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THE ZOOPLANKTON FAUNA OF SIX IMPOUNDMENTS ON RIVER OSUN, SOUTHWEST NIGERIA

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Abstract
This study was carried out on six of the oldest dam impoundments on River Osun and tributaries in Southwest Nigeria to obtain comparative information on the taxa composition, distribution and abundance of the net zooplankton fauna in relation to the physico-chemical water quality, drainage hydrology and basin characteristics of the impoundments. The zooplankton fauna of each impoundment comprised predominantly of rotifers (5-28 species/impoundment) and cladocerans (1-5 species/impoundment) made up altogether of 34 and 8 species respectively. Quantitatively, the fauna was dominated by copepods (272-1472 organisms/l) and rotifers (50-1470 organisms/l) while cladocerans (<80 organisms/l) were relatively sparse. The impoundments generally showed high degree of similarity both in fauna composition and in water quality. The waters all belong to the group of Africa's most dilute freshwaters (Conductivity < 600μScm^{-1}), but fairly well buffered (Total alkalinity =39.0 - 71.1 mg $CaCO_3l^{-1}$), ranging from moderately acidic to moderately alkaline (pH range = 6.6 – 7.8) and with nutrient levels indicative of meso-eutrophic status (NO_3-N range = 0.0 – 105.6 μgl^{-1}, and PO_4 = 98 – 618 μgl^{-1}). Both qualitatively and quantitatively the zooplankton populations showed positive correlation with impoundment age, river order, conductivity and silica but negative correlation with phosphate, total chlorophyll and secchi disc transparency. Ede Reservoir, the oldest of the impoundments and the one with the lowest levels of total chlorophyll and nutrient compounds was characterized by much higher values of zooplankton species number and abundance than the other impoundments (Asejire, Iwo, Esaodo, Ekoende, and Ogbomoso reservoirs).

Keywords: Impoundments, River Osun, Southwest Nigeria, Zooplankton, Water quality, Cluster Analysis.

Introduction

River Osun is one of the two principal rivers in the Ogun-Osun River Basin of Nigeria which is one of the eleven river basins in the country. Its headwaters and those of its primary tributaries (River Ayinba, R. Erinle, R. Oba, and R. Otin) rise from the central highlands in southwest Nigeria and flow down its main course about 270km to empty into Lekki Lagoon close to Epe in Ogun State. The Osun River Basin is remarkable for its many impoundments and fish ponds (Elliot, 1979) especially in the upper basin. Most of the impoundments were created primarily for the provision of public water supply with fisheries development as a major ancillary benefit. In order to fully derive the benefits of impoundments and/or fishponds and to ensure their good management and rational exploitation, adequate scientific information is required on them. Such information commonly include data on water quality, phytoplankton flora and zooplankton fauna.

Zooplankton play an important role in the trophic structure of lakes as consumers of phytoplankton and as a source of food for fish (both finfish and shellfish). In addition, they serve as indicator organisms of water type, fish yield and/or total biological production. All these probably explain why much of the fascination in the study of lakes lies in the structure and dynamics of zooplankton populations (Goldman and Hornes, 1983). It is therefore regrettable that

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inspite of the old age of the six impoundments considered in the present study (age range = 32-51 years) only one of them, Asejire Reservoir, has previously been studied for its zooplankton fauna and water quality (Egborge, 1971; 1972; 1978). This general dearth of limnological information on the other impoundments motivated the present study. The work was undertaken principally to provide information on the taxa composition of the zooplankton populations, abundance and distribution of zooplankters and how they are related to the physico-chemical water quality and basin characteristics of the different impoundments.

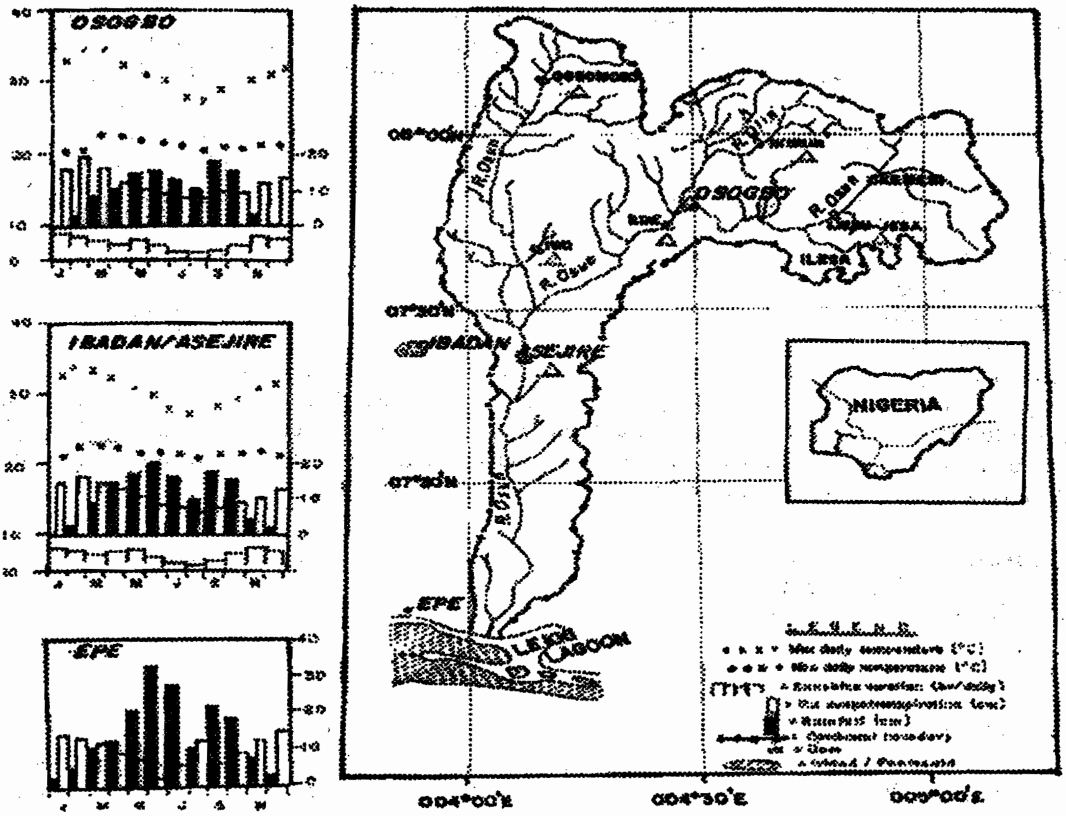


Figure 1: Map of River Osun drainage basin showing the investigated impoundments and representative climate diagrams of the study area.

