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Macroinvetebrate Assemblages In Relation To Water Quality in River Ngadda, North-Eastern Nigeria

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Abstract

To manage river systems effectively, information on their water quality and ecological attributes are essential. The macro invertebrate assemblages in relation to the water quality of River Ngadda, northeastern Nigeria were assessed between May 2013 to January 2014. Two sampling sites, one each at the upstream and downstream part of the river were selected. Water physico-chemical data for some selected parameters were assessed and correlated with macro invertebrate abundance. All physico-chemical parameters with the exception of Nitrate-Nitrogen were within recommended limits while the macro invertebrate fauna was dominated by the Insecta, Bivalvia and Gastropoda groups with the Nematomorpha the least occurring. There was significant difference in the faunal abundance between the seasons at $p < 0.05$ with greater abundance in the Harmattan season and least abundance in the dry season. Temperature, depth, pH, DO, conductivity, phosphorus and Iron demonstrated strong influence on the abundance of macro invertebrates in the River and this was further supported by the dominance of the Insecta group which is known to be pollution sensitive. The study showed River Ngadda has a rich fauna and good water quality that are strongly correlated with each other. However, there is a need to periodically monitor the high nitrate–nitrogen levels in the water body and put in remedial action (s) where necessary to forestall eutrophication.

Keywords: Macro-invertebrates, physico-chemical, abundance, River Ngadda, Nigeria

Introduction

Macro invertebrates play significant role in the circulation and recirculation of nutrients in aquatic ecosystems (George *et al.*, 2009). They serve as a critical link between the bottom detritus and the pelagic fauna as they feed on the detritus and in turn serve as food for several fish species around them (Idowu and Ugwumba, 2005). The decomposition process in the aquatic habitat is catalyzed by macro invertebrates (Gallep, *et al.*, 1978) from which primary producers benefit hence by extension forming a major link in the food chain (Barnes and Hughes, 1988).

Macro invertebrates are also known bio-indicators of the conditions of aquatic system. They provide an understanding of the chemical and microbiological quality of the water bodies (Bailey *et al.*, 2003; Ikomi, *et al.*, 2005) as many macro invertebrate species are known to respond to changes in in their environment thus

affecting abundance, distribution and diversity. For instance the Odonata nymph is found to flourish in only oxygen rich aquatic systems (Calisto *et al.*, 2005). Owing to the specificity of water quality fluctuations between water bodies, and the variation in the tolerance levels of macro invertebrates to such specific fluctuations, the composition, abundance and distribution of species can be impacted (Naseer, *et al*., 2016; Odiete, 1999).

There has been literatures on macro invertebrates on macro invertebrates in relation to their role as bio indicators in various parts of Nigeria (Arimoro *et al*., 2007; Ikomi, *et al*., 2005; Arimoro and Osakwe, 2006; George, *et al.*, 2009; Abowei, *et al*., 2012), no such information is available for River Ngadda hence this attempt at addressing that.

Materials and Methods

Study Area:

River Ngadda, located at latitude 11° 50'N and longitude 13° 09'E is found in Maiduguri, the capital city of Borno state in the north eastern geo-political zone of Nigeria which shares international boundaries with republic of Niger and Chad in the north and Cameroon in the east. It has a population of 4,171,104 (NPC, 2006) and a total area of 70,898 km^2 (27,374 m). The area is semi-arid, with a long summer and short winter and a mean temperature of 25 °C to 37 °C. The mean total rainfall is 150 to 300 mm per year with 80 to 85% of the river annual discharge in the wet season.

The river is used for various human activities including fishing, vegetables irrigation, brick making and by residences along the river banks for bathing, washing and as drinking water by animals. The river originates from Rivers Yedzram and Gombole which meet at a confluent at Sambisa both in Nigeria and flows as River Ngadda into Alau Dam and stretches down across Maiduguri Metropolis then empties into Lake Chad. The river receives copious amounts of wastes from residential houses and abattoirs sited along its course (Akan *et. al.*, 2011).

