Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.17, 2015
www.iiste.org

Physico-Chemical Factors Influencing Zooplankton Community Structure of a Tropical River, Niger Delta, Nigeria

Mandu Essien-Ibok Imaobong Ekpo
Department of Fisheries and Aquatic Environmental Management, University of Uyo, Nigeria

Abstract
The Physical and chemical factors influencing the abundance, diversity and species richness of zooplankton in Mbo River, Akwa Ibom State, Nigeria were studied for twelve months (December, 2009- November, 2010) *using standard analytical methods. The aim was to study the environmental factors determining zooplankton structure as reference point for the sustainable management of the river in view of the proposed development plans for the river basin. The result showed that* Crustacea was highest and constituted 48% in Station I, and 30.8% and 33.3% in Stations II and III respectively. Other taxanomic groups present in this study include Rotifera which contributed to 20.0%, 50.0% and 55.6% in Stations I, II and III, respectively. Mollusc in Station I contributed to 8.0% of the species composition in this Station but was absent in Stations II and III. Protozoa which contributed to 9.1% of the total zooplankton composition in Station I was not recorded in the other two stations. The maximum diversity (Shannon-Weiner Index) per station/month (2.79) was calculated in Station I in September, 2010 and the minimum per station/month (0.93) was observed in Station III in July. Seasonally, the wet season recorded the maximum Shannon-Weiner Index value of 3.02 while the dry season recorded lower values. The significant seasonal variation in zooplankton density (cells/l), diversity and richness was regulated by rainfall, which also modulated the impact of the physico-chemical variables of the river surface water.
Keywords: Community structure, Nigeria, Niger Delta, Physico-chemical factors, Zooplankton

1. Introduction

The increasing water pollution downstream can be revealed not only by the physico-chemical analyses but also by the indicating plankton. It is also noted that in relation to increasing pollution, the distribution pattern of plankton change in the species composition as well as the community structure. This can be attributed to a change in the physico-chemical properties as a result of the deterioration in water quality. Odiete (1993) noted that plankton growth and distribution depend on the carrying capacity of the environment and on the nutrient concentration. Ezra and Nwankwo (2001) observed that changes in plankton population in Gubi Reservoir were influenced by physico-chemical parameters. According to Raymond (1983), physico-chemical parameters also affect plankton distribution, sequential occurrence and species diversity.

Davies *et al* (2009) in their study of the seasonal abundance and distribution of plankton in Minichinda stream, Niger Delta, Nigeria recorded higher quantity of plankton in the wet than in the dry season. They attributed this to the seasonal variations of some physical and chemical factors such as nutrients and pH.

Land use affects the rate and quality of surface runoff, infiltration, water quality and vegetation (Allan, 2001). The river was chosen for the study because in spite of its economic and ecological importance, no published work was available on it as at the inception of the study. The sampling stations were selected to represent different environmental and ecological variations within the river, to better understand the effects of natural and anthropogenic factors on the river's water quality.

2. Materials and methods

2.1 Study area: Mbo River

Mbo River (Fig.1) is one of the major rivers in Akwa Ibom State, Nigeria, traversing across two local government areas (Urue Offong Oruko and Mbo Local Government Areas) and lies within latitudes 4^0 30' to 5^0 30' North and longitudes $7^0$30' to $8^0$30' West on the South Eastern Nigerian Coastline. It is a near coastal river located within the Cross River Basin and drains into the Cross River Estuary at Ibaka in the Bight of Bonny, with which it maintains a permanent mouth thus exposing the system to tidal ebb and flow. It forms part of the Atlantic Drainage system (Anukam, 1997) east of the Niger which comprises the Cross, Imo, Qua Iboe and Kwa Rivers.

Mbo River is located within the tropical rainforest region characterized by tropical humid climate with distinct dry (November – March) and wet (April –October). The dry season is characterized by prevalence of dry tropical continental winds from the Sahara Desert while the wet season is typified by moist tropical wind from the Atlantic Ocean. The vegetation cover of the drainage area is dominantly dense *Nypa fruticans* which seems to have displaced indigenous mangrove trees, *Rhizophora racemosa* (Orok *et al*., 2010). Mbo River is an important ecological ecosystem and supports the local economic activities such as agriculture, fishery, eco-tourism and water transportation. The ecosystem contributes to the urbanization and economic activities that converge along the river corridors. The increasing urbanization and socio-economic activities have in turn impacted the ecosystem through input of domestic and industrial effluents, spent oil from auto-mechanic workshops and petroleum hydrocarbon from motorized river crafts.

For this survey, three sampling stations within the stretch of the river were recognized (Fig1). Station III (Ukontenge creek) located about 1500m upstream of the Mbo Bridge with average depth of about 3.5± m and average current velocity of about 51± cm sec^{-1}. The fringing vegetation is mainly red mangrove (*Rhizophora racemosa*) and the exotic nipa palm (*Nipa fruticans*). Human activities at this site are limited to fishing, palm tapping and occasional bathing. Station II is located between the bridgehead and the defunct Fishing Terminal, at Egbughu with average depth of about 4.1± m and current velocity of about 45± cm sec^{-1}. The fringing vegetation is mainly of *Nypa fruticans* because mangrove species have been felled for construction and firewood for smoking of fish and for domestic use. This station records numerous small scale enterprises, intense fishing and discharge of domestic sewage. Other anthropogenic activities tiver transportation and other commercial services. In addition to these, there is a small landing port for medium sized sea-faring boats, with lots of mechanical repairs. Station I is located at 1,000m to the mouth of the river where the river empties into the Cross River Estuary. The stations were chosen to show the degradation, if any, in the water quality parameters along the river gradient.