Materials and Methods

Study area and investigated impoundments

Osun River basin covers a total area of about 9,000km^2 comprising parts of Oyo, Osun, Ekiti, and Ogun States. Shaped roughly like letter "Y", the basin lies between latitudes 06°20'N and 08°15'N over an altitudinal range of 200-450m above the mean sea level. At its northern end it is bounded by longitudes 004° 10'E – 005°10'E while it stretches between 004°00'E and 004°10'E in the southern end (Fig. 1). Following the scheme of Udo (1970), the area falls largely within the cocoa belt of Nigeria. The upper part overlies Pre-

Cambrian metamorphic rocks of the Basement Complex with ferruginous tropical soil while the southern sedimentary part is of ferralsols (Agboola, 1979). The vegetation extends from freshwater swamp in the extreme southern part through rainforest in the middle part to derived savanna in the northern part.

The climate in the forest belt of the area is of the Humid Semi-Hot Equatorial type while in the derived savanna belt it is of the Hot Equatorial Tropical Type (Papadakis, 1965). The climates are influenced mainly by two wind systems, *viz*: the rain-bearing southwest monsoon originating over the Atlantic Ocean (prevailing mostly April – November) and the dry dusty northeast trade winds originating from the Sahara Desert (prevailing mostly December – March). The pattern of north-south variation in major climate characteristics in the basin is shown in Fig. 1 along with the drainage pattern. Sunshine duration and potential evapotranspiration (PET) decrease steadily from north to south, while monthly mean precipitation exhibits the inverse pattern. For instance, the average total amount of annual rainfall is about 116cm at Osogbo (07°47'N, 004°29'E) increasing to about 123cm at Ibadan (07°26'N, 003°54'E), and 168cm at Epe (06°35'N, 003°59'E).

Table 1 provides information on the location, age and morphometric characteristics of the investigated impoundments. They vary considerably in surface area, catchment basin area, discharge and storage capacity but are generally shallow (mean depth less 4m).

Sampling programme and laboratory analyses

Water sampling for zooplankton and physicochemical quality analyses were carried out monthly (using a hand-rowed dugout canoe on most of the impoundments) for the period January – June 2001. Each monthly sampling programme lasted three consecutive days (covering two impoundments per day) and each impoundment was sampled at a more or less fixed time of the day (altogether within 08.00-18.00 hours) throughout in order to reduce the impact of diurnal variation at each station to the barest minimum.

Sampling for zooplankton (from near the shore at the dam site and in open water) followed the method described by Green (1977). The method involved the collection of known volume (20 litres) of water from just below the water surface and straining it through a zooplankton net (125μ mesh size) to a concentrate volume of about 50ml. The concentrate sample was preserved in 4% buffered formalin solution. The net was thoroughly and carefully washed at the end of each sampling to prevent clogging during the next operation.

Table 1: **Age and morphometric characteristics of six impoundments on Oshun River**

			Impoundment's Information							
SN	Inflow River	River Order*	Location (Fig. 1)	Age**	Area (ha)	Catchment basin (km^2)	Discharge (MLD)	Gross storage (ML)	Mean depth (m)	Drawdown (m)
1	River Ayiba	2	Iwo	1957	48	62.2	7.57	300	0.75	1.9
2	River Oba	2	Ogbomoso	1964	137.6	321.2	5.30	3,520	0.39	ND
3	River Otin	3	Ekoende	1973	297.5	543.9	10.03	3,482	0.85	1.5
4	River Osun	3	Esaodo	1973	50.2	673.4	5.07	492	1.02	ND
5	River Erinle	4	Ede	1954	125	1,372.7	7.57	4,438	3.6	2.0
6	R. Osun	4	Asejire	1972	2,369.1	7,174.3	136.26	7,403	3.2	1.3

* = following Horton-Strahler model (Wetzel and Likens, 2000)
** = year of construction
ha = hectares
ML = Million litres
MLD = Million litres per day
SN = Serial number

In the laboratory aliquot portion of the concentrate plankton sample contained in an improvised counting chamber (Damann, 1950) was examined for zooplankton under a compound microscope equipped with a calibrated ocular micrometer inserted, a movable stage and camera attachment. Photomicrographs of each zooplankton specimen was taken and, by calculation the plankton number per litre and/or % abundance in the original impoundment water obtained. Identification of specimens was based on keys and guides by Ward and Whipple (1959), Green (1960), Needham and Needham (1964), Donner (1966) and Mellanby (1975) as applicable. The relationship between the impoundments with regard to the recorded zooplankton species was based on correlation coefficient, from the matrix of correlation coefficient values obtained, a cluster analysis based on total linkage (or farthest neighbour's method) was developed according to Hedges (1971) to show the relationship between the reservoirs with regard to the occurrence and distribution of zooplankton species in them. The Index of Biota Diversity (IBD) between fauna in the impoundments was calculated according to Koch (1957).

In situ measurements of water temperature and transparency were undertaken during sampling for water quality analyses, using a mercury-in-glass bulb thermometer and Secchi disc respectively. The determinations of pH and electrolytic conductivity were carried out shortly after sample collection using a lovibond pH comparator and a Dionic conductivity meter (at 20°C) respectively. The concentrations of Dissolved oxygen was determined by the popular Winkler's iodimetric titration while total Alkalinity was estimated by titration of sample against standard sulphuric acid (N/50) using methyl red-bromocresol green mixed indicator (Golterman *et al.*, 1978). Nitrate nitrogen ($NO_3^- - N$) and Orthophosphate (PO_4^{3-}) were determined colorimetrically by reaction with Phenol – 2, 4 - disulphonic acid and acidified Ammonium molybdate and Stannous chloride respectively (APHA *et al.*, 1985). Reactive silicate (expressed as SiO_2 i.e. silica) was also determined colorimetrically with Ammonium molybdate while total chlorophyll was extracted in 80% Acetone and measured at various wavelengths of the spectrophotometer (Golterman *et al.*, 1978).

Results

Physico-chemical parameters of impoundments

Tables 2 - 4 provide data on the physico-chemical water quality of the six investigated impoundments on Osun River. Water temperature varied over a wide range of 23.1 – 32.5°C with a gradual increase in mean and median values from morning through afternoon to early evening. On the other hand, the range of values as well as the coefficient of variation from mean values showed a steady increase from morning to evening (Table 2). Temperature generally increased from January to a peak in March and fell thereafter. For instance, for the three stations sampled during the period 08-10hr of the day (i.e. Esaodo, Asejire, and Ogbomoso) the recorded mean surface temperature values were 23.8 ± 0.9°C, 29.5±1.4°C and 28.9±0.8°C for January, March and June respectively. Secchi disc transparency values were generally less than 1.5m (range = 0.6 –1.4m) in the impoundments, mean values per station being in the range of 0.7±0.1m for Ede Reservoir and 1.4 ±0.1m for Ekoende respectively.

