DYNAMICS OF ROTIFER POPULATIONS IN A LAGOON BORDERED BY HEAVY INDUSTRY IN LAGOS, NIGERIA

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ABSTRACT

An investigation into the dynamics of Rotifer populations in Ologe lagoon was carried out for a period of 24 months. The study covered identification, temporal abundance, spatial distribution and diversity of the Rotifera. The study aimed at establishing the influence of some physical and chemical parameters on the abundance, distribution pattern and seasonal variations of the Rotifer .populations. Eleven sample stations including five fishing villages cum farm settlements (Idoluwo, Oto, Ibiye, Obele, and Gbanko) around the lagoon were sampled using standard techniques. Data obtained were statistically analyzed using linear regression and hierarchical clustering. Eight of the twenty three Rotifer populations identified were ephemeral. The Pearson's correlation coefficient ("r" values) between total Rotifer population and some physical and chemical parameters showed that positive correlation occurred with Salinity ($r = 0.043$) having a high level of significance (0.842) and with surface water dissolved oxygen ($r = 0.300$) with low level of significance (0.155).
Linear regression plots indicated that, the total population of Rotifera were mainly influenced and only increased with an increase in value of surface water temperature (Rsq = 0.798) and conductivity (Rsq = 0.602). The total population of Rotifers had a near neutral (zero correlation) with the surface water dissolved oxygen and thus, does not significantly change with the level of the surface water dissolved oxygen. The correlations were positive with NO_3-N at Ibiye (Rsq =0.022) and Gbanko (Rsq =0.013), PO_4-P at Ibiye (Rsq =0.259), K at Idoluwo (Rsq =0.296) and SO_4-S at Oto (Rsq = 0.934) and Gbanko (Rsq = 0.457).
The Berger-Parker Dominance Index (BPDI) showed that the most dominant species was Keratella species (BPDI = 1.000), followed by Trichocerca species (BPDI = 1.320).
Clusters by squared euclidan distances using single linkage between groups showed proximities, transcending the borders of genera. The results revealed that Rotifer populations in Ologe lagoon, had ecotonal differences in spatial distribution, undergo seasonal perturbations and were highly influenced by organic matter and nutrient loading, from Agbara industrial estate and surrounding farmlands.

Keywords: Dynamics, Dominance, Perturbations, Ecotone, Richness.

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INTRODUCTION

Many studies have been carried out on zooplankton and the earliest works dates back to the 19th century. The term plankton refers to all organisms that drift about in water. Zooplanktons are the animal components of plankton while phytoplankton is the plant component. Locomotion in zooplankton is limited to the use of flagella, cilia or change in specific weight of the organisms.

Zooplankton includes representative of all the major invertebrates. However, freshwater zooplankton consists almost exclusively of representatives of only three groups. These three main groups are rotifera, cladocera and copepoda.

Rotifers are microscopic fauna that are prevalent in fresh waters. While a few rotifers are cosmopolitan, many of these animals are highly adapted to a wide range of freshwater conditions (Brummett,2000). The Rotifera is very important in the trophic structure and biological production potential of fresh water habitats. They are also used as indicator organisms for the monitoring of the quality of such habitats (Sladecek, 1983). The Rotifers has been well studied globally, however in Nigeria, the paucity on knowledge of rotifers was attributed to inadequate relevant literature, shortage of illustrated checklists and culture problem (Egborge, 1981; Akinbuwa and Adeniyi, 1991). The high protein content of Rotifers make their populations a veritable source of nutrient for the fast growth of the larvae for most planktivorous species of fish in fresh and coastal marine aquatic habitats, and as such a booster to fish farmers (Kitto and Bechara, 2004).

Globally, it has been observed that some regions possess more zooplankton than the others. The populations of zooplankton have been known to change in both number and composition with the passage of season. At each stage, there is a complex interplay between the chemical and physical factors and both phytoplankton and zooplankton populations.

Interaction between zooplankton and phytoplankton in aquatic environment has been directly or indirectly linked to fisheries. Most commercial fish begins life in plankton and spend their early life in it after hatching. The young fish depends on the plankton for their sustenance. Zooplanktons are known to convert the bulk of primary production to secondary production thus the abundance of zooplankton carry along with it a potential future stocks in fisheries.

The community structure of zooplankton greatly depends on the trophic level of the water body they inhabit. The eutrophication process in shallow water bodies has been known to greatly change the community structure of aquatic organisms. Such change mainly starts with phytoplankton which is known as the first step in the food chain. It is known that eutrophication affects the specific composition of zooplankton through physical and chemical changes in the environments which may also affect the phytoplankton population.

Therefore studies on zooplankton communities in freshwater environments may be instrumental in predicting long-term changes in such environments. Unfortunately at this moment, there is dearth of limnological information on Ologe lagoon with regards to its zooplankton abundance and distribution and water quality.

This research was undertaken to provide information on the taxa composition of the Rotiferan populations, abundance and distribution of Rotifera with regards to the physical and chemical water quality in Ologe lagoon. This may be used for planning and implementation of fisheries policies.

The main objectives are

- To determine monthly fluctuations of water quality parameters prevailing in the water system.
- To establish the monthly distribution pattern, abundance, diversity and monthly variations in the total rotiferal population.
- To establish the major rotiferal species in Ologe lagoon and
- To relate observed rotiferal distribution and abundance to prevailing ecological factors.

MATERIALS AND METHODS

Sampling Program

Sampling was carried out to, as much as possible; ensure coverage of the Ologe lagoon system. Sampling was done along designated transects from specific sites in horizontal direction (Clarke, et al, 2012). Monthly sampling of all marked sampling sites was done every month for twenty four (24) months. Marking of the sampling stations was carried out using the GEOGRAPHICAL POSITIONING SYSTEM (GPS) model–12. This hand–held equipment ensured that the samples were repeatedly collected from exactly the same locations at the various sampling stations or waypoints, throughout the year.

