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Physico-Chemical Parameters and Plankton Community of Egbe Reservoir, Ekiti State, Nigeria

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Abstract: The physico-chemical parameters and plankton of Egbe Reservoir were studied from September 2004 to October 2006. Mean temperature, pH, conductivity, alkalinity, TSS, TDS and DO, BOD were 28.7°C±0.9, 8.3±0.3, 831±172.5 μS cm^{-1}, 165.4±18.3, 0.06±0.1, 0.4±0.6, 7.8±2.4 and 5.1±1.6 mg L^{-1}, respectively. Mean nitrate, phosphate and sulphate were 15.6±8.6, 42.5±19.4 and 72.3±mg L^{-1}, respectively. About 35 genera of phytoplankton and 12 genera of zooplankton were identified in the reservoir. Diatoms dominated the plankton community making up 27.2% of the total plankton abundance by number while the Rotifers dominated the zooplankton, contributing 12.6% of the total plankton abundance. Diatoms showed the highest diversity (d = 1.77, H = 2.51) and are most evenly distributed (J = 0.93) among the phytoplankton while the Rotifers also showed the highest diversity (d = 0.70, H = 1.69) and even distribution (J = 0.94) among the zooplankton. Pollution indicator phytoplankton observed included *Microcystis*, *Anabaena*, *Synedra*, *Melosira*, *Euglena*, *Phacus* and *Lepocinclis*.

Key words: Physicochemical parameters, phytoplankton, zooplankton, species diversity, Egbe reservoir

INTRODUCTION

The relationship between the physico-chemical parameters and plankton production of water bodies are of great importance in management strategies of aquatic ecosystems. Reservoirs, ponds, rivers and ground waters are used for domestic and agricultural purposes. The quality of water may be described according to their physico-chemical and plankton characteristics. The phytoplankton in a reservoir is an important biological indicator of the water quality. While phytoplankton are important primary producers and are at the base of the food chain in open water, some species on the other hand can be harmful to human and other animals by releasing toxic substances (hepatotoxins or neurotoxins etc.) into the water (Whitton and Potts, 2000). Phytoplankton are recognized worldwide as bioindicator organisms in the aquatic environment (Yakubu *et al*., 2000).

Zoooplankton are heterotrophic planktonic animals floating in water which constitute an important food source for many species of aquatic organisms. In addition, they serve as indicator organisms of water type, fish yield and/or total biological production. These probably explain why much of the fascination in the study of lakes lies in the structure and dynamics of zooplankton populations (Goldman and Horne, 1983).

Some reports exist on plankton populations of several water bodies in Nigeria and indeed Africa. These include those of Holden and Green (1960) on the plankton of River Sokoto while Imevbore (1965) gave a preliminary checklist of the zooplankton of Eleiyele reservoir, Ibadan.

Nwankwo (1986) worked on the plankton of Lagos Lagoon, on Oginigba Creek, Port Harcourt (Chinda and Pudo, 1991), others include Nkisa and Orashi rivers in Rivers State (Yakubu *et al*., 2000), New Calabar river (Nwadiaro and Ezefili, 1986; Erondu and Chindah, 1991; Chindah, 1998), Ikpoba reservoir, Edo State, (Kadiri, 1999a, b; 2000, 2002) on Ikogosi Springs, Ekiti State (Fafioye and Omoyinmi, 2006) on Omi river, Ago-iwoye, Ogun State, Okpoba Creek, Port-Harcourt (Akoma, 2008) on an Imo river (Tawari *et al*., 2008) on the lower Sombreiro river, Niger Delta (Davies and Otene, 2009) on Minichinda Stream, Port-Hacourt. However, information on the plankton of Egbe reservoir is scarce.

Ekiti State inherited four major dams from the former Ondo State when it was created on the 1st of October 1996. These dams are located in Ado-Ekiti (Ureje), Gbonyin (Egbe), Moba (Ero) and Ikole (Itapaji) local government areas of the state. Water from these dams is being supplied to the public for domestic purposes. Since, the establishment of these dams few research works have been conducted on them, concerning the

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physico-chemical status of water from these dams. Adefemi *et al.* (2007) carried out an assessment of the physico-chemical status of water samples from these major dams in Ekiti State.

Idowu (2007) reports on the physico-chemical parameters of Ureje reservoir in Ado Ekiti in her research on aspects of the biology of African pike, *Hepsetus odoe* while Oso and Fagbuaro (2008) also investigated the physico-chemical properties of Ero reservoir. Apart from the research of Adefemi *et al*. (2007), no published works exist on Egbe reservoir since the impoundment of Osse river to form the reservoir in 1989. This research will represent the first detailed investigation into the physico-chemical parameters and plankton of Egbe reservoir. This study aims to provide a record of investigations into the plankton abundance, distribution and diversity and physico-chemical parameters in Egbe reservoir and the effect of seasons on these parameters.

MATERIALS AND METHODS

Study area: Egbe reservoir originates from Kwara State, Nigeria and flows from North to South through Ode to Egbe Ekiti (latitude 7°36'N and longitude 5°36' E), Nigeria. It was built in 1975 by damming the Osse river at Egbe Ekiti. It covers an area of 26.5 ha with a depth of 56.4 m at its deepest. The reservoir is located on an undulating plane, surrounded by highlands from which runoffs also feed the reservoir during raining seasons. The capacity of the reservoir is about 144,000,000 million m^3.

The river bedrock is composed of metamorphic rocks and the reservoir is surrounded on each side by a stretch of thick forest. Four sampling station were chosen on the reservoir (Fig. 1).