Two stations on River Ngadda were selected as sampling points i.e. behind State water board and behind the State quarry company as station 1 and 2 respectively. Station 1 which is up stream is characterized by sparse vegetation due largely to the massive soil excavation going on there with minimal human activity overall and absence of settlements. On the

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other hand, station 2 which is downstream is replete with human habitation on both sides of the river with its attendant human activities like waste disposal into the river, fishing and washing occurring there. Sampling frequency was monthly for nine months (May 2013 to January, 2014).

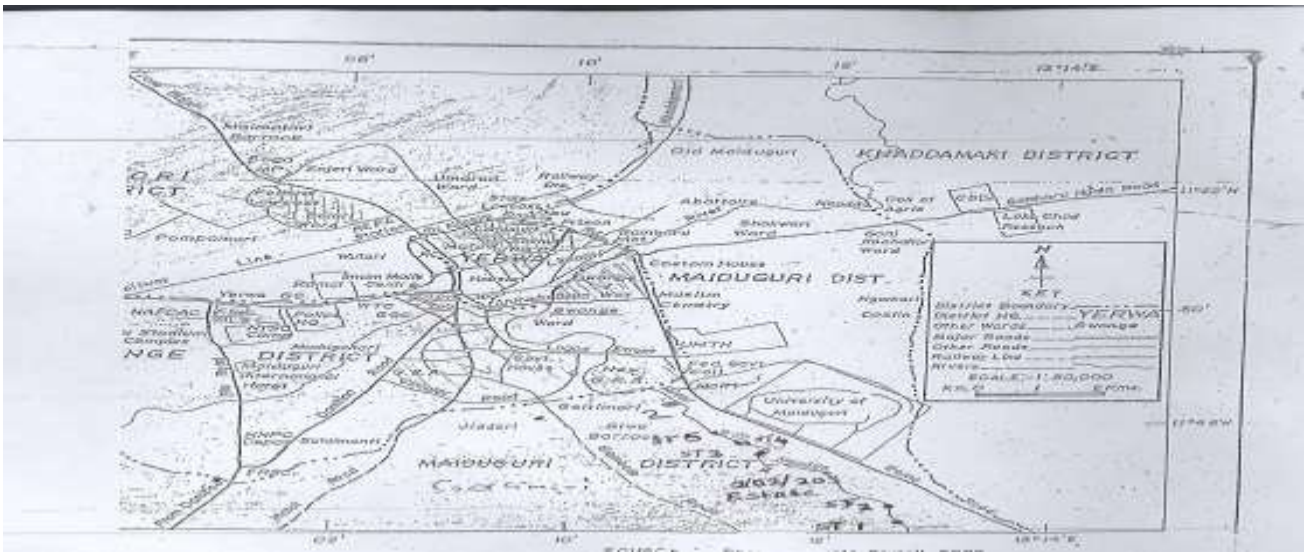

Fig. 1: Map of the sampling stations in River Ngadda showing location in Nigeria

Determination of Physico-chemical Parameters

Temperature and Dissolved Oxygen (DO): The temperature of both stations were measured or obtained by using DO multipurpose (Ex S71 & 11) meter. The probe of this instrument is first rinsed with distilled water before any reading was taken.

Depth: A long graduated metre ruler was used to determine the depth by dipping the meter rule into the water bed and the level was recorded before the metre ruler was removed. The depth was measured to the nearest metre (m).

Water Current: Water current was measured using a buoyant object (i.e. a weighted cork). The cork was placed at a starting point and the distance moved in relation to time (m/min) was noted.

Transparency: A seechi disc was used to obtain the degree of transparency of sampling point, before sample collection. The disc is lowered in water, until it disappears and the

depth recorded. It is then pull upward slowly until it re-appears again, this depth is also recorded. The average of the two depths was considered as the seechi disc visibility.

Hydrogen Ion Concentration (pH): A portable field pH EP meter was used to take the hydrogen ion concentration of each station. The probe was inserted into water, and the reading displayed on the dial recorded. Subsequent reading was taken after rinsing the probes in distilled water.

Dissolved Oxygen (DO): Dissolved oxygen of both stations are obtained using DO multipurpose (EX STIK 11) meter. The probe of this meter is first rinse with distilled water before taking any reading.

