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Comparison of aquatic insect assemblages between managed and unmanaged artificial lakes in Indonesia

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Abstract
Aquatic insects are an example of organisms vulnerable to habitat alteration. Several artificial lakes were constructed with different maintenance pattern (managed and unmanaged) in Bekasi, which could impact development of aquatic insect community differently. Therefore, the present study examined the aquatic insect assemblages between managed and unmanaged artificial lakes in Indonesia from January to June 2016. Additionally, the influences of physico-chemical factors to the aquatic insect communities were assessed. The results showed that the abundance of insects were higher in managed (1059 individuals) than unmanaged lakes (426 individuals) ($p<0.05$, T-test). Significance of the difference of species composition between managed and unmanaged lakes was illustrated by the separated groups in nMDS graph ($p<0.001$, One-way ANOSIM). However, the same dominant species (*Orthetrum testaceum*) was found in both lakes. *O. testaceum* and *Desmopachria latissima* have strong correlation with all physico-chemical parameters. Different management of artificial lakes significantly changed the aquatic insect assemblages and unmanaged artificial lake decreased the abundance of aquatic insect.

Keywords: Artificial, Bekasi, insect, lake, management

1. Introduction

Most swamps and agricultural fields were converted into housing areas in the large cities in Java, Indonesia between 1990 and 2000. This alteration reduced available area for rain absorption and caused flooding, turning it into a big problem [1]. To prevent flooding, some developers built drainage areas in the form of artificial lakes, mostly unmanaged. However, people living in the area surrounding the lake started to take attention and voluntarily maintain the artificial lake. This habitat alteration and management in wetlands can change the composition of aquatic organism, especially insects [2]. Shuey [2] stated that many insects might not adapt and does not have the capability to survive across urban land use conversion.

Environmental management could impact insect assemblages in terrestrial and aquatic ecosystems. In terrestrial ecosystem, Priawandiputra *et al.* [3] revealed that the number of bees collected from managed pine forests was higher than unmanaged pine forests. Meanwhile, beetle abundance was significantly lower in managed pine forests [4]. Whiteson [5] showed that the diversity of aquatic insects between managed man-made ponds and natural ponds were highly similar. Shuey [2] expected that aquatic insect communities could be maintained by the existence of managed open water wetlands.

The presences of several insect species have been recognized as bioindicators of freshwater ecosystem [6-10]. Some aquatic insects utilize different habitats during their life cycle. They spend one or several stages as larva in aquatic habitat and become adults in terrestrial habitat [11]. Their existence often depends on environmental condition especially water chemistry and riparian land use [12, 13]. In freshwater environments, physico-chemical water properties could correlate to the occurrence of several aquatic insects, including diversity, distribution and its composition [14, 15]. The relationship between the occurrence aquatic insects and physico-chemical factors in freshwater has been reported by some researchers, i.e. temperature, pH, dissolved oxygen (DO), free carbon dioxyde, nitrate [12, 16-20] and rainfall density [21].

In tropical Southeast Asia, research on aquatic insects is still limited to taxonomical description and diversity. Aquatic insect research in Malaysia and Thailand are generally conducted in streams, rivers, paddy fields and lakes [22-25]. Research on aquatic insect diversity has also been widely conducted in different habitats in Indonesia, including in paddy fields [26], peat lands [27], rivers [28], natural lakes [29] and swamps [30].

Unfortunately, research on aquatic insects in artificial lakes with differing management regime is not yet widely conducted. Therefore, the aims of this research are i) to assess aquatic insect composition and similarity of artificial lakes in Bekasi, ii) to compare unmanaged and managed artificial lakes in Bekasi and iii) to correlate physico-chemical factors to the presence of aquatic insects in artificial lakes.

2. Materials and Methods

Study Area

This research was carried out in Alamanda and Duta Lakes, representing managed lake (ML) and unmanaged lake (UL), respectively (Fig. 1). Both lakes were artificially constructed during residential development in Bekasi, West Java, Indonesia. ML was created within Alamanda housing complex, North Tambun, Bekasi District with geographical coordinates 06º13'40.5" latitude and 107º02'57.2" longitude. Meanwhile, UL was established in Duta Harapan housing complex, North Bekasi, Bekasi City with geographical coordinates 06º12'53.4" latitude and 107º 01'12.7" longitude. The size of UL (approximately 1 ha) is larger than ML. ML was managed by volunteers and was maintained as a recreation area. In ML, inorganic wastes and blooming aquatic vegetation were regularly removed. Meanwhile, UL has less maintenance. The different vegetation around and within both lakes is presented in Table 1 and 2. Sampling was conducted once a month in each lake from January until June 2016, representing the change between rainy and dry seasons.

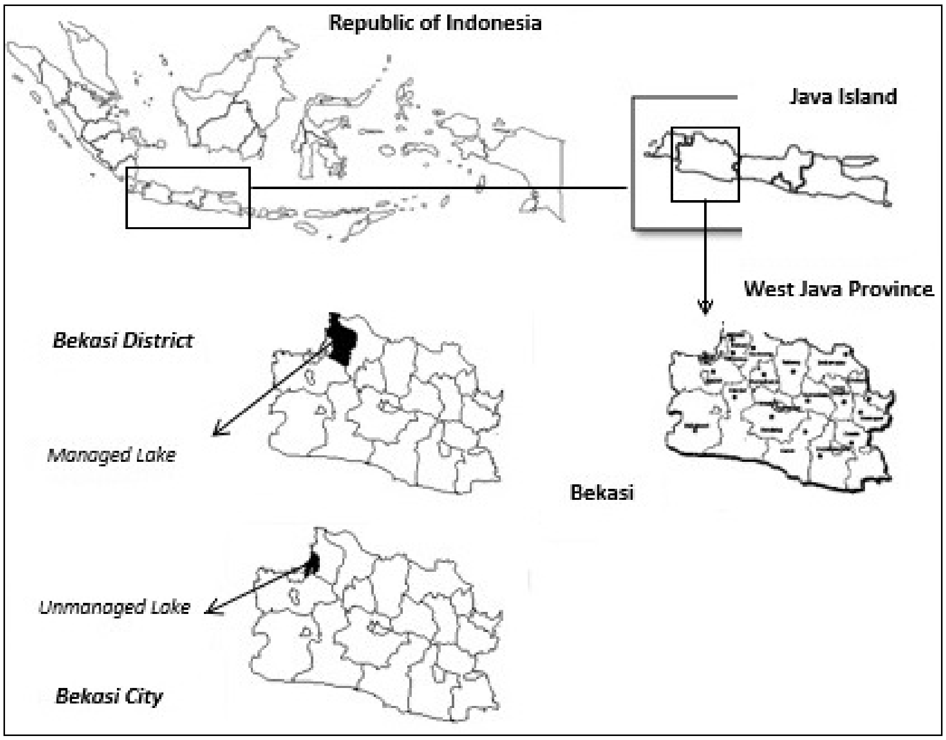

Fig 1: Location of study area in Bekasi, West Java, Indonesia.

