83	418.33 ±6.45
	88	11.83 ±1.94	12.17 ±1.08	0.07 ±0.08	0.14 ±0.04	22.25 ± 0.1	24.53 ±0.34	7.66 ±0.13	7.70 ±0.02	6.52 ±0.18	7.15 ±0.10	347.00 ±3.63	404.00 ±2.52
	93	10.83 ±5.27	20.83 ±4.17	0.12 ±0.17	0.20 ±0.08	22.68 ± 0.46	23.37 ±0.03	6.47 ±0.12	6.28 ±0.04	7.74 ±0.14	7.77 ±0.02	325.50 ±52.10	316.50 ±2.93
	120	17.50 ±4.18	13.83 ±2.79	0.24 ±0.26	0.34 ±0.10	22.78 ± 0.25	23.67 ±0.02	7.20 ±0.39	6.43 ±0.04	7.36 ±0.08	7.31 ±0.09	204.93 ±45.11	157.03 ±0.30
	133	13.33 ±4.23	15.00 ±1.93	0.18 ±0.08	0.41 ±0.16	22.5 ±0.76	24.48 ±0.11	6.58 ±0.12	6.92 ±0.09	7.74 ±0.23	7.29 ±0.08	335.83 ±20.12	152.12 ±0.30
	total mean	**12.67±2.57**	**14.19±2.91**	**0.10±0.07**	**0.18±0.11**	**20.75±2.43**	**21.10±3.10**	**6.78±0.54**	**7.25±0.59**	**7.67±0.45**	**7.67±0.28**	**446.79±127.11**	**341.66±98.43**
2014	1	6.33±1.25	10.67±2.49	0.09±0.02	0.18±0.11	17.8±0	18.93±0.05	6.47±0.07	7.89±0.24	7.87±0.05	8.00±0.22	584.00±0.82	402.33±2.05
	15	6.00±1.63	7.67±2.05	0.17±0.03	0.33±0.03	21.83±0.56	21.03±0.03	5.87±0.13	7.05±0.42	8.17±0.05	8.03±0.00	590.67±0.47	369.67±49.13
	30	7.33±1.25	22.00±5.89	0.12±0.04	0.19±0.06	23.5±0.14	23.37±0.09	5.88±0.11	6.71±0.05	8.30±0.00	8.30±0.00	530.33±1.25	432.00±1.41
	42	10.00±2.83	6.33±2.62	0.13±0.03	1.53±0.33	23.30±0.29	27.80±0.14	5.30±0.21	5.77±0.05	8.13±0.05	8.10±0.08	545.33±42.24	416.33±2.87
	60	7.00±0.82	13.33±4.71	0.13±0.03	0.40±0.06	22.30±0.00	24.20±0.08	6.06±0.07	6.87±0.06	8.25±0.29	7.97±0.05	486.00±4.97	406.67±2.87
	74	10.00±0.82	12.33±2.05	0.14±0.08	0.24±0.06	22.00±0.00	24.03±0.09	5.05±0.12	6.37±0.25	7.87±0.05	7.93±0.09	362.00±1.63	317.00±4.24
	83	-	23.33±10.27	0.08±0.01	0.21±0.04	24.97±0.05	26.87±0.21	5.42±0.28	6.62±0.05	7.90±0.00	7.90±0.00	510.00±7.26	315.33±0.47
	101	7.07±2.20	8.17±1.03	0.20±0.02	0.34±0.08	23.60±0.00	24.40±0.00	4.99±0.11	6.32±0.22	7.97±0.05	7.73±0.12	515.00±1.41	224.33±0.94
	118	10.00±3.36	13.33±4.71	0.10±0.01	0.32±0.02	23.77±0.05	24.90±0.00	5.46±0.16	6.76±0.45	7.87±0.05	7.80±0.00	487.67±1.70	309.00±0.82
	134	6.67±1.70	10.00±5.72	0.30±0.07	0.29±0.05	22.63±0.21	24.17±0.05	6.57±0.40	6.61±0.01	8.00±0.08	7.87±0.05	322.00±0.82	287.67±0.47
	total mean	**7.82±1.59**	**12.72±5.46**	**0.15±0.06**	**0.40±0.38**	**22.57±1.83**	**23.97±2.42**	**5.71±0.53**	**6.70±0.52**	**8.03±0.16**	**7.96±0.15**	**493.30±83.19**	**348.03±64.09**
	***p* (ANOVA)**	Y**, S**		Y**, S**		Y**, Sns		Y**, S**		Y**, Sns		Yns, S**	
	***p* (t- test)**	**	ns	ns	*	ns	*	**	*	ns	*	ns	ns