2.2 Data collection

Sampling was carried out fortnightly at the three established sites from December 2009 to November 2010 inclusive, during the mid morning hours between the hours of 8am and 11am. Morphometric parameters were measured using appropriate procedures (Orth, 1983; Schlosser, 1982; Hanson, 1973; Bartram and Ballance, 1996). The chemical analysis of the waters was done using standard and analytical methods of water analysis (Bartram and Ballance, 1996; Trivedi and Goyal, 1986; APHA-AWWA-WPCF, 2005; USEPA, 1979).

2.3 Zooplankton sampling

Water samples (1,000ml) were collected from approximately 20cm below the water surface mid-stream at each sample site in new, clean 1liter polyethene sample bottles, clearly and permanently labeled. The samples were allowed to stand (sedimentation) for 48 hours, followed by centrifugation before decanting the supernatant leaving an aliquot of known volume (10ml). The concentrated samples were homogenized before 1ml of sub-sample from the original stock was collected wi The sample was fixed with approximately 5ml of 4% formaldehyde solution and taken to the laboratory for analysis.th sample pipette (Onuoha, 2009). The pipette content was transferred unto a Sedgewick – Rafter counting chamber for species enumeration at a microscope magnification of 400_x using the synopsis of Mills (1932), Durand and Leveque (1980), Screenivas and Dulthie (1993), Newell and Newell (1977), Egborge (1973); APHA (2005); Onuoha (2009).

Qualitative estimation of plankton was made using a 30cm square mouthed 70mm mesh bolting silk plankton net (Griffin) and collections were made in triplicate. Plankton samples for qualitative analysis were obtained by placing the net below the water surface (20cm) and the net towed horizontally for 5 minutes until a sufficient quantity of plankton was collected and filling into airtight well labeled 120ml plastic bottles. The sample was fixed for preservation within 5 minutes of collection with 4% formaldehyde solution and taken to the laboratory for analysis.

2.4 Statistical analysis

2.4.1 Data transformation: All the raw data was appropriately transformed to address the normality and homocedasticity requirements of the parametric analysis (Ogbeibu, 2005). Statistical Package for Social Sciences (SPSS) Data Editor was used to compute all measures of central tendencies and dispersion, to characterize the stations in terms of the physico-chemical conditions and fauna abundance, using one way analysis of variance (ANOVA) and the graphics were computed with Microsoft Excel. The biotic community was analysed using diversity and similarity indices adopted from Ludwig and Reynolds, 1988.

2.4.2 Community structure assessment

Shannon – Wiener index of diversity was expressed as:

$H_s = \sum Ni/N \log_e Ni/N$ (Shannon and Wiener, 1963)

Where:

Hs = Shannon – Wiener diversity index

N= total number of individuals in the sample

Ni = the number of individuals in species I in the sample

The principle is that disturbance of the aquatic ecosystem or communities under stress leads to a reduction in diversity. Advantages of diversity indices in biomonitoring include their easiness to use and calculate, and their applicability to all kinds of water courses with no geographical limitations.

3. Results

The result of concentrations of the physico-chemical parameters in the three stations is shown in Tables 1, 2 and 3. There was a spatial variation in the levels of physico-chemical concentrations in Mbo River. The result indicates that certain environmental factors such as biochemical oxygen demand, pH, sulphite, total suspended solids and NH_4 were not significantly different among the stations in the river during the study period. On the other hand, other parameters such as water level, current velocity, Air temperature, transparency, total hydrocarbons (THC), total dissolved solids (TDS), and total solids (TS) were significantly different (P=<0.001) in all the stations.

3.2 Zooplankton community structure

A total of 45 species of zooplankton in eight (8) taxonomic groups were collected. Of this total, Crustacea was present with the highest percentage of 48.0% in the total zooplankton composition in Station I. In the other two stations, Crustaceans did not dominate as in the first station but rather contribured 30.0% and 33.3% in Stations II and III respectively. Other taxonomic groups present in this study include Rotifera which contributed to 20.0%, 50.0% and 55.6% in Stations I, II and III, respectively. Mollusca in Station I contributed to 8.0% of the species composition in this station but was absent in Stations II and III. Protozoa which contributed to 9.1% of the total zooplankton composition in Station I was not recorded in the other two stations. A total percentage of 10.0% and 11.1% was recorded for Ciliates in Stations II and III (Fig.2). These were absent in Station I. Polycheat and Chordata contributed to the percentage composition (4.0% each) only in Station I. Cladocera was scantly recorded in Station II with a percentage contribution of 10.0% of the zooplankton community in this station.

In respect to the different stations, Station I had a higher species richness number (25 species) than Station II (10 species) and Station III (9 species). Therefore, Station I made up 56.8% of the species richness, followed distantly by Station II with 22.7% and Station III with 20.5%.

The analysis of variance (ANOVA) on the total density or abundance of zooplankton shows that the sampling periods (twice a month) were not significantly different. This means that there was no bias in the sampling periods and that the sampling was homogeneous.