Sample collection and analysis: Sampling was carried out twice a month during the months of September 2004 to October 2006 for the study of physico-chemical parameters. Plankton sampling commenced in September 2005 to December 2006. Sampling periods were usually between 8.00 and 12.00 noon. About 2 L water samples were collected at each sampling point using acid pre-washed polyethylene bottles. Water quality parameters and nutrients were analyzed using the standard methods of (APHA, 1998).

The parameters analyzed include pH (pocket pH meter), temperature (Celsius thermometer), conductivity (Conductivity meter), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) (Gravimetry method), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) (Winkler method). Nutrients measured include nitrate (NO_3^-), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}) which were determined by spectrophotometrically. Plankton samples were collected by pouring 50 L of surface water through plankton net of 60 μm mesh size and 30 cm diameter. The filterate was concentrated to 100 mL for each station and 4% formalin added to each sample to preserve the organisms and 3 drops of Lugol's solution was added so as to allow the organisms to settle. The bottles were covered and properly labeled at each

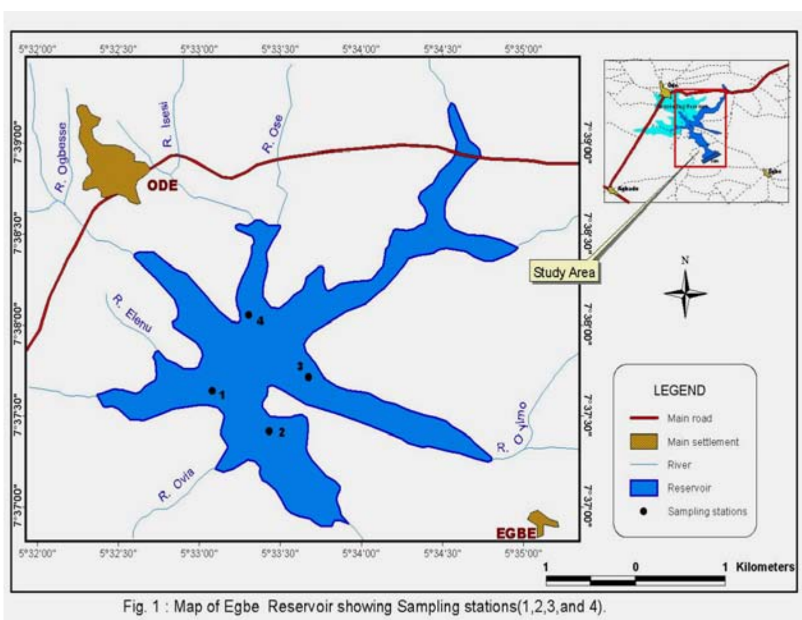

Fig. 1: Map of Egbe reservoir showing sampling stations (1-4)

location. About 0.5 mL sub sample of the concentrated plankton suspension was pipetted onto an improvised counting chamber and all the plankton were identified at least to generic levels and enumerated using keys provided by Whitford and Schumacher (1973), Needham and Needham (1975), Jeje and Fernando (1992) and Nwankwo (2004) and plankton were counted as number per mL and then calculated as number per liter of water. The results of physico-chemical parameters were presented as mean±standard deviation.

Duncan Multiple Range Tests (DMRT) and Pearson correlation were performed on the data using SPSS 10.0 for windows in order to determine significant relationships between the physico-chemical parameters and plankton. Student's t-test was also done to determine the effect of seasons on the measured parameters.

The monthly mean and percentage abundance by number of plankton was calculated for all sampling stations during dry and rainy seasons as well as for entire reservoir.

Paired t-test was also used to determine if there exist significant differences between the rainy and dry season mean total abundance of plankton.

The monthly means were plotted as line graph under Microsoft Excel. Diversity of the plankton was determined using Shannon-Weaver (H), Margalef (d) and Equitability (J) diversity indices. Shannon-Weaver's index is expressed as:

$$H = \sum_{i=1}^{s} P_i \log P_i$$

$$P_i = \frac{ni}{N}$$

Margalef's index is a measure of species richness and was expressed as:

$$d = \frac{S-1}{\mathrm{Log}_e N}$$

Equitability measures how evenly the species are distributed in the sampled community. It was expressed as:

$$J = \frac{Hs}{\mathrm{Log}_2 S}$$

Where:

S = Total number of species
N = Number of individuals in the sample
ni = Number of individuals of species i in the sample
P = Proportion of sample made up by the ith species
d = Margalef's diversity index
H = Shanon-Weaver diversity index
J = Equitability index

RESULTS

The means and ranges of the physico-chemical parameters studied are shown in Table 1 while Table 2 shows the seasonal differences in mean values of physico-chemical parameters. Water temperature in four locations ranged from 26.8°C at Rocky station to 31.8°C at Dam site station and with the mean value of 28.7°C±0.88. The dry season mean temperature was significantly ($p<0.05$) higher than the wet season mean value. The reservoir water was alkaline in nature with the pH ranging between 7.4 at Rocky station and 8.9 at Dam, Rocky and Bridge stations.

There was no significant ($p<0.05$) difference between the dry and wet season mean values of pH (Table 2). The mean conductivity of the water samples fluctuated with the highest value of 1,200 μS cm^{-1} at the Rocky station and the lowest 100 μS cm^{-1} in September 2005 also at the Rocky station and a mean value of 231±172.5 μS cm^{-1}.

Mean conductivity was significantly ($p<0.05$) higher in the wet season than in dry season. Secchi disc transparency varied between 0.56 m at Bridge station and 2.15 m at Dam station with a mean value of 1.09±0.34 m. Transparency had a higher dry season mean value than wet season.

