Influence of Seasons on Water Quality, Abundance of Fish and Plankton Species of Ikwori Lake, South-Eastern Nigeria

***BO Offem, EO Ayotunde, GU Ikpi, SN Ochang, FB Ada**
Department of Fisheries and Aquatic Sciences, Cross River University of Technology, PMB 102 Obubra Campus, Cross River State, Nigeria.

*****Correspondence to: Benedict O Offem, benbeff06@yahoo.com
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Abstract

This study is aimed at assessing the effect of seasons on quality of lake water in relation to changes in fish, plankton abundance and environmental variables. Standard methods were used to analyze monthly fish, plankton and water samples collected from Ikwori Lake during wet and dry seasons for 24 months (January 2008 to December 2009). All measured water parameters except dissolved oxygen (3.3 ± 0.10mgl^{-1}), total dissolved solids (103.2 ± 2.22mgl^{-1}), acidity (4.44 ± 3.91mgl^{-1}), color (60.33 ± 8.38pt. co) and pH (5.8 ± 0.119) showed significant seasonal variation. The highest values of the parameters occur between February and March (dry season) and lowest between May and August (wet season). In addition, total phytoplankton (cells/litre), were significantly more during the dry season than the wet. Out of 16 fish species sampled, 7 species were restricted to dry season, only one i.e. *Polypterus senegalus* was recorded in the wet while 8 species occurred in both seasons. Seasonal differentiation in the richness and diversity indices of all species sampled revealed higher values for the dry season than the wet. Therefore, the influence of season is important in the management of water quality, plankton and fish production of the aquatic system.

Keywords: Phytoplankton; Zooplankton; Fish species; Macrophytes; Diversity indices; Lake Ikwori; Nigeria.

1. Introduction

The Ikwori Lake is used for fishing activities and as a source of domestic water supply to the host community and therefore vulnerable to anthropogenic impact. However, if the lake is properly managed, estimated potential yield of over 6000 metric tonnes per annum is possible.

The effects of inputs on water quality and aquatic life particularly in the Niger-Delta region of Nigeria have been investigated. Akpan and Offem [1] observed that decrease in productivity of most inland wetlands of the region has been attributed to poor water quality caused by anthropogenic inputs from neighboring communities and oil industries. Inadequate management of the resources [2,3] is another reason. Impacted changes in water quality as reflected in the biodiversity, has also been investigated and observation made that both the development period and the hatching period for aquatic organisms are generally shorter at higher temperature than at lower temperature [4]. Species differ in their temperature tolerance during development but generally, there are temperatures which are too low and too high for physiological processes [5]. Other studies on Nigerian aquatic ecosystem impairment have been reported and most of the researchers established that a knowledge of hydrological conditions of any body of water is not only useful in assessing its productivity but will also permit a better understanding of the population and life cycle of the fish community [6]. Major industries responsible for water pollution in Nigeria have been listed to include petroleum, mining, wood, pulp, pharmaceuticals, textiles, plastics, iron and steel, brewing, distillery, fermentation, paints, beverages, food and agriculture [7]. Fertilizer effluents from industrial city of Kano polluted Jakara reservoir [8]. High levels of toxic heavy metals including copper, zinc, chromium, iron and manganese in fish from Warwade Reservoir in Kano was detected [9]. Increased pollution levels of the coastal areas of Cross River State by petroleum product spillage, that is a problem to the fishery industry, had been reported [10].

However, no work had been carried out on seasonality of water quality and biodiversity of lakes in the southeast region of Nigeria. The objective of the study is to provide a quantitative record of the seasonal changes of some macro and micro fauna and flora and to examine their distribution and diversity in relation to environment gradients in a tropical lake.

2. Methods

2.1. Lake characteristics

Ikwori Lake is located in South-Eastern Nigeria between latitude 4^0 25′– 7^0.00′N and longitude 7^0 15′– 9.30′E. It is bounded in the South by the Atlantic Ocean, East by the Republic of Cameroon and the Nigerian states of Benue in the North, Ebonyi and Abia in the West and Akwa Ibom in the South-West (Figure 1). The climate of the study area comprises a wet season (April-October) characterized by high mean precipitation (3050 ± 230 mm), and a dry season (November-March) marked by low mean precipitation (300 ± 23 mm) [10]. Mean temperatures range from 15.5 ± 7.6ºC in the wet season to 32.6 ± 5.4ºC in the dry season. At present, the lake covers an area of approximately 5 hectares and possesses a maximum depth of 8m. The main source of water for the lake is rainfall and springs from the stoned walls. A dense rooted macro-flora, lake-ward from the shore, is composed primarily of *Dactyloctenium aegyptium*, *Eleusine indica*, *Cynodon dactylon*, *Brachiaria ramose*, *Ipomoea pestigridis*, *Monechma ciliatum*, *Eragrostic pilosa* and *Setaria pallide-fusia.* This development of rooted plants ends abruptly at a depth of approximately 1.5 m. *Nymphaea advenna* could also be found along the entire littoral margin. Random bottom samples were obtained. The deposits were sapropel in character revealing large concentrations of organic deposits of autochthonous origin. A fine black muck containing abundant remains of diatoms was common in all deposits of the area. The detritus in the samples were in the advance form of decomposition.

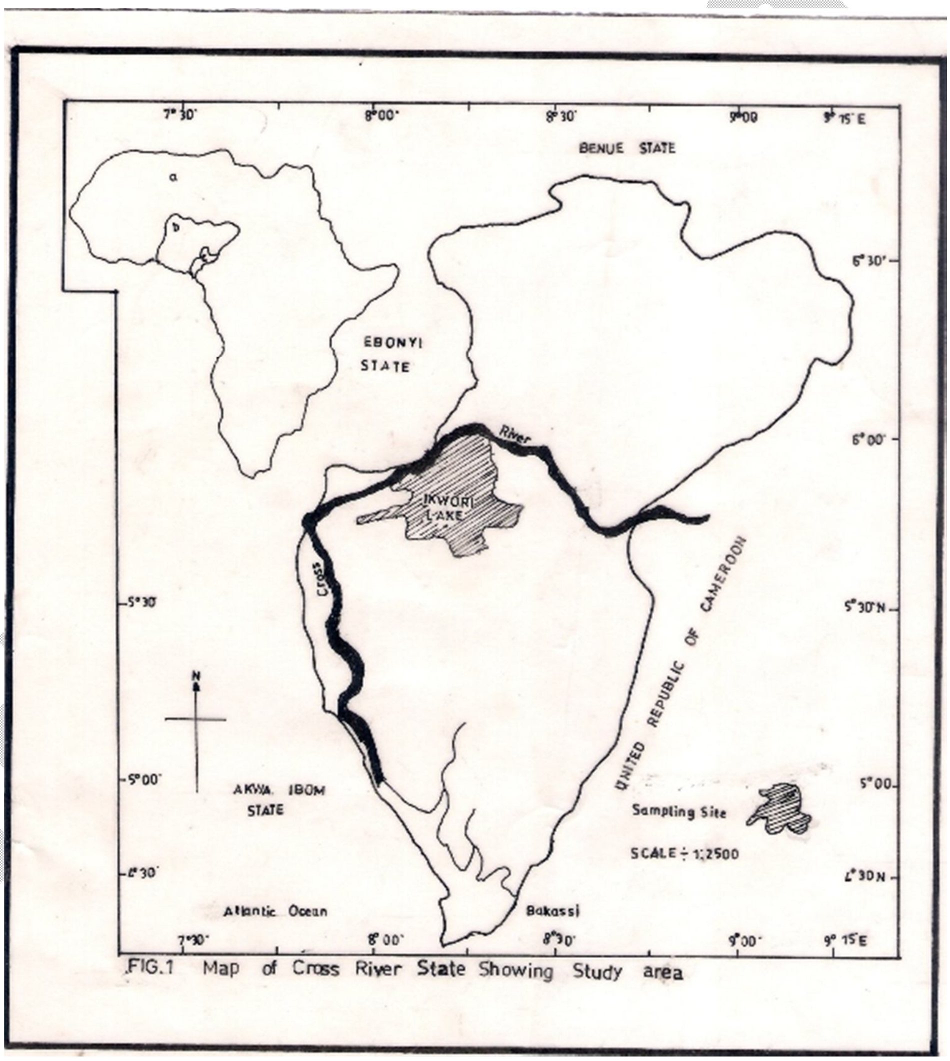

Fig. 1 Map of Cross River State showing study area.