Total Alkalinity: Alkalinity was obtained by measuring 100ml of water sample into 250ml Erlenmeyer flask. Two to four drops of phenolphthalein indicator was added to the sample and titrated over a white slab with 0.02 NH_2 SO_4. The total alkalinity was computed by adding phenolphthalein values and expressed as mg / litre $CaCO_3$. Phenolphthalein alkalinity was calculated as thus:

Phenolphthalein alkalinity = B x N x V 50,000 (mg/l $CaCO_3$)

where B = Average volume of litre; N = Normality of acid 0.02m

Conductivity: Conductivity value of each station was measured using "EC215" conductivity/TDS meter. The probe was inserted into water, and the readings displayed on the dial recorded.

Phosphate – Phosphorus

The phenol disulphonic acid method according to Mackereth (1963) was used. 100ml of water sample in 250ml Erlenmeyer flask was evaporated to dryness. 2ml phenol disulphonic acid was added to the residue and left for about 10minutes. 10 – 15ml of distilled water was then added followed by addition of 5ml strong ammonia solution. The mixture was stirred and allowed to cool. The absorbance at 410nm was measured using UV spectrophotometer. Phosphate concentration in the sample was determined the calibrated curve. Curve was produced by placing the electrode in a series of well stirred standard solution.

Nitrate – Nitrogen

10ml of the sample was put into a digestion tube and 5ml of sulphuric acid was added. The mixture was heated (for about 20 mins) on a digestion rack over a small flame until the

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solution becomes clear and colourless. The distillation apparatus was steamed for 30 minutes and the contents of the cooled digestive tube was washed quantitatively into the Markhem with some water. The delivery tube of the apparatus was arranged below the surface of 5 ml of boric indicator solution in a 25ml measuring cylinder. 10ml of 40% sodium hydroxide was added through the funnel to release ammonia. The stopper was replaced and the contents were steamed until the volume of liquid in the receiver reached about 10ml. The receiver was lowered so that it was above the surface of the liquid and was steamed for some minutes more. The solutions in the measuring cylinder were poured into a 50ml conical flask and titrated against 0.01N HCl until the first pink tinge appeared. This was regarded as (Xml). The volume of (Yml) of the blank was also determined in the same way.

The Nitrate - Nitrogen value was calculated using the expression

Nitrate – Nitrogen = 0.14mg of N_2 x tml x 100 (mg/l)

Tml = (x-y)

Where Xml = titration value for the solution; Yml = titration value for the blank; Tml = titration value for the sample (Olsen, 1975).

Heavy Metals:

Water samples for the analysis of heavy metals concentration were collected in 250ml reagent glass bottles with glass stoppers cleaned to remove all traces of metallic contaminants (Siruempler, 1973). About 50ml of the water sampler was adjusted to pH 2.0 using concentrated HNO_3 (Nitric acid). This solution was filtered using a fitter paper. The filtrate was analyzed for the heavy metals using atomic absorption. Spectrophotometric method (Olsen, 1975), 10ml of a representative portion of the sample which has been adjusted to pH of 2.0 with concentrated HNO_3 was added to a beaker. 5ml of concentrated HNO_3 and 2ml 30% H_2O_2 were added to reduce chromate. The beaker was placed on a hot plate and evaporated to about 20ml. The evaporated solution together with any solid remaining in the beaker was transferred to a 125ml conical flask. 5ml concentrated HNO_3 was used to rinse the beaker and 10ml concentrated H_2SO_4 was added. The solution was evaporated on a hot plate in a fume chamber until dense white fumed of SO_3 just appeared in the flask. This

was cooled to room temperature and carefully diluted to about 50ml with redistilled water. The resulting solution was heated nearly to boiling and filtered and the filtrate was diluted to 100ml mark in a volumetric flask. Portions of this were taken for atomic absorption spectrophotometric reading to determine total heavy metal.

Macro invertebrates sample collection

The benthic samples for the analysis of benthic organism were collected using a Surb sampler ($0.4m^2$, 20nm mesh netting) and a core borer of diameter 15 cm and 20 cm (for sampling the benthos on the water beds and substratum). This involves scraping the substratum and the sediments into the net where the net sampler can't be used while resorting to the core borer. The use of both sampling technique is to take habitat difference into account (Ogbeibu, 2001).