Table 2: Descriptive statistics of diurnal surface water temperature on the six impoundments on River Oshun

Period of day	Temperature (°C)						
	Minimum	**Maximum**	**Range**	**Median**	**Mean**	**s.d**	**%C.V.**
*Morning	23.1	30.1	7.2	28.3	27.8	2.6	9.4
**Midmorning-Afternoon	25.4	30.1	6.9	28.5	28.9	2.4	8.3
***Evening (>16.00 hrs)	28.1	32.5	4.4	29.5	29.5	1.2	4.1

C.V. = Coefficient of variation
* = 8.00 – 10.00 hours
** = 10.00 – 16.00 hours
*** = 16.00 – 18.00 hours

The recorded values of electrolytic conductivity (at 20°C) were in the range of 71-187μScm^{-1} comprising 71-108.3 μScm^{-1} for the 2nd order river impoundments (Iwo and Ogbomoso), 95.0 – 143.7 μScm^{-1} for the 3rd order impoundment (Ekoende and Esaodo Reservoirs), and 95-187 μScm^{-1} for the 4th order river impoundments (Ede and Asejire) respectively. Along the main course of River Osun, mean conductivity fell gradually from 121.7±17.9μScm^{-1} at Esaodo through 115.3±18.3 μScm^{-1} at Ede to 110.3±4.5 μScm^{-1} at Asejire as it is joined by more dilute tributary streams. Water pH varied over one order of magnitude from 6.6 (moderately acidic) to 7.8 (moderately alkaline) with a slight increase along the main course as it is joined by tributary rivers of slightly higher pH values. Total alkalinity varied over a range of 39.0 – 71.1mg $CaCO_3l^{-1}$ with corresponding mean values of 40.4±3.1 – 49.9 ± 6.6mg $CaCO_3l^{-1}$ for the individual impoundments.

Dissolved oxygen concentration values were mostly above 5 mgl^{-1} although values in the range of 0.1 – 9.6mgl^{-1} were actually recorded. Both the mass and percentage saturation values of dissolved oxygen tended to increase along the course of the trunk river from Esaodo through Ede to Asejire while the levels of silica varied in the inverse fashion over a range of 0-20mgl^{-1} SiO_2. On the other hand, the variations in the mass concentrations of NO_3^- -N and PO_4^{3-} did not follow any definite pattern. They occurred in the range of 0-112.6 μgl^{-1} NO_3^- -N and 98-553 μgl^{-1} PO_4^{3-} respectively (Table 3).

For most of the parameters considered higher values were recorded in the dry season (January – March) than in the early rainy season (April-June) as obvious from Table 4. The reverse trend however applied in the case of SiO_2 which was slightly higher in the rainy season than the dry season. It was only for Secchi disc transparency, pH and SiO_2 that the observed seasonal differences were not statistically significant ($P > 0.05$). Zooplankton taxa composition, distribution and abundance.

Information on the composition, distribution (both zonal and seasonal) and abundance of the zooplankton taxa recorded for the investigated impoundments is provided in Tables 5-8. Qualitatively, the fauna of each impoundment comprised predominantly of rotifers and cladocerans most of which

Table 3: The range and mean (±s.d.) values of physico-chemical parameters of six impoundments on Oshun River

Parameter (unit)	Iwo Reservoir	Ogbomoso Reservoir	Ekoende Reservoir	Esaodo Reservoir	Ede Reservoir	Asejire Reservoir
Temperature (°C)	25.4-30.1 (28.5±2.2)	23.1-31.0 (27.5±3.3)	25.9-29.6(28.3±1.7)	23.3-28.4(26.4±2.2)	26.1-31.0 (28.9±2.1)	25.0-32.3(28.7±3.0)
S D Transparency (m)	0.9-1.0 (0.97±0.06)	1.1-1.2 (1.1±0.1)	1.3-1.4(1.4±0.1)	1.1-1.3(1.2±0.1)	0.6-0.8(0.7±0.1)	1.2-1.3(1.3±0.1)
pH (pH unit)	7.3-7.6 (7.5±0.1)	6.8-7.6 (7.3±0.3)	6.9-7.2(7.0±0.1)	6.6-6.9(6.8±0.1)	6.9-7.6(7.1±0.3)	7.0-7.8(7.4±0.3)
Conductivity (μScm^{-1})	80.0-108.3 (91.8±12.0)	71-86 (77.3±6.3)	95-143.7 (112.2±22.3)	98.2-137(121.7±17.9)	96.3-140(115.3±18.3)	105-116 (110.3±4.5)
Alkalinity ($mgCaCO_3l^{-1}$)	39.0-445.7 (40.4±3.1)	39.6-47.3 (43.7±3.2)	47.5-52.4 (49.5±5.0)	42.0-71.1 (58.2±12.1)	42.0-58.2(49.9±6.6)	39.7-55.4(49.6±7.1)
Dissolved oxygen (mgl^{-1})	0.1-8.0 (5.2±3.6)	4.1-9.6 (7.7±2.4)	5.4-7.8 (6.7±10)	5.2-6.3(5.7±0.5)	5.9-9.1(7.1±1.4)	6.3-9.4(7.2±12.7)
DO saturation (%)	1-105 (67±47)	53-117 (94±29)	71-96 (84.7±10.3)	66-75(71±3.7)	78-120(92.3±19.6)	76-129 (98.7±22.3)
Silica, SiO_2 (mgl^{-1})	12-19 (17±3)	10-14 (9±4)	3-10 (7±2.9)	9-18(13±3.7)	11-20(15±3.7)	0-14(6±4.7)
Nitrate-nitrogen ($\mu g\ l^{-1}$)	7.5-91.8 (56.8±35.6)	17.5-78.0 (54.4±26.4)	12.5-76.3(52.1±28.3)	67.65-112.5(60.1±46.2)	5.0-84.9(50.2±33.5)	0-105.60(61.2±44.7)
Orthophosphate ($\mu g\ l^{-1}$)	260-520 (379±107)	260-553 (434±126)	385-488(423±53.1)	98-406(255±125.9)	130-163 (141±27.0)	260-618(379±168.8)
Total Chlorophyll (μgl^{-1})*	1.7	1.6	1.5	1.6	05	2.2

*May 2001 values only
SD = Secchi disc
DO = Dissolved oxygen

Table 4: The seasonal mean values of water quality parameters of the investigated impoundments