The mean total density in Station I is significantly different (P=<0.03) from that of Stations II and III (Table 4). It could thus be surmised that in respect to zooplankton density, the variation in data collected was due to samples collected from Station I. Table 4 also shows that the highest density for zooplankton was recorded in Station I (202.50 cells/l) while the least was recorded in Station II (149.75 cells/l).

In relation to the monthly density of zooplankton (Table 6), the highest density was recorded in September (40.5 cells/l) and the least density was observed in February (22.0cells/l). Zooplankton density in September was significantly different (P=<0.0001) from that of the other months during the sampling period, surmising that the variation in data collected was due to September's abundance.

The results of least significant difference on the seasonal variation in zooplankton density showed that the variation between the two seasons were significantly different from each other (P=0.001) (Table 5). The mean in the dry season was 44.6% less than that of the wet season. This shows that there is a seasonal impact on the zooplankton density.

3.3 Diversity (Shannon-Weinner Index)

The highest diversity index of 2.79 was recorded in the month of September in Station I and the least of 0.93 was recorded in July in Station III (Fig.4). Station I recorded the highest diversity value in all the months of the year with the smallest value of 1.98 recorded in March. In March and April, Station III showed the higher values in diversity index than Station II. Station II on the other hand, had higher Shannon-weinner index values from May to February than station III.

In respect to zooplankton in the surface water of Mbo River, Station I had higher diversity in the wet season (3.02) than in the dry season (2.69) (fig 3). The index was slightly higher in the dry season in Station II (1.64) than in the wet season (1.64). Station III had higher diversity index in the dry season (1.51) than in the wet season (1.46). It could thus be deduced from this study that in the surface waters of Mbo River, zooplankton had higher diversity, that is, more different species in the dry season than in the wet season in Stations II and III. On the other hand, Station I had higher diversity during the months of rainfall than in the dry season.

3.4 Seasonal effect of physico-chemical parameters on zooplankton density

The result of the correlation between the zooplankton density and physico-chemical parameters (Table 7) show a variance in r values between the seasons. The r values in the dry season for color (r=-0.52; p=0.05) and total suspended solids (r=-0.55; p=0.04) show a significant and negative correlation between zooplankton density with these variables. This implies that an increase in the values of these parameters resulted in a decrease in zooplankton density during the dry season. The r value for the correlation of zooplankton density with total dissolved solids showed a good positive and significant correlation (r=0.52; P=0.05). It could be deduced from this positive correlation that an increase in the level of total dissolved solids in the water invariably resulted in an increase in the density of zooplanktonton. From the table also, it is observed that there was no significant correlation between the density of zooplankton and all other physico-chemical variables in the dry season during the sampling period.

On the other hand, in the wet season, some other parameters were also relevant to the abundance of zooplankton (Table 7). During the wet season, water level had a good significant but negative correlation with zooplankton density (r=-0.51; P=02). This shows that a rise in water level during the rains resulted in a decrease in zooplankton density. This also applied to the level of pH in the river water. Contrary to this, an increase in air temperature (r=0.45; P=0.04) during the rains led to an increase in zooplankton density. Likewise an increase in dissolved oxygen (r=0.51; P=0.02), THC (r=0.72; P=0.0002), TDS (r=0.49; P=0.02) and TS (r=0.62; P=0.003) showed a strong correlation with zooplankton density resulting in an increase in zooplankton density during the rains.

3.5 Seasonal influence of nutrient variables on density of zooplankton

Result of the Pierson's correlation between zooplankton density and some nutrients showed some seasonal variations (Table 8). During the dry season NH_4 had a strong correlations (r=0.55; P=0.03) with zooplankton resulting in an increase in the density. Regarding sulphate, there was a significant but negatively strong correlation with zooplankton density (r=0.59; P=0.02) implying that an increase in sulphate led to an invariable decrease in the density. In the wet season, nitrate-nitrogen (r=0.54; P=0.01) and nitrite-nitrogen (r=0.47; P=0.03) were important to the zooplankton density showing a positive and significant relationship with the density. This implies that an increase in nitrate-nitrogen and nitrite-nitrogen during the rains resulted in a slight increase in the density of zooplankton.

3.6 Zooplankton diversity (Shannon-Weinner index) correlated with physico-chemical parameters by season

In the dry season, it was observed that zooplankton diversity correlated significantly with water level (r=0.61; P=0.02) only (Table 6). This implies that an increase in water led to a decrease in the diversity of zooplankton. During the wet season, zooplankton diversity correlated significantly with water level (r=-0.51; P=0.02). Current velocity (r=0.61; P=0.0003), pH (r=0.45; P=0.04),total hydrocarbon (r=0.68; P=0.0007). By this correlation, it means that an increase in the current velocity, pH and total hydrocarbons resulted in an increase in zooplankton diversity.

3.7 Correlation of rainfall with total density of zooplankton

The correlation between rainfall and zooplankton density though a fair one, was not significant (r=0.30; P=0.08). This is an indication that the unset of the rains tends to have no significant effect on zooplankton density.

4. Discussion

Biogeographical and seasonal differences strongly influence the distribution pattern and constituents of aquatic communities. Because of their dynamic physical nature, the physical and chemical variables, floral and faunal composition of an estuary may vary considerably at spatial scales of metres to kilometers, and temporal scales of days to years (Morisey *et al,* 1992).