p indicates the significant difference between groups (Two-way ANOVA or independent t-test(, marked correlations are significant: $^{*}p < 0.05$, $^{**}p < 0.01$, ns - non significant difference, Two-way ANOVA test between year (Y) and stream (S), (YK = Yakruea stream, PL = Phromlaeng stream)

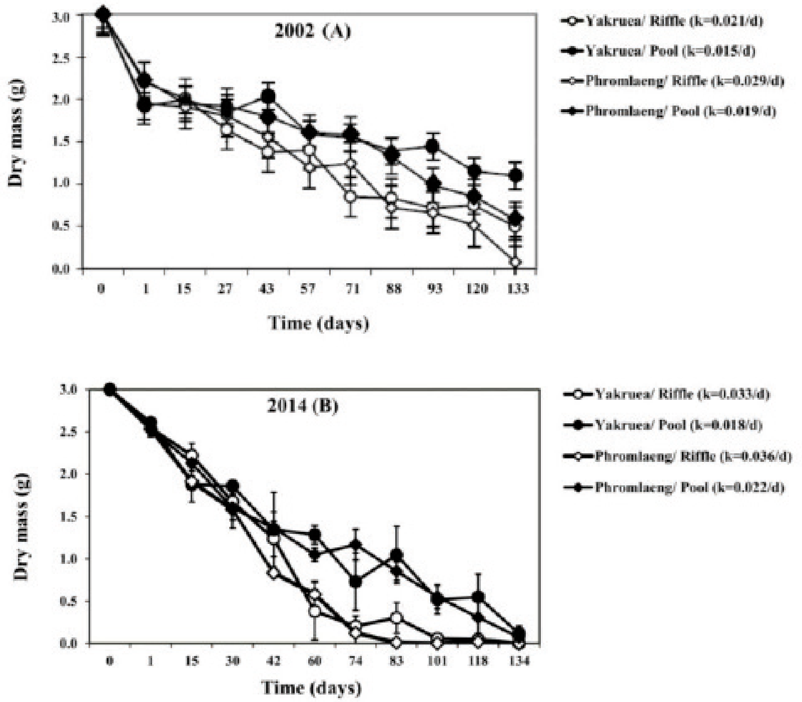

Figure 2. Dry mass remaining (mean±SD) of leaves in riffles and pools at Yakruea and Phromlaeng streams in (A) 2002 and (B) 2014

but a similar trend was observed between 2002 and 2014 (Figure 3 C-D). Chironomid larvae (collector-gatherers) were high numbers in both riffles and pools throughout the experiment.

The collector-gatherers colonized in litter bags in both riffles and pools at the early stage, but they tended to decrease at the last stage of the experiment. Conversely, collector-filterers, predators and scrapers tended to increase at the end of experiment. Shredders had a different trend compared with other group, however they were dominant in a similar period of leaves incubated from both years. It was found that the shredders were high proportion during 15-43 days in riffles and steadily occurred throughout the experiment in pools in 2002. In 2014, they were in a high proportion during 30-60 days, whereas they were the same trend in 2002 at pools.

The two axes of the PCA used to verify the importance of the environmental parameters in the leaf decomposition, explained 20% of the variance among habitat sites and years ($p < 0.01$). Riffle and pool sites were separated along PC1. Water velocity was positively related to riffle sites, especially in 2014 both streams. YK and PL were separated along PC2. In addition, collector-filterers were associated with riffles (Figure 4).