Site and Time Collections

Samples of aquatic insects were collected from 10 littoral stations representing areas in each lake (Table 1 and 2). Physico-chemical water parameters were recorded in the selected stations. All station coordinates were measured using Garmin Global Positioning System (GPS). In each lakes, sampling was started at 7 am to 12 pm, avoided the rain.

Table 1: Station coordinates and vegetation of managed lake (ML).

Station	Coordinate		Vegetation	
	Latitude	Longitude	Terrestrial	Aquatic
1	06º13'42,0"	107º02'56,5"	*Acalypha siamensis*, bushes, *Acacia* sp., *Mangifera indica*, *Pterocarpus indicus*, *Muntingia calabura*, *Saccharum officinarum*, *Bamboosa* sp., *Syzygium malaccense*, *Cerbera manghas*, *Syzygium cumini*, *Terminalia catappa*, *Spondias dulcis*, *Casuarina* sp., and *Achras zapota*	*Cabomba caroliniana*
2	06º13'41,2"	107º02'56,6"		
3	06º13'40,6"	107º02'56,8"		
4	06º13'39,7"	107º02'57,0"		
5	06º13'39,0"	107º02'57,3"		
6	06º13'38,0"	107º02'57,1"		
7	06º13'38,9"	107º02'56,0"		
8	06º13'39,7"	107º02'55,9"		
9	06º13'40,9"	107º02'55,3"		
10	06º13'42,6"	107º02'55,4"		

Table 2: Station coordinates and vegetation of unmanaged lake (UL).

Station	Coordinate		Vegetation	
	Latitude	Longitude	Terrestrial	Aquatic
1	06º12'51,8"	107º01'18,7"	Bushes, *Paraserianthes falcataria*, *Muntingia calabura*, *Samanea saman*, *Bougainvillea* sp., *Cychas rumphii*, and *Elais guinensis*	*Eichornia crassipes*
2	06º12'51,6"	107º01'17,8"		
3	06º12'51,0"	107º01'15,9"		
4	06º12'49,8"	107º01'12,5"		
5	06º12'50,6"	107º01'10,9"		
6	06º12'52,2"	107º01'10,8"		
7	06º12'53,5"	107º01'12,2"		
8	06º12'53,0"	107º01'13,9"		
9	06º12'53,3"	107º01'15,9"		
10	06º12'53,9"	107º01'18,1"		

Collection of Aquatic Insects

These methods were based on Dalal and Gupta [50] with modification. In each station, insects (flying and aquatic insects) were captured within a 4x4 meter plots (16 m^2) and were differentiated between terrestrial and littoral habitats (Fig. 2). In terrestrial, flying insects (only mature stage) within the plots had been collected using insect net in a 30 minutes interval per station. Collected flying insects were injected with ethyl acetate and 70% ethyl alcohol, after which they were pinned and stored into an insect box. In littoral habitat, aquatic insects (immature and mature stages) were differentiated and collected based on below and above water habitats. Aquatic insects in below water habitat were collected by filtering the water for 10 repetitions using a net with 153 µm mesh. In above water, aquatic insects were gathered using insect net in a 30 minutes interval per station (similar with method for collecting flying insect). Collected aquatic insects (below and above habitats) were selected and separated from litter and dirt, then put into bottles filled with 70% ethyl alcohol.

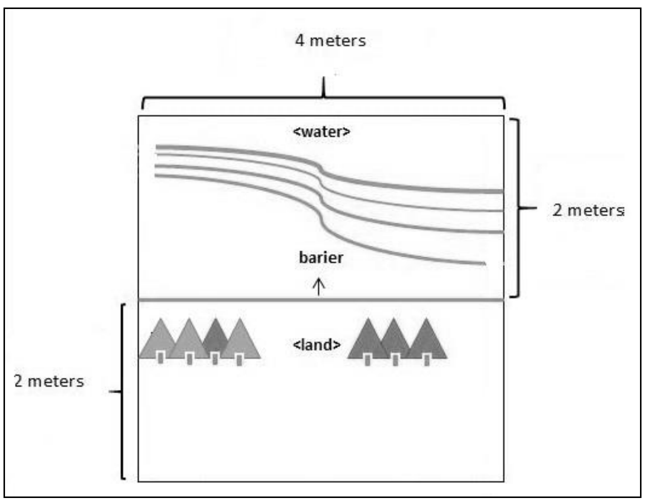

Fig 2: Plot areas for collecting samples.

Identification of Aquatic Insects

Aquatic insects were identified under stereo microscope (LEICA Microscope) until species/genera/morphospecies level based on Chu [31], Clifford [32] and Merrit and Cummins [33]. Insect specimens in the Museum Zoologicum Bogoriense (MZB), LIPI Cibinong, West Java, Indonesia were also used for identification reference. All collected specimens were deposited in the Ecology and Biosystematics Laboratory, Department of Biology, Bogor Agricultural University, Bogor.

Physico-chemical measurements

Physico-chemical factors such as depth, temperatures, pH and dissolved oxygen (DO) were directly measured in each station. Depth of littoral zone was measured approximately 1 meter from shore. A stick was horizontally dipped into water until the base of the lake was reached. Depth was measured using a roll meter from along the stick. Water and air temperature were determined by thermometer. Water pH and DO were assessed using universal pH indicator and DO meter (LUTRON PDO-520), respectively. Rainfall data for both lakes were obtained from Indonesia Agency for Meteorological, Climatological and Geophysics (BMKG), Class 1 Darmaga Bogor.

Data Analysis

T-test was used to compare the abundance of insects and physico-chemical factors between managed and unmanaged lakes. The similarity of insects between two artificial lakes was compared using Bray-Curtis Similarity Index [18, 23]. Community composition in both lakes was analyzed by non-Metric Multidimensional Scaling (nMDS) based on the Bray-Curtis similarity formula and strengthened by One-way ANOSIM analysis. Furthermore, similarity of species composition in both lakes was based on the presence and absence of species analyzed using Sorensen Similarity index. Relationship between the abundance of aquatic insect and physico-chemical factors were analysed and illustrated by Canonical Correspondence Analysis (CCA). Spearman correlation test was used to confirm the correlation between environmental factors and abundance of each insect species. All analyses were calculated used software Paleontological Statistics (PAST) ver. 1.89 [34].

3. Results

Physico-chemical factors in ML and UL

Most of the monthly measured physico-chemical water parameters were higher in ML than UL (Table 3). From January to June, water temperatures were significantly higher in ML than in UL (P<0.05, T-test). Meanwhile from January to March and in May, air temperatures were not significantly different between both artificial lakes (P>0.05, T-test). However in April, air temperature was significantly higher in UL than ML (P<0.05, t=-2.353, T-test). Otherwise, in June, air temperatures were significantly higher in ML than UL (P<0.05, t= 5.783, T-test).

