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SPATIO-TEMPORAL VARIATION OF ZOOPLANKTON AS IT RELATES TO WATER QUALITY IN MAKERA DRAIN AND RIVER KADUNA LOTIC SYSTEMS, NORTHERN-NIGERIA

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Abstract

Surface water Physiochemical characteristics and Zooplankton diversity and abundance of Makera Drain and its point of impact on River Kaduna were determined from January to April 2013. Nine sampling stations were used for the study, Four on Makera drain, four on River Kaduna and one at the point the Makera drain impacts the River Kaduna. pH, Electrical Conductivity, Total Dissolved Solids, Biochemical Oxygen Demand, Sulphate, Chloride and Total Hardness were observed to be significantly higher on sampling stations on the Makera drain (Stations 1 to 4).Anemone larva, *Bomolodius* spp., Crustacean Nauplius, *Discorbis* spp., *Globigerniabulloides, Leptomedusa* spp., *Oikopleura* spp., Ophiopluteus larvae, *Tomopteris* spp. Could be used as indicators of highly organically polluted waters, whereas *Chlorochlasterpyreniger*, Coleoptera, *Hyalodiscus* spp., *Oikopleura* spp., Plecoptera Larva, and *Veliger* larva can be used as indicators of low pollution. High pollution alters the community structure of zooplanktons, increases species Dominance, and reduces species richness, diversity, and abundance. The strict regulation of industrial discharges is highly recommended to mitigate the adverse effects such effluents can have on the environment.

Key words: Zooplankton, pollution, effluents, and Water quality.

INTRODUCTION

Water quality can be thought of as a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics or by a range of variables which limit water use (Meybeck *et al*., 1996; Cordy, 2001; Elovaara *et al*., 2020). Any disturbance in the water body due to various anthropogenic activities that leads to a decline or deterioration in the water quality and quantity will have an impact on the community and the aquatic ecosystem and hence leave a great bearing on the social, economic, and environmental status of a region (Lampert and Sommer, 1997). Since water is the most vital factor for the existence of all living organisms (Adakole *et al*., 2008)), it is therefore necessary to determine the quality of water available for use.

Zooplanktons are myriads of diverse floating and drifting animals with limited power of locomotion which play an important role to study the faunal biodiversity of aquatic ecosystems (Goswami, 2004). The freshwater zooplanktons comprise of Protozoa, Rotifers, Cladocerans, Copepods and Ostracods and with their variability, density and diversity over space and time in any aquatic ecosystem, they can serve as bio indicators to monitor the aquatic ecosystems and integrity or quality of water (Kumari*et al*., 2004; Ferdouz *et al*., 2009; Gansfort *et al*., 2020).

Bioindicators are organism or communities of organism which reactions are observed to evaluate a situation giving clues for the condition of the whole ecosystem. They are also used in monitoring or detecting the negative impacts that industrial and other anthropogenic activities has on the environment (Sakar and Chowdhury, 1999; Gerhardt, 2007). Bioindicators can be used to detect changes in the natural environment, monitor for the presence of pollution or contaminants and its effect on the ecosystem in which the organism lives, and generally to monitor the health of the environment (Kumara, 2008). The aim of this work is to determine the spatial and temporal variation in zooplankton abundance and diversity of zooplankton and how it relates to water quality in Makera drain and river Kaduna.

MATERIALS AND METHODS

Study area

The Makera drain is located in the Kakuri Industrial Area, on the Far East (Nnamdi Azikiwe) western bye-pass road in Kaduna metropolis, Northern Nigeria.

Sampling Stations and Sample collection

Nine sampling stations were selected for the study, four across Makera drain Stations (1 to 4) to capture pollution sources from industries, residential and agricultural areas. Five stations on River Kaduna, with Station 5 at the point at which Makera drain impacts the River Kaduna, Stations 6 and 7 are 100m apart and are located upstream before the point the Makera Drain impacts River Kaduna while Stations 8 and 9 are located downstream of the point of impact and are also100m apart.

Duplicate water samples were collected at each Station for physiochemical parameters

and zooplanktons once a month from January to April 2013.

