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Effect of riparian land-use and water chemistry on zooplankton distribution

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ABSTRACT

The effect of the riparian land use on zooplankton distribution of Kwadon stream was studied over a period of six months. A total of 61,581 zooplankton species were found belonging to the different taxa of Coleoptera, Trichoptera, Ephemeroptera and Pieces. Baikaloperia sp. was ranked as the most abundant species in the four identified taxa. Three sampling stations were chosen for this study, and site A yields the highest species diversity of 31,197 than sites B (23,768) and C (9,594). The physicochemical parameters determined are temperature; turbidity, pH, dissolve oxygen, nitrate, phosphorus, conductivity and alkalinity. The variation of these parameters was found to affect the zooplankton distribution. Kwadon stream constitutes an important water body that provides sources of water for domestic and irrigational usage to the local community; as such the significance of this study is regarding the investigation of most tolerant zooplankton species which can contribute to the effort in finding an efficient zooplankton species for indicating the pollution level of a particular water body.

1. Introduction

Zooplankton are described as a community of plankton that lives in water such as ocean, lakes, streams and rivers. Examples of these organisms include protozoan, metazoan, chordate, and cnidarians. These organisms are known to function as a biomarker of environmental pollution due to their ability to respond to natural and artificial environmental changes. The understanding of how does these microorganisms respond to various environmental structuring can be obtained by studying their interaction with the environment they lived [1, 2].

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Freshwater ecosystems have been under frequent restructuring across the globe. This is due to the continuous increase in the human disturbance. Biomonitoring has emerged as an important tool used to study the effect of the above mention problem. The significance of biomonitoring is to survey and control a particular water body for optimal aquatic life [3]. This application is of enormous important in ensuring long-term conservation of aquatic organisms. Biological monitoring implies the usage of aquatic organisms to detect the pollution level of a particular water body. This is done by measuring the physicochemical parameters of the water and compares it with the diversity of zooplankton species. The hypothesis of biomonitoring stated that certain microorganism cannot survive if the pollution level of the water is high, they either migrate or loose viability because their features do not give them a competitive advantage to thrive in that environment and are thus referred to as indicators of good water quality. Examples of these organisms are members of the genus *Ephemeroptera*, *Plecoptera,* and *Trichoptera*. Whereas the organisms that can survive in a polluted water body are referred to as indicators of poor water quality [4].

Zooplankton are cosmopolitan in nature, occurring in a variety of water bodies comprising of lakes, streams, ocean, rivers, and estuaries. The drifting nature of these organisms can either be slow or fast bottom dwellers and sometimes they are found attached to the rocks, logs, vegetation and floating trash [6]. Various water bodies such as streams, lakes, and rivers have many channels of inflow of water mainly from surface and ground flows. This process has resulted in the enrichment of water body with nutrients such as total ions, nitrogen, and phosphorus. The availability of these nutrients at that zone supports high primary productivity by phytoplankton which causes the migration of zooplankton [7]. Zooplankton basically does not produce their food by themselves; rather they depend on phytoplankton species. Phytoplankton species form the primary link of the food chain. They are mostly small fishes and microalgae. Because zooplankton are filter feeders, they have the ability to filter out millions microalgae species in a number of days. Zooplankton are also important sources of food for planktivorous fishes and other organisms [8]. Saidu *et al*. [4] suggested that their presence or absence is an important strategy of knowing the commercial success of the fish production; so if the lower part of the food chain is healthy, it will be much easier to control the upper organisms by simply monitoring the physicochemical changes of the water body as well as the biological properties. Examples of such benthic planktons include crustaceans, mollusks, worms and other species of insect larvae such as Mayflies, Stoneflies, Caddisflies, and Beetles. The abundance of macroinvertebrate belonging to the order *Ephemeroptera, Plecoptera*, and *Trichoptera* are also confirmed to be highly sensitive to pollution making them an important agent for detecting pollution loads of an environment. Thus the healthy status of the water body depends on the presence or absence of such indicator species [9].