More samples were collected from regions of environmental transition so as to obtain precise estimates of parameters from the most variable component of the planktonic fauna.
The sampling density was for one sample in an average of 1.44km. -- 9.28km, along sites / transects designed to cover the whole lagoon system including portions relatively unaffected by human activity. The stations were sited according to the criteria prescribed by the GEMS / WATER operational guide (1977) on Global Water Quality Monitoring. Identifications of rotifers were made by reference to Ward and Whipple (1959),Hutchinson (1967), Pontin (1978), Ayodele (1979), Sladecek (1983), Jeje and Fernando (1986) and Egborge and Chigbu (1988).

Plankton sampling the net sampling procedure: A standard phytoplankton net, 55µm mesh size, was towed at low speed for five minutes, at each sampling station just below the water surface to collect plankton which were concentrated and collected in the detachable bucket (glass jar) at the rear end of the equipment. When the haul was finished, the sample was tapped directly into a sterilized bottle through the draining tube.

Preservation and storage: Phytoplankton in water samples, keep their viability for sometime provided they are not subjected to rise in temperature and light intensity. Water samples were therefore collected in 500ml sterilized Pyrex quality glass bottles enclosed in polystyrene to prevent mechanical damage. Water samples from bloom situations and net hauls were kept in 1litre bottles to reduce density .All samples were fixed and kept in an ice chest for onward transportation to the laboratory.
Collected samples were fixed and preserved in a laboratory-prepared, 20% aqueous solution of formaldehyde, acidified with glacial acetic acid. That is, 20% distilled water plus 40% p.a. (pro-analysis) grade formalin (HCHO) plus 40% acetic acid according to methods described by Sournia (1978).

For water samples, 2ml of fixing agent was added to 100ml of water i.e. 20ml fixative to 1litre sample. The bottle was then shaken immediately to facilitate instantaneous fixation.
Fixation: For net hauls, the fixing agent was added to make up, about one-third of the volume (dense sample) and properly mixed to prevent decay.

All samples were fixed after collection and transported to the laboratory at low temperature in an ice pack chest. In the laboratory, they were preserved in a refrigerator at temperatures below –10°C.

WATER QUALITY ANALYSIS

The HORIBA U-10 water quality checker was used for the analysis of each water sample collected for conductivity and pH. Salinity was measured by a Refractometer (model New 3 – 100), while in-situ surface dissolved oxygen concentration bottom dissolved oxygen were measured by the use of a YSI model – 57 dissolved oxygen / temperature meter. Other physical parameters were measured at sampling station according to standard methods (APHA, 1980); using a mercury thermometer for surface water temperature and secchi disc for transparency. Rainfall data for the period of sampling were obtained from the Nigerian meteorological station Oshodi, Lagos

PLANKTON ANALYSIS

Centrifugation and / or sedimentation were done with known volumes of water samples, while, enumeration / counting was done per unit area of the floor of a Sedgwick Rafter counting chamber.

Identification of the planktonic organisms was done, by putting a mixed pipette drop of the sub-sample equivalent to 1ml on Sedgwick-Rafter counting chamber. This is covered with a cleaned glass slide and viewed under the powers of an electric binocular compound microscope, at x150 magnification. Identification was done using internationally accepted taxonomic key (Koste, 1978; for Rotifera).

Zooplankton count was done under the following conditions:

Samples were thoroughly mixed prior to sedimentation. The water was allowed to come to room temperature to prevent air bubbles collecting and to allow for uniform settlement. Counting was then carried out along known area transects, which were determined by using a calibrated eye-piece grid. The overall transect area is the sum of the number of fields counted. The bias of non-homogenous distribution was removed by counting a number of transects. The Sedgwick-Rafter counting chamber contains exactly one ml. and has a surface area of 1,000 mm^2. Five grids were viewed within the ocular micrometer, thus the number of organisms counted in five grids were expanded to the total number of organisms per millimeter of the concentrated sample. The number of organisms per millimeter of the concentrated sample was calculated using the following formula:

$$\text{Number of plankters per ml.} = (T)\ \frac{1{,}000}{AN} \times \frac{\text{Volume of concentrate in ml.}}{\text{Volume of Sample in ml.}}$$

Where, *T = total number of plankters counted,* *N = number of grids employed.*
A = area of grids in mm^2*;* *1,000 = area of counting chamber in* mm^2
Source: GEMS Water Operational Guide (1977).

3.7.1. DIVERSITY INDICES

The indices utilized to obtain estimates of species diversity include: -

(a) Richness Index = A measure of species diversity calculated as $d = \frac{(S-1)}{\log N.}$

Where S = Number of species in the habitat or community and

N = the total number of individuals of all species.

(b) Shannon-Weiner (1963) information function 'H' $= -\sum_{i}^{s} pi \log pi$;

Where pi = the proportion of the i^{th} species in the sample.

(c) Sipmson's Index (D) = An index of diversity based on the probability of picking two organisms at random that are different species; calculated as $D = 1 - \sum_{i=1}^{s} (Pi^2)$

Where Pi = the proportion of individuals of species I in a community of "S" species.

(c) Berger-Parker dominance index 'd' $= \frac{Nmax}{Nwt.}$

Where Nmax = value of most abundant species and

Nwt = total number of individuals.

(e) Equitability or evenness of distribution, $E = \frac{H}{\log_2 S.}$

Where S = the number of species (taxa)

H = the Shannon-Weiner index of diversity

and E = Measure of evenness having a maximum value of 1 when all species regardless of their number are present in equal proportions. (Sen Gupta and Kilburne, 1974).

(f) Linear regression was used to decipher the relationship between plankton population flush/crash, Physical and chemical parameters and nutrient imputes into Ologe lagoon.

(g) Absolute correlation between vectors of values of the individual organisms was done using the Pearson methods, to produce proximity matrices. Here, the variables are known to be more strongly correlated when their values are closer to 1 or –1. Absolute similarity matrices were thence, elucidated. A Dendrogram was drawn from these matrices, using single linkage between groups to show proximity / level of correlation and arrangement into homogenous clusters based on their mutual similarities in hierarchy of abundance and / or dominance between and among individual organisms, within subgroups of this class. This hierarchical clustering is a measure of compactness or goodness of partition between groups of plankton.

