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Aquatic Insect and Factors Influencing their Abundance in Temporary Habitats

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Abstract

Temporary water habitats are usually inhabited by a diverse fauna of aquatic organisms such as aquatic and semiaquatic species and may include rare and endangered species. In October and November 2016, aquatic insects were sampled in selected four temporary sampling sites in Kasetsart University, central Thailand. Aquatic D-hand net was used to capture the aquatic insects. Water variables in each habitat were simultaneously measured. A total of 4,820 aquatic insect belonging to 5 orders–Hemiptera (45.119%), Coleoptera (22.51%), Diptera (13.54%), Order Ephemeroptera (10.35%) and Odonata (8.42%) were collected. Eight families were recorded within the Order Hemiptera, with members of Family Notonectidae and the species *Anisops bouvieri* dominating. Five families were registered within Coleoptera, dominated by family Hydrophilidae, while order Odonata had 2 families dominated by family Libellulidae. Order Diptera was dominated by family Chironomidae. Order Ephemeroptera was dominated by family Baetidae. The values of the Shannon-Weiner index of diversity ranged from 2.118 to 2.487. Evenness values ranged from 0.643 to 0.795. The values of the Simpson index ranged from 0.7943 to 0.8900. Data of water variables and aquatic insects were analyzed with Principal Component Analysis (PCA). The correlations were found between aquatic insects and the water quality parameters of orthophosphate, nitrate-nitrogen, ammonia-nitrogen, temperature, alkalinity, electrical conductivity and total dissolved solids, were influenced the aquatic insect species.

Introduction

Temporary water habitats are diverse in form and geography. They are characterized by diverse physical and chemical conditions, regardless of their type and origin (Williams, 1996). The temporary habitats are include any habitat that intermittently has standing water and that, once inundated, holds water long enough for some species to complete the aquatic phases of their life cycle (Blaustein & Schwartz, 2001). This definition includes water body that might be classified elsewhere as temporary lakes, temporary ponds, rice fields or phytotelmata. Rain pools are small temporary ponds of variable duration formed in depressions where the rain

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is accumulated (Williams, 2006). Temporary ponds experience recurrent drought periods that may differ in duration, and are further characterized by the particular fauna that inhabits them and by the size of the populations that they can sustain (Williams, 1997). Temporary environments impose strict conditions on the fauna that inhabits them and require the development of different morphological, physiological and behavioral characteristics and adaptations to survive periods of drought, migration and changes in the life history (Wiggins et al., 1980; Wellborn et al., 1996; Williams, 1996). Temporary water habitats are usually inhabited by a diverse fauna of aquatic organisms, semiaquatic and terrestrial species. The adults of Hemiptera (aquatic bugs), Coleoptera (beetles), Odonata (dragonflies and damselflies), Diptera (true flies) and Ephemeroptera (mayflies) fly into the area and colonize the temporary habitats (Leitao et al., 2007; Pires et al., 2015); while other species spend their larval phase in the moist mud, growing rapidly in the aquatic medium and emerging as adults (Leitao et al., 2007; Pires et al., 2015). Temporary habitat condition was regulated the abundance and diversity of these organisms (Hayasaka et al., 2012; Mogi 2007), and therefore, temporary areas are colonized by organisms with short life cycles that are well adapted to the temporary habitats (Heiss et al., 1986).

Aquatic insect communities in temporary habitats are shaped by both abiotic and biotic factors. Hydroperiod, pattern of the water level in a temporary habitat, is the most important abiotic factor. The onset and duration of the hydroperiod will affect both invertebrate species richness and community composition, and the hydroperiod is at the same time the key factor to maintain distinct communities in temporary habitats (Spencer et al., 1999). Many aquatic insect taxa coexist in the water during floods and interactions between these insects are important for the species community structure. Predation is the most important of these biotic factors. Predatory insects of several taxa have a great impact on community structure in aquatic systems (Blaustein, 1998). Research on aquatic insect fauna in temporary habitat in Thailand is limited. With the aim to increase knowledge of temporary habitat fauna in the university campus, the objectives of this work were (1) to analyze some attributes of aquatic communities in temporary environments (2) to describe the abundance and diversity of aquatic insects in temporary habitats and (3) to relate the different temporary environments and aquatic insects.