Table 3: Physico-chemical water parameters in ML and UL.

Lake	Parameter	Unit	Months					
			January	February	March	April	May	June
ML	WT	ºC	31.55±	29.77±	30.22±	30.86±	31.58±	30.51±
			0.78	0.29	0.63	0.24	0.16	0.17
	AT	ºC	30,13±	29.15±	31.56±	31.84±	32.02±	31.40±
			0.75	1.45	4.71	0.69	0.89	0.92
	pH	-	6.23±	6± 0.00	6±0.00	6.15±	5.79±	5.95±
			0.34			0.23	0.25	0.34
	DO	$mg.l^{-1}$	3.32±	2.63±	3.71±	2.47±	3.85±	3.57±
			1.75	1.59	1.17	1.02	1.12	1.22
	D	m	-	-	-	0.85±	0.83±	0.89±
						0.09	0.09	0,19
	R	mm	144	465	168	118	93	179
UL	WT	ºC	28.33±	28.04±	29.43±	30.28±	30.56±	29.51±
			0.48	0.58	0.21	0.49	0.51	0.17
	AT	ºC	28.51±	30.21±	28.53±	33.04±	31.86±	29.03±
			2.25	1.03	0.98	1.63	2.11	0.73
	pH	-	6.49±	6.60±	6.78±	6.87±	6.47±	6.15±
			0.47	0.45	0.43	0.22	0.42	0.28
	DO	$mg.l^{-1}$	0.59±	0.63±	1.83±	3.93±	2.22±	2.66±
			0.25	0.14	0.67	0.93	1.01	0.71
	D	m	-	-	-	0.66±	0.86±	0.89±
						0.22	0.10	0.10
	R	mm	144	465	168	118	93	179

Note: ML = Managed Lake, UL = Unmanaged Lake, WT = Water Temperature, AT = Air Temperature, DO = Dissolved Oxygen, D = Depth, RI = Rainfall Intensity.

All monthly pH values were lower in ML than in UL. From January to June, water pH was significantly lower in ML than in UL (P<0.05, T-test). All DO values in ML were higher than in UL. From January to March and in May, DO was significantly higher in ML than in UL (P<0.05, T-test). Meanwhile in April and June, DO was significantly higher in UL than in ML (P<0.05, T-test).

Depth of the littoral zone was only measured from April to June. In April, depths of littoral zone were significantly deeper in ML than in UL (P<0.05, t= 1.276, T-test). Meanwhile in May and June, depths of littoral zone were not significantly different in both artificial lakes (P<0.05, T-test). Rainfall density in ML and UL from January to June ranged from 93-465 mm. February has the highest rainfall density (465 mm). May have the lowest rainfall density (93 mm).

Abundance

In total 1485 aquatic insect individuals were collected from both lakes, of which 1059 individuals were collected in ML and 426 individuals were collected in UL. Aquatic insect abundance above and below the water level was significantly greater in ML than in UL (P<0.05, $t_{above\ water}$= 2.505, $t_{below\ water}$= 4.209, T-test). Meanwhile, abundance of flying insects in terrestrial habitats were not significantly different between both artificial lakes (P>0.05, t= 1.446, T-test) (Fig. 3).

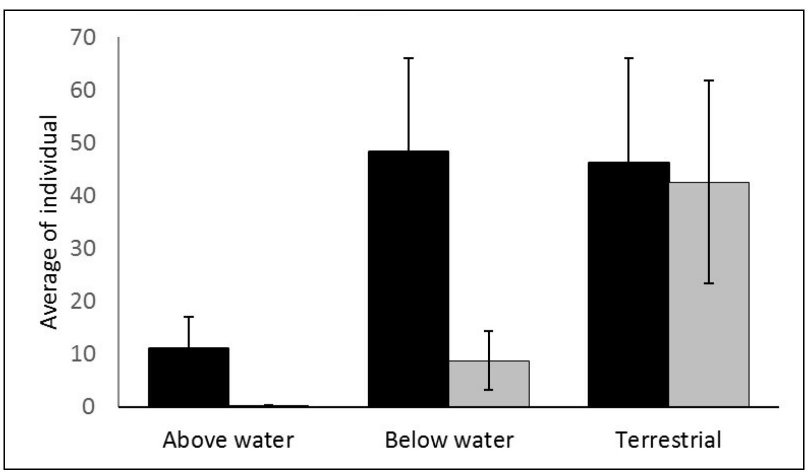

Fig 3: Average number of insects found in ML (■) and UL (□).

Figure 4 compared the rank abundance between ML and UL. Rank abundance in UL sharply decreased at the first rank species to the second rank species, and then decreased constantly from the third rank to the last rank. In ML, third rank to the fourth and fifth ranks sharply decreased. The number of singleton species (Table 4) in UL (5 species) was higher than in ML (1 species), while the number of doubleton species (Table 4) was lower in UL (2 species) than in ML (3 species). However, the first rank species in both lakes was *O. testaceum* (30.03% and 32.15% in UL and ML, respectively). Three species (*O. testaceum, Notonecta undulata* and *D. latissima*) that has the highest number of individual were significantly greater in ML than UL (*P*<0.05, T-test), meanwhile *Ischnura senegalensis* male, *I. senegalensis* female and *Libellula luctuosa* were not significantly different in both artificial lakes (*P*>0.05, T-test).

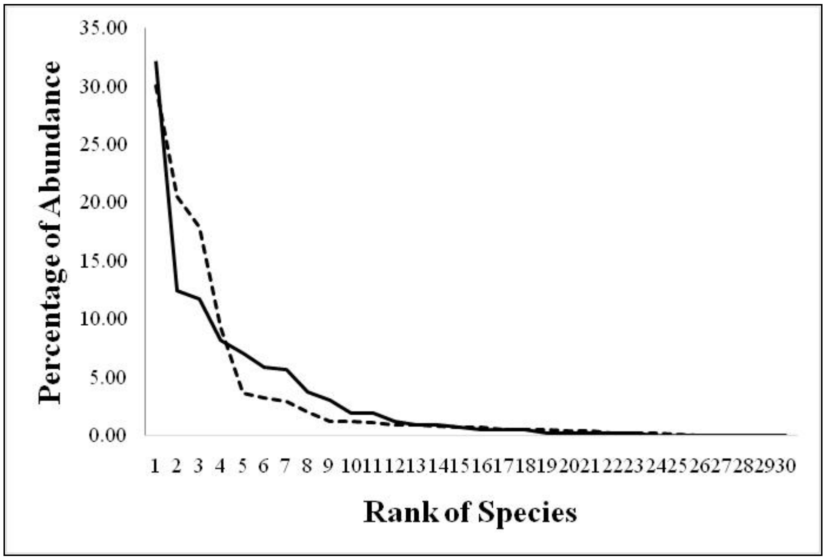

Fig 4: Rank of species abundance in ML (▬ ▬) and UL (▬).