RESULTS

Analysis of the physical and chemical parameters in Ologe Lagoon revealed interesting spatial and temporal variations. The spatial variations of the mean annual air, surface water and bottom water temperatures revealed sample station 4 to have the lowest at 27.9°C, 26.9°C and 26.2°C respectively.

The highest seasonal temperatures were experienced between January and March, at the peak of the dry season and the lowest between May and July during the peak- rainy-season. Temperatures decreased in the order of air, surface water and bottom water respectively (Figure, 1). The mean dry season air, surface and bottom water temperatures were 29.47 ± 1.19, 28.75 ± 0.54 and 28.03 ± 0.45 for the year 2000 dry season and 30.11 ± 0.21, 28.96 ± 0.22 and 27.76 ± 0.29 for the year 2001 dry season. The rainy season values for the period of study were 28.69 ± 1.06, 28.56 ± 1.36, 27.60±, 30.06 ± 0.32, 28.93 ± 0.27 and 27.36 ± 0.18 respectively.

Conductivity ranged between 124 and 280 mohms / cm^2 in station 4 and 1656 and 1588 mohms / cm^2 in station 9. Seasonally, it was lowest in July and highest in December. Conductivity increased and decreased proportionally with salinity and both, was lowest in sample station 4 and highest in sample station 9 (Figure, 2).

The mean dry and rainy season conductivity, for the period of study was 634.09 ±79.38, 633.91 ± 59.78 and 625.30 ±85.18 and 631.74 ±80.63 mhoms/cm^2 respectively.

Salinity ranged between 0.00°/oo and 0.69°/oo with a peak in May of 2001 at 0.69°/oo. The mean dry season salinity for the period of study was 0.21 ± 0.05 °/oo and 0.23 ± 0.59 °/oo, while for rainy season it was 0.14 ± 0.10 and 0.23 ± 0.25 °/oo respectively.

Sample stations 1, 2, 7 and 9 recorded the highest mean surface water and bottom water dissolved oxygen (DO) concentrations, while sample station 4 recorded generally low levels of DO. It was 6.71 mg/L, 6.68 mg/L, 6.48 mg/L, and 6.19 mg/L and 7.15 mg/L, 7.54 mg/L, 6.42 mg/L and 7.57 mg/L respectively for these stations within the period of study (figure 3). Bottom water DO was 3.28 mg/L and 3.08 mg/L at sample station 4 and 5.67 mg/L and 5.73 mg/L at sample stations 7 and 9 respectively.

Cumulatively, the dry season bottom water dissolved oxygen was higher than that of the rainy season. The mean bottom water DO was 4.42 ± 0.84mg/L and 5.21 ±0.68mg/L for the dry seasons while it was 4.46 ± 0.56mg/L and 4.46 ± 0.89mg/L for the rainy seasons.

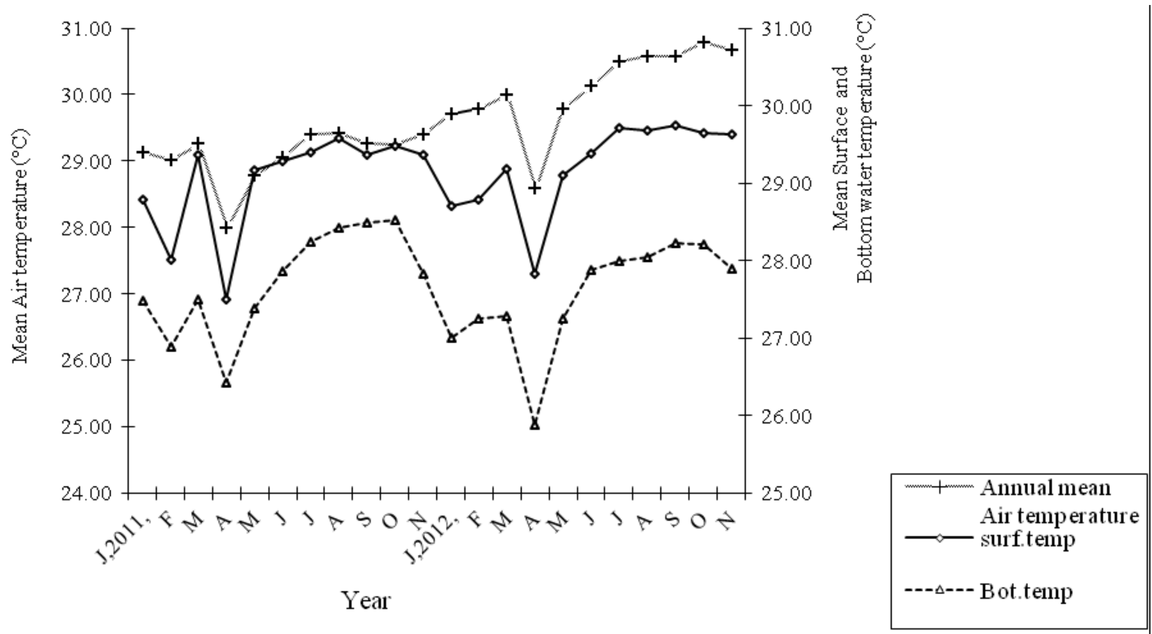


Figure. 1 : Annual mean Air, Surface water and Bottom water temperatures in Ologe lagoon within the period of study.