Materials and methods

1. Sample collection and identification

Four temporary habitats as indicated with KU_KPS1, KU_KPS2, KU_KPS3 and KU_KPS4 (Fig. 1) were selected to sampling aquatic insects. Samples were collected once in October and November 2016 (where accumulation of water was registered). For the collection of aquatic insects, aquatic D-hand net (dimension of 30 × 30 cm frame, 250 µm mesh, 50 cm length) was dragged around the vegetation. At each sampling site, a stretch of approximately 1 m drag was chosen for collection of samples. Three such drags constituted one sample in each site. Collected insects were immediately sorted and preserved in 80% ethyl alcohol and taken back to the laboratory for identification. In the laboratory, aquatic insects were sorted in a Petri dish and identified to the lowest level using taxonomic keys by several authors (Dudgeon, 1999; Wiggins, 1996; Yule & Yong, 2004). Large aquatic insects were sorted by the naked eye whereas the sorting of the smaller ones was done under a dissecting microscope. All the sorted samples were kept in properly-labelled vials containing 80% ethanol.

2. Physicochemical water quality parameters

At the same collected aquatic insect site, selected physicochemical water quality parameters were recorded directly at the sampling site and included pH (measured by a pH-meter Waterproof Model Testr30), water temperature (WT) and air temperature (AT) (measured by a hand-held thermometer), and dissolved oxygen (DO, measured by a HACH® Model sensION 6 DO meter), total dissolved solid (TDS) and electrical conductivity (EC) (measured by a EURECH CyberScan CON110 conductivity/TDS meter). Water samples from each collecting period were stored in polyethylene bottles (500 mL). Ammonia- nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), orthophosphate (PO_4^{3-}), and turbidity (TUB) were determined in accordance with standard procedures [American Public Health Association (APHA) 1992]. Alkalinity (ALK) was measured by titration (APHA, 1992).

3. Data Analysis

The mean and standard deviation for each physicochemical variable was calculated per station. One-way ANOVA in combination with Tukey's (HSD) *post hoc* test was used to test for physicochemical parameters among sampling occasions and among the sampling sites using SPSS Version 20.0. The four community indices included: richness, evenness,

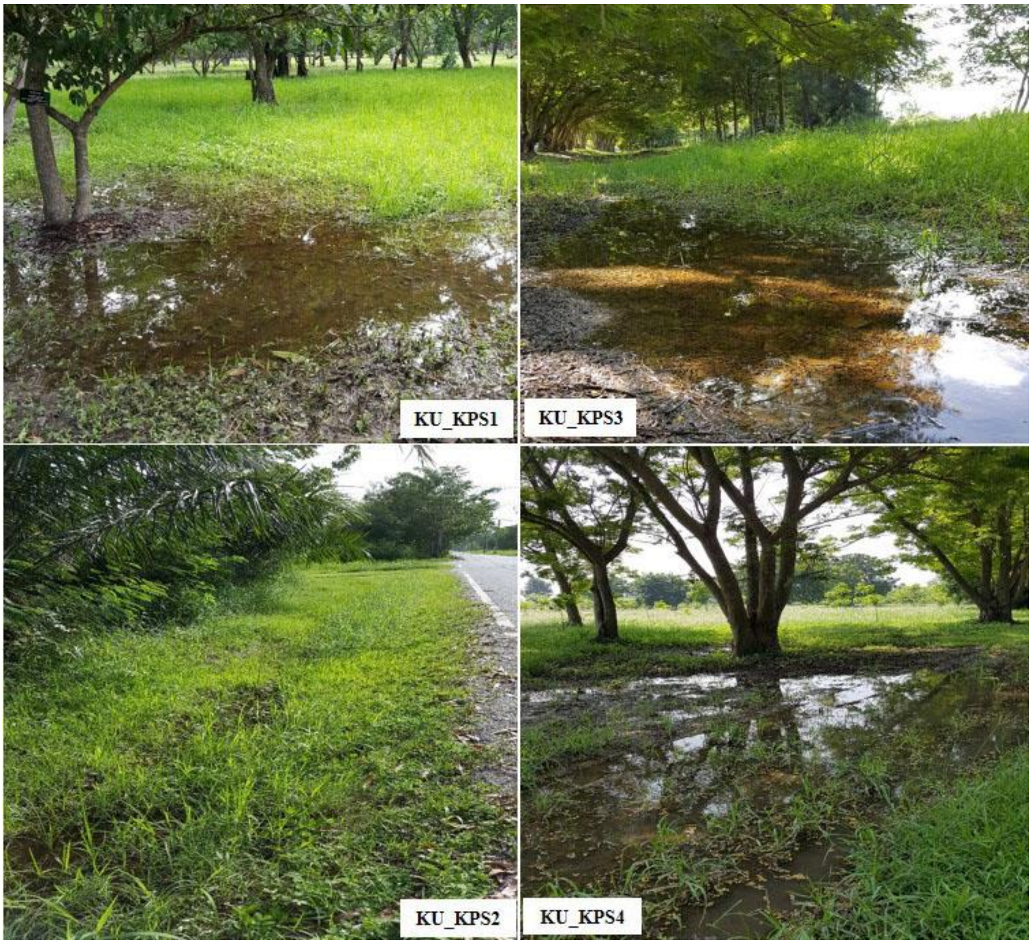


Fig. 1 Pictures of the selected of four temporary habitats sampled in Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom Province, Thailand (14° 0' 50.7204" N, 99° 58' 30.1002" E)