As observed (Table 2) zookplankton density was highest in September. This could be attributed to the high values of phosphate and nitrates which had been recorded in this river for that month (Essien-Ibok *et al*, 2010). High concentrations of these nutrient elements usually give rise to high abundance of some zooplankton species in aquatic environments (Adesalu *et al,* 2010; Nwankwo, 2004). Similar regime has also been observed by some workers (Balogun, 2010; Schaefer and Alber, 2007) where they reported that zooplankton are favoured in nutrient rich environments particularly estuaries.

The assessment of community and ecosystem stability using overall diversity showed Station I as the most complex and stable station. The overall diversity may be the product of all spatial and temporal changes affecting the community (Ogbeibu and Oribhabor, 2001).

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The correlation of zooplankton density with physical and chemical parameters of Mbo River, showed that zooplankton density had its strongest correlation with total hydrocarbons (r=0.72) in the wet season. This could be linked to the species of zooplankton in Mbo River which might have adapted to total hydrocarbons in the water.

The strong correlation of zooplankton density with dissolved oxygen (r=0.51) in the wet season shows that this organisms are more dependent on dissolved oxygen during the wet season, therefore, an increase in dissolved oxygen during this season increases their density. This could be attributed to the washing in of organic load by the rains. This assertion is in agreement with Adesalu *et al* (2010) who noted that an increase in rainfall increases the biochemical oxygen demand and chemical oxygen demand of an aquatic system.

Also worthy of note is the positive correlation between total dissolved solids and zooplankton density in the two seasons. TDS is basically used to define the total ions in solution in the water (Waziri and Ogugbuaga, 2010). It could, therefore, be implied from this positive correlation in the two seasons that an increase in the total ions in solution increases the density of zooplankton. This observation was also reported by Van de Velde (1978) who noted that salts like magnesium and calcium promotes zooplankton growth. Water level rise in the rainy season also decreased zooplankton density as observed by their negative correlation during this season. This is due to the pressure impacted on the cells by the water level. This reduction in density of zooplankton with water level is in accordance with the report of Yakubu (2004) who noted that filling out the river channel results in increase in volume of water flowing through the channel thus affecting the concentration of zooplankton. From the canonical ordination diagram, there is a strong correlation between water level, biochemical oxygen demand, chemical oxygen demand, total suspended, alkalinity and rainfall. This indicates that the major source of organic pollution in Mbo River is through surface run-off. This shows that the source of contamination is washed in with the rains, therefore, organic pollution increases with the rains. This is true of tropical rain forest rivers (Welcomme, 1985).

5. Conclusion

This shows that there is a seasonal impact on the zooplankton density. Zooplankton abundance in this study was associated with the seasonal fluctuations in the some physical and chemical factors of the river such as water level, dissolved oxygen, pH, total hydrocarbons and nutrients.

The positive correlation between dissolved oxygen and zooplankton density in the wet season is a good indication of increased organic load in the surface water during the rains.

6. Acknowledgement

We are grateful to Education Trust Fund (Nigeria) and the University of Uyo, Nigeria for sponsoring part of the grant for this work. We acknowledge the help and contributions of Prof. (Mrs) C. Onuoha of the Department of Fisheries and Aquatic Resources Management, Michael Okpara University of Agriculture, Umudike and Prof. A. W. Akpan of the Hydrobiological Unit, Department of Zoology, University of Uyo. We are also acknowledge Mr. Inyang of the Department of Zoology for his assistance in the field sampling throughout this research.

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BIOGRAPHY

MANDU ESSIEN-IBOK (PH.D)

Mandu Essien-Ibok (Ph.D) was born in Calabar on June 17th, 1969. She acquired B.Sc. (Fisherie) in 1998 and M.Sc. (Fisheries/Hydrobiology) in 2008 both from the University of Uyo, Uyo. Mandu Essien-Ibok holds a Ph.D Hydrobiology/Fisheries (2012) from Michael Okpara University of Agriculture, Umudike, Nigeria. She got into the University of Uyo as Graduate in the Department of Fisheries and Aquaculture and presently holds the position of Lecturer II. Her publications include 1) Seasonality in Physical and Chemical Charateristics of Mbo River, Akwa Ibom State, Nigeria. Nigerian Journal of Agriculture, Food and Environment. Vol 3, 2010.2) Microinvertebrate Composition Structure of a tropical rainforest pond in uyo, Nigeria. International Journal of Chemical, Environmental and Pharmaceutical Research. Vol 15, 2011. She is currently research on characterizing the estuaries in Akwa Ibom State using bioassessment methods and was previously researching on Hydrobiology and Water Quality of Mbo River, Akwa Ibom State, South East Nigeria. Dr. (Mrs) Essien-Ibok is member of the following societies: Fisheries Society of Nigeria (FISON), Nigerian Biological Conservation

Society (NBSC), Association for Aquatic Sciences of Nigeria (AASN), Association for Prompting African Girls in Engineering Science and Technology Education (APAGESTE), International network of Women in Science and Engineering (INWES).

DR. (MRS) IMAOBONG E. EKPO

Dr. (Mrs) Imaobong E. Ekpo, who obtained her B.Sc. and M.Sc. from University of Uyo and Ph.D from Michael Okpara University of Agriculture is a lecturer and research environmental scientist in the Department of Fisheries and Aquatic Environmental Management, Faculty of Agriculture, University of Uyo, Uyo in Nigeria. Her research interest is in the areas of hydrobiology, fisheries and biodiversity.