The highest alkalinity was 215 mg L^{-1} at the Dam station and the least, 125.6 mg L^{-1} occurred at the Bridge station. It however had a significant ($p<0.05$) higher mean value during the wet season. The mean TSS was constant (0.01 mg L^{-1}) in all the stations except at the Rocky station where there was an increase (2.00 mg L^{-1}). TSS also showed no significant difference ($p<0.05$) in mean value during both dry and wet seasons.

The total dissolved solids of the water samples ranged between 0.02 mg L^{-1} at the Rocky and Bridge stations and 2.28 mg L^{-1} at the Inlet station with a mean value of 0.36±0.58 mg L^{-1}. The dissolved oxygen concentration of the water samples varied between 3.00 mg L^{-1} at the Rocky station and 12.7 mg L^{-1} also at the Rocky station with a mean value of 7.84±2.38 mg L^{-1}.

Biochemical oxygen demand of the water samples was minimum 2.01 mg L^{-1} at the Inlet station and maximum was 12.5 mg L^{-1} at Rocky station with a mean value of 5.14 mg L^{-1}. The minimum nitrate concentration of the water samples was 6.82 mg L^{-1} at the Inlet station and the maximum 34.7 mg L^{-1} occurred at the Rocky station with a mean value of 15.6±8.60 mg L^{-1}.

Phosphate ranged between 11.8 mg L^{-1} at the Inlet station and 91.5 mg L^{-1} at the Bridge station with a mean value of 42.5±19.4 mg L^{-1}. Sulphate content of the water samples was found to fluctuate

Table 1: Mean and range of physico-chemical parameters in four locations of Egbe reservoir

Physicochemical parameters	Dam station	Rocky station	Bridge station	Inlet station	Mean±STD (range)	Coefficient of Variation (CV)	WHO/FME (1995) standard	US EPA (2008)
Ph	8.15^{b}	8.30^{b}	8.26^{ab}	8.36^{a}	8.27±0.34 (8.9-7.4)	4.07	7.0-8.5	6.5-9.0
Temperature (°C)	29.2^{a}	28.7^{b}	28.7^{b}	28.7^{b}	28.7±0.88 (31.8-26.8)	3.06	30-32	30-32
Conductivity (μS m^{-1})	830.8^{a}	839.7^{a}	842^{a}	800.3^{a}	231±172.5 (1200-62.5)	20.76	≤1000	-
Transparency (m)	1.53^{a}	1.08^{b}	0.89^{c}	0.92^{c}	1.09±0.34 (2.14-0.56)	31.43	-	-
Alkalinity (mgCaCO$_3$ L^{-1})	167.8^{a}	167.2^{a}	165.4^{a}	162.3^{a}	165±18.25 (215-125.6)	11.03	-	1000
Total suspended solids (mg L^{-1})	0.05^{a}	0.11^{a}	0.06^{a}	0.05^{a}	0.06±0.14 (2.00-0.01)	214.96	≤5	-
Total dissolved solids (mg L^{-1})	0.20^{bc}	0.40^{b}	0.35^{b}	0.65^{a}	0.36±0.58 (2.28-0.02)	160.28	≤200	>5.5-6.5
Dissolved oxygen (mg L^{-1})	8.8^{ab}	6.6^{c}	7.4b^{c}	8.7^{ab}	7.84±2.38 (15.5-3.0)	30.39	≥5	-
BOD (mg L^{-1})	5.2^{a}	5.3^{a}	5.8^{a}	4.4^{b}	5.14±1.64 (12.5-2.01)	31.79	≤5	10
Nitrate (mg L^{-1})	15.4^{b}	16.9^{ab}	14.5^{b}	13.5^{b}	15.6±8.6 (128-6.82)	55.09	≥10	10
Phosphate (mg L^{-1})	42.9^{a}	49.4^{a}	42.3^{a}	41.5^{a}	42.5±19.4 (91.5-11.8)	45.70	≤75	-
Sulphate (mg L^{-1})	73.6^{a}	73.8^{a}	72.7^{a}	74.7^{a}	72.3±14.7 (106-32.7)	20.33	≤200	-

$^{a, b, c}$indicate means not significantly different at $p<0.05$

Table 2: Comparison of physico-chemical parameters during dry and wet seasons of the study period (Sept. 2004-Oct. 2006)

Physico-chemical parameters	Dry season		Wet season			
	Mean±STD	Range	Mean±STD	Range	t-value	p-level
pH	8.28±0.35	8.90-7.50	8.25±0.34	8.9-7.4	0.52	>0.05
Temperature (°C)	29.2±0.9	31.5-27.8	28.5±0.8	31.8-26.8	6.28	<0.05*
Conductivity (μS cm^{-1})	796.1±152.07	1180-62.5	848.6±180.1	1200-100	-2.84	<0.05*
Transparency (m)	1.20±0.32	2.10-0.56	1.04±0.36	2.15-0.58	3.73	<0.05*
Alkalinity (mg L^{-1})	159.4±16.0	195-130.2	169.5±19.0	215-125.6	-4.82	<0.05*
TSS (mg L^{-1})	0.04±0.03	0.21-0.01	0.08±0.17	2.00-0.01	-1.96	>0.05
TDS (mg L^{-1})	0.38±0.54	2.12-0.02	0.41±0.63	2.28-0.02	-0.25	>0.05
DO (mg L^{-1})	7.92±5.09	12.7-3.40	7.85±2.26	15.5-3.00	-0.39	>0.05
BOD (mg L^{-1})	5.29±1.65	8.60-2.01	5.08±1.68	12.5-2.4	0.70	>0.05
Nitrate	14.6±4.36	96.5-44.8	15.3±4.6	34.7-7.7	-1.11	>0.05
Phosphate	41.9±19.4	125.6-42.7	45.3±19.6	91.5-12.2	-1.20	>0.05
Sulphate	70.4±13.4	27.8-6.82	75.7±15.0	106-32.7	-2.63	>0.05

*significant difference ($p<0.05$)

between 32.7 mg L^{-1} at the Bridge station and 106 mg L^{-1} at the Dam station with a mean value of 72.3±14.7 mg L^{-1}.