Shannon-Weiner diversity, and Simpson diversity were calculated using PC-ORD version 5.1 (McCune & Mefford, 2006). The Principal Component Analysis (PCA) was used to evaluate relationships between aquatic insects and environmental variables with PC-ORD version 5.10. Cluster analysis and non-metric multidimensional scaling (NMDS) were used to classify the sampling sites based on the aquatic insects using Ward's linkage method with Euclidean distance measure using PC-ORD software.

Results and discussion

1. Environmental variables in temporary habitat

All environmental variables (temperature, total dissolved solids, electrical conductivity, pH, alkalinity, ammonia-nitrogen, nitrate-nitrogen, orthophosphate and turbidity) showed significant differences ($p < 0.05$) across the temporary habitats (Table 1).

The average air temperature was 31.11ºC. The site of KU_KPS2 had the maximum temperature, and KU_KPS3 site had the minimum temperature. Mean air temperature was significantly high at site KU_KPS2 compared with sites KU_KPS1, KU_KPS3 and KU_KPS4 with significantly higher values ($p<0.05$). The average water temperature was 30.93ºC. The changes of water temperature are influenced by many variables including time of sampling and condition of the habitat. In the temporary habitats, the highest mean temperature was recorded in the KU_KPS4 (32.77±0.38°C) and KU_KPS3 site was recorded the minimum temperature (29.13±0.06°C). Aquatic insects preferred temperatures ranging 27.70 to 32.77°C.

Table 1 Environmental variables of water at four temporary habitats

Parameter/sites	KU_KPS1	KU_KPS2	KU_KPS3	KU_KPS4	*p*-value
Air temperature (°C)	31.17±0.61[a]	32.90±0.01[b]	29.70±0.10[a]	30.70±0.95[a]	0.001
Water temperature (°C)	32.33±0.46[c]	27.70±0.20[a]	29.13±0.06[b]	32.77±0.38[c]	0.000
Electrical conductivity (µS/cm)	209.67±3.06[a]	319.67±2.89[b]	190.13±56.21[a]	229.00±7.55[a]	0.002
Total dissolved solids (mg/L)	103.67±1.16[a]	160.00±2.65[b]	94.53±27.28[a]	114.67±3.22[a]	0.002
Dissolved oxygen (mg/L)	5.48±0.87[c]	2.87±0.98[a]	4.77±0.23[bc]	3.31±0.17[ab]	0.004
pH	7.33±0.06[a]	7.53±0.0.6[ab]	7.70±0.10[b]	7.50±0.10[ab]	0.004
Turbidity (NTU)	6.33±2.08[a]	14.33±1.53[b]	7.00±1.00[a]	38.00±2.65[c]	0.000
NH_3-N (mg/L)	1.20±0.06[c]	0.52±0.07[a]	0.83±0.11[b]	1.06±0.05[c]	0.000
NO_3-N (mg/L)	2.47±0.12[c]	1.50±0.17[a]	1.87±0.15[b]	2.60±0.10[c]	0.000
PO_4^{3-} (mg/L)	3.68±0.03[c]	1.72±0.04[a]	3.95±0.02[d]	2.55±0.17[b]	0.000
Alkalinity (mg/L)	79.33±1.15[a]	196.67±11.02[b]	85.33±2.31[a]	82.67±1.16[a]	0.000

Remark: a-c = the relationship of environmental factors is sinificant differences in the sampling sites

The levels of electrical conductivity at different sites showed wide variation, ranging between a mean of 190.13±56.21 µS/cm for the KU_KPS3 and 319.67±2.89 µS/cm for the KU_KPS2. KU_KPS1 and KU_KPS4 sites also recorded relatively high mean electrical conductivity levels of between 209.67±3.06 µS/cm and 229.00±7.55 µS/cm, respectively. Elevated levels of turbidity, total dissolved solids and electrical conductivity were recorded in KU_KPS2 and KU_KPS4, probably due accumulation of dissolved particles (Dida et al., 2015).

The dissolved oxygen varied considerably among the temporary sites in which the aquatic insects were caught, with the highest DO recorded in the KU_PKS1 (5.48±0.87 mg/L), followed by KU_KPS3 (4.77±0.23 mg/L) and KU_KPS4 (3.31±0.17 mg/L). The lowest (2.87±0.98 mg/L) was recorded in KU_KPS2. It was established that aquatic insects in the temporary sites were appeared in samples with DO values ranging between 2.87 mg/L to 5.48 mg/L.