Sample analysis

Surface water pH, water temperature, Electrical Conductivity and Total Dissolved Solids were measured in situ using a portable HANNA combo meter model: HI 98129, while Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Hardness, Sulphate (SO_4), Alkalinity, Calcium and Chloride were determined using methods described by (APHA, 1985). Zooplankton identification was done using the Cell Count by Drop Count Method (as described by Kasturiranga, 1963; Perry, 2003; Valencar and Desai, 2004; Lynne, 2004; Emi and Caitlin, 2007; David, 2010).

Data Analysis

Analysis Of Variance (ANOVA) was used to compare the means of physicochemical parameters of both months and stations. Tukey's pairwise comparison was used to separate the means where the difference is significant while Community Structure Analysis was done using Paleontological Statistics (PAST version 1.8).

Indicator species were determined by the Individual Value index (IndVal index) modified from (Dufrene and Lagendre, 1997).

$INDVAL_{ij} = A_{ij} \times B_{ij} \times 100$

Where INDVAL = Indicator Value of species *i* in substrate *j*

A_{ij}(measure of specificity) = $\frac{\text{mean number of individuals of species } i \text{ in station } j}{\text{mean number of individuals of species } i \text{ across all stations}}$

B_{ij}(measure of fidelity) = $\frac{\text{number of stations } j \text{ where species } i \text{ is present}}{\text{the total number of stations}}$

The indicator value of a species (i) for a typology of sites is the largest value of $INDVAL_{ij}$ over all groups (j) of that typology.

RESULTS

The Mean surface water pH had a range between7.42 to 9.21. This variation was significant between sampling stations and between months ($p < 0.05$) (Table 1a and 1b). Surface Water temperature was observed to be between 29.13°C to 32.85°C, with the highest temperatures observed on the stations located on the Makera drain. The observed variation in water temperature is significant among the stations and among the months (Table 1a and b).

The mean Electrical Conductivity (EC) and Total Dissolved Solids were observed to show a similar pattern. Decreasing from a maximum at Station 1 (1410.62μS/cm and 720.25 ppm, respectively) to a lowest (142.75μS/cm and 72.63 ppm, respectively) in Station 6 (Table 1a and b).

Sampling stations on the Makera drain (stations 1 to 4) were observed to have significantly ($p < 0.05$) lower Dissolved Oxygen (DO) (0.70 to 1.01 mg/L, than Stations 5-9 (4.20 to 4.58 mg/L). There was also significant difference of Dissolved Oxygen between months with January having the highest value (3.27mg/L) and March having the lowest value (2.71mg/L) (Table 1a and b).Biological Oxygen Demand (BOD) showed significant difference ($p < 0.05$) between stations with Station 4 having the highest value of 4.75mg/L and Station 6, having the lowest value of 0.96mg/L (Table 1a). There is also significant difference

between months where March has the highest value of 4.43mg/L and April has the lowest value of 0.89mg/L (Table 1b).

Total Hardness was observed to vary significantly among sampling stations and among months ($p < 0.05$). Station 4 had the highest value (111.75mg/L) while Station 9 (33mg/L) had the lowest value (Table 1a and b). Total Alkalinity also showed a similar pattern, ranging from 6.06mg/L (Station 1) to 0.58mg/L (Station 9) (Table 1a and b). There was significant variation in Sulphate across stations with Station 4 (153.13mg/L) highest value and Station 9 having the lowest value of 40.63mg/L (Table 1a). There was also significant variation between months with the highest value in January (126.9mg/L) and the lowest in April (62.2mg/L) (Table 1b).

Surface water Calcium was observed to be from 681.36mg/L in Station 1 to 350.7mg/L in Station 9 with no significant difference ($P>0.05$) and it ranges from 530.4mg/L in January to 432mg/L in March with no significant difference ($P>0.05$) (Table 1a and b). A significant variation in Chloride concentration was observed across stations with Station 4 (0.33mg/L) and Station 5 (0.33mg/L) having the highest value while Station 7 has the lowest value (0.23mg/L) (Table 1aand b). There was also significant variation between months with April having the highest value (0.36mg/L) and March the lowest (0.23mg/L) (Table 1b).