Plankton composition of Egbe reservoir

Phytoplankton composition: Table 3 shows the checklist and percentage composition of plankton identified in Egbe reservoir during the period of study. These was comprised of 35 phytoplankton genera made up of 15 genera of Bacillariophyceae (Diatoms), eight genera of Cyanophyceae (Blue-green algae), six genera of Euglenophyceae (Eugenoids), four genera of Chlorophyceae (Green algae), one genus each of Conjugatophyceae (Filamentous green algae) and Dinophyceae (Dinoflagellates).

The phytoplankton population of the reservoir was dominated by Bacillariophyceae which constituted 27.2% by number of the total plankton identified during the study period.

There were 12 pennate and three centric diatoms. The pennate diatom, *Synedra ulna* has the highest percentage abundance (4.3%) by number while the least abundant amongst this family was *Pinnularia braunii* with 0.5% of the total plankton abundance by number (Table 3).

Cyanophyceae constituted 15.3% of the total plankton abundance by number. It was made up of two colonial forms *Microcystis aureginosa* and *M. turgidis* and six filamentous forms namely *Oscillatoria limnosa*, *O. sanota*, *Lyngbya martensiana*, *Anabaena constricta*, *Rivularia* sp. and *Spirulina platensis*. *O. limnosa* was the most abundant constituting 4.2% and *Rivularia* sp. was the least abundant with 0.2% by number of the total plankton abundance. Euglenophyceae made up 12.5% of the total plankton population with *Euglena acus* as the most abundant in this group comprising 3.1% of the total number. The least abundant euglenoid were *Phacus caudricauda* and *Lepocinclis ovum* having 1.4% each of the total plankton by number (Table 3).

Chlorophyceae accounted for 6.7% of the total number of plankton. *Straurastrum leptocladium* and *Closterium* sp. co-dominated this group making up (2.7%) each of the total plankton by number. *Micrasterias* sp. was the least abundant in this family. Conjugatophyceae represented by Spirogyra only constituted 5.5% of the

Table 3: Checklist and percentage composition plankton of Egbe reservoir

Plankton group phytoplankton	Species/Genera	Total abundance (no %)	Dry season (%)	Wet season (%)
Cyanophyceae	*Microcystis aureginosa*	2.2	1.8	2.4
	M. turgidis	1.8	2.1	1.6
	Oscillatoria limnosa	4.2	3.6	4.4
	O. sanota	2.3	2.7	2.1
	Lyngbya martensiana	1.9	2.0	1.9
	Anabaena constricta	0.8	2.7	0.0
	Rivularia sp.	0.2	0.3	0.1
	Spirulina platensis	1.9	1.7	2.0
	Total	15.3	16.9	14.5
Euglenophyceae	*Euglena acus*	3.1	2.3	3.4
	E. viridis	2.4	1.9	2.6
	Phacus caudricauda	1.4	1.0	1.6
	Trachelomonas hisipida	2.6	1.8	3.0
	T. oblonga	1.6	1.5	1.7
	Lepocinclis ovum	1.4	1.1	1.5
	Total	12.5	9.6	13.8
Chlorophyceae	*Straurastrum leptocladium*	2.7	2.3	3.4
	Closterium sp.	2.7	1.9	2.6
	Gonatozygon sp.	1.3	1.0	1.6
	Micrasterias sp.	0.0	1.8	3.0
	Total	6.7	1.5	1.7
Conjugatophyceae	*Spirogyra* sp.	5.5	1.1	1.5
	Total	5.5	9.6	13.8
Bacillariophyceae	*Cyclotella meneghiniana*	2.0	1.7	2.1
	Melosira granulata	3.1	2.4	3.4
	Cymbella affinis	2.2	1.4	2.4
	Pinnularia nobilis	2.9	2.7	3.0
	P. braunii	0.5	0.8	0.4
	Synedra fascicula	3.1	3.6	3.2
	Synedra ulna	4.3	6.9	3.3
	Fragillaria construens	0.7	0.0	1.1
	Navicula cuspidata	1.3	0.0	1.9
	N. mutica	1.2	0.0	1.7
	N. expansa	0.8	0.0	1.1
	N. cryptocephala	1.3	0.8	1.5
	Nitzschia sp.	1.1	0.3	1.4
	Stephanodisus sp.	1.0	0.0	1.4
	Surirella tenera	1.7	2.8	1.2
	Total	27.8	23.0	29.1
Dinophyceae	*Peridinium* sp.	0.8	0.0	0.9
	Total	0.8	0.0	0.9
Zooplankton				
Rotifera	*Lecane bulla*	2.2	2.2	2.2
	Lecane sp.	1.4	1.6	1.3
	Brachionus calyciflorus	3.3	2.2	3.8
	Filinia longiseta	3.2	4.5	2.7
	Keratella quadrata	1.7	3.0	1.1
	Kellicottia longispina	0.8	1.4	0.5
	Total	12.6	14.9	11.6
Cladocera	*Moina reticulata*	3.4	2.9	3.6
	Daphnia longispina	3.3	2.7	3.5
	Ceriodaphnia cornuta	2.7	3.2	2.5
	Total	9.4	8.8	9.6
Copepoda	*Cyclops strenus*	3.7	5.0	3.1
	Thermocyclops nigerianus	3.7	6.0	2.7
	Mesocyclops leukarti	2.7	4.7	1.9
	Total	10.4	15.7	7.7
Grand total		100.0	100.0	100.0