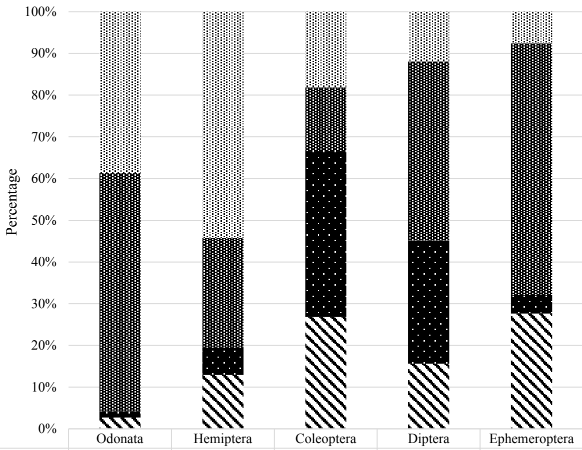
The measurement of water pH was varied markedly between different habitats, ranging between 7.33 to 7.70. The highest mean value (8.2 ± 0.5) was recorded in open puddle habitat KU_KPS3, while the lowest (7.33±0.06) was recorded in KU_KPS1.

As presented in Table 3, the highest mean alkalinity (196.67±11.02 mg/L) was recorded in the KU_KPS2 while the lowest were recorded in KU_KPS1 (79.33±1.15 mg/L). Mean water alkalinity values differed significantly between habitat types. The requirement of alkalinity for aquatic insects in the shared habitats varied, with values ranging between 79.33 mg/L, and 196.67 mg/L.

The orthophosphate concentration was highest (3.95±0.02 mg/L) in KU_KPS3 and lowest (1.72±0.04 mg/L) in KU_KPS2. The high concentration of phosphate in the temporary habitats may be due to land use management practices. Other important sources of phosphorus to freshwater are atmospheric precipitation, geochemical condition, and ground water (Lawniczak et al., 2016). Concentration of nitrate-nitrogen and ammonia-nitrogen ranged from 1.50±0.17 to 2.60±0.10 mg/L and 0.52±0.07 to 1.20±0.06 mg/L, respectively. In natural aerobic water, most nitrogen occurs as nitrates in varying amount depending upon the nature of water shed, seasons, degree of pollution and the abundance of plankton (Maitland, 1978).

2. Species diversity of aquatic insect

A total of 4,820 individuals comprising five aquatic insect orders, 22 families and 34 genera were identified (Fig. 2, Table 2).



	Odonata	Hemiptera	Coleoptera	Diptera	Ephemeroptera
KU_KPS4	157	1181	197	78	38
KU_KPS3	232	573	165	280	301
KU_KPS2	6	142	432	193	22
KU_KPS1	11	281	291	102	138

Fig. 2 The proportion of aquatic insects sampled in each temporary sampling habitats

Hemiptera was the dominant order and highest species richness belonging to eight family, together accounting 45.11% of the total number of aquatic insects collected. Family Notonectidae and the species Anisops bouvieri were highest abundance in all of Hemipteran family and species, respectively. In general, the genus Anisops was dominant and were found at all sampling stations and throughout the sampling time. They found the highest density up to 460 individuals in KU_KPS4. Overall, they also represented the highest abundance in all sites surveyed with 1,102 individuals comprising 22.87% of the total insects collected. The relatively larger size of Notonectidae often makes these insect top predators in systems lacking vertebrates (Runck & Blinn, 1990). It is very common in temporary pools and permanent water bodies. This followed by Belostomatidae (476 individuals) and Gerridae (460 individuals) from orders of Hemiptera.

High abundance of hemipteran families especially Notonectidae, Gerridae and Belostomatidae were most related to the environmental conditions, as indicated by the PCA results. The Hemipterans are regarded as effective predators of freshwater snails and mosquito larvae in the aquatic ecosystems (Saha et al., 2007). It is also well known that notonectids are voracious predators of mosquito larvae (Saha et al., 2007). Gilbert & Burns

Table 2 Order, family, genus and species number for all aquatic insects sampled in four temporary habitats in October and November 2016