Land uses in the riverine areas affect the physicochemical parameters of the water body. For instance, water retention at riverine area showed contamination by pesticide, heavy metal and aromatic compounds. Such water can also exhibit an increase in the amount of nitrate and phosphate thereby causing eutrophication of the water body. Dodson *et al*. [5] showed that the physical chemistry of water body has a strong correlation with zooplankton distribution and composition. This means that zooplankton species can be employed as an absolute system for studying the effect of the human land use on community structure.

Kwandon stream is a stream that has been known to provide services to the local community around Kwadon area. The increase in human population growth coupled together with the activities taking place around that stream has led to habitat destruction, leaving many species isolated on fragments of land and water. This has severely affected the macro-fauna thriving around that region. For the purpose of conserving the microbial community, it is thus crucial to determine the abundance of these indigenous species with the potential factors affecting their distribution and composition.

This study was aimed at providing a comprehensive understand of how human activities affect the survival of indigenous microorganism, and that will help in long-term species conservation.

2. Materials and methods

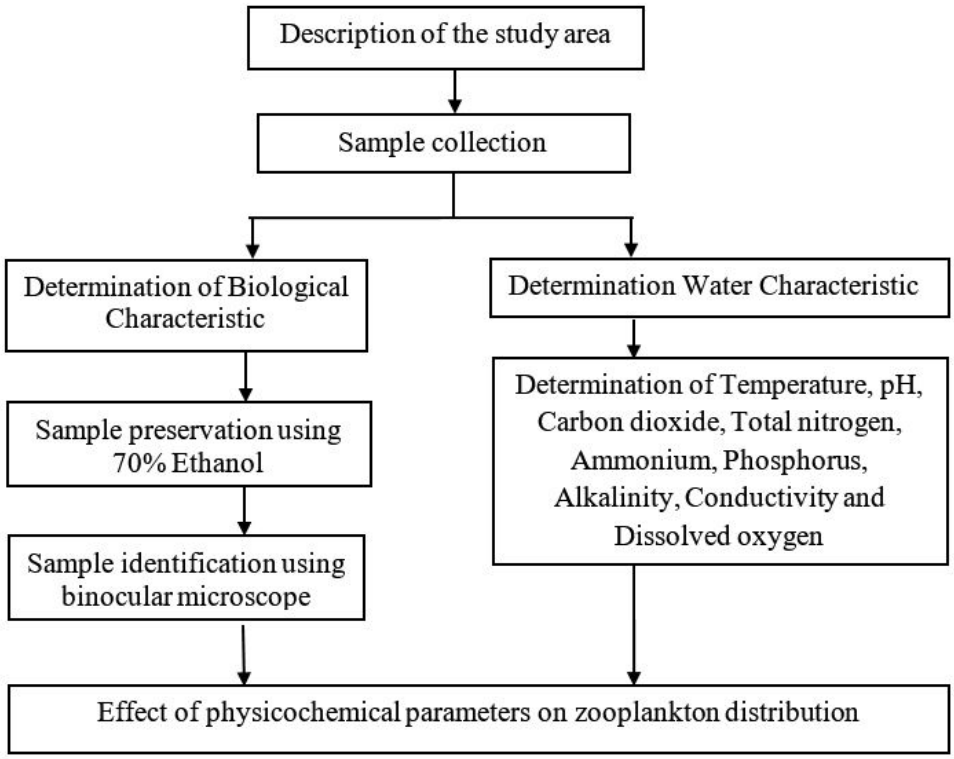

Fig. 1. Methodology flowchart

2.1. Methodology

2.1.1. Study area

Kwadon stream is located in Yamaltu Deba Local Government Area of Gombe State. The area lies between latitude 10° 16' 15'N to 10°17' 7''N and longitude 11°16' 44''E to 11° 18' 28''E. The various human activities carried out at the sites include farming, washing, bathing, and fishing. Three sampling sites were selected and marked A, B and C. Site A is located at the upstream, where fishing activities are carried out. Site B is located at the mid-stream where washing and bathing activities take place. Site C is located at downstream where irrigation was the dominant activities taking place.