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2.2. Hydrological parameters

Monthly rainfall data for the study area were obtained from meteorological station, located at the study area. Water level was determined with a lead sinker attached to a calibrated rope. The sinker was lowered down into water until it reached the substrate. The depth was then read from the calibrated rope. The procedure was carried out in two locations in the littoral zone and one in the limnetic portion of water within the sampling site.

2.3. Sample collection and analysis

Water, plankton, and fish samples were taken monthly for 24 months, from January 2008 to December 2009, to cover both wet and dry seasons.

2.3.1. Water quality parameters

Standard methods for the examination of water and wastewater were used for all measurements. Temperature values were recorded from a mercury-in glass thermometer graduated in units of ^{0}C by immersing the thermometer slightly under the surface of water (2cm) for 5 minutes until mercury stood at one place). Pye Unicam Model 7065 electronic metre at 25ºC after standardization with buffer solution at pH 4, 7 and 9 was used for pH. Dissolved oxygen concentration of the water samples was determined with a Jen-way 9071 digital oxygen analyzer. Water transparency was measured by use of Secchi disc (Golterman, 1969). The disc was lowered into water and the depth at which it became invisible was recorded. It was then gradually withdrawn from the water and the depth at which it became visible was noted. The transparency of the water at that station was the mean of the two readings. For the total dissolved solids (TDS), the Hach TDS meter was put on, the reading zeroed and then the electrode dipped into the water sample and the reading taken. Conductivity was assessed by putting on the Suntex conductivity meter, adjusting the reading portion and dipping the meter into the water sample and approximate reading taken. Total hardness, free Carbon dioxide, Acidity, Chemical Oxygen Demand, was obtained by titrimetric method (APHA 1998). Biological Oxygen Demand was determined by difference between initial and final dissolved oxygen after incubation for 5 days at room temperature of (20^{0}C). Total alkalinity was measured by titrating water samples with sulphuric acid standard solution, using a drop of phenolphthalein solution and one sachet of bromcresol green-methyl red as indicator, until the sample changed from blue green to pink. Total alkalinity, which is expressed in mg/L, is the total number of drops of sulphuric acid solution used multiplied by 17.1 (Fish Farmers' Water Quality Testing Kit Manual, 1990). Nitrate and Phosphate were measured with brucine and Ascorbic acid methods respectively. Salinity was determined using hand held refractometer (S/mill-E 0-100%0). Bicarbonate ion was measured with pH electrode dipped into the tip of the conical container. Sample water was passed through until a constant reading was obtained and a marble powder was added, to completely cover the electrode ball. After about 2 minutes, the pH was read again. The temperature of the marble was monitored with thermometer during measurement. Carbonate ions was determine by placing hydrochloric acid, between 2 and 10ml of water sample in a gas generator and insert tube filled with 20ml hydrochloric acid (10%). After connecting to the apparatus, the graduated tube was filled by raising the level container. The gas generator was then tilted so that the hydrochloric acid makes contact with the floor. A pressure compensation was attained by sinking the container so that, after about 10 minutes the gas volume can be read. Color was determine by assembling Filter apparatus (membrane filter, filter holder, aspirator and folter flask) and allowed about 50ml of dematerialized water to pass through to rinse the unit. Discard rinse water. Approximately 50ml of water sample was filtered and 25ml poured into another clean cell. The dematerialized water was placed in a cell holder and sample compartment door was closed. The demineralization was used to set the zero concentration point.

2.3.2. Plankton sampling

Qualitative plankton samples were collected by towing a 55µm mesh Hydrobios plankton net (Model No. 25) tied to a boat driven at low speed just below water surface for 5 minutes at the three sampling stations; one limnetic and two littoral zones. The samples were immediately fixed in 4% formalin and transported to the laboratory where it was allowed to settle after which decantation method was used to reduced to 10ml. Quantitative samples on the other hand were collected by filtering 100 litres of water fetched with a bucket through a 55µm mesh Hydrobios net. Both samples were preserved separately in 4% buffered formalin solution.

In the laboratory, specimens were sorted and dissected where necessary under a binocular dissecting microscope (American Optical Corporation, Model 570), while counting and identifications were done with an Olympus Vanox Research Microscope (mag X60) Model 230485. Taxonomic keys used for proper identification include: Han [11], Prescott [12], Kadiri [13] Kemdirim [14]. The numerical composition of the specimens was estimated by direct count. Each quantitative sample was concentrated to 10ml and from this; 1ml of sample was taken and all individual taxa present were counted. Numerical composition was calculated as the number of individuals per litre of water filtered through the net.

2.3.3. Fish sampling

The fish fauna of the lake was sampled with gill net of 22-76mm stretched mesh size. Fish weights were measured to nearest 0.1g and total length (TL) to nearest 1cm. Genus and species identifications were carried out following Elvira [15] for the cyprinids; Erkakan et al. [16] for the bagrids, Teugels [17] for the Clariidae; Fisher et al. [18] for the Clupeidae and Mugilidae.

2.3.4. Data treatment and analysis

Mean and standard deviation of each of the physico-chemical parameters were calculated. Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the sampling sites. To calculate mean abundance, numbers in different samples were summed for each species and averaged across all sampling sites. Shannon-Wiener diversity function (H´) was used to calculate heterogeneity for each site.

Richness index was expressed using Margalef's richness index.

$d = (S - 1) / \log N$ [19]

$H' = -\sum_{i=1}^{S} P_i \, Ln \, Pi$ [20]

$E = d / S$ [21]

E = Equitability

d = Margalef's richness index and H´ = Shannon-Wiener Diversity Function

S = total species number

p_i = proportion of each species in each sample

Relative proportion = n/N

n refers to the number of individuals of the species in the samples and N to the total number of individuals of fish caught.

3. Results

3.1. Physical and chemical conditions

All physical and chemical properties are within limits for the survival and development of plankton and fish populations. Table 1 showed that only the values of total dissolved solids (Mg/L), dissolved oxygen (Mg/L), acidity (Mg/L), salinity (Mg/L), color (pt. co) and pH were not significantly different ($p>0.05$) between wet and dry seasons while Figure 2 and 3 showed significant seasonal variation ($p<0.05$) with highest mean values of turbidity (FTU), Total suspended solid (Mg/L), carbonate ions (Mg/L) total hardness (Mg/L), Conductivity (µS/cm) and Alkalinity (mg/l) occurring during the wet season and lowest mean values recorded in the wet. However, highest values of water temperature and bicarbonate ions were obtained during the dry season while lowest values were recorded during the wet.

Table 1. Seasonal variation in the physico-chemical parameters and the t-values of the student's t-test in the Ikwori Lake.