Table 3. Relative abundance (%) and functional feeding groups (FFGs) of the top 30 most abundance of invertebrate taxa found associated with Bambusa arundinacea incubated at Yakruae (YK) and Phromlaeng (PL) streams in 2002 and 2014 (GC = collector-gatherer, FC = collector-filterer, P = predator, SC = scraper, SH = shredder)

Taxon	FFG	2002				2014			
		YK		PL		YK		PL	
		Riffle	Pool	Riffle	Pool	Riffle	Pool	Riffle	Pool
COLEOPTERA									
Dryopidae	SH	0.14	-	-	-	0.68	0.07	0.47	1.29
Elmidae	SC	0.18	0.60	3.78	2.85	0.06	0.04	1.01	1.12
Hydrophilidae	P	1.69	1.60	0.06	-	3.55	0.32	0.47	0.16
Scirtidae									
Elodes	SC	0.87	-	0.03	-	0.79	-	0.16	-
DIPTERA									
Athericidae									
Suragina	P	0.68	-	0.27	0.42	0.64	0.60	0.14	1.25
Ceratopoganidae	P	1.46	0.40	1.43	2.33	1.71	1.76	1.44	2.11
Chironomidae	GC	45.89	64.93	36.22	45.88	56.80	65.23	45.12	57.60
Simuliidae									
Simulium	GC	0.14	-	0.27	-	0.68	-	0.78	0.03
EPHEMEROPTERA									
Baetidae									
Baetis	GC	4.33	1.60	1.22	1.06	2.04	0.39	0.86	0.30
Nigrobaetis	GC	-	-	-	-	0.83	0.46	0.32	0.86
Caenidae									
Early instar	GC	-	-	-	-	0.96	2.86	0.25	2.64
Caenis	GC	21.64	11.82	3.44	28.44	9.53	16.34	1.63	18.74
Ephemerellidae									
Uracanthella	GC	-	-	-	-	0.07	-	2.79	0.26
Leptophlebiidae									
Choroterpes (Choroterpes)	GC	0.05	2.20	0.09	-	-	1.52	-	0.46
Choroterpes (Dilatognathus)	GC	-	0.20	6.55	-	-	-	1.84	-
Choroterpes (Euthraulus)	GC	3.83	3.21	1.19	0.95	1.47	1.06	0.24	0.53
Thraulus	GC	0.23	3.41	0.12	1.48	-	0.92	-	0.46
HEMIPTERA									
Helotrephidae									
Distotrephes shepardi	P	-	-	-	-	0.99	-	0.25	0.13
PLECOPTERA									
Leuctridae									
Leuctra	SH	4.06	-	-	-	-	-	-	-
Nemouridae									
Amphinemura	SH	3.78	-	0.09	-	2.61	-	0.27	-
Perlidae									
Phanoperla	P	-	-	-	-	0.02	0.11	0.89	-
TRICHOPTERA									
Ecnomidae									
Ecnomus	GC	1.55	3.41	0.03	0.11	0.13	1.52	0.01	0.16
Helicopsychidae									
Helicopsyche	SC	0.14	0.20	-	-	3.90	-	0.04	-
Hydropsychidae									
Early instar	FC	-	-	-	-	0.64	-	8.10	0.16
Cheumatopsyche	FC	1.05	-	0.03	0.11	2.28	-	9.12	0.07
Hydropsyche	FC	1.41	0.40	7.92	0.21	0.02	-	5.23	-
Macrostemum	FC	0.46	-	19.53	-	0.63	-	6.26	-
Hydroptilidae									
Orthotrichia	FC	-	-	2.89	0.95	-	0.07	0.45	0.23
Leptoceridae									
Leptocerus	SH	0.09	1.20	2.13	1.69	0.18	0.32	0.29	3.33
Setodes	GC	-	0.40	0.61	0.63	-	0.11	0.27	1.06
Philopotamidae									
Chimarra	FC	3.26	-	6.41	-	4.67	-	6.55	-
Stenopsychidae									
Stenopsyche siamensis	FC	-	-	1.28	0.32	-	-	0.58	0.03
BIVALVIA									
Cyrenidae									
Corbicula	FC	0.05	0.40	-	4.02	0.24	0.04	0.04	0.92