2.1.2. Sample collection and preservation

Three sampling stations were designated for this study. These are Sites A, B and C. Samples of water and zooplanktons were taken at each site over a period of six (6) months from 6 am local time. The water sample was collected in a plastic bottle at about 10 cm below the water surface of the stream and preserved at 4°C under a dark condition with 1:1000 of lugols iodine to facilitate sedimentation. The sampling bottles were initially rinsed with water before being filled with the samples. The bottle was covered immediately to avoid air bubbles. For larger zooplanktons, the sample was collected using net in order to prevent biases in sample collection as some larger zooplankton can easily escape from the path of the bottle sampler. Preservation was made using 70%

ethanol and formalin before being transported to the laboratory for processing. Counting and identification were done using counting chamber and microscope as described by the standard method of APHA [10]. For samples that will be stored for a long period of time, 5% glycerine was added to prevent evaporation. The larger zooplanktons were examined under a compound binocular microscope and counted in a large counting chambers. The numbers of large zooplanktons were expressed as number per cubic meter according to the formula below [10].

$$\text{Number (cm3)} = \frac{C * Va}{Vb * Vc}$$

where,
C = Number of organisms counted
V_a = Number of the concentrated samples in mL
V_b = Volume of samples counted mL
V_c = Volume of the net samples filtered

2.1.3. Determination of temperature

The temperature (°C) readings were taken directly at the sampling sites using mercury bulb thermometer (glaswekwerTein model). The bulb was placed in the water at about 5cm deep, allowed to stay for about two minutes and the readings were taken in triplicate at each site.

2.1.4. Determination of pH

The (pH) of the water body was determined at the sites using a pH meter (model: Hanna instruments model No H18915ATC) as described by [4]. The electrode of the meter was first standardized using buffer solutions, which have the same temperature as that of the water. After calibration, the electrode in the buffer solutions was washed in distilled water before placing deep into water sample for about 2 minutes for equilibration. The electrode was always standardized with a buffer solution before the measurement was taken.

2.1.5. Determination of free carbon dioxide

Free carbon dioxide was determined according to the method described by Sexana [11]. 50 mL of water was placed in the flask and two drops of phenolphthalein indicator were added. It was then titrated against sodium hydroxide solution (reagent) until pink color appeared (end point). The total amount of free oxygen determined was computed according to the following formula;

$$\text{Free CO2 (mg/L)} = \frac{Vt * 100}{Vs}$$

where,
V_T = volume of titrant (mL), V_s = volume of the sample (mL)

2.1.6. Determination of total Nitrogen and Ammonium

The total nitrogen content of the water was determined according to the method described by AOAC [12]. The samples were filtered through pre-rinsed what-man GF/C filter paper. 25 mL of the sample was measured in 150 mL conical flask containing 1mL concentrated H_2SO_4 and a dozen of anti-bumping granules. The measurement was done by standard preparation. The samples were boiled on a hot plate until white fumes of sulfur trioxide appeared, then the flask was removed from the hot plate. 1 g of potassium tri-sulphate was added to the flask. The mixture was strongly heated to a fuming temperature for exactly 10 minutes. Sufficient time was allowed for cooling and 15 mL of distilled water was added and transferred to a 50 mL volumetric flask. The mixture was gently heated to dissolves the remaining suspended particles. The conical flask was rinsed three times with distilled water to ensure a complete transfer of the sample. One drop of methyl red solution and 10 M sodium hydroxide was added until the solution turns clear. The final solution was then titrated by the addition of $4MH_2SO_4$ in dropwise until the solution turns red. The sample was made up to 50 mL with distilled water. 1.0 mL of phenol nitroprusside and 1.5 mL of alkaline hypochlorite was added to the sample and blank. After 24 hours' time, the reading was taken at absorbance 635nm. A calibration curve was prepared using the standard of different nitrogen concentrations.