Parameters	Wet season	Dry season	t-value	t-test
Water temperature (^{0}C)	14	29	4.5	$p<0.05$
Dissolve oxygen (mg/l)	3	3	0.7	$p>0.05$
Phosphates (mg/l)	1	1	1.5	$p>0.05$
Turbidity (FTU)	9	3	3.7	$p<0.05$
Total suspended solid (mg/l)	5	3	4.4	$p<0.05$
Total dissolve solid (mg/l)	109	96	0.7	$p>0.05$
Conductivity (µS/cm)	390	212	3.0	$p<0.05$
Biological Oxygen Demand (mg/l)	1	1	2.9	$p<0.05$
Free carbon dioxide (CO_2) (mg/l)	8	4	4.5	$p<0.05$
Alkalinity (mg/l)	176	81	5.5	$p<0.05$
Carbonate (mg/l)	224	129	3.9	$p<0.05$
Bicarbonate	55	146	4.8	$p<0.05$
Total hardness (mg/l)	166	56	2.7	$p<0.05$
Acidity (mg/l)	5	5	1.2	$p>0.05$
Salinity (mg/l)	0	0	0.8	$p>0.5$
Color (pt. co)	60	65	1.0	$p>0.05$
pH	5	6	2.9	$p>0.05$

$p < 0.05$ (significant) and $p > 0.05$ (not significant)

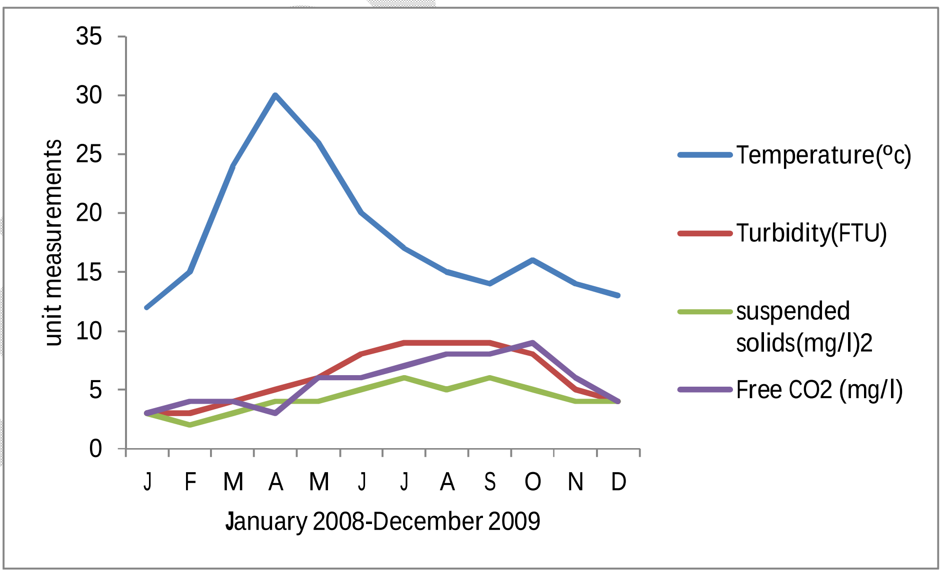

Fig. 2 Seasonal fluctuations in Temperature (°C), Turbidity (FTU), Total suspended solids (mg/l) and Free CO_2 (mg/l).

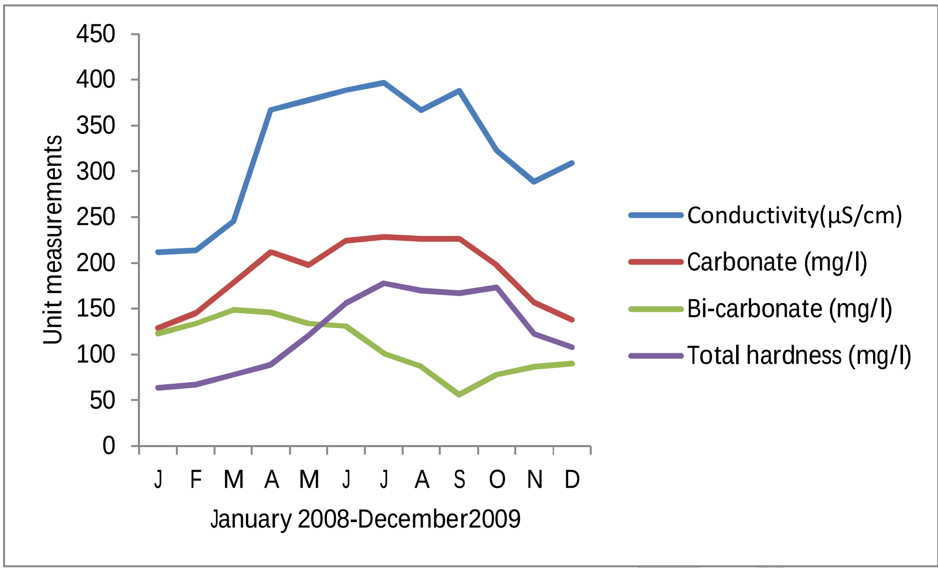

Fig. 3 Seasonal fluctuations in Conductivity (µS/cm), Carbonate (mg/l), Bi-carbonate (mg/l) and Total hardness (mg/l).

3.2. Phytoplankton

Thirty four major species of phytoplankton from four families were identified. Chlorophyceae (green algae) were represented by 16 colonial, filamentous and unicellular forms, which was the largest number of species in any of the given families with many quantitatively significant species (Table 2). Bacillariophyceae (Diatoms) were represented by 10 species but only two species produced large pulses. Cyanophyceae (Blue–green algae) had four species while Dinophyceae had two. Of highest numerical concentrations were *Dictyosphaerium pulchellum*, *Chlamydomonas ehrenbergii* and *Scenedesmus quadricauda*, all from the family Chlorophyceae that produced the major dry season pulses. The Dinoflagellates were rare. Seasonal variation in occurrence of phytoplankton species (cells/ml) pulses showed that dry season pulses were significantly more than the wet season for most of the species. Throughout the 24 months, two major algal pulses were observed and the peaks were recorded in April and November while the lowest counts (cells/ml) occurred in July and December (Figure 4). The seasonal distribution of the three major phytoplankton species was similar at the surface for the three collecting sites (Figure 5). The algal concentration at the littoral stations was generally higher than that in the open water (Figure 6).

Table 2. Seasonal variation in occurrence of phytoplankton species (cell/ml) in Ikwori lake (October 2008 – September 2009).

Family/species	Wet season (cells/ml)	Dry season (cells/ml)	t-value	t-test
Bacillariophyceae (Diatoms)				
Actinolyclus sp.	833.3	-	-	-
Coscinodiscus sp.	500.0	-	-	-
Melosira granulata	833.3	53125.0	5.9	P<0.05
Nitzchia sp.	666.7	-	-	-
Pinnualria sp.	333.3	-	-	-
Asterionella formosa	-	-	-	-
Synedra acus	9987.6	676280.0	-	-
Asterionella formosa	-	208.4	-	-
Navicula digitoradiata	-	208.4	-	-

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Chlorophyceae (Green algae)				
Chlorella viridis	333.3	25000.0	6.5	P<0.05
Coelastrum combricum	4166.7	-	-	-
Cosmarium contractum	18333.3	-	-	-
Pediastrum sp.	1166.7	-	-	-
Scenedesmus quadricauda	1166.7	373264.2	5.7	P<0.05
Selenastrum gracile	116.7	-	-	-
Staurastrum rotula	5083.3	8750.0	3.4	P<0.05
Chlamydomonas ehrenbergii	-	208335.0	-	-
Coelastrium spaericum	-	31042.7	-	-
Cosmarium pyramidatum	-	143541.7	-	-
Dictyosphaerium pulchellum	-	1506875.0	-	-
Pandorina charkowiensis	-	1041.9	-	-
Eudorina elegans	-	8229.0	-	-
Spondylosium planum	-	694.4	-	-
Tetraedron sp	-	6666.7	-	-
Pediastrum simplex	-	8645.9		
Cyanophyceae(Blue–green Algae)				
Merismopedia elegans	500.0	4687.7	10.6	P<0.05
Microcystic sp	1500.0	-	-	-
Oscillatoria probiscens	-	12187.5	-	-
Crucigenia crucifera	-	2604.2	-	-
Dinophyceae				
Peridinium sp	1666.7	-	-	-
Glenodinium quadriens	-	79791.7		

$p < 0.05$ (significant) and $p > 0.05$ (not significant)

3.3. Zooplankton

Total of sixteen (16) species belonging to seven families were identified during the study. Decapoda were the most diverse taxonomic group with 4 species (Table 3). Other important groups were Cladocera, and Copepoda (3 species), Polychaeta and Rotifera (two species) while *Actinophrys sol* and *Paramecium* were the only Holiozoans and Ciliates present in the lake, respectively. Dry season samples were represented by higher ($p<0.05$) number (15) of species than the wet (7). Polychaetes were absent during the wet season while the decapods were scarce being represented by only one species (*Lucifer hansenii*). Only few species including *Ceriodaphnia cornuta* and *Simocephalus* (Cladocera), *Epiphanes* (Rotifera), *Lucifer hansenii* (Decapoda), *Cyclops* (Copepoda) and *Paramecium* (Ciliates) showed year round presence.