Zooplankton Results

Species indicative of the sampling stations on the Makera drain (Stations 1 to 4) which are more polluted based the highest indicator values observed include Anemone larva, *Bomolodius* spp., Crustacean Nauplius, *Discorbis* spp., *Globigerniabulloides*, *Leptomedusa* spp., *Oikopleura* spp., Ophiopluteus larvae, *Tomopteris* spp. Station 5, which is the point of impact has *Fritillaria* spp. and *Kuhniascombri* eggs with the highest indicator values (Table 2).

Stations 6, 7, 8 and 9 have *Chlorochlasterpyreniger*, Coleoptera, *Hyalodiscus* spp., *Oikopleura* spp., Plecoptera Larva, *Tetraedronarthrdesmiforme*, and *Veliger* larva with the highest indicator values (Table 2).

Species Richness was observed to show a discernable pattern. It showed a general increase from Stations 1 to 4 during the four months of the study. Stations 6 and 7 which are before the point of impact are observed to be of higher Species Richness than Stations 8 and 9 which are after the point of impact Species Abundance was lowest in Stations 1 and 2 during the four months of the study, with the highest abundance observed in stations 3 and 4. Shannon-Wiener diversity was observed to show a steady increase from less than 1 in station 1 to values between 2 to 2.5 in Stations 5 to 9. Species Dominance was observed to show a general decline from a maximum of 1 in Station 1 in the Month of April, with the lowest values less than 0.2 observed in Stations 6 to 9 (Fig. 1).

Table 1a: Result showing means of physiochemical parameters within stations with WHO and FEPA standards.

Stations	Temp.^{0}C	pH	TDS(ppm)	EC(*uS*/cm)	DO	BOD	Hardness	Alkalinity	Sulphate	Calcium	Chloride
1	31.43^{a}	9.21^{a}	720.25^{a}	1410.62^{a}	0.75^{b}	2.19^{bc}	97.5^{b}	6.058^{a}	122.50^{a}	681.36^{a}	0.32^{a}
2	31.42^{a}	8.21^{ab}	704.67^{ab}	1414.50^{a}	0.84^{b}	3.16^{bc}	85.25^{c}	5.45^{b}	116.25^{a}	522.05^{a}	0.29^{b}
3	31.40^{a}	8.10^{b}	680.13^{b}	1360.37^{a}	0.70^{b}	1.44^{c}	78.5^{c}	5.92^{ab}	138.75^{a}	501.00^{a}	0.29^{b}
4	31.45^{a}	7.82^{b}	696.75^{b}	1392.87^{a}	1.01^{b}	4.75^{ab}	111.75^{a}	5.26^{b}	153.13^{a}	490.98^{a}	0.33^{a}
5	30.00^{a}	7.42^{b}	91.75^{c}	184.00^{b}	4.76^{a}	1.47^{c}	59.25^{d}	1.56^{c}	66.25^{b}	475.95^{a}	0.33^{a}
6	30.50^{a}	7.57^{b}	81.50^{c}	162.75^{b}	4.20^{a}	0.96^{c}	50.75^{d}	1.08^{cd}	53.75^{b}	385.77^{a}	0.30^{b}
7	30.60^{a}	7.55^{b}	78.75^{c}	157.88^{b}	4.54^{a}	1.29^{c}	40.00^{e}	0.82^{d}	70.63^{b}	435.87^{a}	0.22^{c}
8	30.85^{a}	7.83^{b}	72.63^{c}	142.75^{b}	4.58^{a}	1.56^{c}	37.00^{e}	0.66^{d}	68.13^{b}	375.75^{a}	0.23^{c}
9	30.68^{a}	7.65^{b}	74.75^{c}	144.38^{b}	4.51^{a}	1.27^{c}	33.00^{e}	0.58^{d}	40.63^{b}	350.70^{a}	0.25^{c}
WHO, 2011.	NA	< 8	500	1000	5	5	NA	NA	NA	NA	75
FEPA, 1991	NA	6.5-8.5	2000	NA	Not <2	30	NA	NA	500	5	20

All units are in mg/L except stated otherwise. NA-Not Available, DO-Dissolved Oxygen, BOD-Biochemical Oxygen Demand, Temp.-Temperature, TDS-Total Dissolved Solids, EC- Electrical Conductivity, St.=Standard. Means with the same letter in the same column are NOT statistically significant (p >0.05), a>b.