The total ammonium was determined using the phenol-hypochlorite method as described by Philip [13]. Samples were collected and immediately filtered through pre-rinsed Whatman GF/C filter paper. 1.0 mL of phenol nitroprusside reagent was added to 25 mL of sample. It was then mixed after the addition of about 1.5 mL of alkaline hypochlorite reagent. The flask was immediately covered and the mixture was left to stand in the dark for 1 hour at room temperature. The standard of ammonium stock solution was serially diluted with the same procedure used for the samples and reagents and calibration curves were prepared using standard ammonium concentrations.

2.1.7. Determination of total phosphorus

The total phosphorus was determined as described by AOAC [12]. 5 mL of the sample were measured into a test tube. 1 mL ammonium molybdate solution was added and allowed to stand for 20 seconds. 1 mL of hydroquinone solution was added; the flask was rotated to mix. 1 mL of Na_2SO_3 and 2 mL of distilled H_2O was added to the mixture. The test tube was stopped by the thumb and was shaken to mix thoroughly. The mixture was then allowed to stand for 30 minutes and the measurement was taken using spectrophotometer (model spectronic 20:722-2000) set at 650nm, alongside blank. A calibration curve was prepared using standard phosphorus concentration.

2.1.8. Determination of total alkalinity

Total alkalinity was of the water sample was determined as described by Stirling [14]. Water sample of 50 mL was measured and transferred into a conical flask, followed by the addition of 3 drops of methyl orange indicator. The sample was titrated with standard 0.01M H_2SO_4/ HCL with shaking until the color changes from blue to pale pink. The total alkalinity was calculated from according to the equation below;

$$\text{Alkalinity (mg/L)} = \frac{\text{n} * \text{V2} * 1000}{V1}$$

where,

n = normality of standard H_2SO_4, v_1 = volume of the samples, v_2 = volume of acids used.

2.1.9. Determination of conductivity

The conductivity of the water body was determined at the side using conductivity meter (Model: PHYTE 65667.00). The unit of measurement was expressed in µs/cm. All measurements were made at a temperature other than 25°C. Conductivity of the water was determined using relation;

$$\text{Conductivity (K)} = \frac{\text{C} * 1}{R}$$

where,
C = cell constant, R = Resistance.

2.1.10. Determination of dissolved oxygen

Dissolve oxygen of the water sample was determined as described by AOAC [12]. Glass stoppered of 100 mL was used for sample collection. The sample was fixed with 1 mL of each manganese sulfate and alkaline reagents (potassium iodide plus potassium hydroxide). The stopper was replaced and the bottle was shaken thoroughly. 2 mL of H_2SO_4 was added and shaken thoroughly to dissolve the precipitate. 50 mL of the mixture was transferred gently into a conical flask and about 4 drops of the starch indicator were added. Titration was done against sodium thiosulphate solution and the end point was noted when the initial blue color turns to colorless.
Calculation:

50 mL of contents was used for titration

$$\text{DO (mg/L)} = \frac{V1 * N * 8 * 1000}{V4(V2 - V3)/V2}$$

where,
DO= dissolved oxygen
V_1= volume of titrant (mL)
N= normality of titrant (0.025)
V_2= volume of sampling bottles after placing stoppers (mL)
V_3= volume of $MnSO_4$+(KI+KOH) added (mL)
V_4= volume of the contents used for titration (50 mL)

2.1.11. Data analysis

All data obtained from this study was analyzed using Microsoft excel and SAS (Statistical Analysis System) version 15.0. Residuals of the data were tested for normality and equality of variance to fulfill the assumptions for the parametric test. Shannon-Weiner Diversity index H' was used to determine the diversity of zooplanktons species found at the sampling sites. All experimental data were taken in triplicate and the average values were used for the analysis.

