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PLANKTON ABUNDANCE AND DIVERSITY AS RELATED TO SEASONAL VARIATIONS IN PHYSICO-CHEMICAL PARAMETERS OF RIVER ETHIOPE, NIGERIA

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Abstract

The abundance and diversity of plankton in relation to the physico-chemical parameters of River Ethiope was investigated over nine stations of the river to determine the extent of water quality for fish production. Plankton abundance data from the study stations show that phytoplankton were more in number than zooplankton. During the rainy and dry seasons, phytoplankton species of the Phylum Chlorophyta comprising Chlamydomonas, Cladophora, Pediastrum, Selenastrum, Spirogyra, Ulothrix and Volvox dominated the phytoplankton population with 40.63% and 47.18% seasonal abundance respectively. Zooplankton of the Phylum Arthropoda was more abundant in the rainy (28.01%) and dry (32.73%) seasons respectively. Plankton species diversity indices show that phytoplankton were richer in the dry season than in the rainy season with higher values in Station I in both seasons while zooplankton were richer in Stations IV and VI in the rainy and dry seasons respectively. However, values were not significantly different (P>0.05) among the stations. A significant (P<0.05) negative correlation was observed for phytoplankton with calcium, and with depth during the rains. Magnesium correlated positively with zooplankton (P<0.05) also during the rains. No significant (P>0.05) correlation was recorded between plankton and physico-chemical parameters during the dry periods. The study findings indicate that plankton abundance and diversity were influenced by seasonal changes in the physico-chemical parameters of Ethiope River. The findings also provide other vital information suggesting that plankton abundance and diversity may be used as indices of water quality assessment for increased fish production.

Keywords: Plankton, abundance, diversity, physico-chemical parameters, Ethiope River.

Introduction

Plankton are diverse groups of organisms that drift passively on water surface and live in water column of large bodies of water being incapable of swimming against the current. Plankton may be plant-like organisms, called phytoplankton or animal-like organisms, called zooplankton. Phytoplankton are single-celled photosynthetic bacteria and microalgae while the zooplankton are animals that graze the phytoplankton.

Plankton are a food source for many aquatic organism and in fact are the base of any aquatic food chain. The plankton not only increases fish production but also help in bioremediation of heavy metals and other toxic materials. Bahura (2004) reported that the number and species of phytoplankton serves to determine the quality of a water body. Plankton can also act as biomarker for water quality assessment for fish production (Arunava *et al*., 2008). Phytoplankton serves as indicator organism of water type, fish yield and total biological production (Webber and Wilson- Kelly, 2003; Anen and Hassan, 2003). Zooplankton species assemblage may also be useful in accessing water quality. Zooplanktons play important role in indicating the water quality, eutrophication status and productivity of a freshwater body

(Mikschi, 1989). Zooplankton play a key role as efficient filter feeders on phytoplankton and as a source for other invertebrates such as fish larvae and fish (Deksne *et al*., 2011).

It has been observed that plankton abundance and distribution is dependent on the nutrient concentration, the physical state of the water and the abundance of other plankton. Arimoro and Ikomi (2008) suggest that the physico-chemical parameters of an aquatic eco-system are very important in assessing the composition of phytoplankton and also their sensitivity to pollution. This indicates that the study on physical and chemical parameters is paramount as the base of plankton abundance and diversity. According to Robeston and Bladder (1992), the productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers. Variations in some of the physical and chemical parameters have been reported to influence phytoplankton abundance (Ghousal *et al.,* 2000).

The ability of a river to stabilize in all physico-chemical parameters and plankton abundance is very important as it helps in aquatic productivity in the ecosystem. There is therefore a need to identify the different species of plankton, their abundance and how they relate with the physico-chemical parameter of River Ethiope.

Materials and Methods

Study Area

River Ethiope is located in the western part of Delta State of Nigeria and is situated between Latitude 5.53^o and 6.05^o North and Longitude 5.30^o and 6.05^o East (Okumagba and Ozabor, 2014). River Ethiope is a body of running crystal clear water which originated from the foot of a giant silk-cotton tree at Umuaja in Ukwuani Local Government Area (LGA), Delta State, and flows westerly over 88km through several towns before joining River Benin at Sapele (Oronsanye and Nakpodia, 2005). River Ethiope is one of the two main tributaries of Benin River, the other being the Jamieson River. The river is shared by four local government councils namely Ukwuani, Ethiope East, Okpe and Sapele (Irikkefe, 2013). River Ethiope is about 8.3meters wide and 14.8m deep with mean substratum being mainly fine sand mixed with clay (Igboekwe *et al.* 2005). The area falls within the equatorial climatic belt of the world and tropical rainforest belt of Nigeria with mean temperature of 30^{0}C. The area experiences heavy and torrential rainfall throughout the year. The annual rainfall amounts to 3,098mm with mean monthly rainfall ranging from 25.8mm in December to 628.9mm in September (Efe, 2003). The river serves for recreational purpose as well as other human activities.