Table 3. Seasonal variation in the occurrence of zooplankton in the Ikwori Lake.

Class/species	Wet season	Dry season
Holiozoa		
Actinophrys Sol	+	-
Ciliata		
Paramecium	++	+
Copepoda		

Cyclop	+	+++
Mesocyclop notius	-	+
Merocyclop	-	+
Cladocera		
Ceriodaphnia cornuta	+	+
Daphnia magna	-	+
Simocephalus	+++	+
Rotifera		
Keratella tropica	-	+
Epiphanes macrona	++	+++
Polychaete larva		
Chaetopterus sp	-	+
Ophiodromus sp	-	+
Decapoda		
Lucifer hanseni	+	+
Bipinnaria larva	-	+++
Penaeid nauphlius	-	+
Mysid larvae	-	+

+ = rare, ++ = common, +++ = dominant, - = absent

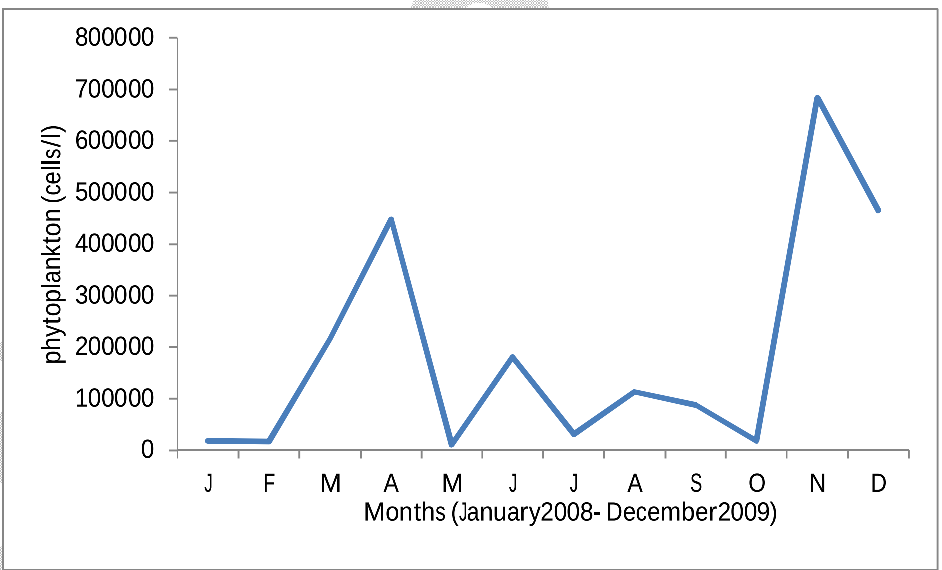

Fig. 4 Monthly distribution of total phytoplankton (cells/l) at the water surface of Ikwori Lake.

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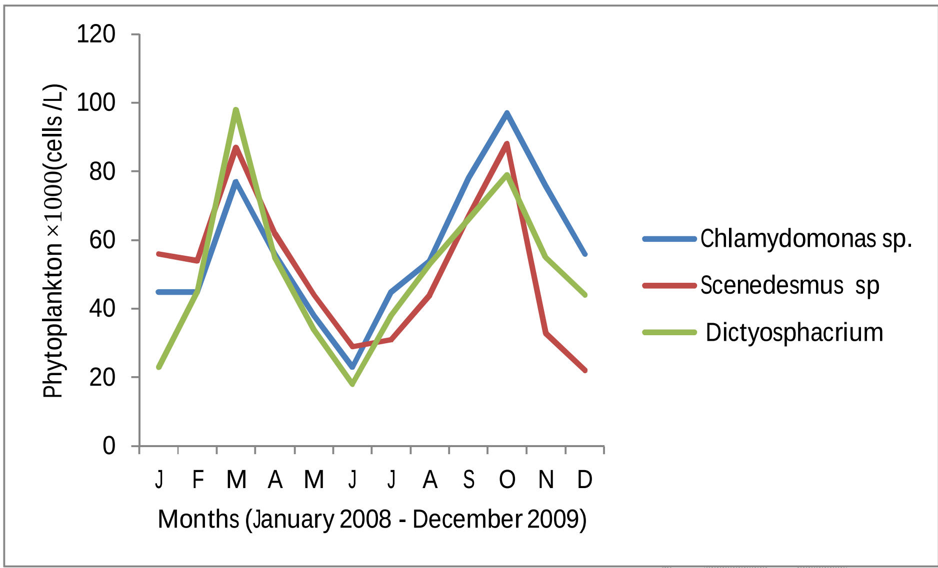

Fig. 5 Monthly distribution of major phytoplankton species *Chlamydomonas chrenbergi, Scenedesmus quadricauda* and *Dictyosphacrium pulchellum* at surface of Ikwori Lake.

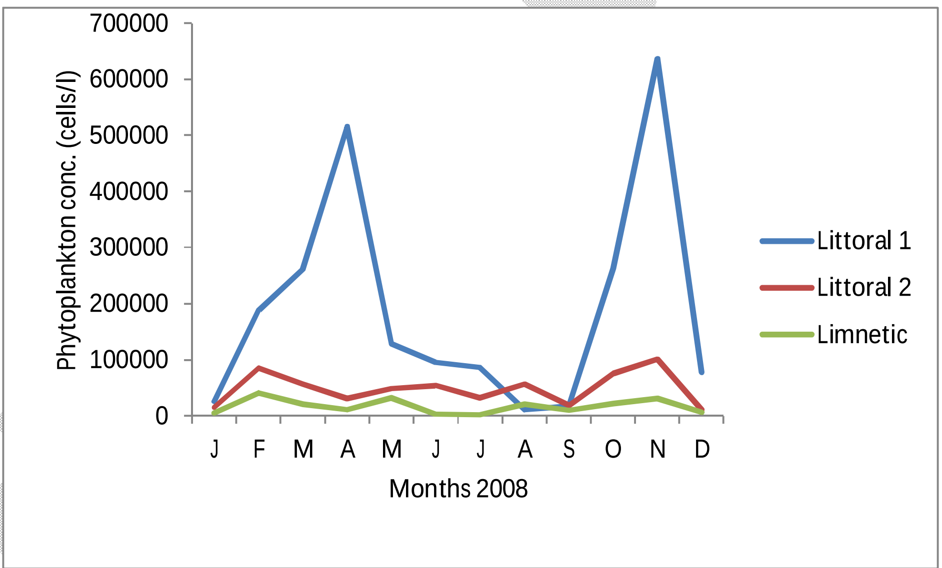

Fig. 6 Monthly variation in the phytoplankton (cells/l) in littoral 1, litoral 2 and the limnetic stations of the Ikwori Lake.