Table 1b: Result showing means of physiochemical parameters within months with WHO and FEPA standards.

Months	Temp.	pH	TDS	EC	DO	BOD	Hardness	Alkalinity	SO4	Calcium	Chloride
January	30.46^{bc}	7.86^{b}	260.40^{d}	518.70^{c}	3.27^{a}	1.70^{b}	34.00^{c}	2.90^{b}	126.90^{a}	530.40^{a}	0.28^{b}
February	29.13^{c}	8.35^{a}	429.50^{a}	846.70^{a}	2.74^{b}	1.03^{b}	41.10^{b}	4.52^{a}	87.20^{b}	440.90^{a}	0.27^{b}
March	32.85^{a}	7.87^{ab}	350.60^{b}	700.60^{b}	2.79^{b}	4.43^{a}	93.10^{a}	3.06^{b}	92.50^{b}	432.00^{a}	0.23^{b}
April	31.02^{b}	7.60^{b}	332.90^{c}	665.60^{b}	2.71^{b}	0.89^{b}	95.30^{a}	1.70^{c}	62.20^{c}	472.10^{a}	0.36^{a}
WHO (2011).	NA	< 8	500	1000	5	5	NA	NA	NA	NA	75
FEPA(1991).	NA	6.5-8.5	2000	NA	Not <2	30	NA	NA	500	NA	600

All units are in mg/L except stated otherwise. NA-Not Available, DO-Dissolved Oxygen, BOD-Biochemical Oxygen Demand, Temp.-Temperature, TDS-Total Dissolved Solids, EC- Electrical Conductivity. Means with the same letter in the same column are NOT statistically significant (p >0.05),where a>b

Table 2: Indicator species analysis of zooplankton in Makera drain and River Kaduna

S/No.	Zooplanktons	1 to 4	5	6 to 9
1	Anemone larva (Class: Anthozoa)	**38**	0	29
2	*Bomolodius* spp. (Fam.: Ergasilioe)	**33**	0	0
3	*Chlorochlasterpyreniger*	0	0	**33**
4	Coleoptera (Insecta)	0	0	**33**
5	Crustacean Nauplius larvae (Copepoda)	**43**	0	24
6	*Discorbis* spp. (Fam.: Ophthalmidiidae)	**67**	0	0
7	*Fritillaria* spp.	7	**20**	7
8	*Globigerniabulloides* (Fam.: Globigerinacea) Protozoa	**33**	0	0
9	*Hyalodiscus* spp. (Fam.: Hyalodiscidae)	10	18	**38**
10	*Kuhniascombri eggs*(Fam.: Mazocraeidae)	0	**33**	0
11	*Leptomedusa* spp.	**33**	0	0
12	*Oikopleura*spp.(Fam.: Oikopleuridae)	**33**	0	**33**
13	Ophiopluteus larvae	**33**	0	0
14	Plecoptera Larva (Stonefly) (Insecta)	11	0	**22**
15	*Tomopteris* spp. (Fam.: Tomopteridae) Polychaeta larvae	**33**	0	0
16	*Veliger* larva	0	0	**33**