Stream Sections and Stations

The sampling area was divided into three: up-stream, mid-stream and down-stream. Up- stream (Umuaja) had three stations namely: Umuaja, Umutu and Obiaruku in Ukwani LGA, representing Stations I, II and III. Mid-stream (Abraka) also had three stations namely: Urhoka (McCathy Beach), Ekrejeta (Resort Beach) and Abraka (Mudi Beach) in Ethiope East LGA, representing Stations IV, V and VI while down-stream, made up of three stations were Amukpe, Okoloko and Puntu in Sapele LGA, representing Stations VII, VIII and IX.

Collection of Samples

Water samples for plankton study and physico-chemical parameters were collected once monthly between the hours of 7.00 and 10.00 every morning on sampling days from April, 2014 to March, 2015. Plankton were harvested by horizontal tows with 0.075µ mesh size bolting silk plankton net at a depth of 25 cm. The collected samples were stored in 10% buffered formalin. Samples were decanted to remove the supernatant. Fresh clean water was added to the sediment and centrifuged. The supernatant was again decanted and fresh water added to make up to10 ml in the centrifuge tube which was agitated and 1 ml of subsample pipetted onto the counting chamber (Neubauer haemacytometer, Marienfeld) for quantitative estimation of species of plankton by examining fraction of each sample under the microscope. Plankton were identified to generic level as much as possible and enumerated by binocular microscopy (x 100 magnification) according to Boyd and Lichtkoppler (1979).

Number of plankton/ml = (T x 1000) ÷ (NA x V);

Where:

T = total number of algae counted

N= number of grid counted

A= area of grid in mm^2

1000 = area of counting chamber in mm^2.

V= volume of concentrate in ml/vol. of sample.

Planktons collected were identified using a microscope with monographs as guide (Kemdirim, 2001; Robert, 2003).

Species richness and diversity were calculated using Margalef's, Shannon-Weiner and Evenness indices given by the following formulae respectively (Shannon-Weiner, 1963):

$$\text{Margalef's Index (d)} = \frac{S-1}{\text{In (N)}}$$

where S = Total number of species

N = Total number of individuals

In = Natural logarithm ($\log_e$)

$$\text{Shannon-Weiner Diversity Index (H)} = \frac{N \log N - \sum_{i=1}^{s} ni \log ni}{N}$$

where H = Shannon-Weiner Index of diversity

n_i = Total number of individuals of a species

N = Total number of individuals of all species

$$\text{Evenness (E)} = \frac{H}{H_{max}}$$

where H = Shannon-Weiner Diversity Index

H_{max} = Maximum diversity

Water samples were collected using 250 ml corked bottles which were immediately transported to the Faculty of Agriculture Research Laboratory for analysis. Some physical parameters determined on site were temperature of water using insulated metal bucket, turbidity by secchi disc, depth using weighted graduated rope and current (speed of water) by a timed floater. Total dissolved solid (TDS) was determined gravimetrically by evaporating a known volume of water to dryness in a pre-weighed crucible on a steam bath.

Chemical parameters determined were pH, dissolved oxygen (DO), biological oxygen demand (B.O.D), chemical oxygen demand (C.O.D), total alkalinity, total dissolved solids, magnesium, phosphate, calcium, nitrate and phosphate according to methods by APHA (1989, 1995).

Statistical Analysis

The data obtained were subjected to descriptive statistics, Student's t test, Pearson correlation analysis, while the treatment mean comparison was carried out using analysis of variance (ANOVA) and significantly different were separated using the Duncan’s Multiple Range Test (DMRT).