total number of plankton composition. *Peridinium* sp. also the only member of Dinophyceae made up the least percentage by number (0.8%) of the plankton population (Table 3). The percentage composition by number of major plankton groups in Egbe reservoir during the dry and rainy seasons of the study period was further shown in Table 3. Bacillariophyceae had the highest percentage composition by number during both seasons 23.0 and 29.1%, respectively. Dinophyceae had the least percentage abundance by number (1.0%) during the rainy season and was not encountered in the samples during the dry season.

Zooplankton composition: The zooplanktons recorded in Egbe reservoir during the period of study were made up of 11 species and one genus belonging to two phyla of Rotifera and Arthropoda.

The Rotifera was represented by five species and one genus while the Arthopoda comprised the order cladocera and subclass copepoda which were each made up of three species (Table 3). The Rotifers were the most abundant zooplankton constituting 12.6% of the total plankton abundance by number.

Brachionus calyciflorus made up the highest percentage composition (3.3%) in this family and the least abundant rotifer was *Kellicottia longispina* which contributed 0.8% to the total zooplankton (Table 3).

Copepoda accounted for 10.1% of the numerical plankton abundance (Table 3). *Cyclops strenus* and *Thermocylops nigerianus* were co-dominant with 3.7% total plankton abundance by number. *Mesocyclops leukarti* was the least abundant with 2.7% of the total plankton abundance by number. Cladocera was the least abundant zooplankton in the reservoir constituting 9.4% of the total plankton abundance by number. *Moina reticulata* accounted for 3.4% of the total plankton by number being the most abundant water flea and the least abundant species was *Ceriodaphnia cornuta,* constituting 2.7% of the total plankton by number (Table 3).

The numerical abundance of zooplankton during the dry and rainy seasons of the study period was also shown in Table 3. Copepods were the most abundant numerically (15.7%) during the dry season followed by the Rotifers with 14.7% by number of the total plankton abundance.

Cladocera was the least abundant during dry season with 8.8% of the total plankton abundance by number. In the rainy season, Rotifers were the most abundant zooplankton, contributing 11.6% to the total plankton abundance by number while water fleas contributed 9.6% numerically to the total plankton abundance and Copepods accounted for the least (7.7%) percentage abundance by number (Table 3).

The percentage composition by number of the major plankton groups in the four sampled stations of Egbe reservoir were shown in Fig. 2-4.

Diatoms had the highest numerical abundance in all the sampled stations with the highest abundance (29.2%) at the Dam station and the least (24.4%) at the Rocky station.

Dinophyceae was the least abundant of all the plankton. It recorded 1.1% by number at the Rocky station

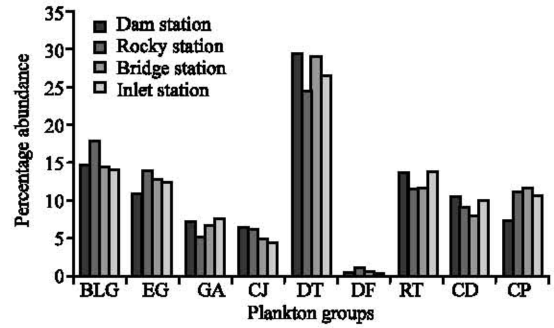

Fig. 2: Distribution of plankton in the four locations of Egbo reservoir during the period of study (BLG = Blue-green algae; EG = Euglenoids; GA = Green algae; CJ = Conjugales; DT = Diatoms; DF = Dinofllagellates; RT = Rotifera; CT = Cladocera; CP = Copepoda

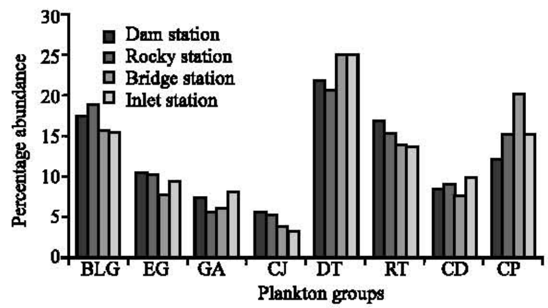

Fig. 3: Distribution of plankton in the four location of Egbo reservoir during dry season (BLG = Blue-green algae; EG = Euglenoids; GA = Green algae; CJ = Conjugales; DT = Diatoms; DF = Dinofllagellates; RT = Rotifera; CT = Cladocera; CP = Copepoda

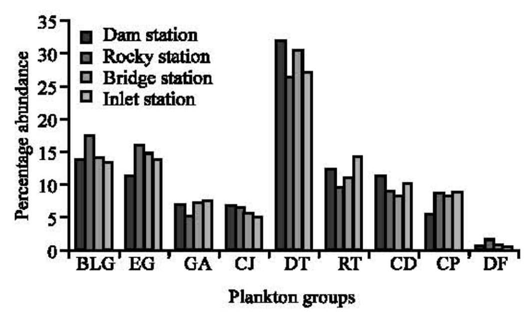

Fig. 4: Distribution of plankton in the four location of Egbo reservoir during rainy season (BLG = Blue-green algae; EG = Euglenoids; GA = Green algae; CJ = Conjugales; DT = Diatoms; DF = Dinofllagellates; RT = Rotifera; CT = Cladocera; CP = Copepoda

and 0.3% by number at the Inlet station. Among the zooplankton, Rotifera contributed the highest numerical abundance of 13.9% to the total plankton population at the Inlet station while its least abundance (11.5%) by number occurred at the Rocky station.