3. Results and discussion

The results of the zooplankton species surveyed across the three sampling sites were summarized in Table 1. A total of 15 Zooplankton taxa were identified during the study of which *Plecoptera* was

recorded as the taxa with the highest species score of 15,157, followed by *Pisces* with 13,865 species, protozoan with 5940 species, *Trichoptera* with 5282 species and then the least was *Odonata* with 562 total numbers of species. Results of the Shannon-Weaver diversity index showed that 61,581 individual species of zooplankton were encountered across the three sampling stations. The most abundant zooplankton species found across the three sites were *Baikaloperia* sp., followed by catfish, *Cryptomonads* sp., *Hydropsychid* sp, and *Dytiscidae* sp.

The three sampling stations used for this study were found to compose of various species of zooplankton. Based on the results in Table 2, sample station A recorded the highest total number of species of 31,197, followed by side B with species composition of 23, 768 and side C with a total of 9,594. There is a great variation in abundance of zooplankton species in the three sampling sites. These variations could be due to the differences in the physicochemical parameters measured which include temperature, pH, dissolves oxygen, nitrogen content, phosphorus content and ammonium content. Literature has reported that these parameters have a strong effect on the survival and distribution of zooplankton species in a particular location [4, 7, 8], that is why the specific standard of physicochemical parameters was set for aquatic life.

Based on the result in Table 3, the temperature of Site A was measured to be 23.17^{o}C which is lower than the temperature of sides B and C (25.83 ^{o}C and 28.33 ^{o}C) respectively. This indicated that the anthropogenic activities taking place around the area have contributed to the temperature variation which has a significant effect on the diversity of zooplankton species. The temperature reported from this study was found to be lower than 31- 34^{o}C obtained at Balanga Dam, Gombe State of Nigeria [4]. The low temperature observed from this study was due to vegetation characteristic found around Kwadon stream as compared with the previous study. The turbidity of a particular water body determined how free it is of suspended material. Water that is less turbid significantly allows maximum light penetration thereby enhancing photosynthesis by the aquatic plant. This process can contribute to the increase in availability of dissolving oxygen for macroinvertebrate [15]. In this study, results in Table 3 showed that the lower the turbidity, the higher the dissolved oxygen and also the higher the species richness. The low turbidity of 2.33 recorded in site A produces the oxygen level of 7.42 which is higher than that of sides B (6.66) and C (5.36). This is the reason why side A support maximum species composition. The increase in dissolved oxygen in the aquatic environment increases with a decrease in dissolved carbon dioxide (CO_2). This is one of the important parameter affecting primary production and phytoplankton biomass. The increase in water acidity is brought about by the increases in dissolved CO_2. However, high rates of dissolved CO_2 in water affect the physiological and metabolic activities of the aquatic biota [16]. The free oxygen levels reported from this research are 11.457, 10.483 and 11.392 for sites A, B, and C respectively.

The conductivity of water was shown to be dependent on pH. The increase in pH of water often causes an increase in conductivity. A conductivity range of 46.48 – 118.83 was reported in this study which corresponds to the pH range of 5.36 – 7.42 between sites A, B and C. Nitrogen and phosphorus constitute an important nutrient for utilization by zooplankton. The mean values of nitrogen and phosphorus reported from this study are .1170 and 0.15067 mg/L and 0.03733 to 0.04917 mg/L respectively. These values can be compared with 0.021-0.046 mg/L reported by Kefas and Abubakar [17] in River Ilagil Ngurore, Yola-south L.G.A Adamawa State.

The alkalinity of the water body is a measure of its capacity to neutralized acid to a designated pH [18]. Measuring alkalinity is important in determining the ability of water body to neutralized acid pollution from rainfall or wastewater. An average alkalinity value of freshwater body is 150 mg/L. According to Lawson, [16] alkalinity between 30 and 500 mg/L is generally acceptable to fish and shrimp production. The alkalinity values obtained from this study were at a range of 15.232 to 15.970

mg/L which is lower than both the two stated assertions. This showed that most of the zooplankton species found at the sampling sites are mostly freshwater organisms.