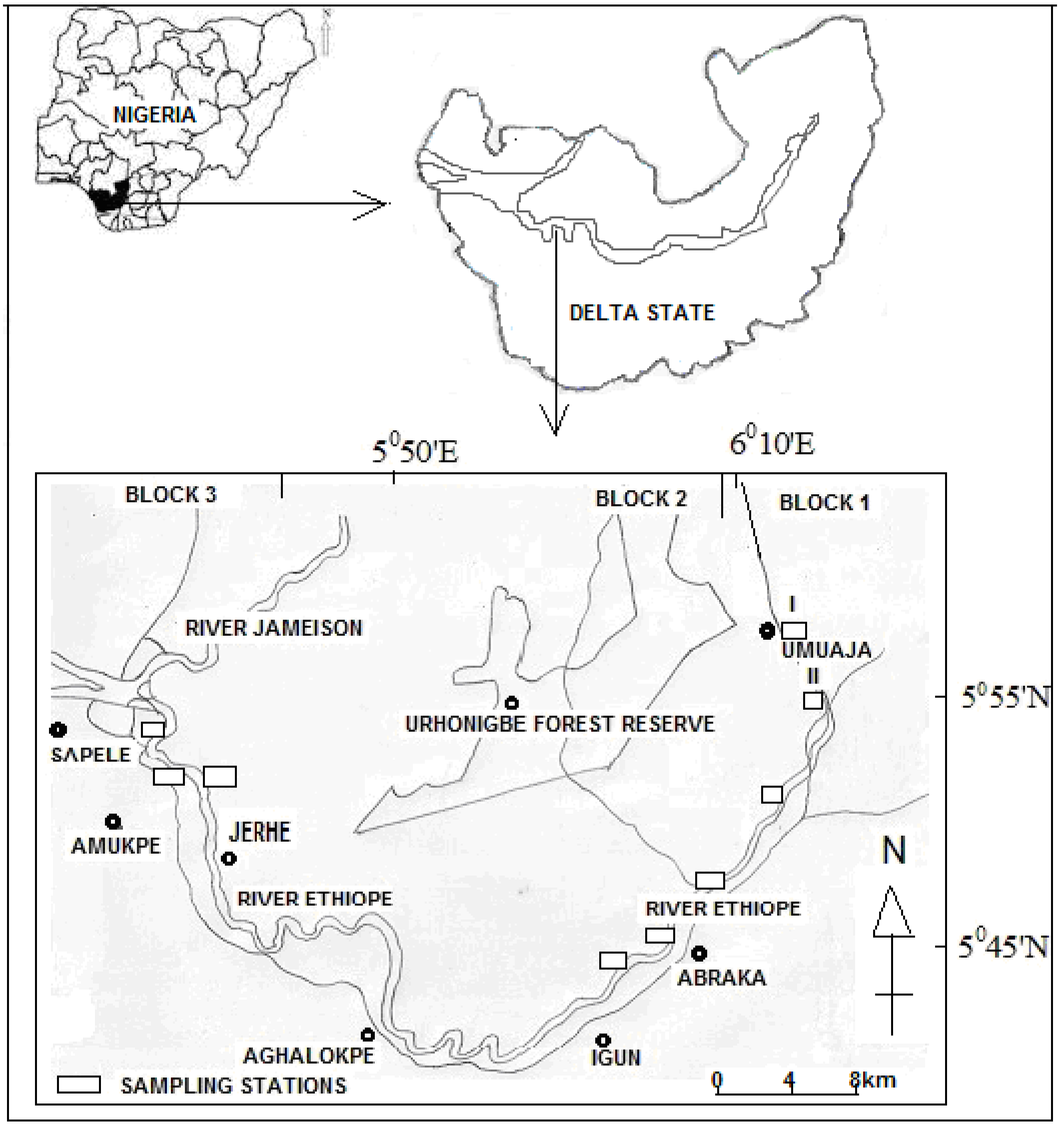

Figure 1: Map of Delta State, Nigeria, showing sampling stations along River Ethiope.

Results

Seasonal variations in phytoplankton and zooplankton abundance are presented in Tables 1 and 2. Plankton abundance distribution in the nine stations shows that phytoplankton were more in number than zooplankton. During the rainy and dry seasons, phytoplankton species of the Phylum Chlorophyta comprising *Chlamydomonas*, *Cladophora*, *Pediastrum*, *Selenastrum*, *Spirogyra*, *Ulothrix* and *Volvox* dominated the phytoplankton population with 40.63% and 47.18% abundance respectively. Zooplankton of the Phylum Arthropoda was more abundant in the rainy (28.01%) and dry (32.73%) seasons respectively. Stations I and VI had more phytoplankton and zooplankton in the rainy while Stations VIII and IV had the highest number of phytoplankton and zooplankton in the dry season.

Table 1: Plankton Abundance (individuals/ml) in the Sampling Stations along River Ethiope during the Rainy Season

Taxa/Phylum	Study Stations									
	I	II	III	IV	V	VI	VII	VIII	IX	
Phytoplankton										Total (%)
Bacillariophyta	56	18	5	36	3	0	59	21	31	229 (31.11)
Chlorophyta	64	106	37	17	12	28	0	35	0	299 (40.63)
Ciliophora	8	0	9	7	1	0	0	0	0	25 (3.39)
Cyanophyta	0	3	0	13	27	17	0	0	0	60 (8.15)
Dinoflagellata	7	0	0	1	0	7	4	0	7	19 (2.58)
Euglenophyta	15	13	0	29	0	0	0	0	0	42 (5.71)
Heterokontophyta	7	13	0	0	0	0	17	7	3	47 (6.38)
Total	157	153	51	103	43	52	80	56	41	736
Zooplankton										
Protozoa	0	0	0	18	1	2	0	0	0	21 (6.84)
Phoronida	0	0	0	1	2	8	0	0	0	11 (3.58)
Rotifera	0	0	0	14	13	16	0	0	0	43 (14.01)
Cnidaria	0	0	0	2	5	5	0	0	0	12 (3.91)
Arthropoda	0	19	8	16	10	15	13	3	2	86 (28.01)
Calanioda	0	0	0	0	0	0	4	2	0	6 (1.95)
Cyclopoida	0	0	0	9	0	0	6	4	2	27 (8.79)
Annelida	0	0	0	2	8	13	0	0	0	23 (7.49)
Tardigrada	0	0	0	0	3	0	0	0	0	3 (0.98)
Nematoda	0	0	2	5	0	0	0	0	0	7 (2.28)
Mollusca	0	0	0	10	8	7	0	0	0	25 (8.14)
Echinodermata	0	0	0	0	0	21	0	0	0	21 (6.84)
Chordata	12	2	0	0	0	0	8	0	0	22 (7.17)
Total	12	21	10	77	50	87	31	9	4	307

Table 2: Plankton Abundance (individuals/ml) in the Sampling Stations Along River Ethiope during the Dry Season