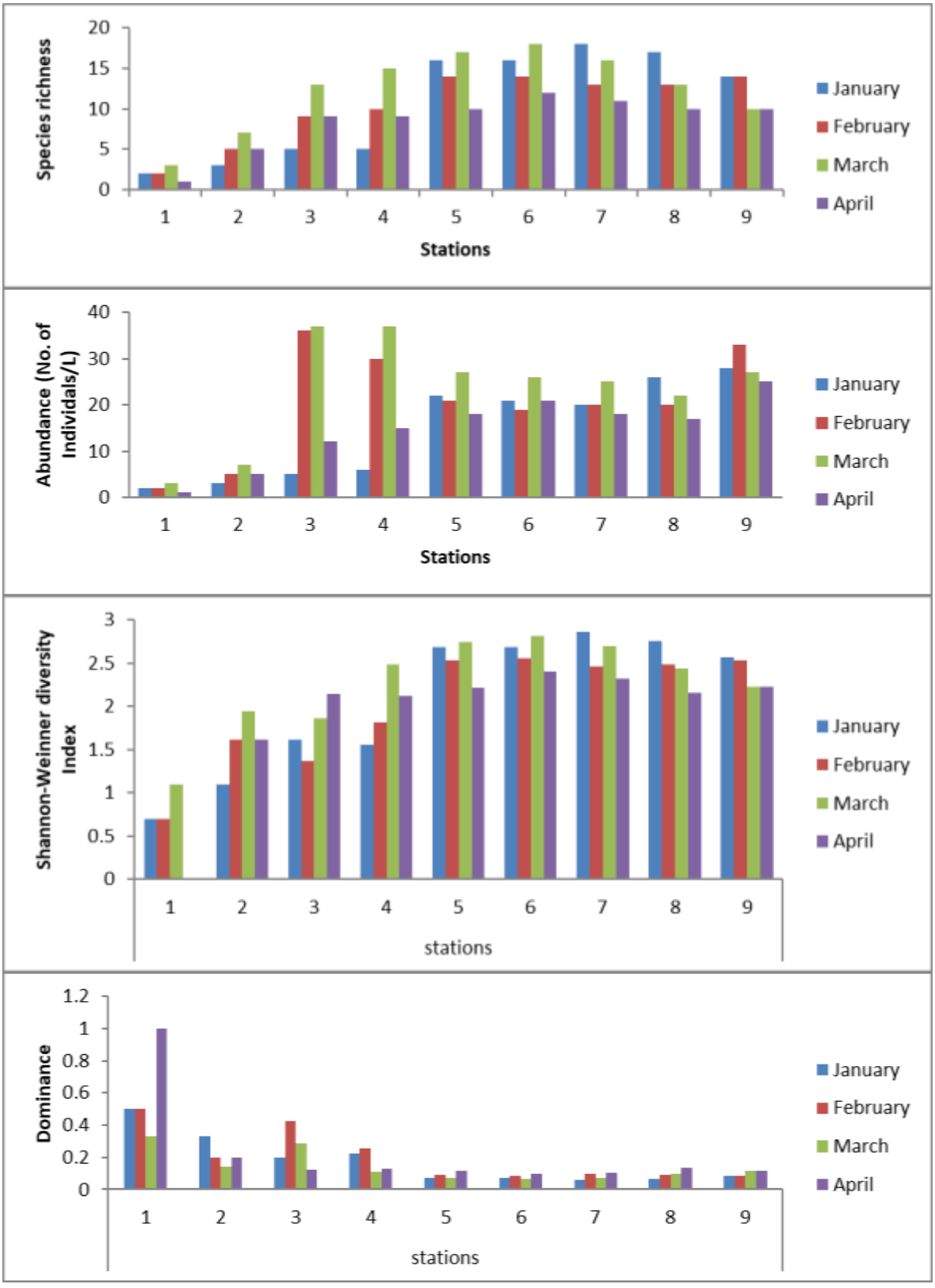


Fig. 1: Species richness, Abundance, Shannon-Weinner diversity and Dominanceof zooplankton in Makera drain and River Kaduna

DISSCUSSION

The absence of significant variation in surface water temperature could be due to the fact that only atmospheric temperature had effect on the water temperature and that effluent temperature does not significantly alter the water temperature of the Makera drain and River Kaduna. Whereas the significantly lower surface water temperatures observed in the months of January and February may be due to the low temperatures experienced between the months of November and February as a result of the harmattan wind. Ezra and Nwankwo (2001) observed similar results in Gubi Reservoir, Bauchi, Nigeria.