3.1. Effects of the riparian land use on the zooplankton distributions

Industrialization and human population growth have led to habitat destruction, leaving many species isolated on fragments of land and water. In fact, many indigenous species worldwide have become extinct as a result of being crowded out by steadily increasing human population, subsequent development, and alteration of the environmental landscape [19]. Although human activities have had an extensive impact on the integrity of the aquatic environments, there is also natural variation in habitat which may affect the community structure of the benthic organisms. Such characteristics include; the amount of canopy cover, direct sunlight, types of substrate, bank erosion, current velocity, riparian width, food plain quality, Sinuosity, development of heterogeneity, gradient and hydrological regime [20-23].

Thus, the occurrence and abundance of *Arcella sp., Dytiscidae sp., Bosmina sp., Brachiomus sp., Hydrosychida sp., Cinetochilum sp., Coleps sp., Criptomonas sp., Enallagma sp*., *Libellulida sp.,* Catfish, *Nymph sp. Senecella sp., Baikaloperia sp., vannella sp.* in sites A, B and C suggest that these species are potential indicators of mainly agricultural impact. However, *Arcela sp, Cinetochilum sp, Enallagma sp.* were absent in Site A, *Bosmina sp., Coleps sp. Nymph sp., Vannella sp.* were absent in site B and *Arcella sp., Bosmina sp., Cinetochilum sp., Enallagma sp., Senecella sp.*were absent in site C. This also indicated that the kind of activities taking place around the stream has a strong relationship with the types of species found.

Table 1
Diversity and Relative Abundance of Zooplankton species in the Riparian Sites

S/N	Zooplankton Taxa	Species	Num of Indiv	RelAb (pi)	Lnpi	pi(lnpi)	% Abundance
1	Protozoa	*Arcela sp*.	1205	0.019567724	-1.70845969	-0.334306671	.956772381
2	Coleoptera	*Dytiscidae sp.*	4574	0.074276157	-1.129150577	-0.0838689657	.427615661
3	Cladocera	*Bosmina sp*.	895	0.014533704	-1.837623702	-0.0267074781	.453370358
4	Rotifera	*Brachiomus sp.*	3032	0.049235966	-1.30771754	-0.0643867364	.923596564
5	Trichoptera	*Hydrosychida sp.*	5242	0.085123658	-1.06994972	-0.0910780348	.512365827
6	Protozoa	*Cinetochilum sp.*	563	0.00914243	-2.038938342	-0.0186408520	.91424303
7	Protozoa	*Coleps sp.*	2630	0.042707978	-1.369490989	-0.0584881914	.270797811
8	Protozoa	*Criptomonas sp.*	5940	0.096458323	-1.015660292	-0.0979688899	.645832318
9	Odonata	*Enallagma sp.*	562	0.009126192	-2.039710421	-0.0186147880	.912619152
10	Odonata	*Libellulida sp.*	2474	0.040174729	-1.396047042	-0.0560858124	.017472922
11	Pisces	Cat fish	13865	0.225150615	-0.647526863	-0.1457910712	2.51506146
12	Emphemeroptera	*Nymph sp.*	2519	0.040905474	-1.38821857	-0.0567857394	.090547409
13	Copepoda	*Senecella sp.*	1497	0.024309446	-01.614224937	-0.0392409142	.43094461
14	Plecoptera	*Baikaloperia sp.*	15157	0.246131112	-0.608833486	-0.1498528632	4.61311119
15	Protozoa	*vannellasp*	1426	0.023156493	-1.635327212	-0.378684432	.35649307
		TOTAL	**61581**			**-0.978809442**	**100%**
			Sh W Index			**0.978809442**	
			Effective no Sp.			**2.661285941**	