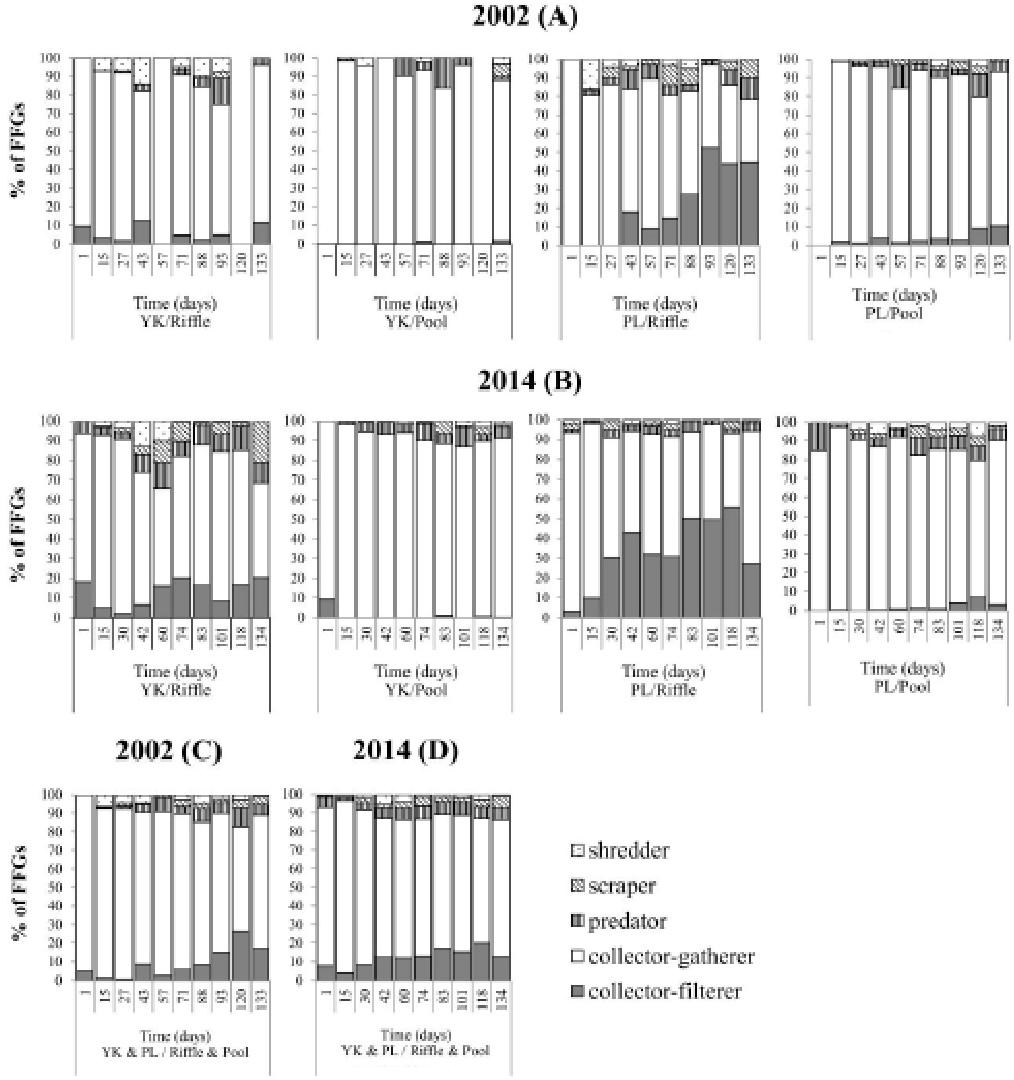

Figure 3. Percentage composition of each functional feeding group (FFG) in riffles and pools at 2 streams in 2002 and 2014, (A) riffles and pools at YK and PL in 2002, (B) riffles and pools at YK and PL in 2014, (C) combined data from riffles and pools of both streams in 2002, (D) combined data of riffles and pools of both streams in 2014