Cladocera were the least abundant zooplankton in all the sampled station with its least abundance (8.0%) at the Bridge station (Fig. 2). Diatoms still recorded the highest numerical abundance in all the sampled stations during the dry season.

It had the highest percentage abundance by number 25.1% both at the Bridge and Inlet station and the least 20.6% at the Rocky station.

Dinoflagellates were not encountered in the plankton samples at all during the dry season. Copepoda was the most abundant (20.2% by number) zooplankton during the dry season at the Bridge station.

It recorded the least abundance 12.2% by number at the Dam station and Cladocera was the least abundant zooplankton in all the sampled stations having the least abundance 7.6% at the Bridge station (Fig. 3). In the rainy season, diatoms also accounted for the highest percentage by number in all the sampled stations.

At the Dam station, it recorded the highest numerical abundance 31.9% and the least 26.3% was observed at the Rocky station. Dinoflagellate, the least abundant plankton recorded 1.6% by number at the Rocky station and 0.5% by number at the Inlet station. Among the zooplankton, Rotifera had its highest percentage abundance by number 14.2% at the Inlet station and the least 9.5% at the Rocky station. Cladocera were next in abundance with 11.3% by number at the Dam station and the least abundance by number 8.2% at the Bridge station. Copepoda was the least abundant zooplankton during the rainy season. However, it accounted for 8.8% of the total plankton abundance by number at the Inlet station and 5.4% at the Dam station (Fig. 4).

The result of correlation coefficients between plankton and physico-chemical parameters of Egbe reservoir is shown in Table 4. The dinoflagellates was observed to have a high positive significant ($p<0.05$) correlation with sulphate ($r = 0.880$). It also had a high though negative insignificant ($p>0.05$) correlation with nitrate ($r = - 0.716$).

Colonial blue-greens also had a high negative but insignificant ($p>0.05$) correlation with transparency ($r = -0.565$). The pennate diatoms had a positive significant ($p<0.05$) correlation with phosphate and magnesium ($r = 0.172$; $r = 0.199$, respectively) and a negative significant correlation with dissolved oxygen ($r = -0.161$). Total phytoplankton abundance had a negative significant ($p<0.05$) correlation with temperature and potassium ($r = -0.162$; $r = -0.136$, respectively). Among the zooplankton, a positive significant ($p<0.05$) correlation and magnesium ($r = 0.172$; $r = 0.199$, respectively) and a negative significant correlation with dissolved oxygen ($r = -0.161$).

Total phytoplankton abundance had a negative significant ($p<0.05$) correlation with temperature and potassium ($r = -0.162$; $r = -0.136$, respectively). Among the zooplankton, a positive significant ($p<0.05$) correlation existed between the rotifera and alkalinity ($r = 0.162$) and also with BOD ($r = 0.136$).

Cladocera exhibited positive significant ($p<0.05$) correlation with nitrate and phosphate ($r = 0.151$ and $r = 0.158$, respectively). And Copepoda had a positive significant ($p<0.05$) correlation with conductivity ($r = 0.151$).

Total zooplankton had a positive significant ($p<0.05$) correlation with dissolved oxygen and biochemical oxygen demand ($r = 0.165$; $r = 0.141$) and a negative significant ($p<0.05$) correlation with nitrate and sulphate ($r = - 0.139$; $r = - 0.139$), respectively.

Plankton taxa diversity indices indicated that among the phytoplankton Bacillariophyceae exhibited the

Table 4: Correlation coefficients between plankton abundance and physico-chemical parameters of Egbe reseroir

Phyto-plankton	Temp	Cond	Transp.	Alk.	DO	BOD	No_3	PO_4	SO_4	K	M_g
Colonia blue green algae	0.068	-0.275	-0.565	-0.246	0.068	0.113	-0.107	-0.025	-0.155	-0.032	0.107
Filamentoous blue green algea	0.042	0.024	-0.066	-0.063	-0.052	-0.041	0.094	-0.02	0.000	0.003	0.069
Euglenoids	0.131	0.087	-0.039	0.089	-0.115	0.028	0.024	0.113	-0.026	0.028	-0.125
Green algae	0.0242	-0.104	0.085	-0.107	-0.142	0.052	-0.089	0.070	0.064	-0.187	0.072
Pennate diatoms	0.103	0.122	-0.089	0.030	-0.161*	0.043	-0.091	0.172*	0.133	-0.051	0.199*
Dinophyseae	0.029	-0.034	0.452	-0.360	-0.288	-0.339	-0.716	-0.497	0.880*	-0.741	-0.647
Rotifera	-0.125	0.061	-0.084	0.161*	-0.085	0.147*	0.009	0.189	0.139	-0.092	0.222
Cladocera	0.017	-0.007	0.034	0.137	0.018	0.017	0.151*	0.158*	0.037	0.045	0.109
Copepoda	0.035	0.151*	-0.051	-0.121	-0.018	0.117	0.141	-0.140	0.006	0.057	-0.120
Total phyto-	-0.162*	-0.042	-0.072	0.002	0.001	-0.098	-0.034	0.053	0.017	0.029	-0.024
Total zoo-	-0.085	-0.076	0.019	0.044	0.165*	0.141*	-0.139*	-0.112	-0.139*	-0.020	-0.069

Table 5: Diversity index value of plankton of Egbe reservoir during the period of study