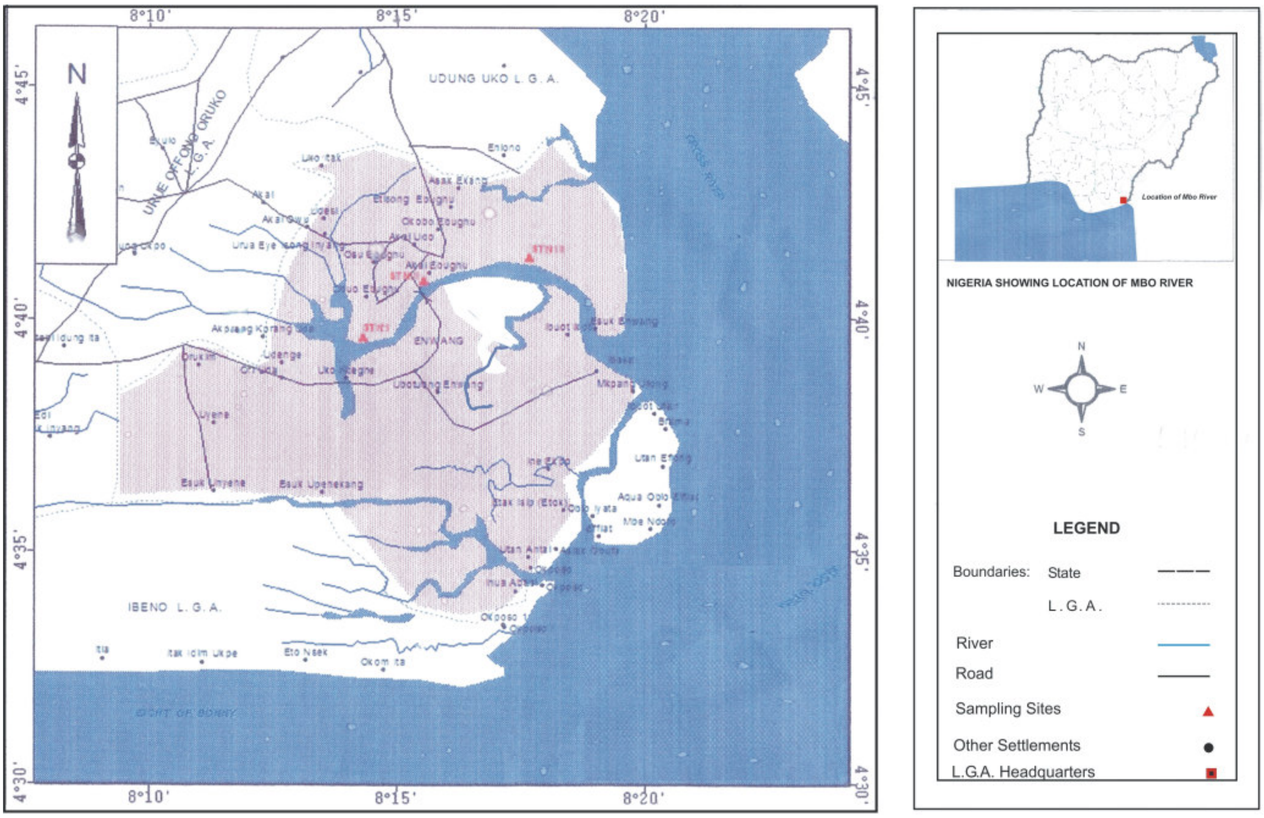


Fig. 1: **Mbo River showing Sampling Sites**
Source: Department of Geography & Regional Planning, University of Uyo, Uyo.

Table 1: Means and standard deviation of physico-chemical parameters of Mbo River

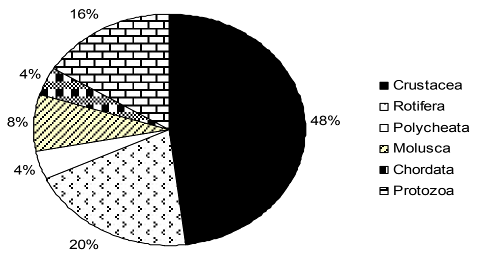
	STATION 1	STATION 2	STATION 3
Parameters			
Water Level (m)	5.66±6.83	3.81±0.71	50.41±0.92
Current velocity ($CmSec^{-1}$)	50.89±3.20	49.67±6.85	39.51±2.03
Color (NTU)	56.12±4.89	52.89±4.57	58.39±5.16
Air Temperature (^{0}C)	30.95±2.16	30.81±1.65	30.67±1.97
Dissolved Oxygen (mgL^{-1})	7.70±0.61	7.40±0.57	7.40±0.72
Biochemical Oxygen Demand(mgL^{-1})	2.80±0.36	2.85±0.28	2.82±0.25
Alkalinity(mgL^{-1})	24.24±3.23	24.09±4.53	25.58±3.84
pH	6.75±0.07	6.76±0.18	6.73±0.18
Water Temperature (^{0}C)	28.13±1.34	28.13±1.23	27.53±0.92
Conductivity (μScm^{-1})	166.12±5.20	165.46±5.09	165.37±4.85
Transparency (cm)	58.58±5.18	65.31±30.96	53.26±0.70
Chemical Oxygen Demand (mgL^{-1})	2.59±0.13	2.55±0.12	2.56±0.13
Nitrate-Nitrogen (μgl^{-1})	318.08±9.12	309.33±15.95	308.20±17.17
Nitrite-Nitrogen(μgl^{-1})	2.03±0.08	20.64±62.96	1.99±0.17
Phosphate-Phosphorus(μgl^{-1})	52.66±2.79	54.01±2.66	54.15±2.69
Sulphite (mgL^{-1})	5.85±7.98	4.25±0.26	4.21±0.24
NH_4 - N(μgl^{-1})	1.53±0.49	1.55±0.48	1.55±0.46
Sulphate (mgL^{-1})	7.53±0.60	6.56±2.47	7.68±0.59
Total hydrocarbon(mgL^{-1})	3.62±1.18	2.80±0.21	2.66±0.23
Total Suspended Solids (mgL^{-1})	0.71±0.21	0.71±0.21	0.70±0.21
Total Dissolved Solids(mgL^{-1})	0.99±0.28	0.92±0.30	0.95±0.29
Total Solids(mgL^{-1})	1.7±0.08	1.67±0.08	1.65±0.09