Table 4: The number of aquatic insects collected in ML and UL.

Aquatic Insect			Lake		Total
Order	Family	Species	ML	UL	
Coleoptera	Dytiscidae	*Desmopachria latissima* le Conte (1851)[2]	190	13	203
Diptera	Calliphoridae	*Chrysomya megacephala* fabricius (1794)[3]	9	35	44
	Chironomidae	*Chironomus* sp.[2]	7	1	8
	Culicidae	*Culex* sp.[2]	7	0	7
	Sarcophagidae	*Sarcophaga* sp.[3]	2	16	18
Hemiptera	Belostomatidae	*Diplonychus annulatus* fabricius (1781)[2]	0	8	8
	Corixidae	*Arctocorixa alternata* abbott (1913)[2]	4	4	8
	Gerridae	*Gerris* sp.[1]	1	0	1
		Limnoporus sp.[1]	98	0	98
	Nepidae	*Ranatra fusca* palisot (1820)[1]	13	1	14
	Notonectidae	*Notonecta undulata* say (1832)[2]	217	50	267
Lepidoptera	Hesperidae	Species 1[3]	13	25	38
Odonata	Aeshnidae	*Anax* sp.[3]	2	0	2
	Coenagrionidae	*Agriocnemis femina* brauer (1868)[3]	12	8	20
		Coenagrion sp.[2]	4	0	4
		Ischnura senegalensis rambur (1842) female[3]	31	24	55
		Ischnura senegalensis rambur (1842) male[3]	21	53	74
		Ischnura sp.[2]	5	2	7
		Species 2[3]	5	4	9
	Corduliidae	*Epitheca canis* McLachlan (1886)[2]	2	1	3
	Gomphidae	*Gomphus* sp.[2]	5	0	5
		Ophiogomphus sp.[2]	10	0	10
	Libellulidae	*Libellula luctuosa* burmeister (1839)[2]	34	5	39
		Neurothemis fluctuans fabricius (1793)[3]	0	1	1
		Orthetrum sabina drury (1773)[3]	39	30	69
		Orthetrum testaceum burmeister(1839)[3]	318	137	455
		Orthetrum testaceum burmeister(1839) male[3]	10	2	12
		Pantala flavescens fabricius (1798)[3]	0	2	2
		Species 3[3]	0	3	3
		Species 4[3]	0	1	1
Grand total			1059	426	1485

Note: [1]= collected from above water, [2]= collected from below water, [3]= collected from terrestrial area

Abundance of aquatic insects was different month-to-month between ML and UL (Fig. 5). Abundance gradually increased in ML from January to May 2016 and decreased abruptly in June. Abundance in UL slightly decreased from January to March, and started to increase from March to June 2016. Nevertheless, the individuals in ML were significant higher than in UL (*P*< 0.05, t= 2.567, T-test). Individual numbers of aquatic insects above and below water level were significantly higher in ML than UL (*P*<0.05, T-test) (Fig. 6). Meanwhile, individual number of flying insects in terrestrial habitats were not significant different between both artificial lakes (*P*>0.05, t= 0.734, T-test) (Fig. 6).

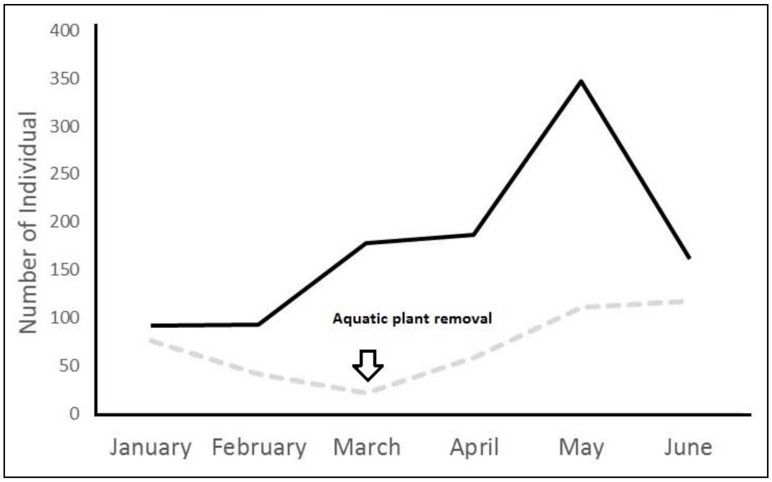

Fig 5: Number of insect individuals in ML (▬) and UL (▬) per month.

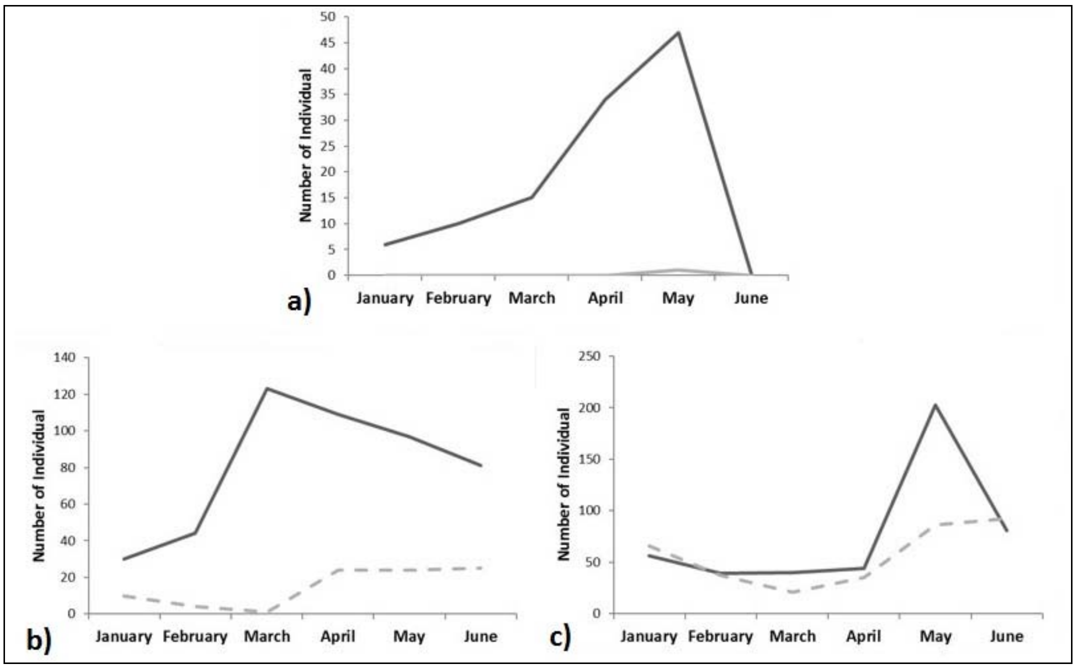

Fig 6: Number of individuals collected from a) above water, b) below water and c) terrestrial habitat in ML (▬) and UL (▬) per month.