Parameter	Iwo		Ogbomoso		Ekoende		Esaodo		Ede		Asejire		All impoundments			
	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS	RS	DS (meant ± s.d)	RS	DS/RS	t
Temperature (°C)	29.3	27.9	28.5	26.6	28.6	28.1	27.1	26.2	29.5	28.3	30.3	17.1	28.8±0.9	27.3±0.8	1.05	3.05
S D Transparency (m)	0.97	0.90	1.20	1.10	1.39	1.30	1.30	1.13	0.74	0.66	1.29	1.22	1.15±0.22	1.05±0.22	1.10	0.79
pH (pH Unit)	7.55	7.35	7.50	7.50	7.15	6.95	6.85	6.70	7.55	6.70	7.70	7.05	7.38±0.29	6.96±0.22	1.06	0.79
Conductivity (∝Scm^{-1})	101	83	85	71	128	96	130	107	133	98	112	108	115±17	94±13	1.22	2.41
Alkalinity ($mgCaCO_3l^{-1}$)	42.5	39.1	45.9	41.5	50.8	48.3	69.5	47.0	56.9	4.30	55.8	42.9	53.6±8.7	43.6±3.1	1.23	2.66
Dissolved Oxygen (mgl^{-1})	7.5	2.8	9.3	5.9	7.4	6.0	6.1	5.3	8.3	6.0	8.0	6.4	7.8±1.0	5.4±1.2	1.44	3.77
DO Saturation (%)	93	41	110	78	94	74	73	69	100	84	113	86	97±13	72±15	1.34	3.08
Slicate, as SiO_2 (mgl^{-1})	15.0	18.0	11.0	15.0	5.0	9.0	10.0	16.0	15.0	17.5	2.5	10.0	9.8±4.7	14.3±3.5	0.68	1.88
NO_3^- - N (∝μgl^{-1})	83	29	72	35	73	31	103	16	75	26	96	24	84±12	27±6	3.11	10.42
PO_4^{3-} (μgl^{-1})	460	300	533	324	483	362	379	129	145	136	490	268	415±130	253±90	1.64	2.51

DS = Dry Season; RS = Rainy Season; t = Student t-test, P = probability; * = P≤0.05; ** = P≤0.01; *** = P ≤ 0.001; NS = P > 0.05

were identified to specific level. Altogether the rotifer fauna consisted of 34 species belonging to 16 genera (Table 5) and 13 families (Table 7). Nine of the rotifer families belong to the Order Ploima while the other four families belong to the Order Flosculariidae, both Orders belong to the Subclass Monogononta of the Class Eurotatoria. The most qualitatively represented family was Brachionidae, accounting for 36.3-61.5% (mean = 53±13% standard deviation) of all rotifer species in the respective impoundments (Table 7). Other families with fairly wide taxa representation over the different impoundments were Synchaetidae, Trichocercidae, Lecanidae and Filinidae, in that decreasing order of importance. The most widely distributed taxa were the rotifers *Brachionus falcatus*, *B. angularis* and *Polyarthra vulgaris* and the cladoceran *Daphnia* sp each of which occurred in all the impoundments (Tables 5 & 6). Majority of the other species occurred either in one or two of the six impoundments. In general, many of the species showed distinct habitat distribution in the impoundments. For instance while most members of the family Brachionidae occurred mostly in open water zone, members of Lecanidae occurred mostly in the littoral zone (Table 5). Again while the commonly occurring species were recorded both in the dry and rainy seasons, the occasional and rare species (i.e. those limited to one or more impoundments) occurred mostly during the period May-June i.e. during early rainy season. Some of the taxa limited to the dry season in occurrence were the rotifer *Keratella quadrata*, *K. tecta*, *Mytilina* sp and *Trichocerca cylindrica* Also in this category were the cladocerans *Chydorus* and *Camptocerrus* sp.

Quantitatively, eleven species out of the 34 rotifers altogether accounted for about 84.5 – 96.5 % (overall mean ± s.e. = 90.7 ± 2.1 %) of the overall mean abundance of rotifers in each impoundment (Table 6). On the other hand, the abundance of crustaceans was due mostly to *Daphnia* sp (20%). *Ostracods* (8%), copepods and their nauplius larvae (65%) (Table 5). In all the stations, the abundance of the zooplankton groups was in the order Copepods > Rotifers> Cladocerans > Ostracods. The predominance of copepods being due to the heavy contribution of their nauplius larvae to the group (Table 8).

Interrelationship between impoundments features and the effects of water quality

The matrix of correlation coefficient values (r) between water quality and other impoundment features against the abundance of zooplankton groups is presented in Table 9. The abundance of total zooplankton, and rotifers as separate taxa groups showed more or less the same degree of relationship with most of the features. Both taxa groups showed significant ($P \leq 0.05$) positive correlation with the age of impoundment but significant negative correlation with transparency, and nitrate-nitrogen levels. On the other hand, the abundance of cladocerans showed significant positive correlation with river order, impoundment storage capacity and catchment basin. The abundance of ostracods showed significant negative correlation with water temperature and pH but positive correlation with total alkalinity.

To varying degrees, river order, conductivity and silica concentrations each showed direct correlation with the different taxa groups while phosphate and total chlorophyll showed negative correlations with the groups. The relationship between the six investigated impoundments with regard to their mean water quality parameters (Table 3) is depicted in Fig 2A.

The correlation coefficient (r) matrix table on which the figure is based consists of r values in the range of 0.797 to 0.997 i.e. they all exhibited significant positive correlation. The correlation coefficient extreme values were between Ekoende and Asejire ($r = 0.997$; $P = 0.001$) on the one hand, and between Ogbomoso and Ede ($r = 0.797$, $P = 0.05$) on the other hand. At the probability level of $P = 0.001$, the six impoundments form two clusters comprising Ede against the other five impoundments.