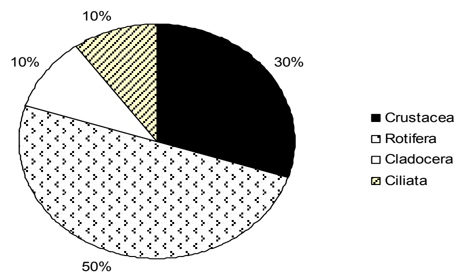
Table 2: Physico-chemical variables of Mbo River (dry season)

Variables	Mean and Standard Deviation	Minimum	Maximum
Water level	4.55±0.99	2.85	6.15
Current velocity	49.36±7.72	36.05	60.65
Color	58.09±4.67	50.75	64.99
Air temperature	30.28±1.63	27.45	32.75
Dissolved oxygen	7.39±0.56	6.03	8.05
Biochemical O_2 Demand	2.91±0.20	2.44	3.22
Alkalinity	27.06±2.24	23.75	31.90
pH	6.80±0.18	6.59	7.25
Water temperature	27.63±1.16	26.15	30.45
Conductivity	166.59±5.95	158.50	176.55
Transparency	57.64±6.40	47.27	70.05
Chemical O_2 Demand	2.66±0.11	2.48	2.80
Nitrate – Nitrogen	313±17.29	276.5	337.00
Nitrate – Nitrogen	1.87±0.11	1.70	2.21
Phosphate-Phosphorous	50.84±1.44	48.30	52.95
SO_3	3.98±0.18	3.59	4.25
NH_4	1.56±0.50	1.05	2.38
Sulphate	7.65±0.74	6.38	8.93
Total Hydrocarbons	2.82±0.16	2.60	3.13
Total Suspended Solids	0.72±0.24	0.36	0.99
Total Dissolved Solids	0.95±0.32	0.59	1.44
Total Solids	1.67±0.09	1.53	1.79
Eindex	38.66±10.59	25.97	62.06
Rainfall	112.16±62.37	44.80	215.20

Table 3: Physico-chemical variables of Mbo River(wet season)

Variable	Mean	Standard Deviation	Minimum	Maximum
Water level	4.06	1.28	2.05	6.65
Current velocity	44.78	5.58	36.05	55.25
Colour	54.17	5.32	43.55	64.15
Air temperature	31.19	2.07	27.15	34.15
DO	7.58	0.65	6.19	8.48
BOD	2.76	0.32	2.20	3.19
Alkalinity	22.90	3.85	18.00	32.30
pH	6.71	0.11	6.50	6.83
Temperature	28.14	1.18	25.65	30.15
Conductivity	164.97	4.26	160.9	175.70
Transparency	55.29	7.10	40.05	66.15
COD	2.50	0.09	2.38	2.67
NO_3	311.02	13.25	284.00	324.00
NO_2	2.15	0.08	2.02	2.29
PO_4	55.58	1.39	50.50	56.90
SO_3	5.33	4.24	4.15	23.85
NH_4	1.53	0.44	1.04	2.18
Sulphate	6.97	1.92	2.48	9.20
THC	3.18	1.04	2.40	6.10
TSS	0.69	0.18	0.49	0.96
TDS	0.96	0.28	0.57	1.33
TS	1.68	0.09	1.50	1.81
Eindex	42.20	16.59	5.98	80.44
Rainfall	602.50	233.01	289.80	947.10





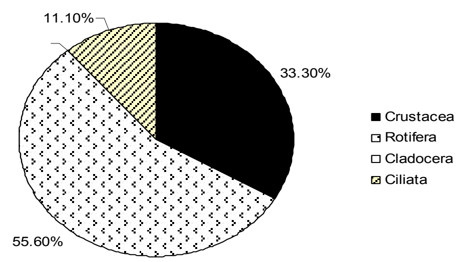


Fig. 2: Richness of zooplankton in the three sampling stations in Mbo River (Station I=a, Station II=b Station III=c)

TABLE 4: Seasonal Variation in zooplankton density (individuals/l) in the two seasons

Season	Mean density
Wet	220.00[a] (107.51)[a]
Dry	121.83[b] (61.94)[b]
LSD	27.03 (9.32)
P	0.001 (0.0006)