Species richness

Thirty species belonging to 16 families under 5 orders was found from both lakes. Twenty-five species were collected from ML, while 23 species were collected from UL (Table 4). The numbers of aquatic insect species found above and below the water level and in terrestrial habitats were very similar in both artificial lakes (*P*>0.05, T-test) (Fig. 7). Shared species richness between both lakes was 18 species (value of Sorensen Index was 0.75), but only 7 species occurred in both ML and 5 species in UL (Fig. 8).

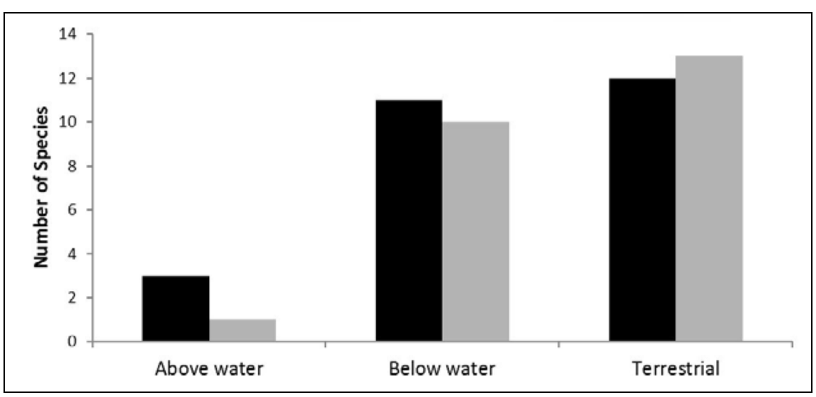

Fig 7: Number of species in three habitats of ML (■) and UL (■).

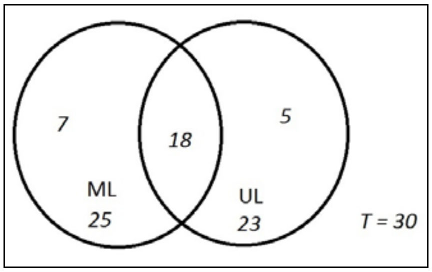

Fig 8: Species number and sharing in ML and UL.

Aquatic insect composition in ML and UL

Based on the nMDS (stress value = 0.177) (Fig. 9), species composition between ML and UL was illustrated by the separated groups. Analysis of the species composition between ML and UL shows that both locations has different species (*P*<0.001, One-Way ANOSIM). Abundance of *Limnoporus* sp. (only collected in ML) was significantly greater than *Diplonychus annulatus* (only collected in UL) (*P*<0.05, t= -5.038, T-test).

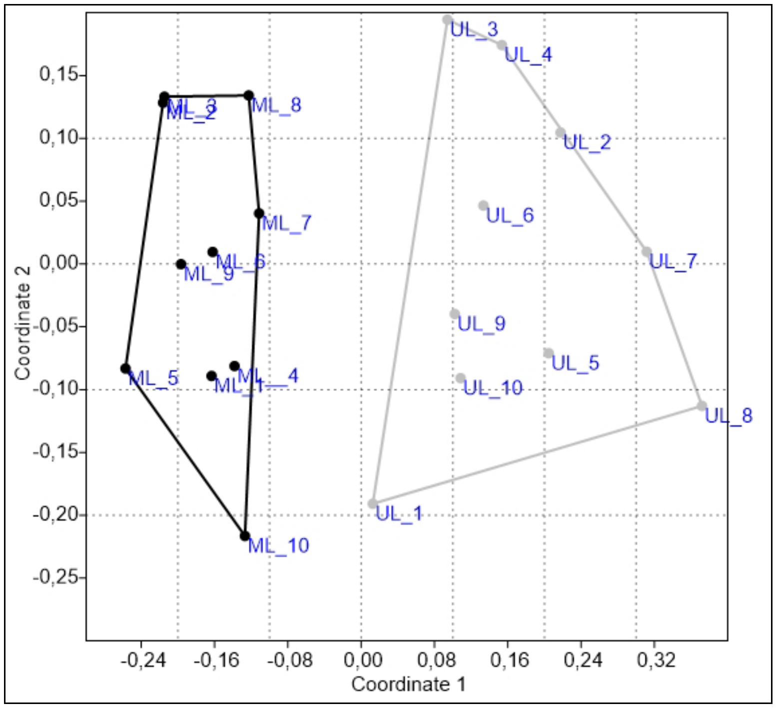

Fig 9: nMDS graphic used the Bray Curtis Index in ML (▬) and UL (▬).

Correlation between aquatic insect abundance with physico-chemical factors

Physico-chemical factors related with presence of a certain aquatic insect species, were determined using CCA (Fig. 10) with axis I 62.19% and axis II 21.45% and Spearman correlation test (Table 5 and 6). Variation in the response of each aquatic insect species to water and air temperature, pH, DO, depth and rainfall were illustrated in Fig. 10. Some species were positively correlated with physico-chemical factors while others were negatively correlated.

Water and air temperatures were positively correlated to five and four aquatic insect species, respectively (R>0.2, *P*<0.05, Spearman correlation). Four species, *C. megacephala* (Cm), *I. senegalensis* male (Ism), *Sarcophaga* sp. (S) and Species 1 (Sp), were positively correlated with pH (R> 0.2, *P*<0.05, Spearman correlation). Positive correlation was found between DO and four aquatic insect species (*D. latissima* (Dl), *Limnoporus* sp. (L), *N. undulata* (Nu) and *O. testaceum* (Ot)) (R>0.1, *P*<0.05, Spearman correlation). *D. latissima* (Dl), *L. luctuosa* (Ll), *N. undulata* (Nu) and *O. testaceum* (Ot) were positively correlated to depth (R>0.2, *P*<0.05, Spearman correlation). No positively correlation between rainfall and any species was found.

Meanwhile, water and air temperature were negatively correlated to four and five aquatic insect species (R> -0.1, *P*<0.05, Spearman correlation). Negatively correlation was found between pH and four aquatic insect species, there were *D. latissima* (Dl), *Limnoporus* sp. (L), *N. undulata* (Nu) and *O. testaceum* (Ot) (R> -0.2, *P*<0.05, Spearman correlation). Negative correlation was found between DO and *C. megacephala* (Cm), *L. luctuosa* (Ll), *Sarcophaga* sp. (S) and Species 1 (Sp) (R> -0.2, *P*<0.05, Spearman correlation). Two species were negatively correlated to depth (*I. senegalensis* female (Isf) and Species 1 (Sp)) (R> -0.2, *P*<0.05, Spearman correlation). *D. latissima* (Dl), *L. luctuosa* (Ll), *Limnoporus* sp. (L) and *O. testaceum* (Ot) were negatively correlated to rainfall (R> -0.2, *P*<0.05, Spearman correlation)