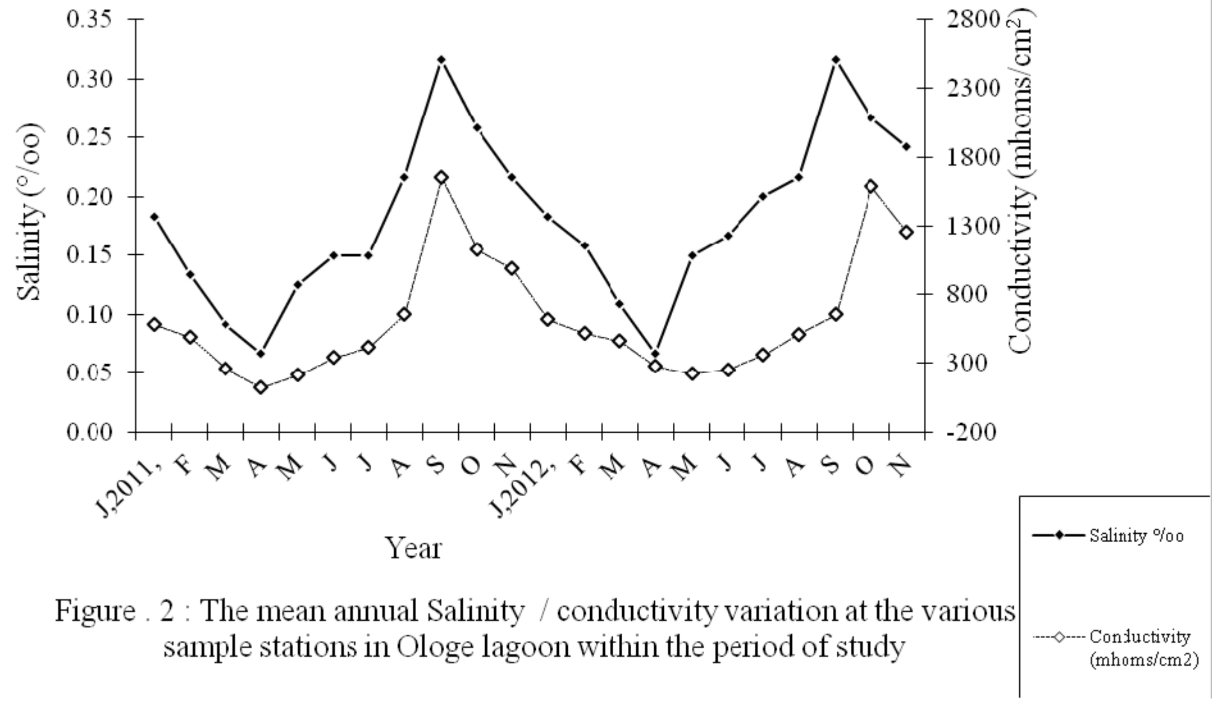


Figure . 2 : The mean annual Salinity / conductivity variation at the various sample stations in Ologe lagoon within the period of study

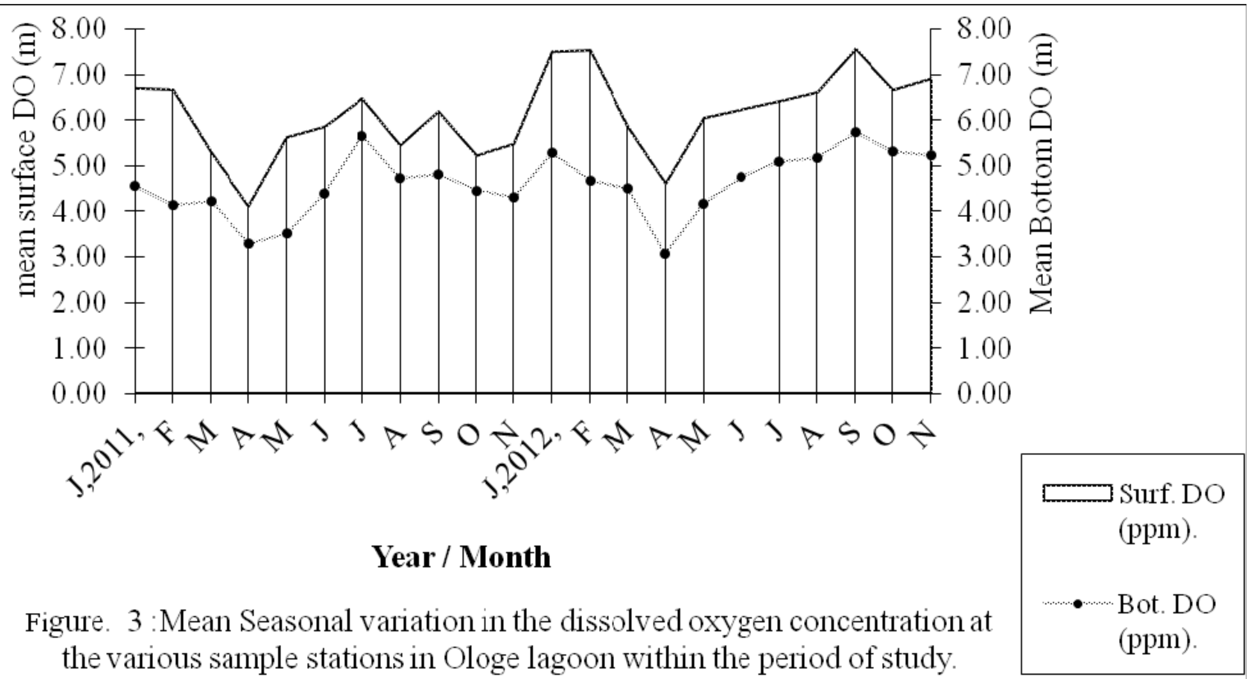


Figure. 3 :Mean Seasonal variation in the dissolved oxygen concentration at the various sample stations in Ologe lagoon within the period of study.