The washed sediment with macro-invertebrates were poured into a wide mouth labeled plastic container and preserved with 10% formalin solution to which Rose Bengal (dye) had been added. The Rose Bengal dye strength was 0.1% selectivity colored all the living organisms in the sample (Claudiu *et al*., 1979; Zabbey, 2002; Idowu and Ugwumba, 2005). The preserved samples were taken to the laboratory for further analysis. The washed and preserved sediment with the benthic macro-invertebrates were poured into a white enamel tray and sorted in the laboratory. For effective sorting, moderate volume of water was added into the container to improve visibility. Forceps were used to pick large benthos while smaller ones were pipetted out. The benthos were sorted into their different groups and preserved in 5% formalin. The preserved benthos were later identified to their lowest taxonomic group under light and stereo dissecting microscope and counted. The identification was done using the keys by Clifford (1991) and Pennak (1978). The monthly percentage occurrence and relative numerical abundance of macro invertebrates were estimated.

Data Analysis

The physico-chemical parameter studied was subjected to normality of data and analyzed by using ANOVA and t-test to determine the level of significance difference at $p < 0.05$. The relationship between each parameter to the distribution was determined by using Pearson Correlation coefficient using SPSS software.

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Physico-chemical parameter data were subjected to means and standard error.

Results

Physico-chemical Parameters

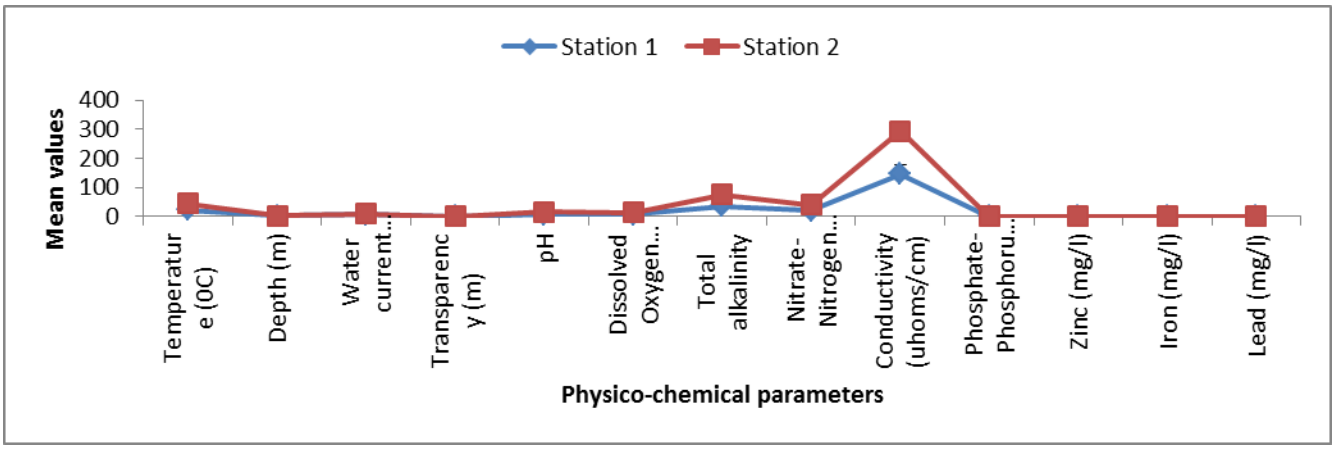

Fig. 2: Mean Physico-chemical parameters across stations

Figure 2 shows the mean values and Standard Deviation (SD) of the physico-chemical parameters of the two sampling stations in the study area. Station 2 showed higher figures for depth (1.14 m vs 1.12 m), transparency (0.38 m vs 0.29 m), phosphate (0.37 mg/l vs 0.31 mg/l), Zinc (0.15 mg/l vs 0.14 mg/l), water temperature (22.38 ^{0}C vs 22.11 ^{0}C), pH (7.58 vs 6.75), DO (6.33 mg/l vs 5.76 mg/l), total alkalinity (39.39 mg/l vs 35.08 mg/l), nitrate-nitrogen (19.61 mg/l vs 18.92 mg/l) and conductivity (147.14 uhoms/cm vs 146.47 uhoms/cm) compared to station 1. Conversely, water current showed higher values in station 1 compared to station 2 (5.29 m/min vs 4.13 m/min). Lead and Iron however recorded similar values across the two stations.