Taxa/Phylum	Study Stations									
	I	II	III	IV	V	VI	VII	VIII	IX	
Phytoplankton										Total (%)
Bacillariophyta	29	3	14	17	1	5	21	11	16	117 (30.00)
Chlorophyta	12	35	9	13	5	18	2	80	10	184 (47.18)
Ciliophora	1	0	0	3	16	0	0	0	0	20 (5.13)
Cyanophyta	0	0	0	7	12	6	0	0	0	25 (6.41)
Dinoflagellata	0	0	0	2	0	4	0	0	2	8 (2.05)
Euglenophyta	0	0	0	18	0	3	0	0	0	21 (5.38)
Heterokontophyta	8	0	0	0	0	0	4	3	0	15 (3.85)
Total	50	38	23	60	34	36	27	94	28	390
Zooplankton										
Protozoa	0	0	0	5	0	0	0	0	0	5 (3.03)
Phoronida	0	0	0	0	5	9	0	0	0	14 (8.48)
Rotifera	0	0	0	4	2	7	0	0	0	13 (7.87)
Cnidaria	0	0	0	0	5	0	0	0	0	5 (3.03)
Arthropoda	7	0	0	14	3	15	11	4	0	54 (32.73)
Calanioda	0	0	0	0	0	0	0	0	0	0 (0)
Cyclopoida	2	0	0	0	0	0	2	0	0	4 (2.42)
Annelida	0	0	0	0	8	4	0	0	0	12 (7.27)
Tardigrada	0	0	0	0	0	0	0	0	0	0 (0)
Nematoda	0	0	0	13	12	13	0	0	0	38 (23.03)
Mollusca	0	0	0	10	0	1	0	0	0	11 (6.67)
Echinodermata	0	0	0	0	0	0	0	0	0	0 (0)
Chordata	0	5	0	0	0	0	6	0	0	11 (6.67)
Total	9	5	0	46	35	48	31	4	0	165

Twenty eight different species of phytoplankton belonging to seven Taxa/Phyla were observed during the study namely: *Anabaena*, *Asteromphalus*, *Ceratium tripos*, *Ceratium furca*, *Ceratium trichocerus*, *Ceratium gibberum*, *Cladophora*, *Chlamydomonas*, *Coelosphaerium*, *Coscinodiscus grani*, *Euglena*, *Flagillariopsis*, *Fragillaria striatula*, *Lauderia annulata*, *Microcystis*, *Navicula*, *Oscillatoria*, *Paramecium*, *Pediastrum*, *Proboscis alata*, *Psedo-Nitzchia* *australis*, *Rhizosolenia*, *Selenastrum*, *Spirogyra*, Tintinnid ciliate, *Ulothrix*, *Volvox* and *Vorticella*. Nineteen species of zooplankton belonging to thirteen Taxa/Phyla encountered were *Actinotroch* larvae, *Actinula* larvae, *Arcella*, *Brachionus plicatilis*, *Choanoflagellate*, Calanoid copepod, Cyclopoid copepod, *Cypris* larvae, *Daphnia*, *Echinopluteus* larvae, *Nauplius* larvae, *Oikopleura*, *Ostracod*, *Podon*, *Polycheate* larvae, *Trichinella*, Tardigrades, veliger larvae and *Trochophore* larvae. There were variations in plankton diversity indices observed for the rainy and dry seasons. The seasonal species diversity indices of phytoplankton and zooplankton in the study stations are presented in Figure 2. Margalef's species richness index shows that phytoplankton were richer in the dry season than in the rainy season and the values were higher in Station I in both seasons while zooplankton were richer in Stations IV and VI in the rainy and dry seasons respectively. The Shannon-Weinner Index shows that the values were not significant different ($P>0.05$) among the stations. No significant difference ($P>0.05$) was observed in the evenness of plankton species during the rainy and dry seasons.

Seasonal variations were observed in physico-chemical parameters of River Ethiope (Tables 3 and 4). Mean values of physico-chemical parameters also varied from station to station along the river, and from season to season. The correlation analysis of phytoplankton abundance in relation to physico-chemical parameters in rainy and dry seasons are presented in Tables 5 and 6. A significant ($P<0.05$) negative correlation was observed for phytoplankton and calcium and with depth during the rains. Magnesium correlated positively with zooplankton ($P<0.05$) also during the rains. No significant ($P>0.05$) correlation was recorded between plankton and physico-chemical parameters during the dry periods.