Taxa	D	H	J
Cyanophyceae	0.95	1.88	0.90
Euglenophyceae	0.70	1.72	0.96
Chlorophyceae	0.39	1.05	0.84
Bacillariophyceae	1.77	2.51	0.93
Rotifera	0.70	1.69	0.94
Cladocera	0.28	0.99	0.90
Copepoda	0.29	1.09	0.99

Table 6: Diversity index values of plankton in Egbe reservoir during dry season

Taxa	D	H	J
Cyanophyceae	1.09	1.93	0.94
Euglenophyceae	0.88	1.60	0.89
Chlorophyceae	0.49	1.09	0.87
Bacillariophyceae	1.41	2.02	0.87
Rotifera	0.81	1.70	0.95
Cladocera	0.36	1.02	0.93
Copepoda	0.33	1.09	0.99

Table 7: Diversity index values of plankton in Egbe reservoir in rainy season

Taxa	D	H	J
Cyanophyceae	0.81	1.73	0.92
Euglenophyceae	0.73	1.71	0.95
Chlorophyceae	0.32	0.98	0.89
Bacillariophyceae	1.84	2.57	0.95
Rotifera	0.74	1.61	0.90
Cladocera	0.31	1.08	0.99
Copepoda	0.32	1.07	0.99

greatest diversity (d = 1.77; H = 2.51) but Euglenophyceae showed the most evenly distributed pattern (J = 0.96). The least diverse and evenly distributed taxa were the Conjugatophyceae and Dinophyceae (Table 5). Rotifera was the most diverse zooplankton, (d = 0.70; H = 1.69) though the Copepods were the most evenly distributed (J = 0.99) and Cladocera showed the least diversity (d = 0.28; H = 0.99) and even distribution pattern (J = 0.90) (Table 5). The seasonal variations in plankton taxa diversity showed that Bacillariophyceae were the most diverse species of phytoplankton during both seasons (d = 1.41; H = 2.02 and d = 1.84; H = 2.57 for dry and rainy seasons, respectively) (Table 6 and 7).

Cyanophyceae were the most evenly distributed (J = 0.94) in the dry season (Table 6) while in the rainy season both Euglenophyceae and Bacillariophyceae were most evenly distributed with similar equitability values of 0.95. Among the zooplankton taxa diversity also showed the same trend during both seasons.

Rotifera were the most diverse in both seasons but the Copepoda and Cladocera were most evenly distributed in the rainy season (Table 7). Rotifera was the most diverse zooplankton, (d = 0.70; H = 1.69) though the Copepods were the most evenly distributed (J = 0.99). Cladocera showed the least diversity (d = 0.28; H = 0.99) and even distribution pattern (J = 0.90) (Table 7).

DISCUSSION

The results obtained from the analysis of water quality of Egbe reservoir shows that most of the measured physical and chemical parameters were below the permissible limits of World Health Organization (WHO) standards for drinking water. This can be attributed to the fact that there are physical, chemical and biological processes which self-purify and restore streams, lakes, creeks, estuaries, rivers and oceans to their pristine conditions (Ellis *et al*., 2004), although they are never restored back to their natural conditions thus, some levels of pollution can be observed in this reservoir. These results also indicate that the physico-chemical status of the water is capable of supporting a diverse biota if well monitored and managed. The plankton of Egbe reservoir varied both qualitatively as well as quantitatively throughout the study period.

These fluctuations could be interpreted as a result of changes in physico-chemical parameters of the river. It has been observed that diatoms and blue-green algae dominate the phytoplankton community of many tropical African lakes (Aboul-Ela and Khali, 1989; Ugwumba and Ugwumba, 1993; Oben, 2000). This was the trend observed in Egbe reservoir during the study. The two main determining factors for this observation appeared to be salinity and nutrient level as reported by Aboul-Ela and Khali (1989). Since, Egbe reservoir is a freshwater environment, nutrient levels and probably temperature regime may have played an important role in diatoms domination. Plant nutrients are derived from both inflows from fertilized farm lands and municipal effluents including sewage and resuspension of bottom sediments.

According to Dart and Stretton (1980), variations in water and temperature may cause changes in ionization and increased solubility or precipitation of bottom sediment deposits. This may ultimately lead to rapid decomposition of excessive oxidizable organic matter soon after the cessation of rains, leading to high nutrient levels.

The nutrient levels observed in Egbe reservoir was generally, higher during dry season than wet seasons. The significant positive correlations observed between pennate diatoms and phosphate and also sulphate and that between total phytoplankton and temperature further emphasizes the fact that diatom domination in Egbe reservoir is related to the temperature regime and nutrient status of the reservoir.

Abundance of diatoms in the rainy season may be ascribed to the mixing of the water during periods of heavy rainfall which would have resulted in recycling of nutrients and probably boosted the growth and subsequent abundance of the algae more in the rainy season (Ugwumba and Ugwumba, 1993).

Cyanophyceae, the subordinate dominants in the reservoir were noted to be higher in the reservoir during dry season. This observation agrees with those of Nwankwo (1986), Ugwumba and Ugwumba (1993) and Akpan (1995). It was also observed that the abundance of blue-green algae was not significantly affected by any physico-chemical parameter. This may be the reason for their high proliferation in the reservoir. However, the negative significant correlation noticed between the colonial blue-green forms and alkalinity of the water may probably be fortuitous.

