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Assessment of Water Quality of Kware Lake Using Aquatic Insects as Bioindicators

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Abstract:
Water quality of Kware Lake was assessed through the abundance of aquatic insects as indicators from April to September, 2016. Samples of aquatic insects were obtained from the lake with a dip-netby dipping on monthly basis at four designated sampling stations. The insect samples collected were sorted in the laboratory and identified to order and family levels using aquatic insects' taxonomic keys. The results generated ware used to calculate insect abundance and biotic index for water quality. Standard methods of analyses were used for analyzing the physicochemical status of the water samples collected from the Lake. Pearson's Correlation was employed to relate between the abundance of insects and physicochemical parameters of water from the Lake. A total of 878 insects representing 26 families from 5 orders were observed. The bioticindex calculated for the families of Coleoptera, Diptera, Ephemeroptera, Hemiptera and Odonata were 1.11, 1.20, 1.50, 1.11 and 1.14 respectively indicating excellent water quality. Analyses of physicochemical parameters showed variable ranges and some differ in concentrations among periods of sampling but the pH, turbidity, NO_3, and PO_4were found to have significant correlation (P> 0.05) with the abundance of the insects. Measures of controlling negative human activities around the lake need to be enforced.

Keywords: *Aquatic insects. bioindicators, kware lake, water quality*

1. Introduction

Kware Lake is an important source of fresh water to its neighboring communities; it is very popular for dry farming, fishing, and recreational activities. Available studies made on the Lake centered mainly on productivity, yield and management of fish and to a lesser extent water quality. A more related study of aquatic insects for the Lake shows that dragon fly (*Cordylegaster boltonii*) had the highest abundance while the water beetle (*Haliplus solitarus*) had the lowest among all the species identified (Yahaya *et al*., 2009) Presumably, the Lake has been under environmental stress resulting from human's detrimental activities. Detrimental changes to surface water quality of a lake can impact other bodies of water, a sensitive issue of environmental concern. Aquatic insects, an important component of aquatic ecosystems are very abundant and diverse group that inhabits a variety of aquatic environments (Barman and Gupta, 2015). They play an important role in ecosystem functioning and are used as bioindicators. Among the known species of insects, only 3% are aquatic or semi-aquatic, which these counts (42000 species) live in aquatic ecosystem in high populations (Merritt and Cummins, 1996). The concept of biological indicators using aquatic insects is based on their diversity, abundance and distribution in relation to the physical and chemical conditions of the habitats (Hanna and Shekha, 2015).

An indicator species is those taxa group (Ephemeroptera, Plecoptera, and Trichoptera) known to be particularly sensitive to environmental factors so that their presence or absence may be directly reflected on environmental change. Data provided by indicator organisms can be used to estimate the degree of environmental impact and its potential dangers for other living organisms (Wahizatul *et al*., 2011).Biological methods could be a tool of choice for complementing physical and chemical measurements in assessing water body conditions especially in developing countries like Nigeria. Moreover, the effects on biota are usually the final point of environmental degradation and pollution of a water body and thus are an important indication of ecosystem health (Barbosa *et al*., 2001) In this regard; Hilsenhoff (1988) study is an indispensable piece of reference in determining the biotic index (BI) and water quality. The resistance of various insects to different pollutants are determined and ranked between 0-10 in which, 0 represents the intolerance or hypersensitiveness to low concentration of dissolved oxygen in the water and 10 representing high tolerance of the organisms in high water pollution. The objective of the present study is to apply the concept of biotic index for assessing water quality status of Kware Lake.

2. Materials and Methods

2.1. Study Site

The study site represents a naturally occurring fresh water Lake at kware (Figure 1), some 25 Kilometers north of Sokoto township, Nigeria. It is located on latitude 13^{o} 13'5 "North and longitude 5^{o} 16'2 East. The lake has a surface area of 200 hectares and about 12 Km in length covering area of land that stretches from Kware to Kainuwa in Sokoto State. Kware Lake is fed by River Shella and its tributaries in the vicinity of Gwadabawa area (Kwafo and lpinjolu, 1995).