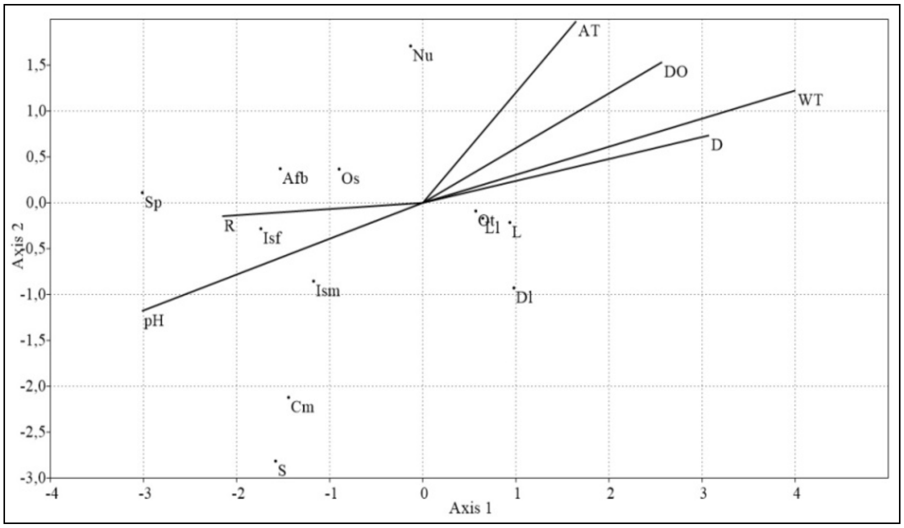

Fig 10: Canonical Correspondence Analysis for correlation between aquatic insects abundance with physico-chemical parameters. WT = Water Temperature (ºC), AT = Air Temperature (ºC), DO = Dissolved Oxygen (mg.l-^{1}), D = Depht (m), R = Rainfall Intensity (mm), Afb = *Agriocnemis femina* brauer, Cm = *Chrysomya megacephala*, Dl = *Desmopachria latissima*, Isf = *Ischnura senegalensis* female, Ism = *Ischnura senegalensis* male, Ll = *Libellula luctuosa*, L = *Limnoporus* sp., Nu = *Notonecta undulata*, Os = *Orthetrum sabina*, Ot = *Orthetrum testaceum*, S = *Sarcophaga* sp., Sp = Species 1.

Table 5: Value of correlation used Spearman Correlation Test.

Insects	WT	AT	pH	DO	R	D
Afb	-0.049	0.031	0.004	0.004	0.095	-0.063
Cm	-0.361	-0.279	0.216	-0.234	0.168	-0.057
Dl	0.546	0.227	-0.411	0.293	-0.270	0.431
Isf	-0.196	-0.178	0.057	-0.084	0.035	-0.280
Ism	-0.105	0.095	0.226	-0.137	-0.105	0.025
Ll	0.262	0.215	-0.105	0.215	-0.233	0.219
L	0.324	0.142	-0.305	0.182	-0.246	0.118
Nu	0.239	0.232	-0.227	0.409	-0.069	0.338
Os	-0.062	0.268	0.029	-0.021	-0.019	0.089
Ot	0.501	0.281	-0.403	0.367	-0.272	0.419
S	-0.275	-0.201	0.178	-0.234	0.155	-0.026
Sp	-0.287	-0.207	0.278	-0.241	0.153	-0.482

Table 6: Significancy values used Spearman Correlation Test.

Insects	WT	AT	pH	DO	R	D
Afb	0.599	0.735	0.963	0.966	0.306	0.495
Cm	<0.001	0.002	0.018	0.010	0.069	0.541
Dl	<0.001	0.013	<0.001	0.001	0.003	<0.001
Isf	0.033	0.053	0.538	0.367	0.705	0.002
Ism	0.255	0.305	0.013	0.138	0.255	0.784
Ll	0.004	0.019	0.255	0.019	0.011	0.017
L	<0.001	0.124	<0.001	0.048	0.007	0.203
Nu	0.009	0.011	0.013	<0.001	0.458	<0.001
Os	0.503	0.003	0.755	0.820	0.839	0.335
Ot	<0.001	0.002	<0.001	<0.001	0.003	<0.001
S	0.002	0.029	0.053	0.010	0.093	0.782
Sp	0.002	0.024	0.002	0.008	0.098	<0.001

4. Discussions

Forming aquatic insect composition in artificial lakes

Bekasi was mostly covered in paddy fields and swamps (wetlands) twenty years ago. Buildings (housing, shopping and business centres) were only recently constructed extensively in the area [35]. Martono [35] showed that land uses in Bekasi District area (127,388 ha) were distributed between wetland agriculture (58.42%), industry areas (5.07%) and housing (11.67% or 1,232 ha) [36]. Meanwhile, data from Bekasi city profile showed that the total Bekasi city land was 90% used for housing land (21,000 ha), 4% for industry, 3% for business centre, 2% for education and government lands and 1% for public building [37]. Consequently, existing swamp and paddy fields were highly reduced and aquatic biodiversity were gradually lost. Housing developers built artificial lakes to control flooding, facilitate recreation for the local community, which improved and preserved aquatic biodiversity. Unfortunately, attention paid for aquatic habitat development such as artificial lakes and ponds are still low, even though well-protected lakes can function as a biodiversity provider [38]. Research from Dalal and Gupta [38] found that managed artificially built urban ponds surrounded by commercial and residential areas provide a good habitat for aquatic insect. The present study has found similar results and concludes that managed artificial lakes contribute to biodiversity of aquatic insects within resident areas.

Although alteration of swamp and paddy field decimated local insect populations, the present results showed that aquatic insect composition recovered and improved in artificial lakes where some aquatic insect population in present study has similar composition to other populations in swamp and paddy field. Rizal and Deptalia [39] had also identified the same five orders of aquatic insects with present data, i.e. Coleoptera, Diptera, Hemiptera, Lepidoptera and Odonata. A result of a study by Asikin [40] in swampy area has found the same four similar species with present study (*Agriocnemis femina, O. sabina*, *I. senegalensis* and *D. annulatus*). All families of aquatic insects in our artificial lakes location were also found in paddy field. Ponraman *et al*. [41] obtained several orders and families of aquatic insect in paddy fields such as Coleoptera (Hydrophilidae, Dytiscidae and Gyrinidae), Diptera (Chironomidae and Culicidae), Ephemeroptera (Baetidae and Caenidae), Hemiptera (Nepidae, Hydromatridae, Notonectidae, Corixidae, Belostomatidae, Gerridae) and Odonata (Aeshnidae, Coenagrionidae and Libellulidae). In our artificial lakes location, only insects from the Hydrophilidae and Gyrinidae Families (Coleoptera) and Ephemeroptera Order were not found in both artificial lakes.

Comparison between managed and unmanaged lakes

Céréghino *et al*. [42] stated that many developed and managed ponds serve as artificial habitat contributing to aquatic biodiversity. In Loktak Lake, protected area and management of land around the protected area by minimizing disturbance through land use and alteration could preserve aquatic biodiversity [43]. Those research data supported the current results where managed artificial lakes provided water for aquatic insects.