Oder	Family	Genus/Species	KU_KPS1		KU_KPS2		KU_KPS3		KU_KPS4	
			Oct	Nov	Oct	Nov	Oct	Nov	Oct	Nov
Odonata	Coenagrionidae	*Enallagma* sp.		5		3	3	2	28	31
	Libellulidae	*Hydrobasileus* sp.		4	2		28	3	39	
		Cratilla sp.		2		1	108	88	15	44
Hemiptera	Belostomatidae	*Diplonychus nitidus*				32	22	9	40	20
		Diplonychus rusticus		2	14	27	45	13	137	114
		Lethocerus indicus						1		
	Gerridae	*Limnogonus nitidus*	23	87	9	2	45	21	147	21
		Limnogonus sp.		38		5		57	3	2
	Helotrephidae	*Hydrotrephes yangae*				1				14
	Hydrometridae	*Hydrometra annamana*		1			1		3	3
		Hydrometra cracens					1			
		Hydrometra greeni		1				1	1	2
	Mesoveliidae	*Mesovelia horvathai*							1	
		Mesovelia vittegera	16	10	15	10		1		9
	Micronectidae	*Micronecta quadristrigata*	1		6	3			7	
	Notonectidae	*Anisops bouvieri*			9		201		435	25
		Anisops breddini	7						9	144
		Anisops lansvuryi		5			2	8		
		Anisops tahitiensis	2	65		2	59	39	2	
		Anisops sp.					37	10	2	39
	Veliidae	*Mircrovelia dauglasi*	13	1						
		Microvelia leveillei	6							
		Microvelia sp.		3	4				1	
Coleoptera	Dytiscidae	*Rhantus* sp.	10	12	29	25	13	3	22	5
		Hyphydrus sp.		61		1			4	
		Laccophilus sp.	3		6			2	2	2
		Neptosternus sp.	2	2	26	4	5		1	
		Copelatus sp.	2		6	32	30	22		
		Hydrovatus sp.	3		2					3
	Hydrophilidae	*Laccobius* sp.	8	19	12	26	2		2	
		Berosus sp.	20	14	12	5	5		17	
		Hydrophilus sp.	40	79	95	110	36	46	85	34
	Noteridae	*Canthydrus* sp.		1	3	1				2
	Scirtidae	*Hydrocyphon* sp.	3	4	5	13				
	Spercheidae	*Spercheus* sp.	4	4	13	6	1		14	4
Diptera	Ceratopogonidae	*Leptoconops* sp.				3				
	Chironomidae	*Chironomus* sp.	71	17	84	90	204	55	43	24
		Clinotanypus sp.			2					
		Parametriocnemus sp.					1			8
	Culicidae	*Aedes* sp.	4	2	2	2	2	7		1
		Culex sp.	2		4	1	6	2		1
	Tipulidae	*Limnophila* sp.		2				3		
	Stratiomyidae	*Odontomyia* sp.	2	1	3	5			1	
	Syrphidae	*Eristalis* sp.	1							
Ephemeroptera	Baetidae	*Cloeon* sp.	92	46	7	15	255	46	30	8

(1999) concluded that notonectid predators have the potential to alter mosquito communities via direct or indirect effects. Direct evidence of notonectid predation on mosquito larvae was later noted and this further confirmed their predominant role in mosquito larvae control (Chesson, 1984).

The second higher abundance of aquatic insect was order Coleoptera found in this study. Five families were registered within Coleoptera, accounted for 22.51%, dominated by family Hydrophilidae and Dytiscidae. Aquatic Coleoptera can be found in all types of freshwater (Fairchild et al., 2003) and they include a wide range of different feeding behaviours, represented by different families (e.g. many Dytiscidae are predators, many Hydrophilidae are algivores and detrivores) (Fairchild et al., 2000). Dytiscidae have three larval instars which pass their development in water, all adults are aquatic but may leave the water during migration or for over-wintering on land (Nilsson, 1996). Both larval and adult Dytiscids are generalist predators in aquatic habitats and feed on many different prey (Lundkvist et al., 2003). The dytiscid larvae are strictly predatory while the adults are partly scavengers, and larval prey choice is largely correlated with body size (Nilsson, 1996). Apart from predation on other invertebrates, large dytiscid larvae may also feed on small vertebrates. For example, increasing densities of Dytiscus larvae resulted in higher predation pressure on tadpoles (Pearman, 1995). This dominance of diversity and abundance of the Hydrophilidae among the Coleoptera is a common phenomenon in permanent and temporary ponds (Torres et al., 2012; Macchia et al., 2015). Ribera et al. (2003) considered both families typical of temporary environments. According to Ribera & Vogler (2000) the presence of Hydrophilidae and Dytiscidae in temporary ponds is due to their exceptional capacity to disperse.

Diptera with six accounted for 13.54% of the total number aquatic insects, dominated by family Chironomidae. Chironomidae are generally the most successful aquatic insect taxa and they inhabit all freshwater bodies, including polluted and eutrophic waters (Mackie, 2001). One of the main reasons for the great abundance of Chironomidae is that they exhibit all types of feeding behaviour and food preference (Nilsson, 1997). The larval abundance of the Culicidae, *Aedes* sp. and *Culex* sp. was low in number in all sites, because of high abundance of mosquito larvae predator were presented in all sites. Kweka et al. (2012) point out that the higher grass cover reduces sunlight penetration to the habitat which affects the algae biomass photosynthesis efficiency and other aquatic forms which are other sources of food to mosquito larvae. Grass cover influences oviposition site selection by mosquitoes hence directly effect on larvae abundance as observed by other researchers (Mala et al., 2011; Bashar, 2016).