2.2. Sampling Stations

Four locations were selected from the Lake for sample collection and were designated as stations A (Gidan Tudu), B (Bye Pass Road), C (Yadi) and D (Gidan Kifi). The selected locations comprised both upstream and downstream points as significant pollution outfalls,

2.3. Insect Sample Collection

Aquatic insects were collected on monthly basis at each sampling station between 9:00am- 12:00 noon, for six (6) months. An aquatic dip-net with dimensions of 40 × 40cm frame, 60cm long handle of 25mm mesh size was used. The procedure was by gently dragging the dip- net beneath the water surface at the bottom for one minute and between aquatic vegetation for another minute. In this way, both aquatic insects and other macro fauna were sampled. Organisms observed were removed from the dip-net and placed into labeled buckets provided; those attached to the fabric were picked out with forceps. Rocks and wood logs found within samples were gently lifted and held over a white bucket to brush up any crawling or loosely attached insects, so that they drip into the bucket. Samples obtained were transferred into separate killing jars saturated with 70% formalin for fixing. All the samples obtained, were labeled according to location and date immediately before conveyed to the laboratory.

2.4. Preservation and Identification of Insect Samples

In the laboratory, the samples were washed and screened separately through a sieve with mesh size of 2.0 mm to eliminate the excess sediments while detritus were hand-picked up the collections. The larger specimens were sorted with naked eyes while those of the smaller ones were sorted using a dissecting microscope. Sorted specimens were preserved separately in labeled bottles containing 96% ethanol and subsequently identified to order and family levels using standard aquatic insect taxonomic keys (Michael, 1977; Parker, 2012).

2.5. Physicochemical Measurements of Water Samples

Water samples were collected from each of the designated sampling stations immediately before collection of the insects. Three replicate samples were obtained and analyzed for physicochemical water quality variables such as pH, temperature, turbidity, nitrate (NO_3^-), phosphate (PO_4^-), dissolve oxygen (DO), biological oxygen demand (BOD) and conductivity using standard methods(APHA, 1999; Onwughara *et al*., 2013).

2.6. Data Analysis

The data obtained was analyzed and presented as insect abundance in per cent while biotic index formula presented by Hilsenhoff (1988) was used to determine the rate of the water pollution; $BI=\sum \frac{niai}{N}$.(*ni* = number of specimens per taxonomic group, *ai* = pollution tolerance score and N = number of insects in sample).Results of the physicochemical analyses was presented as means ± SE. Pearson's Correlation was used to compare the abundance of the aquatic insects in relation to variations of physicochemical parameters of the Lake.

3. Results and Discussion

A total of 878 individuals of aquatic insects representing 26 families from 5 orders were successfully collected and identified from Kware Lake between April to September, 2016. The result in Table 1 shows that, among the insect families of Kware Lake, Chironomidae was the most dominant family with members accounting for 25.63% abundance followed by the family Corixidae whose members recorded 15.03% abundance while the rest of the members of other families recorded lesser per cent of abundance. Observation made in the present study is similar to the report of Wahizatul *et al*. (2011) who observed Chironomidae members as the most dominant while Vallidae and Muscidae were less dominant among aquatic insects' communities of Terengganu Malaysia. This dominant group is known to be popular with a variety of feeding habits and wide habitat selection, features that could contribute to their abundance. According to Yule (2004), Chironomidae is probably the most diverse and abundance group of all steams macro invertebrates. However, the observation in this study contradicts the lesser abundance of Chironomidae observed by Bashti and Ostovan (2014) in the streams of Shiraz region, Iran. Collectively however, the families of the order Hemiptera ware more in abundance (31.66%) followed by those of Diptera (29.49%) while those of Ephemeroptera (0.91%) were the least abundant in Kware Lake (Table 2). Bashti and Ostovan (2014) also recorded dominance of members of the order Hemiptera in streams while Hamideh *et al*. (2013) found the same for both Diptera and Coleoptera in river. A study in the lower reach of Moirang River in Manipur N.E India also showed higher Hemiptera diversity and density (Takhelmayun *et al*., 2013). Similarly, in Du river basin in northern Vietnam, Hemiptera was found to be the most diverse order (Huang *et al*., 2010). The Hemipteran group contained pond skaters that can walk on the surface of water and can utilize atmospheric variables without totally depending on water (Barman and Gupta, 2015). This dual advantage might have helped those members for dominance over others.