Table 5: Occurrence, distribution and relative abundance of zooplankton in the six impoundments on Oshun River

	Taxon	Impoundments						Habitat Distribution		Mean Abundance*	Seasonal occurrence	
		Iwo	Ogbomosho	Ekoende	Esaodo	Ede	Asejire	Littoral Zone	Open water zone	%	DS	RS
	Rotifera (Monogononta)											
1	*Branchionus angularis* Gosse	+		+	+	+	+		+	11.2±3.2	+	++
2	*B. calyciflorus* (Palias)					+		+		<0.5	+	+
3	*B. caudatus* Barri and Daday				+	+			+	1.7±1.2	++	+
4	*B. falcatus* Zacharias	+	+	+	+	+	+		+	18.7±6.1	++	+
5	*B. quadridentatus* Hermann	+	+	+	+	+	+		+	3.3±3.0	++	+
6	*B. urceolaris* O.F. Muller	+		+		+	+		+	<0.5	+	+
7	*Keratella cochlearis* Gosse	+		+		+	+		+	7.7±2.3	+	+
8	*K. lenzi* Hauer					+			+	<0.5		+
9	*K. quadrata*	+		+					+	<0.5	+	
10	*K. tecta*					+	+		+	2.2±1.4	+	
11	*K. tropica* Apstein	+	+	+		+	+	+	+	3.2±1.5	+	+
12	*Platyias quadricornis* Ehrenberg	+				+		+		<0.5		+
13	*Trichotria tetractis* Ehrenberg					+				<0.5	+	+
14	*Lophocaris* sp.			+					+	<0.5		+
15	*Mytilina* sp.					+			+	<0.5	+	
16	*Lecane luna* O.F. Muller				+			+		<0.5	+	+
17	*Monostyla bulla* Gosse		+		+	+	+	+		2.0±0.7	+	++
18	*M. colsterocerca* Schmorda					+		+		<0.5		+
19	*M. lunaris*					+		+		<0.5		+
20	*Mononmata grandis* Harring & Myers					+		+		<0.5		+
21	*Trichocerca bicristata* Gosse			+	+				+	<0.5		+
22	*T. cylindrica* Imhof				+	+	+	+		2.5±3.0	++	
23	*T. porcellus* Gosse					+			+	<0.5		+
24	*T. similes* Wierzejski	+				+		+		<0.5		+
25	*Gastropus hyptopus* Ehrenberg						+		+	<0.5		+
26	*Asplanchna* sp.	+			+	+		+	+	3.7±3.0		+
27	*Polyarthra vulgaris*	+	+	+	+	+	+	+	+	25.8±6.9	+	++
28	*Filinia longiseta* Ehrenberg, 1834					+			+	<0.5		+
29	*F. opoliensis* Zacharias	+		+	+	+	+		+	11.0±2.7	+	++
30	*F. terminalis* (Plate)						+		+	<0.5		+
31	*Horaella* sp					+		+		<0.5	+	+
32	*Hexarthra intermedia* Wisznlewski					+			+	<0.5		+
33	*H. mira* (Hudson)	+				+			+	<0.5		+
34	*Floscularia* sp.					+		+		<0.5		+
	Total Rotifers	13	5	11	11	28	12			100.0		
	Crustacea (Cladocera)											
1	*Diaphonosome excisum* Sars		+	+		+				<1.0		+
2	*Ceriodaphnia cornuta* Sars					+		+		2.0		+
3	*Daphnia* sp.	+	+	+	+	+	+	+		20.1	++	+
4	*Bosmina* sp.						+		+	<0.5		+
5	*Macrothias* sp.				+			+		<0.5		+
6	*Kurzia latissima*				+			+		<0.5		+
7	*Chydorus* sp.				+				+	<0.5	+	
8	*Camptocerus* sp.				+			+		1.5	+	
	Cepepoda											
9	Calanoid spp (unidentified)	+	+	+	+	+	+	+		10	+	++
10	Cyclcocid spp (unidentified)	+	+	+	+	+	+	+		20	+	++
11	Nauplius larvae	+	+	+	+	+	+	+	+	35	+	++
	Ostracoda											
12	Ostracod spp (unidentified)		+	+	+	+	+	+		8	+	
	Total Crustacean	4	6	6	9	7	6			100	23	39
	Total Zooplankton	17	11	17	20	35	18					

DS = Dry Season (January – March), RS = Rainy Season (April – June)

Table 6: Percent (%) contribution of the most occurring species to total rotifer abundance.

Taxon	Sampling Station						Mean ± s.e
	Iwo	Ogbomoso	Ekoende	Esaodo	Ede	Asejire	
Branchionus angularis	24.8	1.0	23.6	12.7	4.7	1.5	11.2±3.2
Branchionus caudatus	0.0	0.0	0.0	8.6	1.7	0.0	1.7±1.2
Branchionus falcatus	20.6	60.0	14.8	5.4	6.5	4.6	18.7±6.1
Branchionus quadridentatus	0.0	20.0	0.0	0.0	0.0	0.0	3.3±3.0
Keratella cochalearis	8.1	0.0	17.7	0.0	3.7	16.9	7.7±2.3
Keratella tecta	0.0	0.0	0.0	0.0	1.2	12.3	2.2±1.4
Keratella tropica	0.0	1.0	9.3	0.0	10.2	0.0	3.2±1.5
Monostyla bulla	0.0	4.0	0.0	5.5	1.0	1.5	2.0±0.7
Asplanchna sp.	1.0	0.0	0.0	20.0	1.0	0.0	3.7±3.0
Polyarthra vulgaris	35.8	10.5	8.5	16.6	53.9	29.2	25.8±6.9
Filinia opoliensis	1.0	0.0	22.6	14.6	9.4	18.5	11.0±2.7
Total	**91.3**	**96.5**	**96.5**	**83.4**	**93.3**	**84.5**	**90.7±2.1**

* total rotifer abundance

Table 7: Family representation (%) of Rotifers in the six impoundments on River Oshun

Order	Family	Species	% Distribution in impoundment					
			Iwo	Ogbomoso	Ekoende	Esaodo	Ede	Asejire
Ploima	Brachionidae	13	61.5	60.0	72.7	36.3	37.0	50.0
	Trichocercidae	4	7.7	0.0	9.1	18.2	7.4	8.3
	Lecanidae	4	0.0	20.0	0.0	18.2	10.8	8.3
	Synchaetidae	1	7.7	20.0	9.1	9.1	3.7	8.3
	Asplanchinidae	1	7.7	0.0	0.0	9.1	3.7	0.0
	Mytilinidae	1	0.0	0.0	0.0	0.0	3.7	0.0
	Trichotridae	1	0.0	0.0	0.0	0.0	3.7	0.0
	Notommatidae	1	0.0	0.0	0.0	0.0	3.7	0.0
	Gastropopidae	1	0.0	0.0	0.0	0.0	0.0	8.3
Flosculariacea	Filinidae	3	7.7	0.0	9.1	9.1	7.4	16.7
	Hexarthridae	2	7.7	0.0	0.0	0.0	7.4	0.0
	Flosculariadae	1	0.0	0.0	0.0	0.0	7.4	0.0
	Testuduellidae	1	0.0	0.0	0.0	0.0	3.7	0.0
	Total	34	100.0	100.0	100.0	100.0	100.0	100.0

Figure 2B is the cluster analysis diagram showing the relationship between the six impoundments on the basis of the identified zooplankton taxa in Table 5 (this is limited to rotifers and Cladocerans only). The correlation coefficient values (r) were in the range of −0.264 (between Ede and Esaodo reservoirs) to 0.619 (between Iwo and Ekoende reservoirs). At the probability level of 5% (P = 0.05) the six impoundments could be grouped into three clusters, comprising: (i) Ede, (ii) Iwo, Ekoende, Ogbomoso and Asejire, and (iii) Esaodo. Cluster i (Ede reservoir) consists of 13 endemic species as opposed to 5 endemic species in cluster iii (Esaodo) and only 0-3 endemic species for members of cluster ii (Iwo, Ekoende, Ogbomoso, and Asejire Reservoirs).