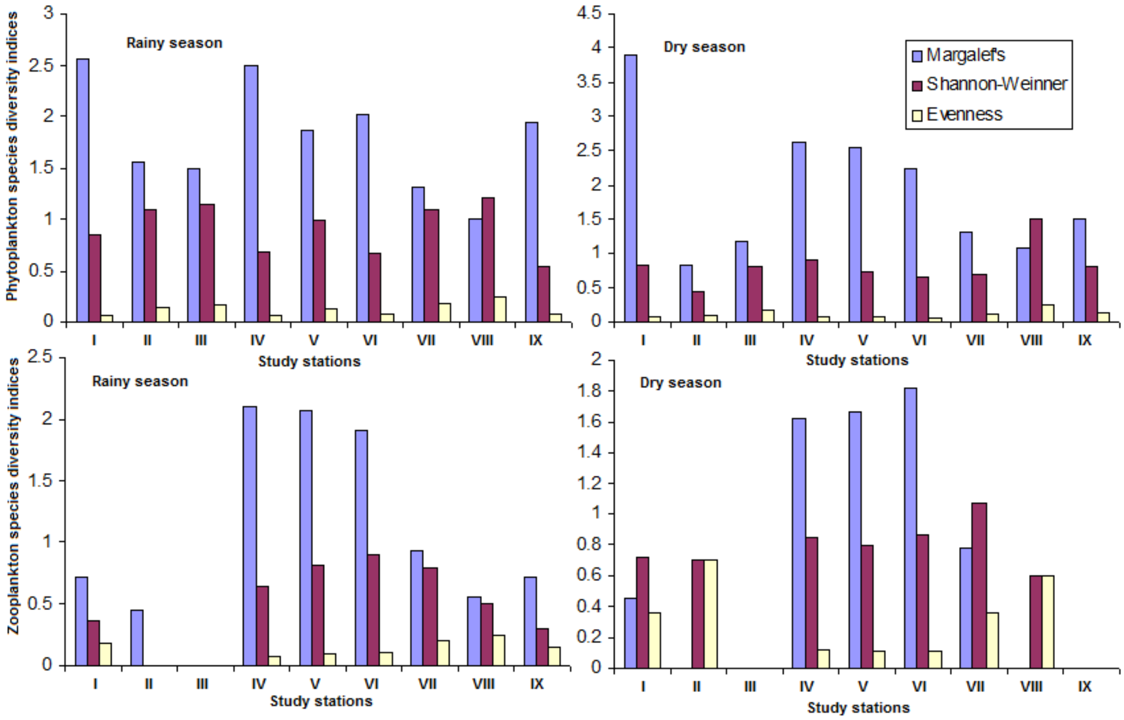

Figure 2: Seasonal variations in plankton species diversity indices in the study stations.

Table 3: Mean (± S.E.M) Physicochemical Parameters of R. Ethiope in the Nine Stations during the Rainy Season

Physicochemical Parameters	Study Stations								
	I	II	III	IV	V	VI	VII	VIII	IX
Physical									
Temperature (°C)	28.33+0.33^{ab}	30.33+0.33^{d}	31.67+0.33^{e}	27.67+0.33^{a}	29.00+0.58^{bc}	30.33+0.33^{d}	28.00+0.58^{ab}	28.67+0.33^{abc}	29.67+0.33^{cd}
Depth (cm)	30.93+0.69^{a}	178.33+1.45^{b}	243.33+7.50^{c}	573.67+0.33^{d}	591.33+1.67^{e}	612.00+2.00^{f}	910.33+6.06^{g}	934.67+2.02^{h}	960.33+0.88^{i}
Current (cm)	4.62±2.09^{a}	24.06±1.04^{ab}	25.99±1.15^{ab}	17.20±3.23^{ab}	21.79±6.96^{ab}	22.69±7.35^{ab}	25.80±10.17^{ab}	31.58±8.54^{b}	31.58±8.54^{b}
Turbidity (cm)	29.07±2.22^{a}	144.67±21.86^{b}	144.67±13.92^{b}	145.00±1.53^{b}	157.67±2.60^{b}	168.83±3.84^{bc}	209.00±4.93^{d}	208.67±14.05^{d}	202.00±20.79^{cd}
Total Dis S (g/dl)	0.05±0.01^{a}	0.43±0.07^{bc}	0.48±0.03^{c}	0.96±0.07^{d}	0.81±0.15^{d}	0.97±0.11^{d}	0.73±0.19^{cd}	0.07±0.08^{cd}	0.15±0.02^{ab}
Chemical									
DO (mg/l)	9.07±0.41^{abc}	9.30±0.57^{abc}	10.30±1.08^{bc}	9.00±1.10^{abc}	10.07±0.93^{bc}	10.80±1.03^{c}	5.90±0.70^{a}	6.80±1.33^{ab}	7.27±1.79^{abc}
BOD (mg/l)	10.10+0.71^{a}	11.53+0.23^{abc}	10.97+0.73^{ab}	12.40+0.53^{bc}	13.12+0.98^{c}	12.73+0.69^{bc}	9.90+0.87^{a}	9.76+0.38^{a}	9.77+0.23^{a}
COD (mg/l)	135.00±10.69^{a}	157.00±5.13^{a}	174.00±17.01^{a}	332.67±26.74^{c}	285.67±37.02^{bc}	375.33±56.09^{c}	212.53±0.38^{ab}	168..00±8.67^{a}	217.53±43.56^{ab}
pH	5.83+0.38^{a}	6.10+0.05^{a}	6.16+0.01^{ab}	6.73+0.20^{abc}	7.64+0.38^{c}	6.47+0.18^{abc}	6.03+0.12^{a}	7.40+0.95^{bc}	6.90+0.26^{abc}
Conductivity (μ hom/cm)	1.67+0.33^{b}	1.00+0.00^{a}	1.00+0.00^{a}	1.00+0.00^{a}	1.40+0.31^{ab}	1.03+0.03^{a}	1.00+0.00^{a}	1.00+0.00^{a}	1.00+0.00^{a}
Total Alkalinity (mg/l)	362.42+25.18^{a}	350.47+39.42^{a}	401.84+22.64a	502.00+11.55b	508.8+39.62b	602.67+9.68c	540.33+11.55bc	522.67+5.55b	513.00+16.92b
Magnesium (mg/l)	3.87+0.38^{abc}	2.40+0.35^{a}	4.93+0.42^{d}	4.87+0.46^{cd}	5.57+0.44^{d}	5.70+0.30^{d}	2.43+0.18^{a}	3.40+0.17^{ab}	2.87+0.15^{ab}
Calcium (mg/l)	8.40±3.28^{bc}	4.20±0.85^{a}	3.87±0.72^{a}	16.30±0.23^{d}	17.03±0.52^{d}	16.63±0.28^{d}	6.77±0.24^{ab}	8.87±0.26^{bc}	10.90±0.75^{c}
Sulphate (mg/l)	21.15±8.50^{b}	16.83±5.27^{b}	17.69±5.75^{b}	7.95±1.47^{ab}	9.30±1.96^{ab}	7.95±1.96^{ab}	3.25±1.59^{a}	2.81±0.90^{a}	3.29±1.71^{a}
Nitrate (mg/l)	0.77±0.32^{a}	0.65±0.28^{a}	0.68±0.32^{a}	0.52±0.19^{a}	0.57±0.22^{a}	0.54±0.24^{a}	0.50±0.01^{a}	0.52±0.19^{a}	0.310±0.13^{a}
Phosphate (mg/l)	2.46±0.88^{a}	1.57±0.88^{a}	2.45±0.81^{a}	1.08±0.19^{a}	1.22±0.15^{a}	0.93±0.46^{a}	1.03±0.14^{a}	0.99±0.26^{a}	1.09±0.12^{a}