Table 1: Monthly physico-chemical parameters in River Ngadda

Parameters	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Temperature (^{0}C)	27.45	25.85	25.83	20.43	21.7	20.98	20.15	18.63	19.18
Depth (m)	0.81	0.92	0.94	0.73	1.8	1.88	0.86	0.7	0.54
Current (m/min)	3.6	3.97	4.73	7.63	7.53	4.6	3.9	3.28	3.15
Transparency (m)	0.26	0.29	0.29	0.71	0.46	0.28	0.27	0.24	0.23

Ph	7	7.13	7.25	7.83	7.73	7.93	7.35	7.03	6.68
DO (mg/l)	7.63	7.5	6.33	4.6	4.45	5.05	6.33	6.55	5.98
Total alkalinity (mg/l)	34.45	37.55	41.15	42.3	40.4	36.25	34.75	35.33	32.95
Nitrate-Nitrogen (mg/l)	18.75	19.9	23.48	19.58	19.55	18.18	18.03	18.03	17.88
Conductivity (uhoms/cm)	119.18	130.93	150.7	193.95	191.88	162.4	136.35	119.15	116.73
Phosphate (mg/l)	0.39	0.37	0.36	0.28	0.27	0.27	0.33	0.43	0.32
Zinc (mg/l)	0.12	0.15	0.16	0.15	0.16	0.16	0.13	0.14	0.13
Iron (mg/l)	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.03
Lead (mg/l)	0.04	0.04	0.05	0.06	0.06	0.05	0.05	0.05	0.01

Table 1 represents the monthly values for physico-chemical parameters of River Ngadda. The range of temperature was 18.63 ^{0}C (December) to 27.45 ^{0}C (May). Depth was lowest in January (0.54 m) and highest in October (1.88 m); water current ranged between 3.15 m/min (January) to 7.63 m/min (August); transparency was highest in August (0.71 m) and lowest in January (0.23 m); pH ranged between 6.68 (January) to 7.93 (October); Dissolved oxygen ranged between 4.6 mg/l (August) and 7.63 mg/l in May; total alkalinity was lowest in January (32.95 mg/l) and highest in August (42.3 mg/l); Nitrate-Nitrogen was also lowest in January (17.88 mg/l) but highest in July (23.48 mg/l) while phosphate was lowest in September and October (0.27 mg/l) and highest in December (0.43 mg/l). Conductivity recorded the highest values in August (193.95 uhoms/cm) with the lowest in January (116.73 uhoms/cm), same pattern was recorded for Lead with 0.01 mg/l and 0.06 mg/l for January and August respectively.

Macro invertebrates Composition and Abundance

Table 2: Macro invertebrate class composition and abundance across stations

Class	Station 1	Station 2	All stations
Gastropoda	482	360	842
Bivalvia	1379	343	1722
Oligochaeta	261	506	767
Hiruidinea	28	134	162
Insecta	592	1705	2297
Arachnida	83	0	83
Nematomorpha	0	39	39

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Total	**2825**	**3087**	**5912**