As shown in Table 3, the FBI values calculated for the families of Coleoptera, Diptera Ephemeroptera, Hemiptera and Odonata (1.11, 1.20, 1.50,1.11 and 1.14 respectively) indicated that the water quality of Kware Lake was excellent. Normally, water quality index values less than 4.6 indicate clean condition, values greater than 6.7 indicate severe pollution and intermediate values indicate moderate pollution. The BMWP score values for individual families reflect their pollution tolerance based on the knowledge of distribution and abundance. Pollution intolerant families have high BMWP scores while pollution tolerant families have low scores (Sivaramakrishnan, 1992). In the current study,the result of BMWP indicated a good water quality for Kware Lake (Table 3). The Average Score Per Taxon (ASPT) represents the average tolerant score of all taxa within the community. A high ASPT usually characterizes clean site with relatively large number of high scoring taxa. Approximately, 6 ASPT value meant that the system supports some high scoring taxa. that is, good quality of system (Barman and Gupta, 2015). Values calculated in this respect for the insect families recorded in this study, indicated fairly clean water condition for Kware Lake (Table 3). The EPT index indicated abundance and distribution of sensitive aquatic insect orders which reflect the relative cleanliness of the water. According to Margalef's water quality index, values greater than 3 will indicate clean water conditions (Lenat *et al*., 1980). In Kware Lake the Margalef's water quality index value was less than 2.0, indicating that the water quality was rather unclean, which is of serious concerned since the other parameters indicated the opposite. More so, is the fact that these sensitive taxa or pollution intolerant group are the best bioindicators of agricultural impact. They also indicate pristine forest condition with intact riparian vegetation and a high percentage of marginal vegetation (Selvakumar *et al*., 2014). In a similar study, Mona *et al*. (2015) characterized impacted site of Egyptians streams by the presence of banks with little or no vegetation in the margin, presence of household waste, huge amount of refuge, domestic animal dung and dead animal left rotten in stream among others.

Members of EPT are considered to be sensitive to environmental stress, thus their presence in high abundance signified a relative clean environment (Armitage *et al*., 1983). Therefore, the relative absence of these sensitive groups in Kware Lake could be attributed partly to several man-induced activities, like sedimentation, sewage / nutrient runoff and agricultural pesticides. Wahizatul *et al*. (2006) found clear association between the reductions in species diversity of aquatic insects' communities and human activities such as recreational and agricultural activities in Sekayu stream. Moreover, the absence of Plecoptera and dominance of Chironomidae in Kware Lake suggested that the water body was disturbed. Chironomidae were indicative of poor water quality from various anthropogenic activities (Yakub, 2004) and dominated in heavy organic polluted water bodies (Ali *et al*., 2003). Its abundance was related to the amount of detritus, which in turn was negatively correlated with flow velocity (Doisy and Rabeni, 2001). The occurrence of the members of Ephemeroptera as the only sensitive group present in Kware Lake was confusing, but it was possible that members of Plecoptera and Tricoptera occupied a suitable clean niche within the Lake but missed in samples. Emere and Nasiru (2009)earlier reported low numbers of Plecoptera and suggested that they occupied niche in Perennial Northern Nigerian Streams where the oxygen concentration was higher than values recorded for the stream.

The result of physicochemical measurements of water from Kware Lake shows variable ranges between the months with pH range of 6.99±0.09 to 8.21±0.21, temperature 26.25±0.5 to 29.00±0.82 ^{o}C, turbidity 4.00±0.84 to 13.15±0.87 NTU, NO_3 1.53±0.17 to 6.43±0.21mg/L, PO_4 0.33±0.05 to 3.30±0.08mg/L, DO 3.275±0.17 to 4.375±0.21mg/L, BOD 1.33±0.13 to 2.95±0.17mg/L and conductivity 575.00±4.08 to 678.75±9.46 µs/cm (Table 4). The water variables like pH, turbidity, nitrate, phosphate and conductivity were found to have significant positive correlation (P> 0.05) with the abundance of the aquatic insects (Table 5).The range of pH observed presently was higher than pH of 6.22 reported by Barman and Gupta (2015) in Bakuamari stream India but close to pH range of 6.0-7.0 in Awba reservoir, Nigeria observed by Popoola and Otalekor (2011). The range of pH between 6.5 and 8.5 is normally accepted as per WHO (2011) standard. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters (Barman and Gupta, 2015). However, pHaffects the dissolve oxygen level of the water, photosynthesis of aquatic organisms (phytoplankton) and the sensitivity of these organisms to pollution, parasites and diseases (Ngodhe *et al*., 2014). A change in pH also affects aquatic life indirectly by altering other aspects of water chemistry (Prommi and Payakka, 2015). The USEPA (1986) indicated that a pH range of 6.5 to 9.0 provides adequate protection for the life of fresh water fish and bottom dwelling macro invertebrates. Scheibler *et al*. (2014) reported that tax richness density of invertebrates and diversity increased along river continuum with increases in pH, hardness and nutrients. Variations in water temperature were also reported by Barman and Gupta (2015) and Prommi and Payakka (2015). Water flow, temperature and substrates are the major factors determining the composition and abundance of benthic invertebrates (Ward and Stanford, 1979). Similarly, temperature impacts both the chemical and biological characteristics of surface water (Prommi and Payakka 2015). Typical example is the absence of the members of the order Plecoptera. The Plecoptera order is typical of cooler latitude (Sivec and Yelu, 2004). Turbidity in drinking water may be due to the presence of inorganic particulate matter in some ground waters or sloughing of biofilms within the distribution system (WHO, 2003). Particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth. In the current study, the turbid condition of the Lake was acceptable as per WHO (2003) standard only from April to June when turbidity was less than 5NTU. It is also the maximum allowable limit in Nigeria (NIS, 2007).