Table 2
Percentage Distribution of Zooplankton Species in the Various Sites

S/N	Zooplankton	Species	Site A	% Abundance	Site B	% Abundance	Site C	% Abundance
1	Protozoa	*Arcela sp.*	0	0	1705	4.336248156	0	0
2	Coleoptera	*Dytiscidae sp.*	623	3.38852243	1925	6.927201411	1416	9.247044994
3	Cladocera	*Bosmina sp.*	893	2.459872471	0	0	0	0
4	Rotifera	*Brachiomus sp.*	736	2.022867194	1645	5.919608478	651	4.251289754
5	Trichoptera	*Hydrosychida sp.*	3260	8.95998241	2440	5.18190651	542	3.539476262
6	Protozoa	*Cinetochilum sp.*	0	0	563	2.025981503	0	0
7	Protozoa	*Coleps sp.*	1331	3.658201407	0	0	1299	8.482988311
8	Protozoa	*Criptomonas sp.*	4409	12.11796394	963	3.465399978	568	3.709266636
9	Odonata	*Enallagma sp.*	0	0	562	2.022382957	0	0
10	Odonata	*Libellulida sp.*	1453	3.993513632	673	2.421821584	348	2.272578855
11	Pisces	Cat fish	8584	23.59278804	4229	13.41897873	1552	10.13517926
12	Ephemeroptera	*Nymph sp.*	2451	3.98801711	0	0	1068	6.97446614
13	Copepod	*Senecella sp.*	1538	2.852902375	459	1.6517327	0	0
14	Plecoptera	*Baikaloperia sp.*	4950	13.60488127	8514	30.63802224	1693	11.05596552
15	Protozoa	*vannella sp.*	969	2.663258575	0	0	457	2.984392346
	Total		31197		23768		9594	

Table 3
Mean Distribution of Physiochemical Parameters across the sampling sites

Site		Temperature (°C)	Turbidity	pH	Dissolved O_2	Conductivity	Ammonium	Nitrogen	Phosphorus	Alkalinity
A	Mean	23.17	2.33	7.67	7.42	111.83	.04183	.14817	.04917	15.970
	Std. Deviation	1.835	.516	.644	1.617	12.914	.022956	.065356	.011907	5.3892
	Variance	3.367	.267	.415	2.616	166.779	.001	.004	.000	29.043
	N	6	6	6	6	6	6	6	6	6
B	Mean	25.83	3.50	8.77	6.66	79.03	.04550	.11700	.04800	15.233
	Std. Deviation	1.169	.837	1.460	.873	13.896	.010232	.007642	.014832	5.1310
	Variance	1.367	.700	2.131	.762	193.100	.000	.000	.000	26.327
	N	6	6	6	6	6	6	6	6	6
C	Mean	28.33	5.17	11.55	5.36	46.48	.05000	.15067	.03933	15.403
	Std. Deviation	.816	1.169	1.419	1.983	8.072	.024650	.054924	.005922	5.0746
	Variance	.667	1.367	2.013	3.931	65.164	.001	.003	.000	25.751
	N	6	6	6	6	6	6	6	6	6
Total	Mean	25.78	3.67	9.33	6.48	79.11	.04578	.13861	.04550	15.536
	Std. Deviation	2.510	1.455	2.039	1.708	29.644	.019398	.049082	.011708	4.8953
	Variance	6.301	2.118	4.157	2.917	878.771	.000	.002	.000	23.964
	N	18	18	18	18	18	18	18	18	18

4. Conclusion

The effect of the riparian land use on the zooplankton abundance and physicochemical characteristics of Kwadon stream was investigated in this study. The results of the study showed that 15 zooplanktons taxa were encountered in all the sampling stations, among the various taxa, *Coleoptera, Trichoptera*, *Ephemeroptera,* and *Pieces* were identified as the most abundant taxa in terms of species richness. The various activities taking place in the three sampling stations were found to cause a variation in the physicochemical parameters of the stream. Variation of the physicochemical parameters was seen as an important factor determining the diversity and abundance of zooplankton species in the stream. If that is the case, there is an urgent need for government to impose regulations that will govern how toxic materials either in solid or liquid form should discharge; otherwise direct discharge into the stream can severely alter the physicochemical features of the water body. Therefore, the study of these zooplankton species can be beneficial for monitoring the level of pollution impact due to agricultural and other human activities around the stream.

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