In general, there is a high degree of similarity between the clustering patterns of the six impoundments with regard to both physico-chemical parameters (Fig. 2A) and zooplankton taxa composition (Fig. 2B) although the cluster based on the latter is much more pronounced than the one based of the former. The calculated IBD for the rotifer species for the six impoundments was 27.02 suggesting that the degree of diversity or dissimilarity between the impoundments with regard to rotifers was low i.e. the impoundments showed high degree of similarity in their rotifera composition.

Table 8: Mean (±20% s.d) abundance of zooplankton at the six impoundments on Oshun River (org/l)

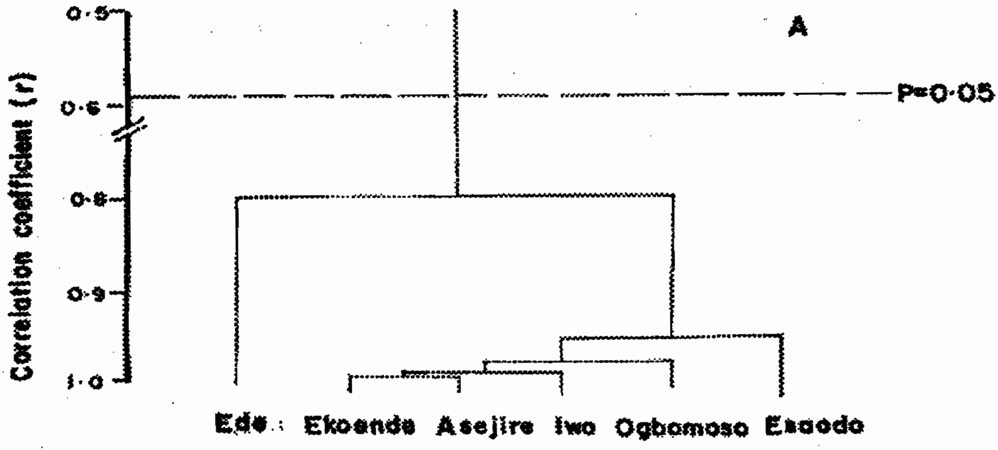
Taxon	Impoundment					
	Iwo	Ogbomoso	Ekoende	Esaodo	Ede	Asejire
Ostracods	4	2	14	46	8	4
Cepepods	1288	278	872	286	1,470	660
Cladocerans	4	4	42	26	74	78
Rotifers	766	50	820	110	1,470	130
Total Zooplankton	2,062	382	1,348	468	2,794	872

s.d = standard deviation

Table 9: Correlation (r) of physico chemical parameters (x) with abundance of zooplankton groups (y) on six impoundment features on River Oshun

Parameter	Correlation with plankton abundance (r)				
	Total zooplankton	Rotifers	Cladocerans	Copepods	Ostracods
Impoundment feaures					
Age	0.7548*	0.7340*	0.0945	0.5007	-0.4881
River Order	0.2956	0.3186	0.9927***	0.1703	0.0802
Storage capacity	-0.0163	-0.0341	0.7696*	-0.0412	-0.4990
Catchment basin area	-0.1486	-0.2530	0.7119*	-0.052	-0.2319
Discharge	-0.2126	-0.3332	0.5989	-0.0680	-0.2750
Surface area	-0.2242	-0.3413	0.6220	-0.0979	-0.3273
Water quality					
Temperature (°C)	0.6003	0.4815	0.4400	0.7024	-0.8252*
Conductivity	0.2026	0.2460	0.6558	0.0461	0.6295
pH	0.1743	-0.0024	-0.1203	0.3738	-0.8383*
Silica (SiO_2)	0.1720	0.0864	0.6711	0.3062	0.2500
DO saturation	-0.0917	-0.03777	0.5937	0.1772	-0.5156
DO concentration	-0.1924	-0.0915	0.4035	-0.3161	-0.4614
Alkalinity ($CaCO_3$)	-0.2697	-0.1613	0.4197	-0.4472	0.8410*
Phosphate (PO_4^{3-})	-0.5455	-0.6213	-0.4681	-0.3669	-0.3620
Total Chlorophyll	-0.7865*	-0.8077*	-0.2128	-0.5574	-0.0193
SDTransparency	-0.7245*	-0.7247*	-0.0441	-0.6283	0.2361
Nitrate – nitrogen	0.7759*	-0.7191*	-0.0042	-0.3860	0.3391

* = $P \leq 0.05$ r = Correlation coefficient
** = $P \leq 0.001$ DO = Dissolved oxygen
*** = $P \leq 0.001$ SD = Secchi disc



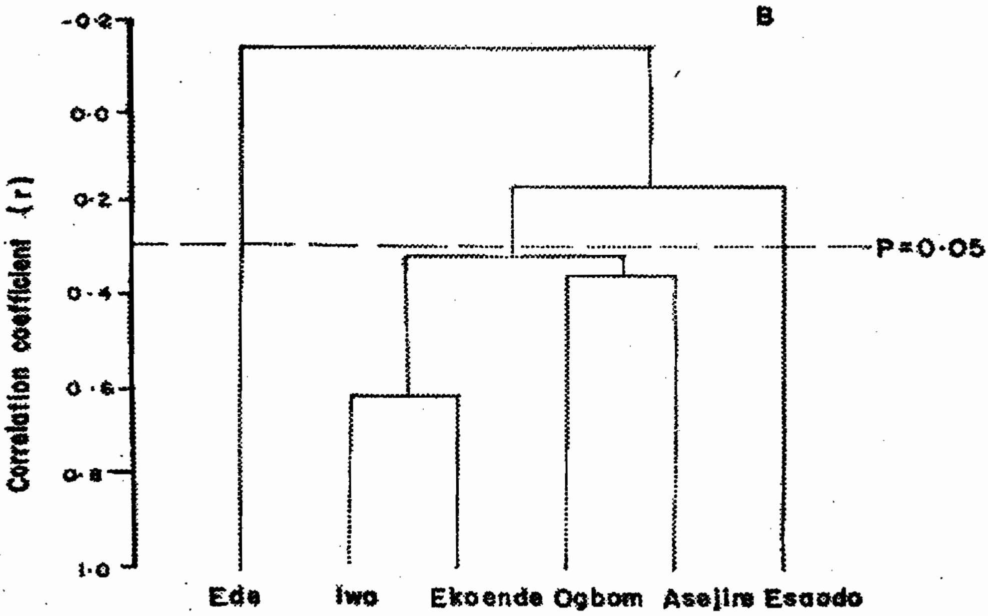


Figure 2A: Cluster analysis showing the relationship between the investigated impoundments based on physico Chemical water quality parameters.