Nitrogen and phosphorus are the basic nutrients which influence productivity of aquatic ecosystems (Barman and Gupta, 2015). The range of both NO_3^- and PO_4^- in the present study were below WHO (2011) and Nigerian Industrial Standards (NIS, 2007) of water quality. This might imply that the input of some pollutants in the Lake is rather minimal. Moreover, the natural levels of nitrate are usually less than 1 mg/L and concentrations over 10 mg/L will have an effect on the freshwater aquatic environment (Sharon, 1997). But, the *Hydroptila* sp. (Trichoptera), *Bagous affinis*, *Dineutus* sp. (Coleoptera), *Notapictinus aurivilla* (Hemiptera) ware found associated with high nitrate content (Barman and Gupta, 2015). The concentration of dissolve oxygen (DO) is one of the most important parameter to indicate water purity and to determine the distribution of various aquatic insect groups (Wahizatul *et al*., 2011). Presently however, DO content was lower than the range of 5-13 mg/L for natural stream water. Stoyanova *et al*. (2014) found that gill-breathing aquatic insects (e.g. caddisflies, mayflies and stoneflies) are affected by conditions that reduce the dissolve oxygen of the water, like pollution.

Another important parameter of water quality is the BOD which was observed in normal range throughout the period of the study. The accepted ranges are within 1-2 and 3-5mg/L (USEPA, 1986). However, change in BOD could affect the aquatic life diversity. Higher diversity of species in El-Kassed and Rasheed streams correspond with lower BOD, while lower diversity in the fish aquaculture was correlated to the higher BOD (Mona *et al*., 2015). Electrical Conductivity (EC) is an index to represent the concentration of soluble salts (inorganic ions such as sodium, chloride, magnesium and calcium) in water. It can serve as an indicator of other water quality problems (Prommi and Payakka, 2015). Waters with high total dissolve solids are unpalatable and potentially unhealthy (Prommi and Payakka, 2015). In the present study, acceptable value of conductivity (1000µS/cm) was observed. However, EC was found to have positive significant correlations with species richness and density of insects (Barman and Gupta, 2015). Presently, the pH, turbidity, nitrate, phosphate and conductivity had significant positive correlation with the abundance of the aquatic insects while temperature, DO and BOD had not (Table 5). Therefore, the water physico-chemical parameters, together with the presence/absence of aquatic insects indicated a function of a combination of natural and anthropogenic influences (Wahizatul *et al*., 2011).

4. Conclusion

The present study established that, among the insects collected from Kware Lake, members of the family Chironomidae (Diptera) were the most abundant while those of Ephemeroptera were the less abundant members. The family biotic indices calculated for the insect groups of the Lake categorized the water quality from excellent to fairly good. These also remain true for other parameters of water quality like BMWP and ASPT. Similarly, the EPT: C ratio indicated an impacted water condition. The water variables like pH, turbidity, nitrate, phosphate and conductivity were found to have significant positive correlation (P> 0.05) with the abundance of the aquatic insects