Means ±S.E.M. on same rows with different superscript are significantly different (P<0.05) while Means ± S.E.M. on same rows with the same superscript are not significantly different (P>0.05).

Discussion

Seasonal variations in plankton abundance was observed in this study. Higher number of plankton individuals was obtained per ml of water samples in all the study stations during the rains than in the dry periods. Santhosh and Perumal (2012) reported seasonal variations and attributed these variations to the distribution of nutrients being mainly based on the season tidal conditions and fresh water flow from land source.

Table 4: Mean (± S.E.M) Physicochemical Parameters of R. Ethiope in the Nine Stations during the Dry Season

Physicochemical Parameters	Study Stations								
	I	II	III	IV	V	VI	VII	VIII	IX
Physical									
Temperature (°C)	28.57+0.57^{a}	29.9+0.10^{abcd}	30.9+0.67^{d}	29.67+0.33^{abcd}	30.00+0.00^{bcd}	30.67+0.33^{cd}	29.00+0.58^{ab}	29.33+0.33^{abc}	30.33+0.33^{bcd}
Depth (cm)	20.79±9.66^{a}	114.82±56.72^{b}	159.15±78.85^{c}	571.33±0.67^{d}	592.67±1.76^{e}	610.00±1.15^{f}	910.33±6.06^{g}	934.67±2.03^{h}	960.33±0.88^{i}
Current (cm)	76.08±48.01^{a}	81.58±42.69^{a}	80.31±43.01^{a}	42.01±9.57^{a}	30.66±10.16^{a}	15.89±5.85^{a}	25.80±10.16^{a}	31.58±8.54^{a}	34.15±15.19^{a}
Turbidity (cm)	10.34±9.93^{a}	76.27±38.17^{b}	92.60±45.89^{b}	165.00±19.52^{c}	166.67±7.86^{c}	167.00±5.57^{c}	213.67±2.03^{c}	200.33±6.89^{c}	190.67±10.89^{c}
Total Dissolved Solids (g/dl)	0.15±0.11^{a}	0.40±0.06^{a}	0.51±0.07^{ab}	1.31±0.18^{d}	1.08±0.23^{bcd}	1.23±0.29^{cd}	0.73±0.19^{abcd}	0.67±0.08^{abc}	0.48±0.31^{ab}
Chemical									
DO (mg/l)	9.27+0.13^{c}	10.27+0.18^{cd}	12.53+0.35^{d}	9.0+1.40^{bc}	9.03+0.69^{bc}	9.57+1.04^{c}	5.70+0.60^{a}	6.47+1.17^{ab}	6.00+1.11^{a}
BOD (mg/l)	10.53+0.29^{a}	11.40+0.12^{a}	12.37+0.15^{a}	11.07+0.53^{a}	12.13+1.33^{a}	11.47+1.05^{a}	6.40+3.07^{a}	7.07+3.31^{a}	7.67+3.54^{a}
COD (mg/l)	136.67+12.02^{a}	175.60+40.29^{ab}	190.23+47.40^{ab}	299.0+12.01^{c}	253.33+16.22^{bc}	312.67+30.82^{c}	131.17+3.68^{a}	165.20+24.15^{ab}	202.70+34.86^{ab}
pH	6.17+0.12^{a}	6.13+0.03^{a}	6.53+0.33^{ab}	6.37+0.32^{ab}	7.13+0.52^{b}	6.40+0.26^{ab}	6.23+0.13^{ab}	6.38+0.16^{ab}	6.91+0.28^{ab}
Conductivity (μ hom/cm)	1.33+0.33^{a}	1.00+0.00^{a}	1.00+0.00^{a}	1.33+0.58^{a}	1.00+0.00^{a}	1.33+0.58^{a}	1.00+0.00^{a}	1.00+0.00^{a}	1.00+0.00^{a}
Total Alkalinity (mg/l)	351.43+25.68^{a}	354.4+36.35^{a}	409.0+43.80^{ab}	490.33+20.74^{bc}	552.93+15.56^{c}	568.33+40.34^{c}	530.33+9.21^{c}	532.67+1.52^{c}	562.67+36.70^{c}
Magnesium (mg/l)	2.93±0.42^{ab}	2.40±0.21^{a}	4.87±0.35^{d}	5.93±0.19^{ef}	6.57±0.27^{f}	5.67±0.15^{e}	3.33±0.24^{bc}	3.53±0.12^{bc}	3.87±0.29^{c}
Calcium (mg/l)	5.73±0.29^{b}	4.20±0.23^{a}	3.87±0.24^{a}	16.8±0.38^{e}	17.83±0.59^{e}	17.40±0.64^{e}	7.37±0.12^{c}	9.63±0.56^{d}	10.47±0.14^{d}
Sulphate (mg/l)	25.49±2.77^{a}	24.64±0.79^{a}	26.33±0.28^{a}	7.18±0.59^{a}	6.28±0.85^{a}	6.91±0.99^{a}	32.9±31.60^{a}	7.62±6.94^{a}	8.17±7.15^{a}
Nitrate (mg/l)	1.07±0.01^{b}	0.72±0.06^{a}	0.75±0.02^{a}	0.75±0.02^{a}	0.82±0.05^{a}	0.80±0.04^{a}	0.79±0.72^{a}	0.74±0.59^{a}	0.80±0.04^{a}
Phosphate (mg/l)	1.45±0.95^{a}	0.49±0.23^{a}	0.44±0.19^{a}	1.38±0.11^{a}	1.28±0.07^{a}	1.29±0.09^{a}	0.23±0.05^{a}	0.77±0.37^{a}	0.54±0.34^{a}