Order Ephemeroptera were less presented with the family Baetidae and comprised 10.35% of the aquatic insect in temporary habitats. The family Baetidae can be found in all temporary habitats in this study which this families are very common in any kind of freshwater. They are mainly diversified in unpolluted running water, especially in the tropics. Although they are less diversified in standing waters, with genera like *Cloeon,* the Baetidae constitute an important part of the insect biomass in ponds. Most species of Baetidae are collector-gatherers, feeding mainly on detritus (Gattolliata & Nieto, 2009).

Odonata with two family accounted for 8.42% of the total number aquatic insects, dominated by family Libellulidae and genus *Cratilla.* Anisoptera was abundant in most of the water bodies sampled. This might be due to their high dispersal ability (Lawler, 2001; Kadoya et al., 2004) and their adaptability to wide range of habitats (Suhling et al., 2004; 2005). Less abundance of damselflies was probably due to their limited dispersal ability, undulating environment afforded by the temporary water bodies (Kadoya et al., 2004) and partial or absence of shade cover (Clark & Samways, 1996). The abundance of damselflies temporary habitat could be attributed to the presence of shade over the habitat from the trees present around the water bodies and to the presence of aquatic vegetation. This is in confirmation with the findings of Subramanian (2005) who revealed that shade and aquatic vegetation could favour Zygoptera more than Anisoptera. The abundance of Libellulidae (Anisoptera) and Coenagrionidae (Zygoptera) in the present study might be due to their shorter life cycle and widespread distribution (Norma-Rashid et al., 2001) and tolerant to wide range of habitats (Samways, 1989).

Table 3 showed the species diversity indices. The highest Shannon-Weiner index of diversity of 2.487 was recorded in KU_KPS1_Nov and the lowest (2.118) was in KU_KPS4_Nov, indicating the presence of a quite high diversity of aquatic insects in temporary ecosystems. Normally, the Shannon index in real ecological units ranges between 1.5 and 3.5 (Magurran, 2004). The value of diversity index can indicate the level of diversity in temporary habitats. Higher value of H′ indicates that the species diversity in the location is high. The diversity of insects in aquatic ecosystems tends to increase with increased nutrients and these optimum environmental conditions favour their abundance in this habitat. Their abundance has been associated with the presence of high food quality and better water quality conditions prevailing in the habitats (Hepp et al., 2013).

Table 3 Number of individual, taxon richness, Shannon-Weiner diversity index, Simpson`s diversity index and Evenness index of the four sampling stations

Sites/month	Total individual	Taxon richness (S)	Evenness index (E)	Shannon-Weiner index (H')	Simpson dominance (D`)
KU_KPS1_ Oct	335	23	0.742	2.328	0.8504
KU_KPS1_ Nov	488	27	0.755	2.487	0.8886
KU_KPS2_ Oct	370	24	0.777	2.469	0.8620
KU_KPS2_ Nov	425	26	0.739	2.406	0.8619
KU_KPS3_ Oct	1112	24	0.722	2.296	0.8614
KU_KPS3_ Nov	439	22	0.795	2.457	0.8900
KU_KPS4_ Oct	1091	27	0.643	2.118	0.7943
KU_KPS4_ Nov	560	24	0.762	2.421	0.8666

Evenness values ranged from 0.643 in KU_KPS4_Oct to 0.795 in KU_KPS3_Nov. The evenness value in the present study was recorded as high in almost all the sites, indicating a relatively even distribution of taxa in the habitats. The high species diversity and evenness in almost all the sites are an indication of good water quality (Abhijna et al., 2013). The values of the Simpson index ranged from 0.7943 in KU_KPS4_Oct to 0.8900 in KU_KPS4_Oct. The high scores of diversity indices, such as those of the Shannon-Wiener index and Simpson's index, indicate that clean or unpolluted water support more diverse taxa, thus making them useful for detecting organic pollution (Maneechan & Prommi, 2015). Higher numbers of taxa (family) collected from a habitat imply a richer community that usually lives in a healthier environment. Based on the scores, all temporary sites supported relatively rich aquatic insect fauna.