The significantly higher pH and Alkalinity values observed in Stations on the Makera drain may be arise due to the alkaline nature of the effluent coming from the brewery effluent. Brewery effluents have been reported to have an alkaline pH and high total alkalinity values (Adebayo *et al*., 2007; Alao *et al*., 2010; Inyang *et al*., 2012; Olowu *et al*., 2012). The brewing process includes the addition of some alkaline substances like caustic soda (Bokulich *et al*., 2013), some of which may be discharged in the effluent thereby making the pH of the receiving water alkaline and increasing its total alkalinity.

Industrial and domestic effluents may be implicated for the observed higher Electrical Conductivity, Total Dissolved Solids, Hardness, Sulphate, Calcium and Chloride in stations 1-4. These activities have been implicated to introduce pollutants which dissociate into ions in water thereby raising the concentration a number of chemical substances to sometimes above the range found in natural waters (Tyokumbur *et al*., 2002; Dadi-Mamud *et al*., 2012, Sotelo *et al*., 2019).

DO concentration in Stations 1-4 are less than both (WHO, 2011) and (FEPA, 1999) Standards and this could be attributed to the fact that those stations contain high level of pollutants whereby the organism there has used up the oxygen to break down the pollutant which serves as their nutrients. BOD concentration in these stations could be attributed to effluent and wastewater contamination (UNESCO/WHO/UNEP, 1996).

Indicator species analysis shows that there is a clear preference of Zooplankton species to specific sampling stations, such preferences suggests that these species could be used as bioindicators of the water quality in such stations. Anemone larva, *Bomolodius*s pp., Crustacean Nauplius, *Discorbis* spp., *Globigerniabulloides, Leptomedusa* spp., *Oikopleura* spp., Ophiopluteus larvae, *Tomopteris*s pp. With the highest Indicator Values on stations on the

Makera drain could be considered to be indicators of waters with high Electrical Conductivity, Total Dissolved solids, Hardness, Alkalinity, Sulphate, Chloride, Calcium, BOD, and low Dissolved Oxygen.

Station 5, which is the point the Makera drain impacts the River Kaduna could be considered moderately polluted in relation to Stations 1 to 4 and Stations 6, 7, 8 and 9.*Fritillaria* spp. and *Kuhniascombri* eggs with the highest indicator values at Station

5, could be considered as indicators of moderately polluted waters. Stations 6, 7, 8 and 9 have *Chlorochlasterpyreniger,* Coleoptera, *Hyalodiscus* spp., *Oikopleura* spp., Plecoptera Larva, *Tetraedronarthrdesmiforme,* and *Veliger* larva with the highest indicator values, making them indicators of water bodies with low pollution.

The lower Species Richness, species Abundance and Shannon-Weiner Diversity Index with a corresponding high species Dominance observed in stations on the Makera drain as compared to the contrast observed in stations on River Kaduna during the four months of the study may explained by the reason that only high pollution tolerant species can adapt and thrive in such stations. Tripathi*et al*., (2008) reported a similar finding JalaserTaal, Mandalgarh, Bilwara.

Reference (Whilm and Doris, 1966) have suggested a relationship between species diversity (Shannon-Weiner diversity index) and pollution status of aquatic system and classified as follows; > 3 = Clean water, 1-3 = moderately polluted < 1 = Heavily-polluted. Based on this classification, Station 1 one can be classified as highly polluted in the months of January and February, while Stations 2 to 9 as moderately polluted. A similar classification was used by references Tanimu *et al*. (2013) and Shehata *et al*. (2001).

CONCLUSION

In conclusion, the introduction of effluent into the drain impairs the water quality of Makera Drain as this is seen in Station 1 to Station 4 whereby pH, Total Dissolved Solids and Electrical Conductivity are higher than WHO (2011) standards. Anemone larva, *Bomolodius* spp., Crustacean Nauplius, *Discorbis* spp., *Globigerniabulloides, Leptomedusa* spp., *Oikopleura* spp., Ophiopluteus larvae, *Tomopteris* spp. Could be used as indicators of highly organically polluted waters, whereas *Chlorochlasterpyreniger,* Coleoptera, *Hyalodiscus* spp., *Oikopleura* spp., Plecoptera Larva, and *Veliger* larva can be used as indicators of low pollution. High pollution alters the community structure of zooplanktons, increases species dominance, and reduces species richness, diversity, and abundance.

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