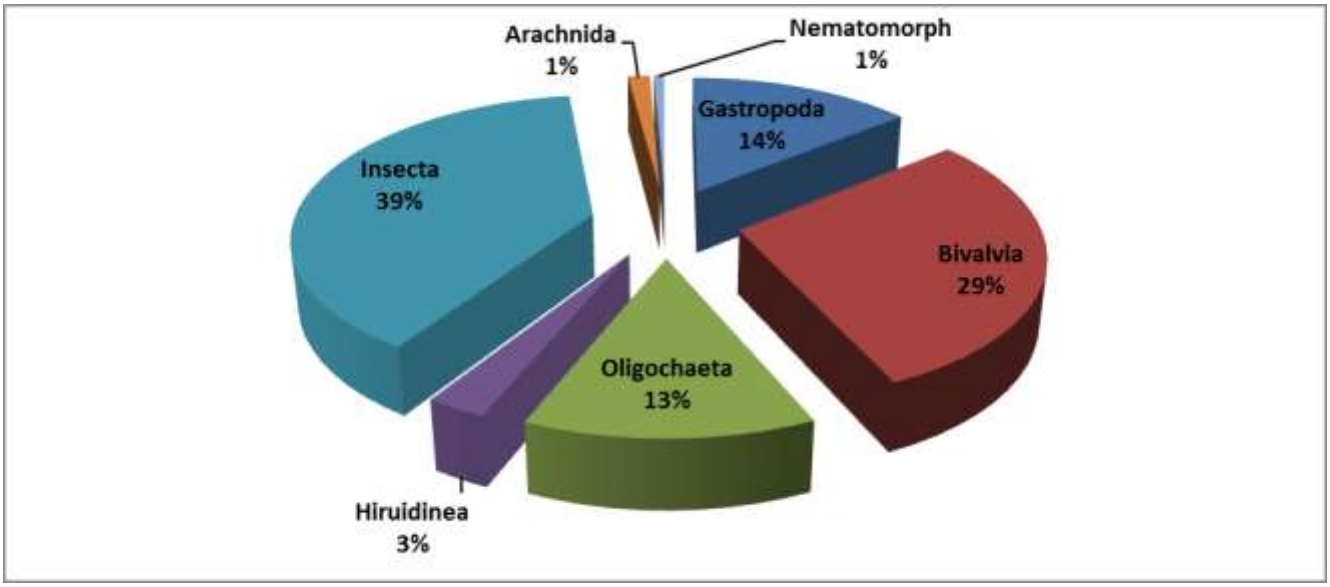

Fig. 3: Macro invertebrate class percentage abundance

Table 2 shows the composition and abundance of macro invertebrate classes across stations. A total of seven (7) classes were encountered with station 2 recording the most abundance of 3087 individuals while station 1 had 2825 individuals. The fauna, by class was dominated numerically by Insecta (38.9%) followed by Bivalvia (29.1 %), Gastropoda (14.2%), Oligochaeta (13.0 %) while Nematomorpha (0.7 %) recorded the least abundance (fig.3).

Table 3: Macro invertebrate family composition across stations

Family	Station 1	Station 2
Hydrobiidae	√	X
Bithynidae	√	X
Lymnaeiidae	√	X
Valvatidae	√	√
Viviparidae	√	√
Physidae	√	√
Dreissenidae	√	X
Sphaeriidae	√	√
Unionidae	√	√

Nuculoida	√	√
Lumbriciidae	√	√
Tubificidae	√	√
Naididae	X	√
Glossiphoniidae	√	√
Chironomidae	√	√
Simullidae	√	√
Gamphidae	√	√
Culicidae	√	√
Aeshnidae	√	√
Pisauridae	√	X
Mermithae	X	√
21	**19**	**16**

***√ = Found in the station x = Not found in the station**

Table 3 shows the complete benthic faunal composition of the two stations. A total of seven (7) classes spread across twenty one (21) families and forty (40) species. The table also indicated that the nematomorpha class was absent at station 1 while station 2 recorded the class Arachnida as been absent. Overall, station 1 had a higher composition with 19 families than station 2 which had16 families.

Table 4: Number of families and species in each class of macro invertebrates

Class	Total families	Total number of species	Percentage species composition (%)
Gastropoda	6	9	22.5
Bivalvia	4	8	20
Oligochaeta	3	8	20
Hirudinea	1	1	2.5
Insecta	5	10	25
Arachnida	1	2	5
Nematomorpha	1	2	5
Total	**21**	**40**	**100**

Table 4 show the number of families and species and the percentage species composition of each class of macro invertebrates. The gastropoda class had

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the highest number of families (6) followed by the insecta class (5) while the arachnida, nematomorpha and hirudinea recorded the least number of families with one each. In terms of species number, the insecta class recorded the highest number of species (10), followed by gastropoda (9) while hirudinea (1) recorded the least number of species. Correspondingly, the insect class had the highest species composition (25%), followed by gastropoda (22.5%) with arachnida and nematomorpha recording the least both with 5% species composition each.