Monthly distribution of zooplankton at the water surface showed highest percentage occurrence in the months of April and November while the lowest was in September and December (Figure 7). The seasonal distribution of the three major zooplankton species was similar at the surface for the three collecting sites (Figure 8). The percentage occurrence at the littoral regions was generally higher than that in the limnetic region with highest percentage occurring in the months of March and December. The zooplankton occurrence at the littoral stations was generally higher than that in the open water (Figure 9).

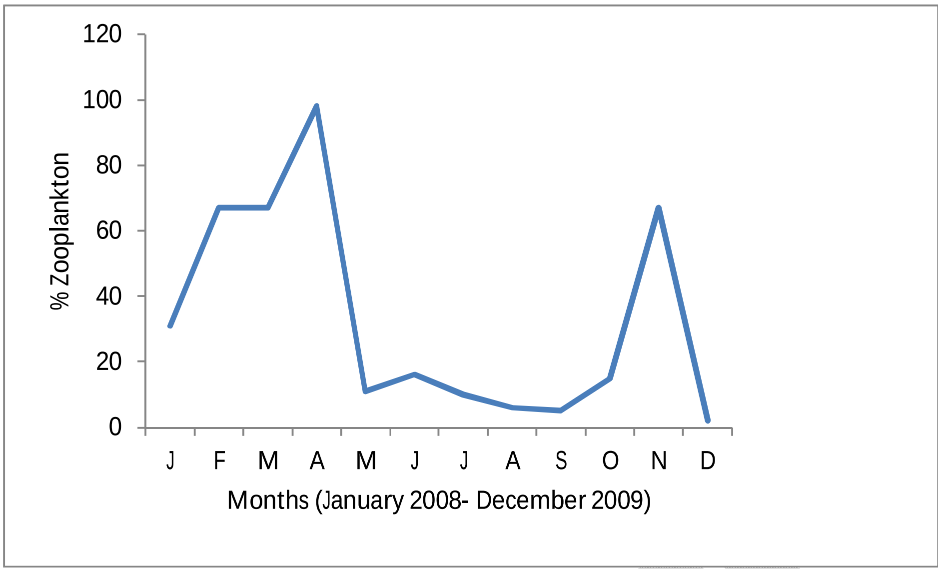

Fig. 7 Monthly variation in the zooplankton at the water surface of the Ikwori Lake.

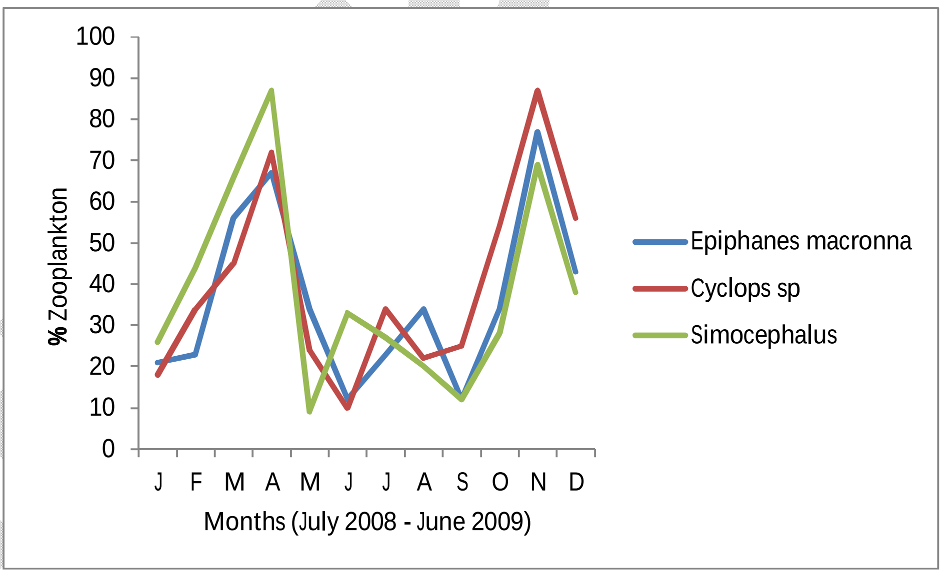

Fig. 8 Monthly distribution of major zooplankton species on the surface of the Ikwori Lake.

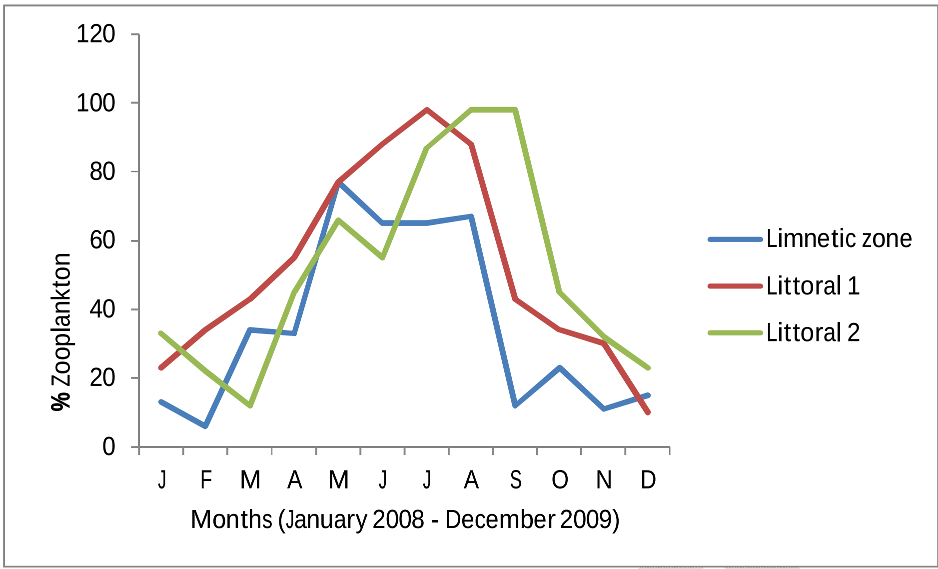

Fig. 9 Monthly distribution of zooplankton in the limnetic, littoral 1 and littoral 2 of the Ikwori Lake.

3.4. Fish species

A total of 4046 fish representing 16 species belonging to 10 families were sampled during both dry and wet seasons, with 7 species (*Hemichromis fasciatus, H. bimaculatus*, *Protopterus annectens*, *Heterotis niloticus*, *Bagrus bayad*, *Malapterurus electricus* and *Chrysichthys filamentosus*) being restricted to wet season and only *Polypterus senegalus* in the dry (Table 4). Cichlidae recorded the most species accounting for 26.6% while Bagridae had 15.0% and Nile tilapia *Oreochromis niloticus* and the African catfish *Clarias gariepinus* dominated overall catch, constituting 22.2% of wet season catch and 14.7% of dry.

Seasonal differentiation in the richness and diversity indices of the plankton and fish species revealed higher values for the dry season samples than wet (Table 5). The equitability index values were low for the two seasons.

Table 4. Seasonal variation in the proportion of fish species in Ikwori Lake.

Families/species	Wet season	Dry season	t-value	t-test
Cichlidae				
Oreochromis niloticus	0.097	0.122	0.071	P>0.05
Tilapia guineensis	0.007	0.021	3.340	P<0.05
Hemichromis fasciatus	-	0.002	-	-
Hemichromis bimaculatus	-	0.001	-	-
Protopteridae				
Protopterus annectens	-	0.003	-	-
Polypteridae:				
Polypterus senegalus	0.003	-	-	-
Osteoglossidae	-	0.004	-	-

Heterotis niloticus				
Mormyridae				
	0.002	0.001	3.221	P<0.05
Mormyrus tapirus				
Characidae				
	0.041	0.008	2.887	P<0.05
Alestes nurse	0.001	0.006	3.122	P<0.05
Alestes macrocephalus				
Clariidae				
	0.051	0.102	4.229	P<0.05
Clarias gariepinus				
Bagridae				
	-	0.005	-	-
Bagrus bayad	0.001	0.003	2.8	P<0.05
Chrysichthys auratus				
	-	0.005	-	-
Chrysichthys filamentosus				
Mochokidae	0.002	0.014	4.111	P<0.05
Synodontis omias				
Malapteruridae	-	0.001	-	-
Malapterurus electricus				

$p < 0.05$ (significant) and $p > 0.05$ (not significant)

Table 5. Seasonal variation in the richness index, diversity function, equitability and the relative proportion of phytoplankton, zooplankton and fish species.