Ravera [44] stated that water depth influences the number of organisms present in the lake. UL often receives input from either household or industry waste around the lake, while the ML in this research only accepted rainwater as its water source. Depth of littoral zones in ML is deeper than UL, and its depth is relatively constant compared to UL. This indicated that input into the water decreases UL depth.

Temperature fluctuation is a factor which can inhibit growth of insects that require a specific range of water temperature [16]. Water temperature in UL was lower than ML. This indicated that dense terrestrial vegetation around UL reduced sunlight exposure and reduced the air temperature. Water pH in ML is lower than UL and might affect the abundance of aquatic insects. Thorp and Covich [45] stated that water chemistry such as pH can restrict the occurrence or abundance of aquatic insects. Discharge of untreated domestic, industrial and commercial waste into a water body is an example of poor management of water ecosystem [46]. Although ML has higher DO concentration than UL, DO concentration in both lakes was low compared to other literature. Lack of water inflow into both lakes reduces water renewal, resulting in low DO. Low DO may also be caused by discharge of household waste.

Insects may use aquatic angiosperms as a source of air or as a site for reproduction or protection from predation [47]. Aquatic plants or macrophytes living in ML, *Cabomba caroliniana* might provide a place or habitat for aquatic insects which facilitates reproduction, and also supplying oxygen as result of photosynthesis. UL was filled by aquatic plant, *Eichornia crassipes* before they were totally removed in March 2016. This might the reason why the number of aquatic insect individuals in UL was less than ML. Based on the monthly monitoring, trash on the surface of ML were always removed unlike in UL. Watercolour in UL was dark green and released pungent odour. Discharges of organic substances into aquatic environment are usually characterized by a pungent odour and will reduce environmental aesthetics [48].

Effect of physico-chemical factors to aquatic insects

All parameters (water and air temperature, pH, DO, depth and rainfall) were significantly correlated to eleven species of insects (flying and aquatic insects). Several studies also supported the present study results where air temperatures, water temperature, DO, depht and pH generally influenced aquatic insect structure of species richness, abundance and diversity [18, 23, 43, 49].

The present study results clearly showed that only *O. testaceum* and *D. latissima* have strong correlations with all physico-chemical parameters in both lakes. This indicated that those species had high tolerance level to varying physical factors compared to the other species. During the study, *Gerris* sp. and *Limnoporus* sp. (Hemiptera) were only found in ML. This indicated that both species could not survive on low DO concentration in UL. Dalal and Gupta [50] supported this hypothesis, showing that presence *R. varipes* (also Hemipteran) was positively correlated with increasing of DO concentration.

5. Conclusion

The present study revealed that there were significantly differences between managed and unmanaged artificial lakes in terms of its abundance, composition and similarity of aquatic insects. Aquatic insect compositions in both artificial lakes were significantly different, while differences in flying insect abundance in terrestrial habitats were not significantly. The existence of bioindicator insects from the Gerridae family (*Limnoporus* sp.) in the managed lake affirmed that managed lakes provide good aquatic habitats reflecting good physico-chemical water parameters. Some species were positively correlated with physico-chemical factors while others were negatively correlated. *O. testaceum* and *D. latissima* were significantly correlated with all parameters.

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7. References

1. Subagyo H. Characteristic and management of swamp land: tidal swamp land (in Indonesian Language). Hall of the Research and Development of Agricultural Land Resources, Bogor (ID), 2006, 92-93.
2. Shuey JA. Habitat re-creation (ecological restoration) as a strategy for conserving insect communities in highly fragmented landscapes. Insects. 2013; 4:751-780.
3. Priawandiputra W, Barsulo CY, Permana AD, Nakamura K. Comparison of abundance and diversity of bees (Hymenoptera: Apoidea) collected by window traps among four types of forest on Noto Peninsula, Japan. Far Eastern Entomologist. 2015; 287:1-23.
4. Barsulo CY, Nakamura K. Abundance and diversity of flying beetles (Coleoptera) collected by window traps in satoyama pine forests in Noto Peninsula, Japan, with special reference to the management conditions: a family level analysis. Far Eastern Entomologist. 2011; 222:1-23.
5. Whiteson KK. A comparison of aquatic insect communities between man-made and natural ponds. Master's Theses and Graduate Research, San Jose State University, 2009.
6. Abhijna UG, Ratheesh R, Kumar AB. Distribution and diversity of aquatic insects of Vellayani Lake in Kerala. Journal of Environmental Biology. 2013; 34:605-611.
7. Barman B, Gupta S. Aquatic insects as bio-indicator of water quality- A study on Bakuamari stream, Chakras hila Wildlife Sanctuary, Assam, North East India. Journal of Entomology and Zoology Studies. 2015; 3(3):178-186.
8. Ciamporova-Zatovicova Z, Ciampor Jr F. Aquatic beetles of the alpine lakes: diversity ecology and small-scale population genetics. Knowledged and Management of Aquatic Ecosystem. 2011; 402(10):1-20.
9. Da Rocha JRM, Almeida JR, Lins GA, Durval A. Insects as indicators of environmental changing and pollution: A review of Appropriate Species and their monitoring. HOLOS Environment. 2010; 10(2):1-13.
10. Dijkstra KDB, Monaghan MT, Pauls SU. Freshwater biodiversity and aquatic insect diversification. The Annual Review of Entomology. 2014; 59:143-163.
11. Dreyer J, Townsend PA, Hook JC, Hoekman D, Zanden MJV, Gratton C. Quantifying aquatic insect deposition from lake to land. Ecology. 2015; 96(2):499-509.
12. Sardans J, Rivas-Ubach A, Penuelas J. The elemental

stoichiometry of aquatic and terrestrial ecosystems and its relationships with organismic lifestyle and ecosystem structure and function: a review and perspectives. Biogeochemistry. 2011; DOI 10.1007/s10533-011-9640-9.