In contrast to most other studies where the dominant blue-green algae are *Microcystis* and *Anabaena* (Burgis *et al*., 1973; Egborge, 1981; Ugwumba and Ugwumba, 1993), the dominant blue-green algae in Egbe reservoir were the filamentous nitrogen-fixing genera *Oscillatoria. Oscillatoria* has also been found to be the dominant blue-green algae in river Ona (Akin-Oriola, 2003) in the rainy season than the dry season. This might be explained by the generally, low nutrient status of such inland waters which necessitates an increase in the nitrogen fixing blue-greens to ensure maximum utilization of nutrients. The other blue-green algae equally found in appreciable quantities in Egbe reservoir were *Microcystis, Lyngbya* and *Spirulina* which have been implicated as indicators of organic pollution in surface waters (Akin-Oriola, 2003).

The euglenoids, generally had higher abundance in the wet season and its abundance was not significantly affected by any of the measured physico-chemical parameters. This observation had also been made by Ugwumba and Ugwumba (1993). The relatively alkaline environment of Egbe reservoir coupled with the presence of high nutrient levels may probably account for prolific euglenoid growth during the study period. Some euglenoids can tolerate various levels of organically polluted waters and therefore can be used as indicators of organic pollution (Nwankwo, 1995) such euglenoids include *Euglena* and *Phacus* (Nkechinyere and Domrufus, 2006), Nwankwo and Akinsoji, 1988) and the species *Lepocinclis ovum* (Munawar, 1972).

All these species were encountered in Egbe reservoir during the study period. Egborge (1994) pointed out that the euglenoids are not only planktonic but good indicators of polluted or meso and eutrophic freshwater bodies. It therefore, follows that there is the possibility of bloom formation if there is excessive nutrient enrichment of the water, even as other bloom forming genera such as *Microcystis, Anabaena* and *Oscillatoria* are present in appreciable quantity in the water. Bloom-formation was however, not detected in the reservoir during this period of study which therefore, indicated that Egbe reservoir could be a highly dynamic reservoir tending towards being eutrophic (Sawyer, 1966; Wetzel, 1983). The lower abundance of chlorophyta in Egbe reservoir is an attestation to the fact that the environment was not conducive for their proliferation. This could also be the reason for the observed low abundance of green *algae-spirogyra* sp. and the dinoflagellate, *Peridinium* sp. The predominance of rotifers in this reservoir in terms of species diversity and numerical abundance is generally, characteristic of eutrophic systems (Gibbons and Funk, 1982; Sendacz, 1984). The predominance of rotifera in some inland freshwaters has also been reported by Egborge (1972a, b) and Ayodele and Adeniyi (2006) also in Oshun river, Nigeria, Saint-Jean (1983) in lake Chad, Jeje and Fernando (1992) in Sokoto river, Nigeria and Ugwumba and Ugwumba (1993) in Awba reservoir, Ibadan, also in Nigeria.

The abundance of the genera *Brachionus*, *Lecane* and *Keratella* showed that the rotifer fauna was made up of a typical tropical assemblage (Jeje, 1986). The predominance of the *Brachionidae* could however be attributed to their omnivorous nutrition and widespread geographical distribution of most of the members (Goldman and Horne, 1983).

In the present study, members of the *Brachionidae* were dominant both in species number and abundance. Qualitatively, the order of zooplankton abundance in the reservoir was Rotifera>Copepoda>Cladocera. The same order was observed in dry season while in the wet season, the order was Rotifer>Cladocera>Copepoda. This observation was also in accordance with those of Oben (2000). The increased number of zooplankton observed during the rains could be linked to the influx of nutrient rich flood waters as well as mixing of autochthonous material that likely accelerated primary production and consequently, zooplankton production/abundance (Petersen and Cummin, 1974; Evans *et al*., 1993).

The observed change in the order of abundance during dry and rainy seasons in the abundance of dominant zooplankton in the same body of water as observed in this study have been well documented by Egborge (1981) in Asejire Lake and Meyer and Effler (1980) in Onondaga Lake in New York. These changes have been observed to be as a result of changes in environmental factors such as light, oxygen and temperature which was the principal factors noted by Begg (1976) to be affecting migration of zooplankton in Lake Kariba, Rhodesia. It was also observed that mixtures of both clean water and pollution indicator genera/species were identified in the reservoir. The diatoms have been used by ecologists to indicate pollution in water bodies and other variations of ecological conditions (Tassaduqe *et al*., 2003). The diatom, Cyclotella when in high numbers is an indicator of relatively clean waters (Oben, 2000). However, this genus has also been taken as an indicator of acidification by Boney (1983). *Stephanodisus*, also a diatom is a useful incidator of eutrophication (Tassaduqe *et al*., 2003). Other diatoms like *Synedra*, *Nitzschia melosira* and *Navicula* when in large numbers are indicators of sewage pollution and eutrophic conditions (Mason, 1991). *Spirogyra*, a green algae also indicate eutrophy.

The blue-green algae, Microcystis, Oscillatoria and Anabaena assayed in this study are potential indicators of organic pollution. The implication of the above therefore is that the level of organic pollution apparent from the physico-chemical conditions of the reservoir may lead to a structural shift in the plankton community resulting in a dominance of few stress tolerant species of algae. Such structural shifts in community in relation to limnological conditions have been observed by Boney (1983), Akpata *et al*. (1993), Nwankwo (1994) and Akin-Oriola (2003).

The diversity indices used in this present study, Shanon-Weiner's (H) Margalef's (d) and Pielou's (J) showed the same trend in values for phytoplankton and zooplankton in Egbe reservoir during the period of the sampling, this indicates that samples taken were true representative of the population. Despite the greatest diversity exhibited by diatoms, the euglenoids were the most evenly distributed. Among the zooplankton, the rotifers were the most diverse while copepods were the most evenly distributed. The overall diversity and even distribution of zooplankton species exhibit seasonal fluctuations.

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