Rainfall showed three peaks; recording 189.4mm in April, having a slight variation in range of 338.4mm and 347.9mm between June and July and 233.9mm in October (Figure, 4). Rainfall was observed to be inversely proportional to transparency, which was highest at sample station 4 with a mean of (0.73m and 0.83m) and sample station 7 (0.73m and 0.80m). It was lowest during the peak of the rains and at stations 5,6,9 and 10 (0.55m, 0.56m, 0.57m, and 0.56m for the first year) and

0.61m, 0.59m, 0.63m and 0.65m for the second. The highest mean seasonal variation in transparency was recorded in April (1.2m) while the lowest (0.5m) was in September (Figure, 4).
The mean transparency for the dry seasons of both years was 0.71 ± 0.04m and 0.74 ± 0.14m while the rainy season values were 0.57 ±0.07m and 0.62 ±0.11m.
The highest depths were recorded at sample station 4 (9.53m) and 7 (6.01m), while the shallowest points on the lagoon were sample stations 3 (1.68m) and 9 (1.84m), throughout the period of study. However, the highest seasonal depth was in July and the lowest in March. The mean depth recorded for the dry seasons were 3.07 ±0.29m and 3.11 ±0.48m whereas, the rainy season means were 3.43 ±0.35 and 3.48 ±0.29m.
The pH ranged between 4.83 at sample station 4 and 7.95 at sample station 9 (Figure, 5). The mean hydrogen ion concentration was observed to be inversely proportional to depth. However, it was higher in the dry seasons (6.82 ±0.55 and 6.87 ±0.60) than the rainy seasons (6.79 ±0.29 and 6.85 ± 0.27.

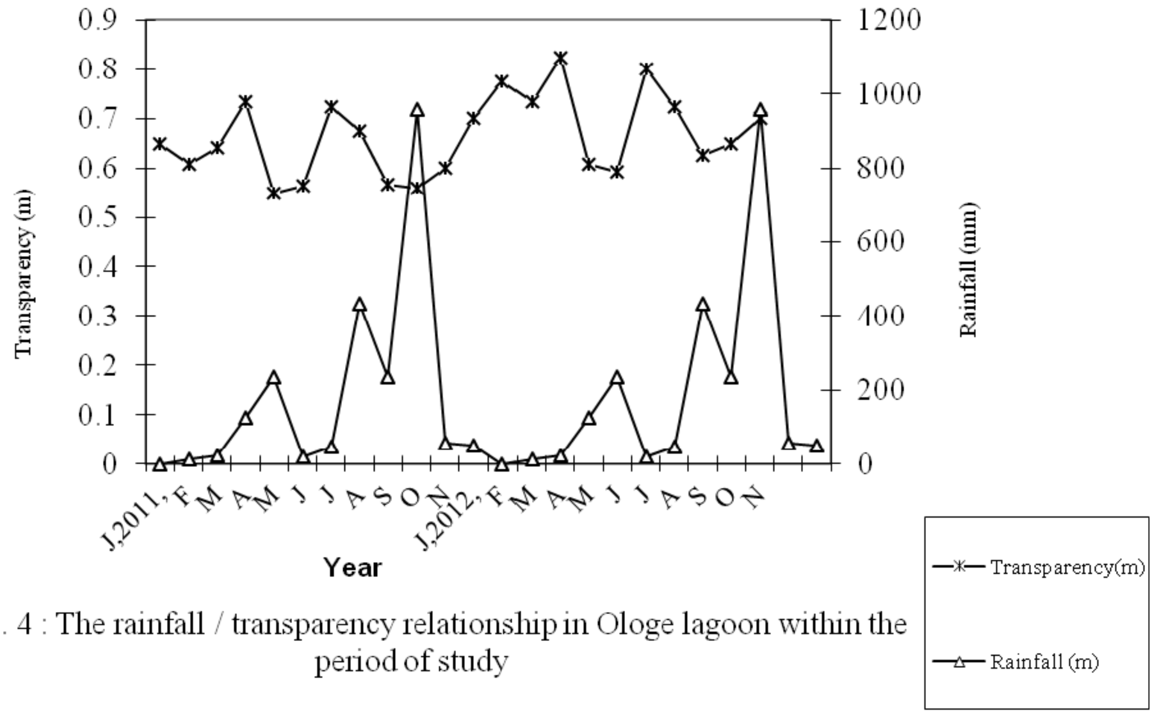


Figure. 4 : The rainfall / transparency relationship in Ologe lagoon within the period of study

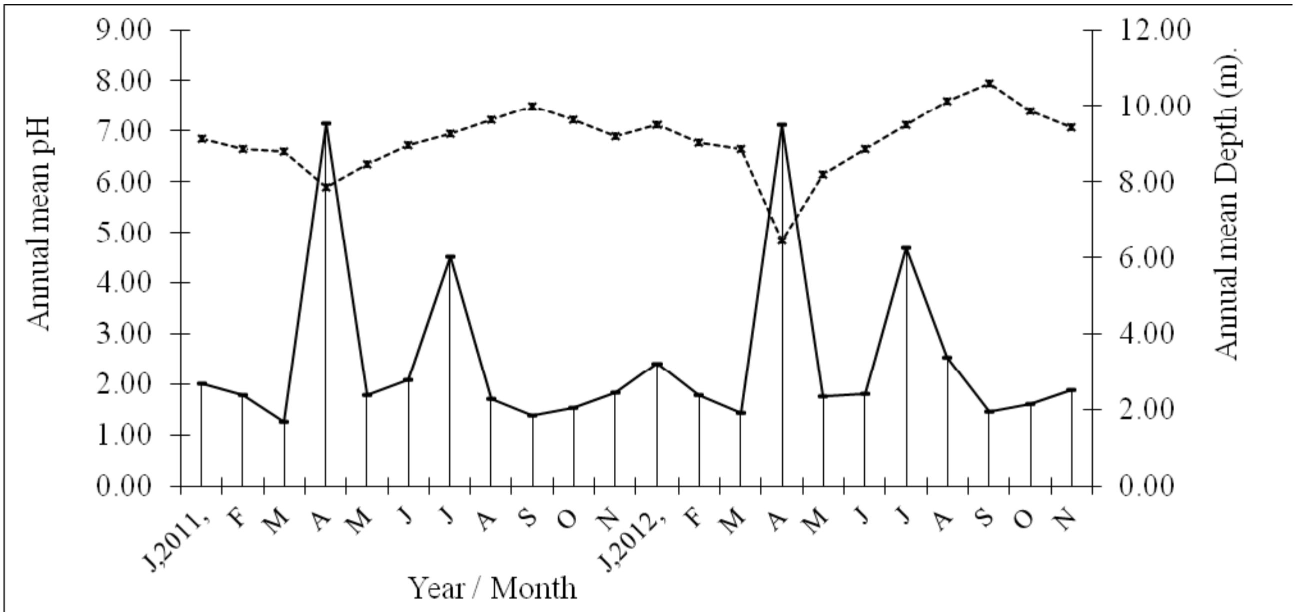


Figure. 5 :The annual mean pH and annual mean depth variations in Ologe lagoon within the period of study.