Seasonality in Macro invertebrate abundance

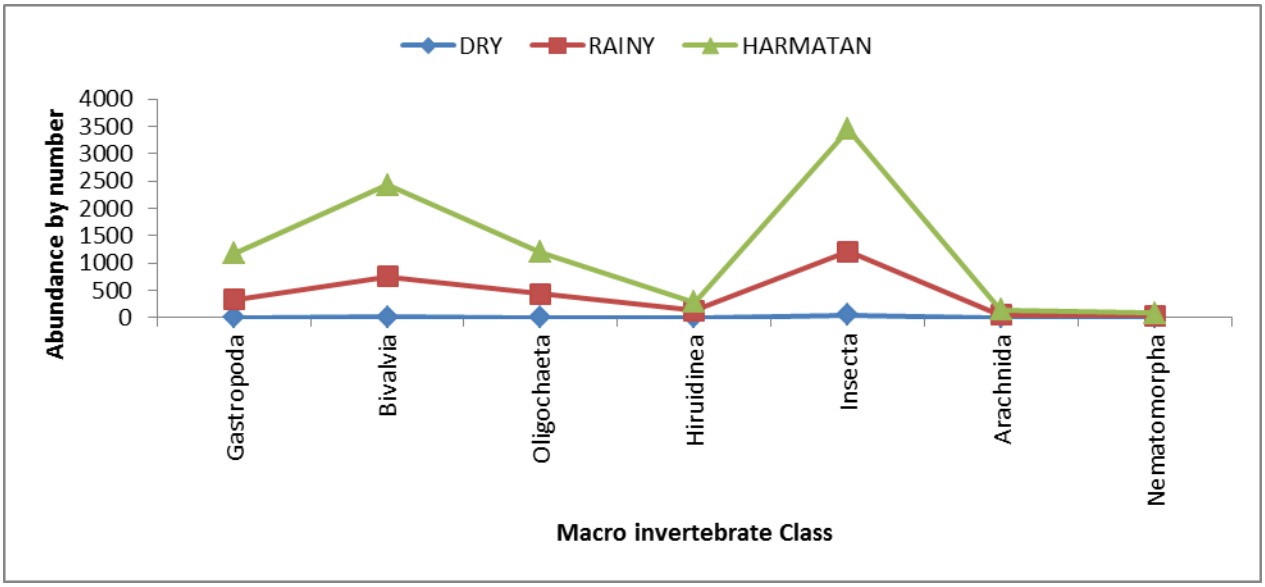

Fig. 4 Seasonal variations in macro invertebrate Class abundance in River Ngadda

Figure 4 show the seasonal abundance of macro invertebrates by class. In all the classes, the harmattan season recorded the highest abundance with Insecta and Bivalvia having the highest while nematomorpha had the least. Same trend was shown in the dry and rainy seasons. However, the rainy season recorded the second highest abundance across all classes with the dry season recording the least.

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Relationship between macro invertebrate and physico-chemical parameters

Table 5: Correlation between macro invertebrates and physicochemical parameters

S/N	Macro invertebrate Vs Physico-chemical parameters	Correlation (r) and significance level
1	Gastropoda Vs Temperature	0.812**
2	Bivalvia Vs Temperature	0.872**
3	Oligochaeta Vs Temperature	0.748*
4	Hirudinea Vs Depth	0.814**
5	Hirudinea Vs pH	0.798**
6	Hirudinea Vs DO	- 0.708*
7	Hirudinea Vs Conductivity	0.682*
8	Hirudinea Vs Phosphorus	- 0.757*
9	Insecta Vs Temperature	- 0.914**
10	Insecta Vs pH	- 0.677*
11	Insecta Vs Iron	0.855**
12	Arachnida Vs DO	- 0.721*
13	Arachnida Vs pH	0.736*