Figure 2B: Cluster analysis showing the relationship between the investigated impoundments with regard to zooplanktons species occurrence and distribution.

Discussion

Perhaps the most striking feature of the zooplankton fauna of the six investigated impoundments in this study was the predominance of rotifers which were in turn dominated by members of the family Brachionidae both in species number and in abundance. Qualitatively, the order of dominance of the main zooplankton groups in all the impoundments was: Rotifers> Cladocerans>Copepods>Ostracods while quantitatively the order was Copepods> Rotifers>Cladocerans>Ostracods. The qualitative composition and order thus observed follow the general pattern for most Nigerian water bodies adequately studied notably: River Sokoto (Green, 1960; Holden and Green, 1960), Eleiyele Reservoir (Imevbore, 1967), Asejire Lake (Egborge, 1972, 1978) and indeed freshwaters in general where rotifers (which are believed to evolve from freshwater) often dominate the zooplankton fauna (Cole, 1975). Copepods and other crustaceans tend to be less in number than the rotifers because of the greater selective predation on the copepods being generally bigger than the rotifers. It is well known that fish predating on zooplankton select their prey visually and that bigger preys (crustaceans) are selected in preference to smaller ones e.g. rotifers (Hillbricht-Ilkowska, 1964; Zaret, 1972; Dodson, 1974). For instance, before the introduction of fish in snowflake lake in Canada, Diaptomus articus (body size = 2.2.-3.5mm) was the dominant zooplankton while rotifers were scarce. After the introduction of fish, Cyclops vernalis (body size = 0.8-1.8mm) and the rotifer Kellicottia imyispina (body size = 0.4-0.8mm) increased in number (Anderson, 1972). Such selective pressure of zooplankton predation by fish in the investigated impoundments could have been responsible for the subdominance of copepods to rotifers in species number but vice versa in abundance which was dominated by the immature stages, notably nauplius larvae.

The dominance of the rotifers by members of the family Brachionidae as observed in the present study (Table 7) is also in agreement with the known pattern for virtually all the previous studies on Nigerian freshwater bodies except for Ikpoba River in which members of the family Lecanidae were dominant over the Brachionidae (Egborge and Chigbu, 1988). The predominance of the Brachionidae could be attributed to their widespread geographical distribution and the omnivorous mode of nutrition of most of the members (Goldman and Hornes, 1983). The nominate taxon Brachionus with its many species has exploited a whole range of freshwaters both in the tropics and in the temperate regions. In general, Brachionus calyciflorus, B. falcatus, B. mirabilis and Keratella tropica are common in tropical waters while Keratella quadrata, K. hiemalis and K. cochllearis are widespread temperate forms. In the present study Brachionus falcatus, B. angularis and Keratella tropica were the dominant species with 100%, 83% and 67% distribution occurrence and accounting for 18.7%, 11.2% and 3.2% mean abundance of total rotifers respectively.

With a rotifer species number in the range of 5-28 per impoundment and 34 altogether (for the six impoundments), the investigated impoundments seem rather poor qualitatively. Although the number of recorded rotifer species for individual water bodies in Nigeria is quite variable (range = 5 –120 species/waterbody) on the average most of them occur within the range of 33-61 species per waterbody. The low recorded number for the six investigated water bodies could be attributed largely to the low value of IBD among the species and to a lesser extent also to the low intensity of sampling carried out being an introductory study. More species might have been recorded if diurnal and/or sampling through the vertical column of the impoundment were also carried out. In comparison to the extensive sampling programme undertaken by Egborge (1978) and Akinbuwa (1999) involving vertical profiling of diurnal and regular collections at close intervals, the recorded species in this study probably represent only some percentage of the actual species of rotifers in the respective impoundments.

This study has made it possible to undertake a comparative assessment of the zooplankton fauna including the physico-chemical causal factors of species richness. Of all the probable causal factors considered in the present work, the age of impoundment, the river order and catchment area seem to be the most important in determining the number of total zooplankton as well as rotifera taxa in the Osun River Basin (Table 9). This observation agrees with that of Welch (1952) who found that the age of impoundment is an important factor determining the number of species in a lake. It is not surprising then that Ede Reservoir which is the oldest of the six impoundments was the richest qualitatively and quantitatively in its zooplankton fauna, including the number of endemic species (13 of the recorded species occurred only in the impoundment as can be observed in Table 5). This is expected as impoundments tend to become more diverse in habitat with age, especially through the development of littoral macrophytes. Ede Reservoir has actually shown signs of eutrophication including reduced Secchi disc transparency (.0.7m) and low levels of water nutrient compounds (N & P) probably due to uptake of the nutrients by extensive associated aquatic flora (both phytoplankton and macrophytes). Raspopov et al. (1986) in a study of three lakes situated in the northwest of the USSR noted that the zooplankton of macrophyte thickets was characterized by a great species diversity. Side by side with the pelagic form, the phytophillous species also occurred. A total of 28 rotifer species was recorded from Ede reservoir in contrast to only 5 – 13 in the other reservoirs. Among the indicator species of eutrophication recorded for Ede Reservoir were Keratella cochllearis and Tricocerca cylindrica.

The greatest zooplankton population density recorded was during the early rainy season period (May-June). Many of the occasional species occurred only during this period while the most widely distributed species were most abundant then. For example, the population density of Polyarthra vulgaris, the most abundant species of zooplankton in the reservoirs (about 26% total abundance of rotifers) was as high as 580 specimens per litre of water in May. It is reasonable to link the abundance of zooplankton to the availability of food during this period of the year which corresponds with the influx of nutrient rich early rain flood water. Again a lot of nutrients is usually released from the breakdown of stratification established during the dry season. This tends to suggest that zooplankton fauna is also to some extent influenced by the hydrological regime of the impoundments and their inflow rivers.