POPULATION DYNAMICS: The Rotifers showed spatial homogeneity in all the sampling stations throughout the year except between January and March when the population was sparse.

The monthly Rotiferal distribution (figure 6) showed that *Keratella sp*., *Brachionus sp., Trichocerca sp., Kellicotia sp. and Lecane sp*. were all perennial except *Lecane sp*. and *keratella sp*. which were not observed in March and April respectively. All others including *Asplanchna sp*. (April - Dec.), *Lindia sp*. (Mar. – Oct.), *Proales sp*. (Feb. – Aug.), and *Testudinella sp.* (June – Dec.), were present for most part of the year.

Argonotholca sp. was individually less than one percent of the total Rotiferal density in the lagoon, (figure 7). Percentage Rotiferal density in Ologe lagoon decreased in the order of *Keratella sp*. (37 %), *Trichocerca sp. (*24.2%), *Kellicotia sp*. (12.3 %), *Brachionus sp*. (11.1 %), *Lecane sp.* (3.8 %), *Asplanchna sp*. (2.2 %), *Pleurotrocha sp*. (1.6 %), *Lindia sp*. (1.4 %) and *Euchlanis sp*. (1.1 %). Rotifers including *Cupelopagis sp., Ascomorpha volvolicola, Epiphanes sp., Balatro sp., trochosphaera sp., Eosphora sp., and Polyarthra sp which* were individually less than one percent of the total rotifers observed, made up 5.2% of the twenty three species identified.

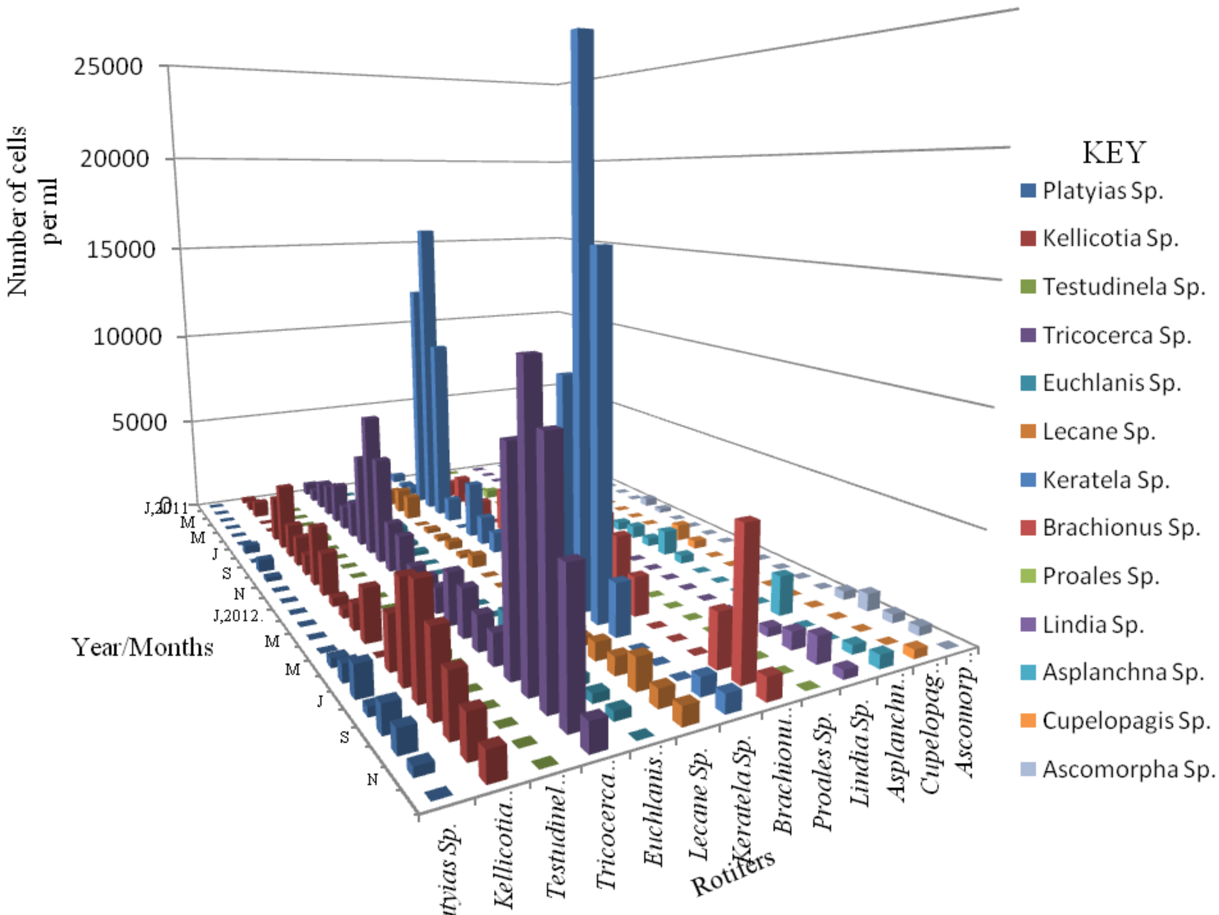


Figure. 6 :Seasonal variation in the population of Rotifers in Ologe lagoon within the period of study.