Indices	**Phytoplankton** Wet season	Dry season	**Zooplankton** Wet season	Dry season	**Fish species** Wet season	Dry season
No of species	16	20	7	15	9	15
Richness index (d)	3.3	10.4	1.7	8.8	6.1	12.4
Diversity function(D)	0.8	6.5	0.3	4.5	0.5	5.3
Equitability (E)	0.1	0.7	0.1	0.5	0.1	0.2
Relative proportion	0.4	0.6	0.2	0.8	0.3	0.7

4. Discussion

4.1. Physico-chemical parameters

The higher turbidity in the wet season is contrary to Otobo [22] and Payne [23] and can be explained that as flooding occurred due to heavy rainfall and consequent rise in water levels, run-off from nutrient rich agricultural lands increased, some particles and debris were carried along while others were re-suspended under action of wind. High salinity (0.32 – 0.42 ppt) during the wet season was been associated with increased in-flow of water from rocky farmland and bottom nature of the lake. If the rocks contain, calcium salts with mineral containing sodium chloride, it will leach and dissolves into making it salty [22,23]. Low dissolved oxygen observed during dry season could be attributed to oxidation of humic compounds available for decomposition and wind velocity that seemed to be lower thus reducing the movement of the waters by wind action [24,25]. Dissolved oxygen level recorded in this study is lower compared to 4.94-5.9mg/l recorded for Ogun river and 3.4-7.0Mg/L for Calabar River [12] both in Nigeria. High organic enrichment of lakes had been suggested by Mason [26] as the possible reason responsible for such low oxygen values. The values of dissolved oxygen fell below the ranges (5.0- 9.0mg/l) documented by Swingle [27], Boyd [4] and Alabaster [28] for good water quality suitable for aquatic organisms. None of the samples used for determining TDS was up to maximum admissible concentration (600mg/l) of total solids as stipulated by WHO and EEC. Conductivity range (177-214us/cm^{-1}) was higher in the wet season. The higher value could be due to ground water and surface runoff from the grounding farmlands that might have increased ionic substances such as nitrate, chloride and phosphate from fertilizers [29]. Conductivity of fresh water ranged from 10 – 1000 us/cm^{-1} but may exceed 1000 us/cm [30]. The guide limit of water conductivity set by EEC [31] is 400µs/cm and our data showed that both the wet and dry season samples do not exceed this limit. High values of phosphate ions concentration in the lake in both seasons could be attributed to effluents from agricultural lands with high content of phosphate fertilizers. Average pH values obtained in this study agree with those documented by Swingle [32], Boyd [12], EEC [33], Baijot et al. [34] and Unoha [35] as values most suitable for maximum productivity of aquatic organisms. The values are within the range commonly found in oligotrophic and eutrophic lakes where typical reading lies between pH 6.0 and pH 9.8 [36]. High mean value recorded during wet season could be due to combined effects of run-off from agricultural lands (with high concentration of lime) and photosynthetic activity of macrophytes. Rippey and Rippey [37] observed that there was increase in pH with photosynthesis. Low pH value in dry season was attributed to anthropogenic acidification of allochthonous organic matter. The onset of the rains caused increase in pH, this dilution effect of rains ameliorated biological conditions in lakes [38]. The low biological oxygen demand value recorded contradicts observation by Nwankwo et al. [39] of high values in lake or creek in Western Nigeria. This may be a reflection of the low amount of decomposing materials within the water arising from the surrounding derived savannah vegetation. Alkalinity value is within the reported range of 20 -150 mg/l [40] considered to contain suitable quantities of carbon dioxide (CO_2) to permit plankton production for fish culture. Low alkalinity during dry season is supported by Nwadiaro et al. [41] who reported that alkalinity of Oguta Lake was low during the dry season. The high level of carbon dioxide is as a result of high respiration from aquatic biota, during aerobic and anaerobic heterotrophic decomposition of suspended and sedimented organic material. The high value for colour in the study site was an indication of the higher level of biological activity [42]. Carbonate value range (21.2 – 33.0 mg/l) was high compared to UNESCO recommend carbonate of 10 mg/l and bicarbonate of 42.2 – 55.6 mg/l as against surface waters usually less than 500mg/l and commonly less than 25mg/l. UNEP observed that weathering process of rock contributes about 50 percents of carbonate and bicarbonate in natural rocky waters.

4.2. Phytoplankton

Phytoplankton communities in tropical lakes and reservoirs represent summer communities of temperate lakes with a large number of tropical taxa including pan-tropical and regional endemic elements [43]. Progressive decline in phytoplankton diversity towards tropics has been suggested by Lewis [44]. The phytoplankton composition of the lake in this study agreed with reports of Adebisi [2] and Ayodele and Ajani [3] that blue-green algae, green algae dominate most tropical African Lakes. The dominance of *Chlorophyceae* in respect of species number and population density in Ikwori Lake had also been observed elsewhere [45-47] and the overwhelming presence in the dry season had been attributed to the presence of bright sunshine, isothermal water column and extensive catchment area draining calcium rich agriculture land [48,49]. Physiological and behavioural flexibility of Chlorophyceae can accommodate environmental stresses better than most fast growing species [50]. Second to Chlorophyceae in prominence was Cyanophyceae, which were also found to be prominent in Bulgaria [51], in Hungary [52] and in Sanabria Lake (Spain) [53]. Cyanophyta dominance, and sometimes bloom are amongst the most visible symptoms of accelerated eutrophication of lakes [55]. The observation in Ikwori Lake is similar to findings by Adeniyi [56] that the abundance of phytoplankton increases with increase in transparency, which normally associated with black flood (dry season), while the high turbidity associated with the white flood (wet season) results in a decrease in its abundance. It was also reported, during monsoon, mostly in ponds and reservoirs in Asia, where phytoplankton minimum can be observed during the wet months [47]. According to Sugunan [57], most of the reservoirs in India have three plankton pulses coinciding with the post-monsoon (October to November), winter (December to February) and summer (March to May) seasons, all within the dry season. During the wet months (June-August) flushing disturbs the standing crop of plankton. However, when the destabilising effects wean away, the nutrient input favours an accelerated plankton growth in November. The annual black and white flood pattern of the lake is the most important factor regulating phytoplankton production [58,59]. Phytoplankton abundance, seasonality of aquatic invertebrates [60,61] and annual colonisation of shoreline by aquatic macrophytes in Kainji Lake [62] vary with flood condition. In Ikwori Lake dry season mostly starts in November. The high temperature, bright sunlight and rapid tropholytic activities by the decrease in water level and the movement of the deep, nutrient-rich areas into the fold of tropholytic zone, increase plankton biomass during dry month of November and April. Increased in phytoplankton biomass was not observed in December despite being dry month probably due to the North-East Trade wind (Hammatan) and comparatively low amount of nutrients indicated by low values of Alkalinity, TDS and Conductivity during this period.

The considerable fluctuations in the seasonal distribution of total phytoplankton concentrations at the 2m depth as against the similar pulse pattern observed at surface and 1m levels, may be as a result of the settling of plankters from the upper levels which tend to increase their numbers after the phytoplankton development of the upper strata.