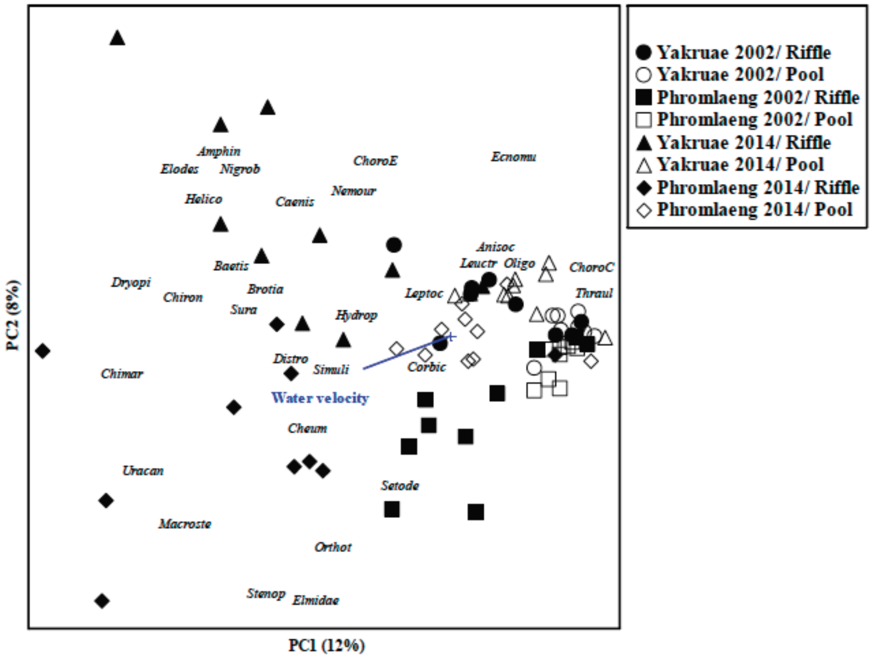

Figure 4. Result of principal component analysis of environmental factors at different habitat sites and years

4. Discussion

Two-way ANOVA revealed that there were significant differences among physical and chemical parameters in both time and space. Moreover, most physical and chemical parameters had more temporal variation than spatial variation. These may be due to both streams are located in the National Park where have less anthropogenic disturbance. Mean water velocity, water depth, water temperature and DO were significantly higher in 2014 than those of 2002. These are probably due to high precipitation and temperature in 2014. Higher precipitation can cause higher water velocity (Jung et al., 2014) and high water velocity promote DO (Ferreira and Graça, 2006; Martins et al., 2015). From the present study, water temperature was higher in 2014 than that of 2002, which was corresponded with air temperature. Marks (2011) stated that Thailand is already experiencing the impacts of global climate change and annual mean temperature in Thailand rose by approximately 1 °C from 1981 to 2007. In addition, average annual temperatures at Phetchabun Province have significantly risen between 1970-2014 (R. Somnark, unpublished data). The present results indicated the effect of climate change in increasing of water temperature and precipitation in Nam Nao National Park.

Principle Component Analysis showed that water velocity was the principle abiotic factors in leaf litter decomposition. The fastest decomposition was observed in riffle of PL 2014 followed by riffle of YK 2014, riffle of PL 2002, respectively and the slowest rate was in pool of YK 2002. This results was supported by several authors (Belancic et al., 2009; Rincón and Santelloco, 2009; David and Boonsoong, 2014), who studied in tropical headwater streams and reported that litter breakdown rate was rapidly in site with high current velocity. In addition, the decomposition of leaves was more accelerated in sites with fast flow velocity than in sites with slow flow velocity by increasing physical fragmentation (Ferreira et al,. 2006; Belancic et al., 2009), improving the transport and colonization of fungal species, and supplying DO and nutrients to microbioal communities (Rincón and Santelloco, 2009).