Means ±S.E.M. on same rows with different superscript are significantly different (P<0.05) while Means ± S.E.M. on same rows with the same superscript are not significantly different (P>0.05).

Table 5: Correlation Between Plankton Abundance and Physico-chemical Parameters in the Rainy Season

	Temperature (^{0}C)	Depth (cm)	Current (µhom/cm)	Turbidity (cm)	Total Dissolved Solids (g/dl)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	pH	Conductivity (mg/l)	Total Alkalinity (mg/l)	Magnesium (mg/l)	Calcium (mg/l)	Sulphate (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Phytoplankton (cells/ml)	Zooplankton (cells/ml)
Temperature (^{0}C)	1																	
Depth (cm)	-.309	1																
Current (µhom/cm)	.355	.702*	1															
Turbidity (cm)	.063	.869	.924	1														
Total Dissolved Solids (g/dl)	-.054	.089	-.044	.202	1													
DO (mg/l)	.535	-.651	-.380	-.485	.392	1												
BOD (mg/l)	.120	-.226	-.202	-.098	.790*	.758*	1											
COD (mg/l)	-.106	.311	.019	.258	.840	.375	.745*	1										
pH	.128	.559	.451	.478	.062	.033	.288	.335	1									
Conductivity (mg/l)	-.308	-.504	-.782*	-.785*	-.269	.238	.037	-.242	-.078	1								
Total Alkalinity (mg/l)	-.235	.815	.426	.673*	.487	-.206	.206	.733*	.494	-.386	1							
Magnesium (mg/l)	.179	-.191	-.275	-.223	.551	.769*	.748*	.663	.336	.212	.294	1						
Calcium (mg/l)	-.354	.309	-.152	.075	.570	.304	.667*	.865	.574	.136	.655	.672*	1					
Sulphate (mg/l)	.360	-.988**	-.663	-.864	-.192	.608	.120	-.408	-.566	.531	-.849	.148	-.389	1				
Nitrate (mg/l)	.155	-.890	-.682*	-.792*	-.097	.499	.135	-.376	-.487	.555	-.691*	.208	-.348	.883**	1			
Phosphate (mg/l)	.364	-.827	-.528	-.764*	-.407	.375	-.207	-.599	-.550	.509	-.823	.054	-.554	.897	.781*	1		
Phytoplankton (cells/ml)	.190	-.723*	-.411	-.624	-.588	.075	-.386	-.818	-.551	.439	-.837	-.327	-.743*	.770*	.813**	.787*	1	
Zooplankton (cells/ml)	-.272	.107	-.215	.064	.917	.411	.832	.924	.229	-.076	.550	.667*	.813	-.227	-.109	-.474	-.639	

* correlation is significant at 0.05 level (2-tailed)

Nutrient availability in the aquatic habitat is essential for growth, reproduction and metabolic activities of organisms. During the study phytoplankton was observed to be more in number than zooplankton. Phytoplankton was also richer in diversity than zooplankton.