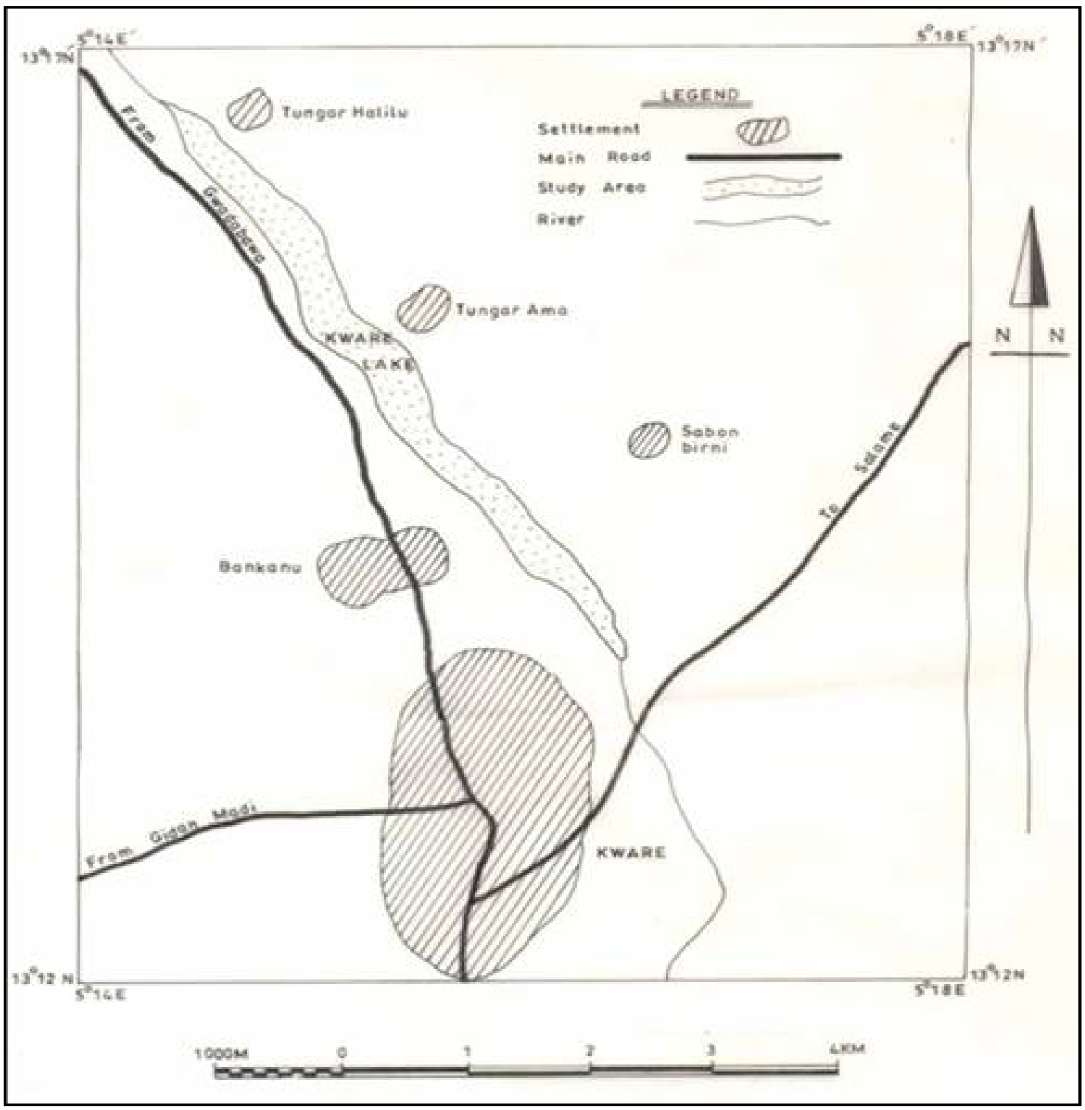

Figure 1: Map of the study (Kware Lake) Drawn from Sokoto Topo 10

Order	Family	A	B	C	D	Abundance (%)
Hemiptera	Belostomatidae	0	11	9	2	2.51
	Corixidae	14	12	97	9	15.03
	Gerridae	0	8	4	1	1.48
	Naucoridae	4	36	30	7	8.77
	Nepidae	2	0	9	1	1.37
	Notonectidae	5	11	2	3	2.39
	Vellidae	0	0	0	1	0.11
Coleoptera	Curculionidae	0	2	0	0	0.23
	Dytiscidae	2	21	51	15	10.14
	Elmidae	0	0	0	1	0.11
	Gyrrinidae	0	0	2	0	0.23
	Hydrophilidae	3	12	40	27	9.34
Ephemeroptera	Baestidae	0	3	0	5	0.91
Diptera	Ceratopogonidae	3	0	0	0	0.34
	Muscidae	0	0	1	0	0.11
	Stratiomyidae	0	0	1	0	0.11
	Syrphidae	0	0	0	1	0.11
	Chironomidae	127	23	5	70	25.63
	Culicidae	6	6	0	10	2.51
	Tipulidae	3	0	1	0	0.46
	Psychodidae	0	0	1	1	0.23
Odonata	Libellulidae	0	0	1	1	0.23
	Lestidae	2	14	6	1	2.66
	Cordulidae	5	5	58	36	11.85
	Coenagrionidae	0	7	16	0	2.62
	Aeshnidae	0	3	0	2	0.57