*Means with same letters show no significant difference

Table 5: Effect of different sampling months on zooplankton density

Months	Zooplankton
August	33.8[b] (16.3)[b]
September	40.5[a] (19.3)[a]
October	34.0[b] (16.6)[b]
November	27.7[d] (14.0)[de]
December	25.0[e] (12.7)[fg]
January	23.8[ef] (11.9)[gh]
February	22.0[f] (11.7)[h]
March	23.3[ef] (11.7)[gh]
April	23.0[ef] (11.8)[gh]
May	28.8[cd] (14.9)[cd]
June	28.8[cd] (15.1)[c]
July	31.0[c] (13.5)[fe]
LSD	2.58(0.96)
P	<0.0001 (<0.0001)

* Means with the same letters are not significantly difference
* Values in parenthesis represent means of transformed data

Table 6: Spatial Variation in the density of zooplankton in the study sites in Mbo River

Station	Mean zooplankton density
I	202.50[a] (114.12)[a]
II	149.75[b] (70.63)[b]
III	160.50[b] (69.42)[b]
LSD	33.11 (11.42)
P	0.03 (0.002)

*Means with same letters are not significantly different
*Figure in parenthesis represent transformed data means

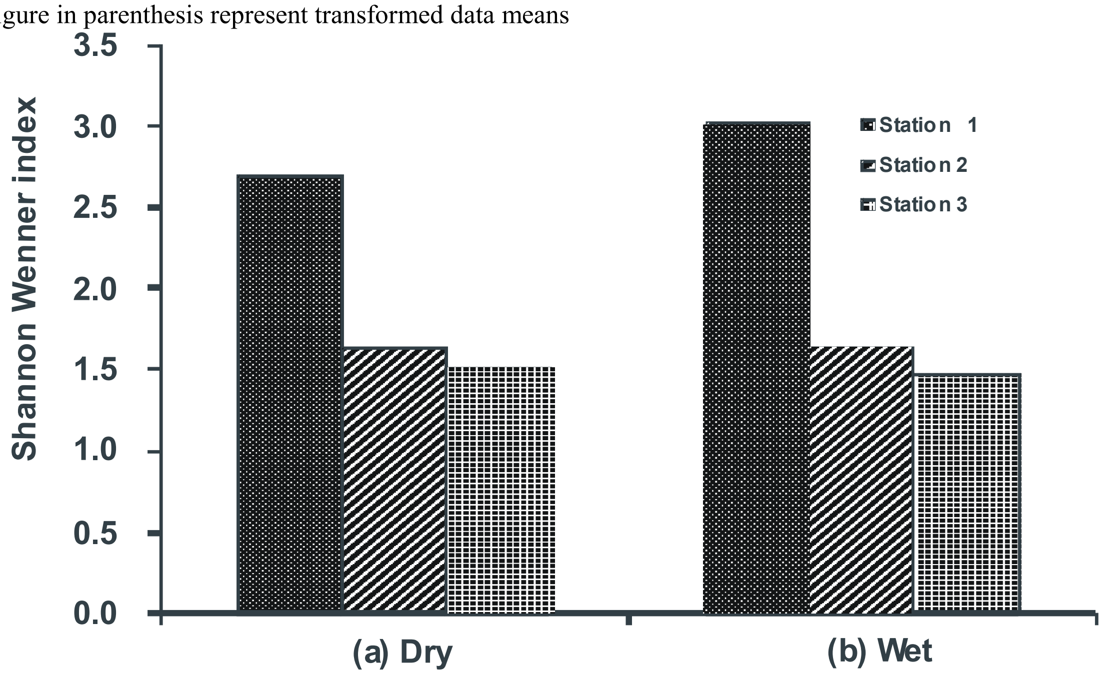


Fig. 3: Seasonal variation in zooplankton diversity in the two seasons (a) Dry (b) Wet

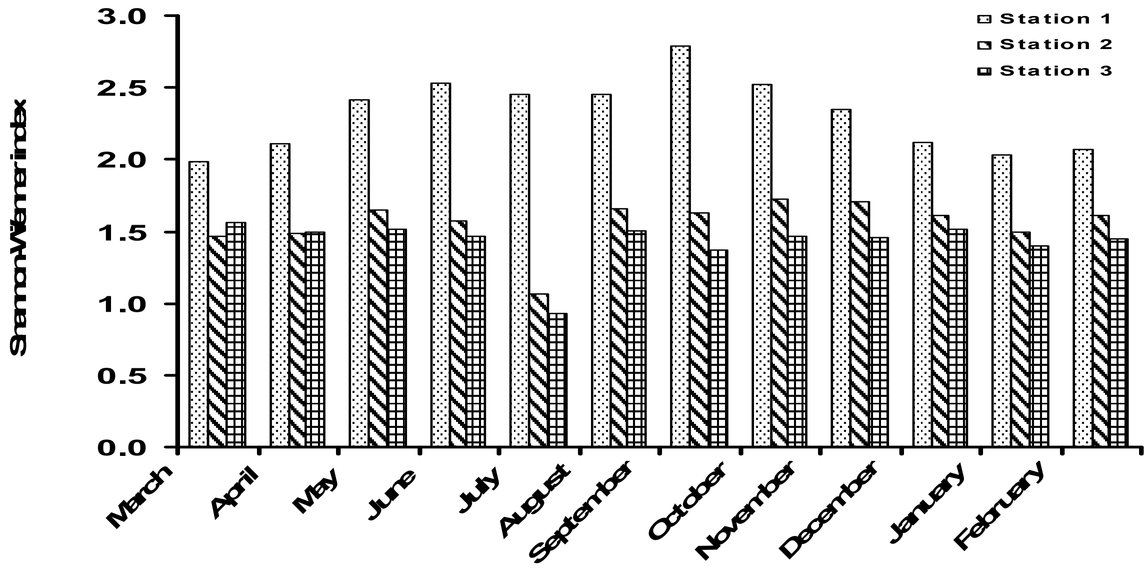


Fig 4: Monthly variation in zooplankton diversity in Mbo River (December, 2009-November, 2010)