In the present study, biplot of PCA showed that distance between pools in ordination space were closed together which indicated the similarity of their macroinvertebrates community structure. Choroterpes, Ecnomus, Lecutra, Leptocerus, Thraulus and Oligochaeta were relative abundance in pools; in addition, most trichopteran larvae and other collertor-filterers were abundance in riffles. Among macroinvertebrates colonized in the leaf litter bags, chironomid larvae were the most abundant group, which was similar to the reports of previous studies (Gonçalves Jr et al., 2006; David and Boonsoong, 2014; Oliveira et al., 2014) with suggested that it is important for the structure of the invertebrates community during the decomposition of organic detritus (Benstead, 1996). Chironomidae and other collector-gatherers were found in high density, which was agreed with several authors (Benstead, 1996; David and Boonsoong, 2014; Oliveira et al., 2014; Yule et al., 2015). High numbers of chironomids contributed to the dominance of the collector -gatherers to colonize in litter bags at riffles and pools in both years since the beginning and throughout of the study. This is mainly due to their high capacity on colonization (Batzer and Wissinger, 1996) and chironomids tend to have generalist and opportunistic feeding habits that enabling them to colonize leaf litter regardless of the quality and/or decomposition time (Gonçalves Jr et al., 2006). Shredders had a small proportion of individual in the present study, which was agreed with Mathuriau and Chuvet (2002), Rinćon and Santelloco (2009) and David and Boonsoong (2014). Shredders play a major role in leaf litter decomposition in temperate streams (Gonçalves, Jr et al., 2006; Boyero et al., 2009), but they have a minor role in tropical streams (Mathuriau and Chuvet, 2002; Rinćon and Santelloco, 2009; David and Boonsoong, 2014). However, Jinggut and Yule (2015) reported that shredder guild may be important in the tropical streams, particularly streams at higher altitudes and when litter N is not limiting. In headwater stream, the shredders seemed to play as a crucial role in litter breakdown, but their importance appears to decrease at downstream (Graça and Canhoto, 2006). In addition, Martins et al. (2015) reported that the shredders were the most important biotic factor for leaf-litter breakdown in softer leaf tissues, but microbes were not important for leaf-litter breakdown rates of those species. In the present study, Amphinemura, Leuctra, Leptocerus, Anisocentropus and Dryopidae were dominant shredders. These shredders were found in low density and they were not found in completely decomposed litter bags. This finding may indicate that the shredder density was according to available of coarse particle organic matter (CPOM) in the litter bags. Other FFGs including predators and scrapers were high percentage at the later stage of the study. They seemed to have no effect on leaf decomposition because none of them fed on decaying organic matter. They used litter bags as a habit for feeding or sucking the preys (Carvalho and Uieda, 2009).

Apart of water velocity, decomposition rate tended to increase with increasing temperature as does microbial metabolism (Suberkropp and Weyers, 1996; Wantzen et al. 2008). Microbial biomass associated with decomposing leaf litter and metabolic activity of both fungi and bacteria. The effect of temperature on decomposition has also been shown to increase with increasing temperature (Suberkropp and Weyers, 1996). In the present study, decomposition rate in litter bags were faster in 2014 than those of 2002 in both riffles and pools. The result of PCA did not show water temperature as a principle factor on decomposition. Due to no effect of water velocity in pool; therefore, the faster decomposition rate in 2014 may be caused by increasing of water temperature. According to Ferreira and Chauvet (2011), water temperature played a key role on decomposition rate because metabolism of microbes and invertebrates depended on temperature as well as Taylor and Chauvet (2014) stated that water temperature influenced directly on decomposition rate through microbial metabolism and indirectly through the structure of shredder communities. Thus, decomposition tended to proceed more quickly in the stable and moderately high water temperature with favoring strong biological activity (Mathuriau and Chauvet, 2002).

In conclusion, the decomposition rate in riffles and pools at Nam Nao National Park were faster in 2014 than those of 2002 and higher rates were observed in riffles. Colonization of macroinvertebrates in leaf litter bags was similar in both 2002 and 2014. Effects of temperature and benthic macroinvertebrates on decomposition rate were not clear. Water velocity was importance factor accelerated decomposition. Increase in water velocity was a consequence of increase in precipitation which was directly related to climate change.

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