Cluster analysis based on Bray-Curtis similarity distance (Fig. 3) showed that sites Oct_2 and Nov_2 showing high similarity followed by sites Oct_3 and Nov_3. Sites Oct_4 and Nov_4 had the most distinctive aquatic insect composition comparing to other sites. This was expected as this site had the high taxa richness (27 and 23 genera) and taxa abundance (range from one to 435). This station also recorded the low to slightly high diversity (2.118 and 2.421) as illustrated by Shannon-Weiner index.

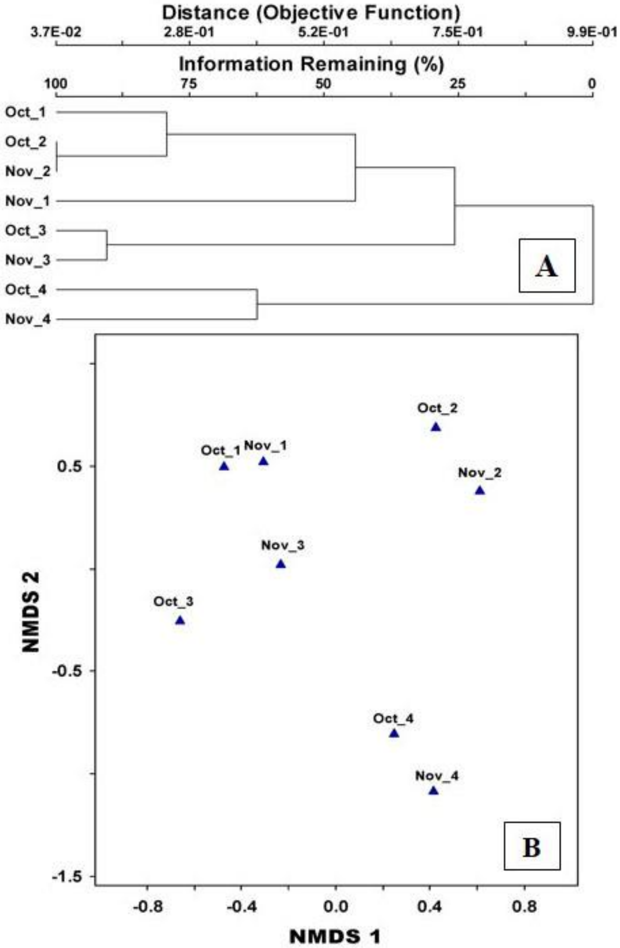


Fig. 3 Cluster analysis of aquatic insects collected during October and November 2016 in four temporary habitats (A) and Non-metric Multidimensional (NMDS) Scaling (B) of sampling sites based on aquatic insect data

3. Aquatic Insects and Environmental Parameters.

In order to determine the trend of the relationship between the physicochemical parameters with the aquatic insects in each site, a principal component analysis (PCA) was performed.

PCA ordination for data of aquatic insects can be separated into three groups (Fig. 4). The first group was located in the Oct_1, Nov_1, Oct_2 and Nov_2. The second group was located in the Oct_3 and Nov_3. The third group was located in the Oct_4 and Nov_4. PCA analysis revealed a correlation between the aquatic insect taxa and physicochemical variables (Fig. 4).

Aquatic insects, *Hydrocyphon* sp., *Laccobius* sp., *Odontomyia* sp., *Neptosternus* sp., *Clinotanypus* sp., *Laccophilus* sp., *Eristalis* sp., *Leptoconops* sp., *Berosus* sp., *Canthydrus* sp., *Spercheus* sp., *Hydrophilus* sp., *Rhantus* sp., *Helochares* sp., *Mesovelia* sp., *M. vittegera, M. leveillei* and *M. dauglasi* were negatively related to temperature, alkalinity, total dissolved solids and electrical conductivity in the first group.

Aquatic insects, *Limnophila* sp., *Copelatus* sp., *Aedes* sp., *Limnogonus* sp. *Chironomus* sp., *Culex* sp., *Cratilla* sp., *Cloeon* sp., *Hyphydrus* sp., *Copelatus* sp., *A. lansvuryi, A. tahitiensis, H. cracens* and *L. indicus* were positively related to ammonia-nitrogen, orthophosphate and dissolved oxygen in the second group.

Water quality variables such as turbidity and nitrate-nitrogen were positively related to aquatic insect *Hydrobasileus* sp., *Hydrovatus* sp., *Amphiops* sp., *Enallagma* sp., *Anisops* sp., *Parametriocnemus* sp., *A. breddini, H. yangae, H. greeni, D. indicus, D. rusticus, H. annamana* and *M. horvathai* in the third group.