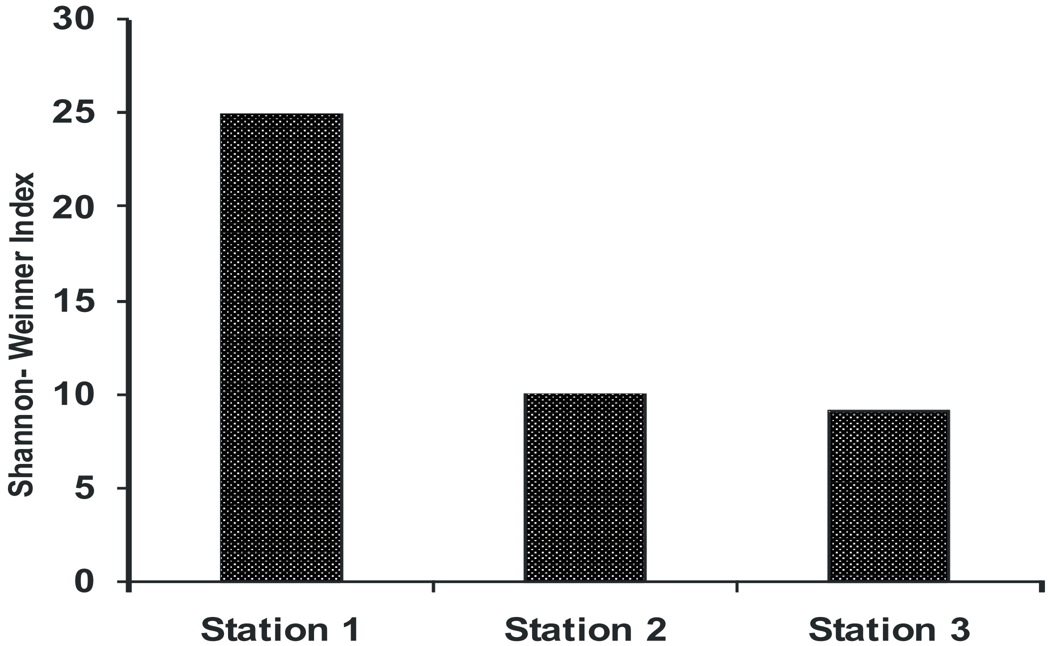


Fig. 5: Spatial variation in zooplankton diversity in Mbo River (December, 2009-November, 2010)

TABLE 7: The correlation coefficient for the seasonal relationship between zooplankton density and physico-chemical variables (r) coefficients

Variable	Dry	Wet
Water level (m)	0.09 (0.76)	-0.51 (0.02)
Current Velocity (CmSec^{-1})	-0.43 (0.1)	0.32 (0.16)
Color (NTU)	-0.52 (0.05)	-0.22 (0.34)
Air temperature (^{0}C)	0.36 (0.19)	0.45 (0.04)
Dissolved Oxygen (mgl^{-1})	0.26 (0.31)	0.51 (0.02)
Biochemical Oxygen Demand (mgl^{-1})	-0.21 (0.45)	-0.19 (0.40)
Alkalinity (mgl^{-1})	-0.41 (0.12)	-0.25 (0.27)
Ph	-0.06 (0.84)	-0.43 (0.05)
Water temperature (^{0}C)	-0.14 (0.61)	0.02 (0.92)
Conductivity (Scm^{-1})	0.48 (0.07)	0.27 (0.22)
Transparency (cm)	-0.02 (0.95)	0.05 (0.82)
Chemical Oxygen Demand (mgl^{-1})	-0.30 (0.3)	0.09 (0.68)
Total hydrocarbon(mgl^{-1})	-0.30 (0.28)	0.72 (0.0002)
Total Suspended Solids(mgl^{-1})	-0.55 (0.04)	-0.37 (0.10)
Total Dissolved Solids(mgl^{-1})	0.52 (0.05)	0.49 (0.02)
Total Solids(mgl^{-1})	0.39 (0.15)	0.62 (0.003)
Rainfall (mm)	0.13 (0.64)	-0.06 (0.81)

TABLE 8: The correlation coefficients (*r*) between zooplankton density and nutrient variables. Values in parenthesis indicate levels of significance

Nutrient Variables	Dry	Wet
Nitrate-Nitrogen(gl^{-1})	0.39 (0.15)	0.54 (0.01)
Nitrite-Nitrogen(gl^{-1})	-0.21 (0.46)	0.47 (0.03)
Phosphate-Phosphorus(gl^{-1})	0.38 (0.26)	0.02 (0.93)
Sulphate	0.31 (0.26)	0.12 (0.61)
NH_4 – N (gl^{-1})	0.55 (0.03)	0.36 (0.10)