This study has also revealed a high degree of similarity among the investigated impoundments in terms of physico-chemical water quality (Table 3, Fig. 2A). In general, the waterbodies were all characterized by low values of electrical conductivity which, following the scheme of Talling and Talling (1965) suggest that they all belong to the most dilute group of African freshwater bodies (Class I) which have electrical conductivity less 600μScm^{-1}. The general degree of similarity could be due to the fact all the impoundments and their catchment basin occur within a narrow range of latitudes, In addition, all the impounded rivers have their origin from the same source (the Central Highland of Southwest Nigeria) and are underlain by rocks of the same geological type and age (The Pre-Cambrian Basement complex). They also all occur within areas of the same levels of urbanization, landuse development, and cultural practices.

Conclusions

The present study has made it possible to undertake a comparative assessment of the zooplankton fauna of six of the oldest impoundments on River Osun and its tributaries in Southwest Nigeria. They all showed a high degree of similarity in their zooplankton fauna as well as in water quality parameters probably due to the closeness of their geographical locations and having the same headwater origin and bedrock underlain by the same type of geology. The zooplankton fauna were qualitatively poor probably due to the high degree of similarity among the impoundments. Ede Reservoir the oldest of the impoundments showed evidence of eutrophication both in terms of its zooplankton fauna and water quality status.

References

Agboola, S.A. (1979). An agricultural atlas of Nigeria. Oxford University Press 248pp.

Akinbuwa, O. (1999). The rotifer fauna and physico-chemical onditions of Erinle lake and its major inflows at Ede, Osun State, Nigeria. Ph.D. Thesis Obafemi Awolowo University. 330pp.

Anderson, S.R. (1972). Zooplankton Composition and Change in an alpine Lake. Verh. Internat. Verein. Limnol. 18: 264-268.

APHA, AWWA and WEF (1985). Standard methods for the examination of water and wastewater 19th ed. Washington.

Cole, G. A. (1978). A textbook of limnology. The C.V. Mosby Company

Damann, K.E. (1950). A simplified counting method. Illinois Academy of Science Transactions. 43: 53-60.

Dodson, S.I. (1974). Zooplankton competition and predation: an experimental test of the size efficiency hypothesis. Ecology 55: 605-613.

Donner, J. (1966). Rotifers. Frederic Warne and Co. Ltd. London. New York.

Egborge, A.B.M. (1971). The chemical hydrology of the River Osun, Western State, Nigeria. Freshwater Biology, 1: 257-271.

Egborge, A.B.M., (1972). A preliminary checklist of the zooplanktonic organisms of the River Osun in the Western State of Nigeria. Nig. J. Sci. 6(1): 67-71.

Egborge, A.B.M. (1978). The hydrology and plankton of the Asejire Lake. Ph.D. Thesis University of Ibadan, Nigeria.

Egborge, A.B.M. and Chigbu, P. (1988). The rotifers of Ikpoba River, Bendel State. The Nigerian Field. 53:117-132.

Elliot, O.O. (1979). The fisheries potentials of River Osun Basin, Nigeria. In: Proceedings of the International Conference on Kainji Lake and River Basins Development in Africa. Vol. II: 348-354.

Goldman, C.R. and Hornes, A.J. (1983). Limnology McGraw-Hill Book company, New York. p. 221-241.

Golterman, H.L., Clymo, R.S. and Ohnstad, M.A.M. (1978). Methods for physical and chemical analysis of fresh waters IBP Handbook No. 8. 2nd ed. Blackwell Scientific Publications. Oxford. 213pp.

Green, J. (1960). Zooplankton of the River Sokoto. The Rotifera. Proc. Zool. Soc. London. 135: 491-523.

Green, J. (1971). Association of Cladocera in the zooplankton of the lake sources of the White Nile. J. Zool. Soc. Lond. 165: 373-414.

Green, J. (1977). Sampling rotifers. Arch. Hydrobid. Bain. Ergebn. Limnology. 8: 9-12.

Hedges, A.J. (1971). Principles of Microbial taxonomy. In. Hawker, L.E. and Linton, A.H. (eds).Micro-organisms: function, form and environment. 458-478. Edward Arnold (Publishers) Ltd.

Hillbricht-Ilkowska, A. (1964). The influence of the fish population on the biocenosis of a pond, using Rotifera fauna as an illustration.

Ekologia Polsha. Ser. A 12(28): 454-503.

Holden, M. J. and Green, J. (1960). The hydrology and plankton of the River Sokoto. Journal of Animal Ecology. 29: 65 – 84

Koch, L.P. (1957). Index of biotal dispersion. Ecology 38: 145-148.

Imevbore, A.M.A. (1967). Hydrology and plankton of Eleiyele Reservoir Ibadan, Nigeria. Hydrobiologia 30(1): 154-176.

McColl, R. H. S. (1972). Chemistry and trophic status of seven New Zealand lakes. New Zealand Journal of Marine and Freshwater Research. 6(6): 67 – 84

Mellanby, H. (1975). Animal life in freshwater (A guide to freshwater invertebrates). Chapman and Hall. London.

Needham, J.G. and Needham, P.R. (1964). A guide to the study of freshwater Biology 5th ed. Holdenday. Inc. San Francisco.

Papadakis, J. (1965). Crop ecologic survey in West Africa (Liberia, Ivory Coast, Ghana, Togo, Dahomey, Nigeria). Vol. II – Atlas. FAO. Rome

Raspopov, I.M., Alenxandrova, D.N., Petrova, N.A., Rychkova, M.A., Slepukhina, T.D., Smirnova, T.S.a nd Shirokova, M.Y. (1986). Limnology of the lakes Kubenskoye, Vozhe and Lacha. In: Hejny , S. Raspopov, I.M. and Kuet, J. (eds.). Studies on Shallow Lakes and Ponds. pp. 11-69 Academia. (Zechoslavak Academy of Sciences).

Talling, J.F. and Talling, I.B. (1965). The chemical composition of African Lake waters. Internationale Revue der Gesamtem Hydrobiologie. 50: 421-463.

Udo, R. K. (1970). Geographical regions of Nigeria. Heinemann. London.

Ward, H.B. and Whipple, G.C. (1959). Freshwater Biology. 2nd edition. Edited by Edmondson, W.T. John Wiley & Sons. Inc. London.

Welch, P.S. (1952). Limnology. 2nd ed. McGraw-Hill Book Co. Inc. New York. Toronto. London.

Wetzel, R. G. and Likens, G. E. (2000). Limnological Analysis. 3rd edition. Pp: 57 – 72. Springer – Verlag, New York, Inc.

Zaret, T.M. (1972). Predators, invisible prey and the nature of polymorphism in the cladocera (Class Crustacea). Limnology Oceanography. 17:171-184.