In this study temporary habitats were sampled during flood, which were the periods of greatest rain fall in the study area. It is likely that the abundance and richness of aquatic insects in this flood period is associated with heavy precipitation that favored the formation of temporary habitats and individuals dispersal flights. Various research work in other countries (Schneider & Frost, 1996; Wellborn et al., 1996; Spencer et al., 1999; Boix et al., 2001) postulated the presence of various factors that influence the structure of the communities living in temporary environments, emphasizing the importance of hydroperiods. An association between species richness and water permanence has already been reported in the literature (Schneider & Frost, 1996; Spencer et al., 1999; Fontanarrosa et al., 2009), this association was also found in several temporary ponds during this study. At longer hydroperiods, more species will be able to complete their development and maintain viable populations. According

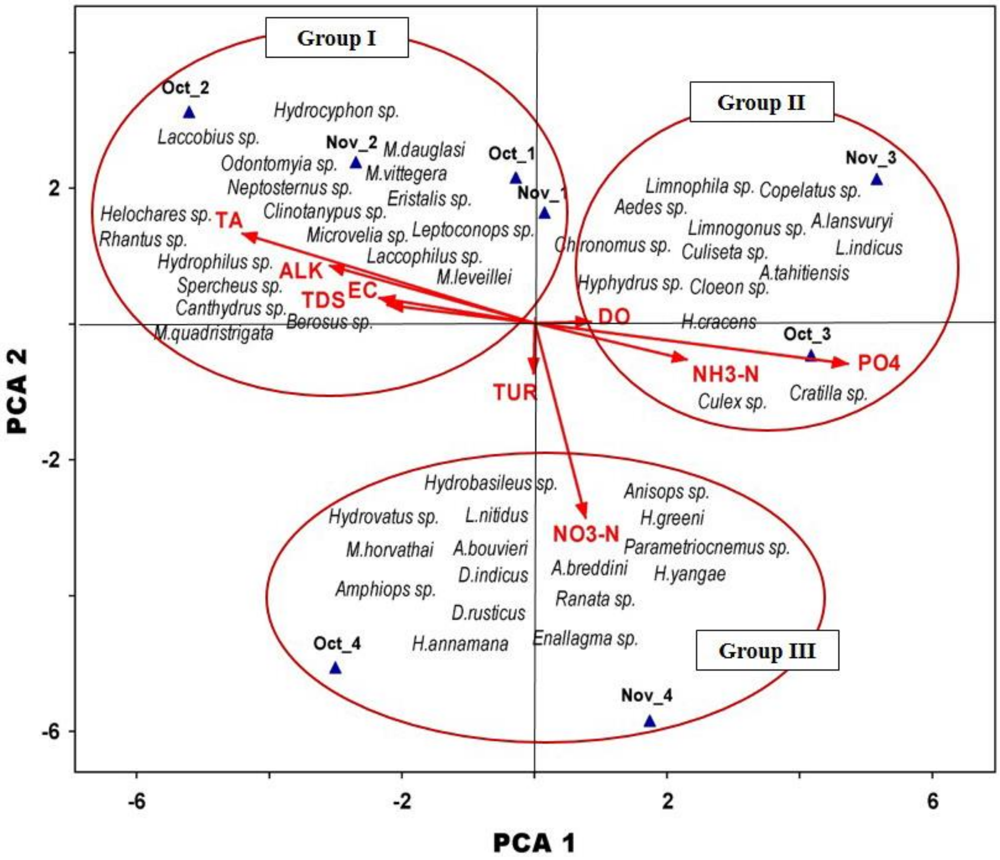


Fig. 4 Principal component analysis (PCA) on aquatic insects, environmental variables and sampling sites. The first and second PC axes explain 23.91% (eigenvalue: 10.75) and 20.93% (eigenvalue: 9.41), respectively, of the variation in the data set

to Spencer et al. (1999) the longer permanence of ponds also implies a longer time available for colonization. In this contribution, the temporary ponds that remained for a maximum of 10 days showed very few significant correlations between the analyzed variables, perhaps due to the rapid drying.

Conclusion

This is the first of a series of contributions which intend to study and evaluate the dynamics of aquatic insects in temporary environments. Based on the results, the aquatic insect communities inhabiting temporary habitats in the University in central Thailand are diverse, and include several species, such as *Diplonychus rusticus, Limnogonus nitidus, Rhantus* sp., *Hydrophilus* sp., *Chironomus* sp., *Aedes* sp., *Culex* sp. and *Cloeon* sp., that frequently inhabit these environments due to their biological adaptations. Also, less frequent and abundant species, such as *Hydrometra cracens, Mesovelia horvathai* and *Eristalis* sp. were registered in once time. Finally, the environmental variables are the factors that mainly determine the composition of these environments. We are aware that there are numerous open questions and unresolved issues that need to be addressed in future investigations. However, these data contribute to the knowledge about aquatic insects, as well as the ecology of the species that inhabit these temporary environments, which is currently very limited.

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