**** Significant at p < 0.01**
*** Significant at p < 0.05**

Table 5 shows the relationships between macro invertebrate abundance and physico-chemical parameters. The Gastropoda class had a very strong positive relationship (0.812) with temperature, so does Bivalvia (0.872), Oligochaeta (0.748) and Insecta which showed a negative strong relationship (-0.914). Hirudinea, Arachnida and Insecta also showed strong relationships with pH at 0.798, 0.736 and – 0.677 respectively. Hirudinea and Arachnida both indicated strong negative relationships with DO at -0.708 and -0.721 respectively. Hirudinea correlated with depth (0.814), conductivity (0.682) and phosphorus (-0.757). Arachnida showed a strong relationship with Iron (0.855).

Discussion

This study found that the dominant groups of macro invertebrates were Insecta > Bivalvia > Gastropoda > Oligochaeta > Hirudinea > Arachnida > Nematomorpha respectively. In terms of overall community structure, a total of 40 species in 21 families and 7 classes. The marked dominance by the insecta, Bivalvia and gastropoda groups varies from other reports on macro invertebrates in Nigeria waters. The macro invertebrate abundance in the study is quite higher than that of George *et al.*, (2009)

who found macro invertebrates in 19 species, 12 families and 6 classes in Okpoba creek in the Niger delta. The finding of this study is also higher than those reported by Sikoki and Zabbey (2006) in River Imo where 14 species and 11 families were reported, so also for the 20 species and 5 classes reported for Bonny River by Ansa (2005). However a higher abundance of 43 species was recorded for Lagos Lagoon and 46 species for Okazuwa in Benin City as reported by Ajao and Fagade (1990) and Olomukoro and Ovoijie (2015) respectively. The dominance of the insecta group in this study is similar to that of Okazuwa in Benin city (Olomukoro and Ovoijie (2015) and Mahato (2000) but at variance with George *et al*., (2009) and Hart (1994) who both found polychaeta as the most dominant at Calabar River and Mangrove swamp of Port-Harcourt respectively. There was significant difference between the macro invertebrate abundance across the three seasons with the Harmattan season recording the highest abundance, followed by the rainy season with the dry season recording the least.

The water quality status of the River Ngadda were similar at the two stations with all tested parameters falling within recommended standards except Nitrate-Nitrogen which was above the recommended limit but higher at station 2 with a corresponding reduction in DO compared to station 1. The increased human activity in Station 2 probably accounted for this difference. Studies had shown that intense human activities resulting from discharge of organic pollutants into streams lead to increase in nutrients levels and in biochemical oxygen demand which in turn affects the distribution and abundance of benthic invertebrates (Atobatele *et al*., 2005; Zabbey and Hart, 2006).

The study results showed strong relationships between some key physico-chemical parameters and the abundance of macro invertebrates in the study area. This is an indication of the ability of the organisms to survive, adapt, migrate or die under favorable and unfavorable environmental conditions (Tyokumbur *et al*., 2002). Temperature, depth, pH, DO, conductivity, phosphorus and Iron were significantly correlated to macro invertebrate abundance with temperature showing the strongest relationship while pH demonstrated the least strength. Other related studies by Baker *et al*. (1979), Ebele (1981), Ajao and Fagade (1990), Matagi (1996) and

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Ogbogu (2001) showed similar trends in the correlation between the physico-chemical quality and the abundance of macro invertebrates. However the demonstration of weak correlation by the macro invertebrates in this study to some of the physico-chemical parameters could be attributed to their physiological adaptations to the unfavorable environmental conditions (Tyokumbor *et al*., 2002).

Conclusion

This study established the abundance of macro invertebrates in River Ngadda and the relationship the physico chemical conditions around them have on their survival. Significant relationship between these two variables were established which was further buttressed by the dominance of the Insecta group in the River which is a bio indicator of fair to good water quality as it is a pollution sensitive class of macro invertebrate. This conclusion has been supported by other studies (Miserendino and Pizzolon, 2003; Adakole and Annune, 2003). Overall, the study found the macro invertebrate fauna of River Ngadda to be rich with water quality within recommended limits which demonstrated a strong relationship to the abundance of the fauna.

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