13. Selvakumar C, Sivaramakrishnan KG, Janarthanan S, Arumugam M, Arunachalam M. Impact of riparian land-use patterns on Ephemeroptera community structure in river basins of the southern Western Ghats, India. Knowledged and Management of Aquatic Ecosystem. 2014; 412(11):1-15.
14. Majumder J, Das RK, Majumder P, Ghosh D, Agarwala BK. Aquatic insect fauna and diversity in Urban Fresh Water Lakes of Tripura. Northest India. Middle East Journal of Scientific Research. 2013; 13(1):25-32.
15. Wahizatul AA, Long SH, Ahmad A. Composition and distribution of aquatic insect communities in relation to water quality in two freshwater streams of Hulu Terengganu, Terengganu. Journal of Sustainability Science and Management. 2011; 6(1):148-155.
16. Devi MBDOS, Singh SD. Preliminary study of aquatic insect diversity and water quality of Loktak Lake. Manipur. International Journal of Integrative Sciences, Innovation and Technology. 2013; 2(3):33-37.
17. Fontanarrosa MS, Collantes MB, Bachmann AO. Aquatic Insect assemblages of artificial permanent ponds, Buenos Aires City, Argentina. Neotropical Entomology. 2013; 42(1):22-31.
18. Gupta S, Narzary R. Aquatic insect community of lake, Phulbari anua in Cachar, Assam. Journal of Environmental Biology. 2012; 34:591-597.
19. Hussain QA, Pandit AK. Macroinvertebrates in streams: A review of some ecological factors. International Journal of Fisheries and Aquaculture. 2012; 4(7):114-123.
20. Yapo ML, Atsé BC, Kouassi P. Diversity and community structure of benthic insects in fish farm ponds in Southern Côte d'Ivoire, West Africa. American Journal of Experimental Agriculture. 2015; 5(1):82-93.
21. Maramis RTD, Makal HVG. Species diversity and aquatic insect population abundance as biological indicator of water pollution in watershed of Langowan (in Indonesian Language). Eugenia. 2011; 17(2):95-101.
22. Harun S, Al-Shami SA, Dambul R, Mohamed M, Abdullah MH. Water quality and aquatic insects study at the Lower Kinabatangan River Catchment, Sabah: In response to weak La Niña event. Sains Malaysiana. 2015; 44(4):545-558.
23. Mohmad AH, Shafie MSI, Hui AWB, Harun S. The aquatic insect communities of Universiti Malaysia Sabah (UMS), Sabah, Malaysia. Journal of Tropical Resources and Suistanable Science. 2015; 3:1-5.
24. Namwong N, Santasup C, Phalaraksh C. Agricultural impacts on aquatic insect communities and water quality of irrigation in organic and conventional rice fields in Chiang Mai-Lamphun Basin. Proceedings: International Graduate Research Conference, Chiang Mai University, Thailand, 2013.
25. Prommi T, Payakka A. Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. Sains Malaysiana. 2015; 44(5):707-717.
26. Ansori I. Odonata nymphs (*Dragonflies*) diversity in several rice field around Bandung West Java (in Indonesian Language). Jurnal Exacta. 2008; 6(2):42-50.
27. Mirwan. Aquatic insects diversity in peatland of UIN SUSKA Riau areas (in Indonesian Language). Student thesis, Agrotechnology Study Program, Agricultural and Animal Sciences Faculty, Islamic State University of Sultan Syarif Kasim Riau, Pekanbaru (ID), 2013.
28. Leba GV, Koneri R, Papu A. Aquatic insect diversity in Pajowa River Minahasa District, North Sulawesi (in Indonesian Language). Jurnal MIPA UNSRAT Online, 2013; 2(2):73-78.
29. Farhani SA, Wardiatno Y, Krisanti M. Comparison of Chironomidae larvae abundance of two different lakes in Jambi Province (in Indonesian Language). Jurnal Ilmu Pertanian Indonesia. 2014; 19(3):183-188.
30. Aslamiyah S, Rizal S. Community structure and species composition of aquatic insects in Lebak Deling Swamp, Ogan Kemilir District, South Sumatera Province (in Indonesian Language). Sainmatika. 2014; 11(2):19-32.
31. Chu HF. The immature insects, WM.C. Brown Company Publishers, USA, 1949.
32. Clifford HF. Aquatic invertebrates of Alberta: An illustrated guide, University of Alberta, Canada, 1991.
33. Merritt RW, Cummins KW. An introduction to aquatic Insects of North America, Kendall/Hunt Publishing Company, United States of America, 1978.
34. Hammer O, Harper DAT, Ryan PD. PAST-PAlaeontological STatistics. ver. 2009, 1.89. http://folk.uio.no/ohammer/past. 19th June, 2016.
35. Martono DN. Spatial study of housing physico-environmental quality: Bekasi District case study (in Indonesian Language). Student's Disertation, Postgraduate School, Bogor Agricultural University, Bogor (ID), 2007.
36. [BAPPEDA] Local Development Planning Agency (in Indonesian Language). Bekasi District in Number, Bekasi District, West Java, Indonesia, 2005.
37. [BPS] Central Agency on Statistics (in Indonesian Language). Bekasi City in Number, Bekasi City, West Java, Indonesia, 2003.
38. Dalal A, Gupta S. A comparative study of the aquatic insect diversity of two ponds located in Cachar District, Assam, India. Turkish Journal of Zoology. 2016; 40:392-401
39. Rizal S, Deptalia. Structure and composition of aquatic insect in Lebak Jungkal Swamp, Ogan Komering Ilir District, South Sumatera Province (in Indonesian Language). Sainmatika. 2013; 10(2):10-18.
40. Asikin S. Insects and natural enemy insects associated with dominant wild plant in tidal swamp (in Indonesian Languange). National Seminar Proceedings of Inovasi Teknologi Pertanian Spesifik Lokasi, Banjarbaru, South Borneo, Indonesia, 2014, 385-394.
41. Ponraman G, Anbalagan S, Dinakaran S. Diversity of aquatic insects in irrigated rice fields of South India with reference to mosquitoes (Diptera: Culicidae). Journal of Entomology and Zoology Studies. 2016; 4(4):252-256.
42. Céréghino R, Biggs J, Oertli B, Declerck S. The ecology of European ponds: defining the characteristics of a neglected freshwater habitat. Hydrobiologia. 2008; 597:1-6.
43. Takhelmayum K, Gupta S. Aquatic insect diversity of a protected area, Keibul Lamjao National Park in Manipur, North East India. Journal of Asia-Pacific Entomology. 2015; 18:335-341.
44. Ravera O. Biological Aspects of Freshwater Pollution, Pergamon Press, London, 1978.
45. Thorp JH, Covich AP. Ecology and cclassification of

North American freshwater invertebrates, Elsevier Inc, Oxford UK, 2010, 603.

46. Beyene A, Legesse W. Pollution Status of River Borkena, Ethiopia. Sponsored Jimma University and Ethiopian Science and Technology Agency. Unpublished, 2005.
47. Barman A, Baruah BK. Macrophyte preference and aquatic entomofaunal diversity of Kapla Beel, A freshwater wetland of Barperta District of Assam, India. Asian Journal of Science and Technology. 2015; 6(3):1205-1210.
48. [KLH] Kementerian Lingkungan Hidup (Ministry of Environment), Water pollution control (in Indonesian Language), Jakarta (ID), 2004.
49. Ngodhe SO, Raburu PO, Achieng A. The impact of water quality on species diversity and richness of macro invertebrates in small water bodies in Lake Victoria Basin, Kenya. Journal of Ecology and the Natural Environment. 2014; 6(1):32-41.
50. Dalal A, Gupta S. Aquatic insect diversity in two temple ponds of Silchar, Assam, N.E. India and their conservation values. Knowledged and Management of Aquatic Ecosystem. 2014; 415(9):1-14.