4.3. Zooplankton

The zooplankton population dominated by decapods followed by copepods and cladocerans was similar to Egborge [63] documentatioon. There may be alternation in abundance between crustaceans and rotifers as reflected in the distribution and abundance of zooplankton in the sampled lake. These alternation in the abundance of species in Lake Asejire was regarded as a booster of all year round food for fish in the lake [64]. This study showed that the seasonal variation in zooplankton concentration could largely be due to the Rotifera, which normally constitute major diet items of larger zooplankton. Species of rotifers and crustaceans considered good indicators of the trophic state of the lakes were identified in the zooplankton community. Rotifers species recorded were typical of oligotrophic to mesotrophic systems and these include *Keratella tropica* and *Epiphanes macronna*. The crustacean zooplankton community was made up of copepods and cladocerans. Copepod abundance was caused by increase in Cyclopoid copepodids and Mesocyclops which are indicative of good water quality. [65]. Zooplankton occurrence is generally high during the dry season because temperature and the availability of food are about the most important factors controlling the abundance of zooplankton in lakes [58]. In this study, with higher temperature regimes pervading the entire dry season, the high level of food in the water as a result of high primary productivity can be responsible for the high populations of zooplankton. With the beginning of the rainy season, nutrients are carried to the Lake allowing the growth of phytoplankton [66] and this is associated with high temperature that increases zooplankton breeding and consequently a high production occurred during the dry season. In the dry season, the zooplankton population appeared to have great stability and in the rainy season, the population is suspected to lack stability. This may depend on the residence time of water and on the abrupt water change, which occur frequently during the rainy season [67]. The increased turbidity of the white flood (dry season) destroys the periphytic algae and causes a decline in the amount of phytoplankton [63,61], which in turn reduces the standing crop of the herbivorous invertebrate fish food [63]. Zooplankton and fish distribution is restricted to aerate upper water layers and littoral regions of the lake during dry season [63,67].

4.4. Fish species

Seasonal differentiation in the ichthyofauna, evident in higher number of species and individuals caught during dry months of the study period, agree with results from Kainji Lake [68], Asejire Lake [65], Jebba Lake [61] and Asa Lake [69] who described larger ichthyofaunal densities in water bodies in the dry season. Reasons for the variation were ascribed to the large volume of water during the wet season, available fish were now dispersed over a wider area, and fishing became more difficult. Also during wet season the high level of water and subsequent flood favored reproductive activities, hence fish species show restricted movement making them less vulnerable to catch. Fishermen's catches improve greatly during the dry season due to the migration of deep water fishes away from the anoxic deep waters to the aerated upper waters during this period [70].

4.5. Diversity

The average diversity function calculated by Shannon-Wiener Diversity index, was higher for the dry season than wet for all species studied, revealing that dry season samples were more diversified and stable.

Based on the present observation, Ikwori Lake is rich in plankton and the nutrient status is high enough to support plankton populations in both seasons. If the integrity of such lakes in the tropics is protected, they will support fish growth and survival especially in the dry season. This lake appeared to be under pollution pressure due to high phosphate concentration in both seasons. Management efforts must therefore be directed towards ensuring that only treated effluents are allowed into Ikwori Lake. In addition, waste facility must be provided for the surrounding communities by the managers. Activities whose by-products result in organic effluents into lakes must be discouraged.

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Competing Interests

The work was funded with Senate Research Grants from the Cross River University of Technology. Otherwise, the authors declare that they do not have any competing interests.

Authors' Contributions

BO headed the research team, worked on the experimental design, sampling and analysis of water quality, assembled and discussed the various aspects of the work. EA sampled and analyzed the phytoplankton, GI worked on the zooplankton aspects, SO sampled and analyzed the fish while FA carried out the statistical analysis.

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References

[1] Akpan ER, Offem JO, 1993a. Seasonal variation in water quality of the Cross River State Nigeria. Hydrobiologia, 26: 95-103.

[2] Izonfuo LWA, Bariweni AD, 2001. The effects of urban runoff water and human activities on some physico-chemical parameters of the Epie Creek in the Niger Delta. Journal of Applied Science and Environmental Management, 5: 47-56.

[3] Olajire AA, Ayodele ET, Onyedirdan GO, Oluyemi EA, 2003. Levels and speciations of heavy metals in soils of industrial Southern Nigeria. Environment Monitoring and Assessment, 85: 135-144.

[4] Boyd CE, 1981. *Water quality in warm water fish ponds*. Auburn University Publishers, Alabama.

[5] Ezra AG, Nwankwo DI, 2001. Composition of phytoplankton algae in Gubi reservoir, Bauchi. Nigerian Journal of Aquatic Science, 16: 115-118.

[6] Antia ES, Holzlohner S, 1996. Bibliography of a decade 1975-1985 of coastal studies of the Cross River estuary and environs by the Institute of Oceanography, University of Calabar, Nigeria. Journal of Coastal Resources, 1: 40-42.

[7] Smith CL, Powell CR, 1971. *The Summer Fish Communities of Brier Creek*, Marshall County, Oklahoma, Museum Novit, 2459: 1-30.

[8] APHA, 1998. *American Public Health Association: Standard methods for the examination of water and wastewater*. 20th edn Washington D.C.

[9] Azionu BC, 1983. Spatial and diet variations in some hydrological features of the Shehu Reservoir, Plateau State. Journal of Aquatic Science, 10: 14-20.

[10] Imevbore AMA, 1967. Hydrobiology and plankton of Eleyele Reservoir, Ibadan, Nigeria. Hydrobiologia, 30: 154-175.

[11] Enin UI, 1994. The artisanal shrimp fishery of the Outer Cross River Estuary, Nigeria. Ph.D. Thesis, University of Calabar, Institute of Oceanography.

[12] Golterman HI, 1969. *Methods for chemical analysis of freshwater*. Int. Biol. Program. Handbook & Oxford, Blackwell Scientific Publications.

[13] Han M, 1978. *Illustration of freshwater plankton*. Agricultural Press, 1-45.

[14] Prescott GW, 1982. *Algae of the West Great Lakes Area*. W.M.C. Brown Company Publishers, Dubugue Press, Towa, 200-300.

[15] Kadiri MO, 1988. Seasonal changes in the phytoplankton biomass of shallow tropical reservoir. Nigeria Journal of Botany, 6: 167-173.

[16] Kemdirim EC, 2001. Checklist of phytoplankton of Shedam reservoir in Plateau State. Nigeria Journal of Aquatic Science, 16: 61-66.

[17] Elvira M, 1987. Taxonomic revision of the genus *Chondrostoma* Agassi 1835 (Pisces: Cyprinidae). Cybium, 11: 111-198.

[18] Erk'akan F, Nalbant TT, Ozeren SC, 2007. Seven new species of *Barbatula*, three new species of *Schistura* and a new species of *Seminemacheilus* (Ortariophysi: Balitoridae: Nemachellinae) from Turkey. Journal of Fisheries and Aquatic Science, 2: 69-85.

[19] Teugels GG, 1982. Preliminary results of morphological study of five African species of the subgenus *Clarias* (Pisces: Clariidae). Journal of Natural History, 16: 439-553.

[20] Fischer W, Schneider M, Bauchot ML, 1987. *Mediterranee et Mer Noire Zone De Peche 37 Revision Volumn II Vertebrates*. FAO, Rome, 763-1578.

[21] Clarke KR, Warwick RM, 1994. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. Natural Environmental Research Council, Bournemouth, 231-235.

[22] Krebs CJ, 1978. *Ecology: The experimental analysis of distribution and abundance*. Harper Intellectual Edition, New York, 12-35.

[23] Zar JH, 1996. *Biostatistical Analysis*. Prentice-Hall International, London, 45-48.

[24] Khan MA, Ejike A, 1984. Limnology and plankton periodicity of Jos Plateau water reservoir, Nigeria. Hydrobiologia, 114: 189-199.

[25] Ovie SI, Adeniji FS, 1993. *Mass production of zooplankton in outdoor concrete tanks for fish culture*. New Bussa Publishers, 129-135.