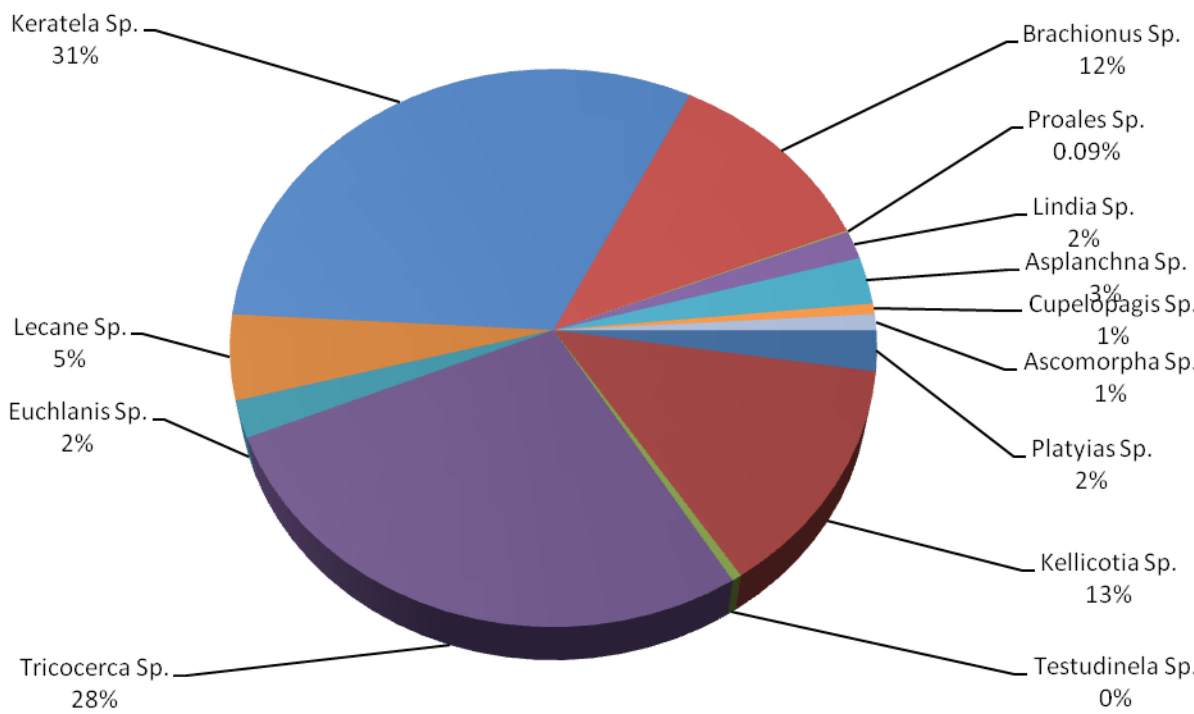


Figure.7: The relative density of Rotifers in Ologe lagoon within the period of study.

Most of the physical and chemical parameters showed negative correlations with the total population of Rotifers. These included transparency (-0.068), air temperature (-0.346), surface water temperature (-0.247), bottom water temperature (-0.242), bottom water dissolved oxygen (-0.095), Depth (-0.003), pH (-0.325), conductivity (-0.112) and rainfall (-0.026) with a high level of significance for transparency (0.754), bottom water dissolved oxygen (0.662), conductivity (0.606),) and rainfall (0.945) respectively (Table,1).

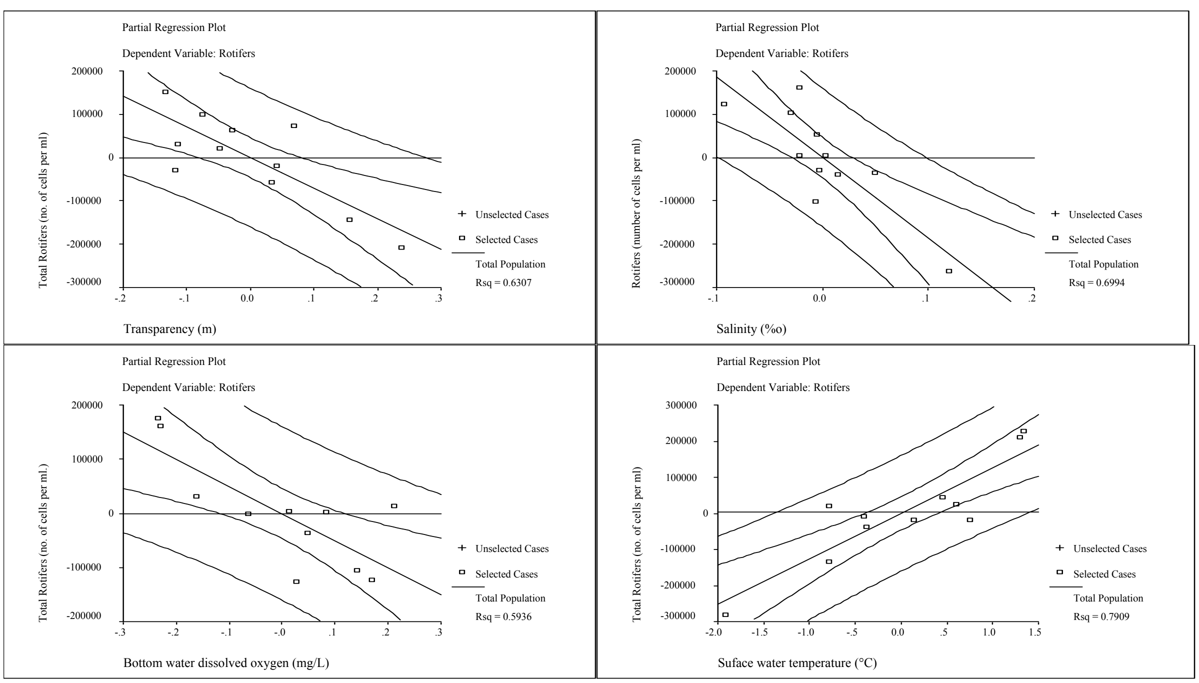
The parameters that were positively correlated with the total Rotiferan populations included, Salinity (r = 0.042) with high level of significance (0.844) and surface water dissolved oxygen (r = 0.299) with low level of significance (0.155). The parameters with high significant values in decreasing order included depth (0.988), salinity (0.844), transparency (0.753), bottom water dissolved oxygen (0.660) and conductivity (0.604).