Table 6: Correlation Between Plankton Abundance and Physico-chemical Parameters in the Dry Season

	Temperature (^{0}C)	Depth (cm)	Current (µhom/cm)	Turbidity (cm)	Total Dissolved Solids (g/dl)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	pH	Conductivity (mg/l)	Total Alkalinity (mg/l)	Magnesium (mg/l)	Calcium (mg/l)	Sulphate (mg/l)	Nitrate (mg/l)	Phosphate (mg/l)	Phytoplankton (cells/ml)	Zooplankton (cells/ml)
Temperature (^{0}C)	1																	
Depth (cm)	-.023	1																
Current (µhom/cm)	-.046	-.865	1															
Turbidity (cm)	.145	.951	-.869	1														
Total Dissolved Solids (g/dl)	.324	.401	-.682*	.592	1													
DO (mg/l)	.493	-.836	.648	-.668*	-.022	1												
BOD (mg/l)	.496	-.737*	.440	-.562	.215	.912	1											
COD (mg/l)	.584	.116	-.431	.276	.852**	.265	.519	1										
pH	.496	.115	-.071	.174	.106	.058	.273	.266	1									
Conductivity (mg/l)	-.113	-.280	-.083	-.306	.316	.221	.331	.483	-.519	1								
Total Alkalinity (mg/l)	.251	.853	-.903	.840	.467	-.585	-.432	.287	.312	-.208	1							
Magnesium (mg/l)	.508	.169	-.454	.339	.830	.253	.492	.837	.338	.254	.393	1						
Calcium (mg/l)	.225	.435	-.742*	.518	.887	-.162	.183	.849	.274	.395	.567	.824	1					
Sulphate (mg/l)	-.614	-.566	.488	-.754*	-.600	.122	.062	-.476	-.464	.436	-.548	-.427	-.400	1				
Nitrate (mg/l)	-.540	-.389	.229	-.590	-.425	.005	.055	-.298	-.314	.496	-.277	-.202	-.129	.937	1			
Phosphate (mg/l)	-.138	-.240	-.139	-.267	.389	.211	.471	.548	-.067	.772*	-.073	.502	.625	.377	.530	1		
Phytoplankton (cells/ml)	.146	-.148	.440	-.035	-.241	.222	.009	-.298	.152	-.635	-.327	-.360	-.501	-.400	-.661	-.601	1	
Zooplankton (cells/ml)	.188	.063	-.426	.231	.890**	.172	.446	.850	.018	.581	.140	.808	.834	-.250	-.093	.625	-.431	1

* correlation is significant at 0.05 level (2-tailed)

Chandy *et al*. (1991) reported that all other living forms of higher trophic levels are directly or indirectly dependant on phytoplankton which performs a vital function of energy supply. Phytoplankton growth is promoted by the presence of nutrients such as nitrates, phosphates, silicates as observed by Chandy *et al.* (1991) who also reported that phytoplankton species are predominantly autotrophic or holophytic organisms building organic matter from inorganic materials present in their environment. Phytoplankton is therefore an important base in the aquatic food chain providing food for zooplankton and then fish. Zooplanktons have been described to improved fish flavour and texture and further enhance high survival of fish larvae and fry (Arimoro, 2005).

The Shannon-weaver index was low for zooplankton both in the rainy and dry seasons. The low diversity index observed for zooplankton is an indication that the number of different species were low but not in the density and the abundance. This fact may be due to poor distribution which has to do with the Index of Evenness expressing how evenly the individuals in a community are distributed among the different species, that is, the richness of the species in an area (Claude, 1972). Low Shannon-Weiner Index has been noted to be an indication of poor distribution (Adesalu and Nwankwo, 2008). In the rainy season, zooplankton richness was negatively affected by a reduction in the temperature of water. However, zooplankton population during the dry season was positively affected by temperature. This corroborates the reports of Ozyge and Unluturk (2009) that species richness of zooplankton is positively affected by increasing temperature. This study has shown that physico-chemical variables play a key role in the distribution of plankton in River Ethiope. Phytoplankton abundance had negative significant correlation with calcium and depth during the rains. Freshwater has been known to have a lot of calcium than magnesium due to abundant calcium in the earth crust and so calcium is one of the major inorganic cations or positive ions in salt and freshwater. Calcium concentration during the study period was similar to the findings of a study by Fella *et al.* (2013). Values of calcium obtained in this study were within the typical range of calcium (4 - 100mg/l) in fresh water. Ekelemu and Zelibe (2006) studied the aspect of hydrobiology of lake Onah and reported that the magnesium ion concentration ranges between 3.40mg/l and 3.89mg/l. Magnesium is a dietary mineral for any organism except insect and the average value of magnesium in water particulates is 1.2% (McLennan and Murray, 1999). According to Adeyemo *et al.* (2009) a change in physico-chemical aspect of a water body can bring about a corresponding change in relative composition and abundance of the organism in the water.

Conclusion

This study shows that plankton abundance and diversity were influenced by seasonal changes in physico-chemical parameters of Ethiope River. It also provides vital information on the plankton abundance and distribution, hence the study is useful in further assessment and monitoring of the ecology of River Ethiope. Plankton are therefore an index of water quality assessment for increased fish production.

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