Table 1: Composition and abundance of aquatic insects sampled at Kware Lake in four sampling stations
Sampling stations

		Biotic indices			
Order	Family	Ni	ai	bi	Abundance (%)
Coleoptera	Curculionidae	2	5	0.06	
	Dytiscidae	89	5	2.53	
	Elmidae	1	4	0.02	
	Gyrinidae	2	4	0.05	
	Hydrophilidae	82	5	2.33	
					20.04%
Diptera	Ceratopogonidae	3	6	0.06	
	Muscidae	1	6	0.02	
	Stratiomyidae	1	7	0.03	
	Syrphidae	1	10	0.04	
	Chironomidae	225	8	6.94	
	Culicidae	22	8	0.68	
	Tipulidae	4	3	0.04	
	Psychodidae	2	8	0.06	
					29.49%
Ephemeroptera	Baetidae	8	5	5	
					0.91%
Hemiptera	Belostomatidae	22	6	0.47	
	Corixidae	132	5	2.37	
	Gerridae	13	5	0.23	
	Naucoridae	77	6	2.79	
	Nepidae	12	6	0.26	
	Notonectidae	21	6	0.45	
	Vellidae	1	4	0.01	
					31.66%
Odonata	Libellulidae	2	2	0.03	
	Lestidae	23	6	0.88	
	Cordulidae	104	5	3.31	
	Coenagrionidae	23	8	1.17	
	Aeshnidae	5	3	0.09	
					17.89%

Table 2: Species biotic indices and abundance of aquatic insects in kware Lake

Insect taxon	FBI	Class	BMWP	Class	ASPT	Class	EPT:C
Coleoptera	1.11	Excellent	110	Good	6.4	Fairly clean	-
Diptera	1.20	Excellent	131	Good	7.3	Fairly clean	-
Ephemeroptera	1.50	Excellent	134	Good	6.8	Fairly clean	1:28
Hemiptera	1.11	Excellent	122	Good	6.6	Fairly clean	-
Odonata	1.14	Excellent	128	Good	6.3	Fairly clean	-

Table 3: Status of water quality of Kware Lake based on biological indices

FBI -Family Biotic Index, ASPT – Average Score Per Taxon, BMWP – Biological Monitoring Work Party,EPT:C – Ephemeroptera, Plecopteraand Triconptera: Chironomidae

Months	Physicochemical parameters							
	pH	Temp (^{0}C)	Turbidity (NTU)	NO_3 (mg/L)	PO_4 (mg/L)	D.O (mg/L)	BOD (mg/L)	Conductivity
April	7.05±0.23	27.00±0.82	4.15±0.74	2.63±3.58	0.33±0.05	3.275±0.17	1.33±0.13	575.00±4.08
May	6.99±0.09	27.00±0.82	4.00±0.84	1.53±0.17	0.45±0.13	3.400±0.27	1.50±0.08	582.25±2.06
June	7.73±0.26	26.25±0.5	4.48±0.97	1.83±0.1	0.80±0.08	3.950±0.17	2.55±0.1	615.00±5.77
July	7.80±0.16	29.00±0.82	11.00±0.82	2.48±0.13	1.20±0.14	4.100±0.14	2.73±0.1	663.75±2.5
August	8.05±0.13	27.25±0.5	13.00±0.82	6.23±0.17	3.13±0.15	4.225±0.19	2.83±0.28	677.50±5
September	8.21±0.21	27.75±0.5	13.15±0.87	6.43±0.21	3.30±0.08	4.375±0.21	2.95±0.17	678.75±9.46

Table 4: Mean ± SD of water physicochemical parameters in Kware Lake from April to September, 2016

Parameters	r=0.01/0.05
pH	0.502*
Temperature (^{0}C)	0.176
Turbidity (NTU)	0.526**
NO_3 (mg/L)	0.583**
PO_4 (mg/L)	0.606**
Dissolved Oxygen (mg/L)	0.34
Biochemical Oxygen Demand	0.369
Conductivity (µs/cm)	0.444*

Table 5: Pearson's correlation coefficient (r) between selected physico-chemical parameters and aquatic insect's abundance

***Correlation is significant at the 0.01 level*

** Correlation is significant at the 0.05 level*

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