[26] Grossman GD, Freeman MC, 1987. Microhabitat use in stream fish assemblage. Journal of Zoology, 212: 151-176.

[27] Egborge ABM, 1977. The hydrology and plankton of Asejire Lake. University of Ibadan Publishers, Nigeria, 67-78.

[28] Odinetz CO, 1989. Qquel characteristiques physiochemiques d'un lac de varzea enema zarie central lago do rei, ile de careiro. Hydrobiologia, 22: 191-199.

[29] Enrique V, 1992. Temperature and dissolved oxygen in Lake of the Lower River Floodplain (Venezuela). Hydrobiologia, 25: 23-33.

[30] Asuquo FE, 1999. Physico-chemical characteristics and anthropogenic pothition of the surface waters of Calabar River, Nigeria. Global Journal of Pure and Applied Science, 5 (4): 595-600.

[31] Mason CF, 1992. *Biology of fresh water pollution*. Wiley and Sons, New York.

[32] Swingle HS, 1969. *Relationship and dynamics of balanced and unbalanced fish population*. Alabama Polytechnic Institute of Agriculture & Experimental Station, 34-67.

[33] Alabaster JS, 1982. *Report of the EIFAC*. Workshop on fish farm effluents. Technical Paper 41, FAO, Rome.

[34] Phiri P, Mumba O, Moyo BHZ, Kadewa W, 2005. Assessment of the impact of industrial effluents on water quality of receiving rivers in urban area of Malawi. Aquafield, 3: 12-15.

[35] Deborah C, 1992. Water quantity assessments: A guide to the use of biota, sediments and water in environment monitoring. Air, Water and Soil Pollution, 34: 56-78.

[36] European Economic Community (EEC), 1976. *EC Drinking Water Standards*. Directive 80/778/EEC. EEC Brussels, 34-54.

[37] Baijot E, Bouda S, Quedraogo L, 1997. *Physical, chemical and biological characteristics of reservoir in Burkina Faso*. C. T. A. Publication, Quagadogo, 39-48.

[38] Unohia CG, 2001. Studies on the physico–chemical characteristics and productivity of concrete reservoir. Global Journal of Agricultural Science, 1 (2): 23-56.

[39] Rippey I, Rippey B, 1986. Chemical limnology of two artificial lakes. Hydrobiologia, 139: 234-237.

[40] Fagade SO, Olaniyan CIO, 1993. Seasonal distribution of the fish fauna of the Lagos lagoon. Journal of Aquatic Science, 34: 123-130.

[41] Nwankwo DIK, Onyema T, Adesah A, 2003. A survey of harmful algae in coastal waters of southwestern Nigeria. Journal of Nigerian Environmental Society, 9: 23-45.

[42] Boyd CE, Lichtkoppler F, 1979. Water quality in warm water fish pond. Agricultural Experimental Station, Auburn University, AL, 45-54.

[43] Nwadiaro CS, 1984b. The longitudinal distribution of macro-invertebrates and fish in a lower Niger delta river - River Sombreiro in Nigeria. Hydrobiologia, 18 (2): 133-140.

[44] Fjellherm A, Radum G, 1990. Acid precipitation; Biological monitoring of streams and lakes. Journal of Aquatic Science, 44: 23-33.

[45] Vyverman W, 1996. The Indo-Malaysian North-Australian phycogeographical region revised. Hydrobiologia, 118: 107-120.

[46] Lewis WM, 1996. Tropical lakes, how attitude makes a difference. In: (Schiemer F, Boland KT, eds.) *Perspective in Tropical Limnology*. SPB Academic Publishing, Amsterdam.

[47] Tressler WL, Tiffany LH, Spencer WP, 1940. Limnological studies of Buckeye Lake. Ohio Journal of Science, 40: 261-266.

[48] Willen T, 1959. The phytoplankton Gordon, A bay of Lake Maleren. OIKOS, 10: 241-274.

[49] Silva EIL, 2005. Ecology of phytoplankton in tropical waters: Introduction to the topic and ecosystem changes from Sri Lanka. Pollution, 4: 25-35.

[50] Pennack RW, 1949. The dynamics of fresh-water populations. Ecological Monograph, 16: 342-366.

[51] Kurasawa H, Shiraishi Y, 1954. *Studies on the biological production of Lake Suwa*. Research Institute of Natural Resources, 22-57.

[52] Silva EIL, 2004. Phytoplankton Characteristics, Trophic Evolution and Nutrient Dynamics in an Urban Eutrophic Lake: Kandy Lake in Sri Lanka. Edited by Reddy MV; *Restoration and Management of Tropical Eutrophic Lakes*. Oxford and IBH Publishing, New Delhi.

[53] Stoyneva MP, 2003. Steady-state phytoplankton assemblage in shallow Bulgarian wetlands. Hydrobiologia, 502: 169-177.

[54] Padisak J, Reynolds CS, 1998. Selection of phytoplankton associations in Lake Balaton, Hungary in response to eutrophication and restoration measures, with special reference to the Cyanoprokaryotes. Hydrobiologia, 384: 46-56.

[55] Hoyos C, Comin FA, 1999. The importance of inter-annual variability for management. Hydrobiologia, 395/396: 281-291.

[56] Moss B, Madgwick J, Phillips G, 1997. *A Guide to the Restoration of Nutrients - Enrich Shallow Lakes*. W.W. Hawes, UK. 23-43.

[57] Adeniyi HA, 1978. Diurnal vertical distribution of zooplankton during stratification in Kainji Lake, Nigeria. International Journal of Limnology, 20: 1677-1689.

[58] Sugunan VV, 2000. Ecology and fishery management of reservoirs in India. Hydrobiologia, 430: 121-147.

[59] Karlman SG, 1982. The annual flood regime as a regulatory mechanism for phytoplankton production in Kainji Lake, Nigeria. Hydrobiologia, 86: 93-98.

[60] Adeniji A, 1979a. Seasonal variation in pelagic primary productivity of the Kainji Lake and the river below the dam. KLRI, 10: 23-45.

[61] Halstead LD, 1971. Freshwater bivalves of the shores of Lake Kainji. The Nigerian Field, 36 (3): 125-139.

[62] Bidwell A, 1979. Observation on the biology of the nymphs of *Povilla adusta* (Ephemeroptera) in Lake Kainji. Hydrobiologia, 67 (2): 1022-1085.

[63] Obot EA, Ayeni JSO, 1987. *A handbook of common aquatic plants of Kainji Basin – Nigeria*. Kainji Lake Research Institute/Saolog Printing Production, Ilorin.

[64] Egborge ABM, 1981b. The composition, seasonal variation and the distribution of zooplankton in Lake Asejire, Nigeria. Revista de Zoologia Africana, 95: 136-144.

[65] Sendacz S, Kubo E, Cestarolli MA, 1985. Limnologia de reservatios do estado do Sao Paulo, Brasil. VIII Zooplankton, 145-176.

[66] Imoobe TOT, Adeyinka TO, 2010. Crustaceans of Jamieson River, Nigeria. Ph.D. Thesis of the University of Benin, Benin, Nigeria.

[67] Turner JL, 1970. The fish population of impounded Kainji Lake. FAO Technical Report, No. 1: 1-59.

[68] Imevbore AMA, 1975. The chemistry of lake Kainji waters. Edited by Imevbore AMA, Adegoke SO; *Ecology of Lake Kainji, Transition from River to Lake*. University of Ife Press.

[69] Vander-Heide J, 1982. *Lake Brokopondo: Filling phase limnology of a man-made lake in the human tropics*. Alblasserdam Offsedrukkerij Kanters, B.V.

[70] Adeniji HA, 1991. Limnology and biological production in the pelagic zone of Jebba Lake, Nigeria. Ph.D. Thesis, Univ. of Ibadan, 89-122.

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