The linear regression plots (Figures 8 & 9) further showed that, the amplitude of variation in the total population of Rotifers was mainly influenced, and only increased with an increase in value of surface water temperature and conductivity. The total population of Rotifers had a near neutral (zero correlation) with the surface water dissolved oxygen and therefore does not significantly vary with a change in the level of the SDO.

Table.1: Correlation coefficient 'r' values of the Total Rotifers and some physicochemical factors in Ologe lagoon within the period of study (Significant values at P ≤0.05)

Parameters	Pearson's 'r' value	Asymptotic Standard Error [a]	Approximate 'T' [b]	Approximate Significance [c]
Total Rotifers / Transparency	-0.068	0.059	-0.318	0.753
Total Rotifers / Salinity	**0.042**	0.095	0.199	**0.844**
Total Rotifers / Air temperature	-0.346	0.074	-1.728	0.098
Total Rotifers / Surface water temperature	-0.247	0.135	-1.193	0.245
Total Rotifers / Bottom water temperature	-0.242	0.111	-1.170	0.254
Total Rotifers / Surface water Dissolved Oxygen	**0.299**	0.154	1.471	**0.155**
Total Rotifers / Bottom water Dissolved Oxygen	-0.095	0.062	-0.445	0.660
Total Rotifers / Depth	-0.003	0.060	-0.015	0.988
Total Rotifers / pH	-0.325	0.136	-1.613	0.121
Total Rotifers / Conductivity	-0.112	0.054	-0.527	0.604
Total Rotifers / Rainfall	-0.026	0.262	-0.078	0.939

[a] – Not assuming the null hypothesis
[b] – Using the asymptotic standard error assuming the null hypothesis
[c] - Based on normal approximation.



Figures 8: Partial regression plots showing the relationship between the total population of Rotifers, Transparency, Salinity, Bottom Water Dissolved Oxygen and Surface Water Temperature within the period of study.

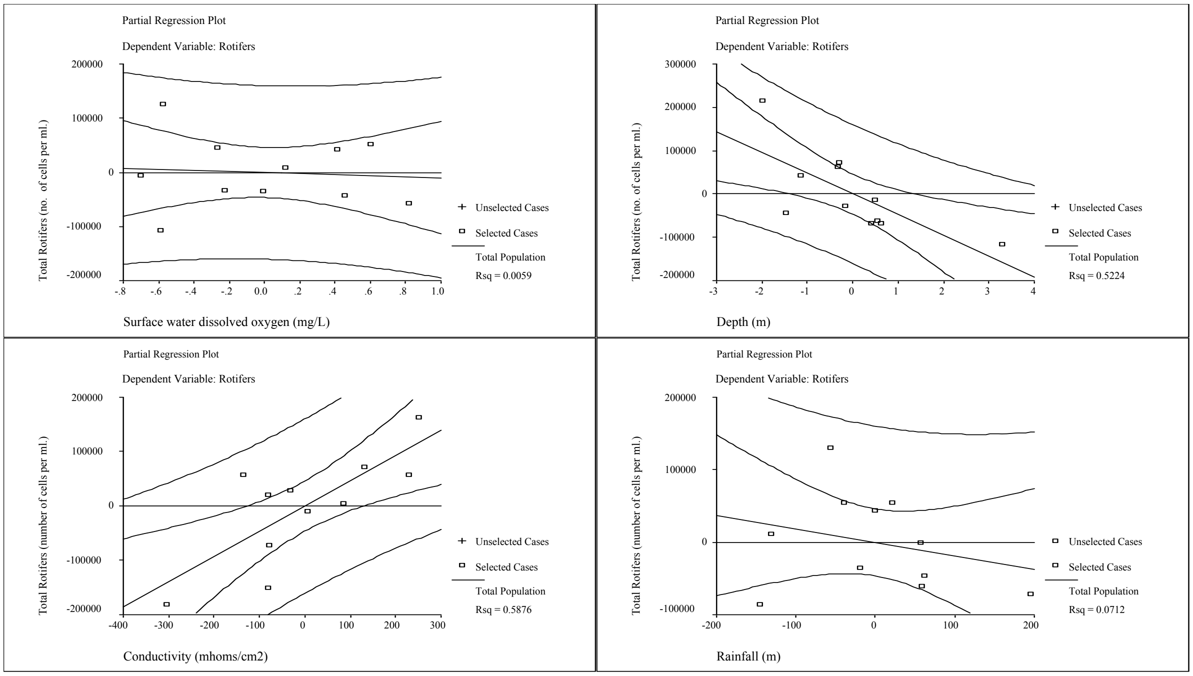


Figure.9: Partial regression plots showing the relationship between the total population of Rotifers, Surface Water Dissolved Oxygen, Depth, Conductivity and Rainfall within period of study.

The Rotifers responded positively to NO_3-N at the Ibiye (Rsq = 0.0217) and Gbanko (Rsq = 0.0133) sample stations. They were however not responsive (Figure 10) at Oto (Rsq = 0.0000) and correlated negatively at Idoluwo (Rsq = 0.0521), with NO_3-N.

The mid-stream rotifers at Ibiye (Figurre 11) correlated positively with PO_4-P (Rsq = 0.2583), negatively with PO_4-P at Idoluwo (Rsq = 0.1319) and Gbanko (Rsq = 0.0225). The correlation was zero, with (PO_4-P) at Oto (Rsq = 0.0001).

Potassium (K) had a zero correlation with the rotifers at Ibiye (Rsq = 0.0004) and negative correlations (Figure 12), at Oto (Rsq = 0.1578) and Gbanko (Rsq = 0.0784). The rotifers positively correlated with potassium (K) at Idoluwo (Rsq = 0.2954).

The preponderance of the rotifers (Figure 13) was positively influenced by SO_4-S at Oto (Rsq = 0.0945) and Gbanko (Rsq = 0.4589). The case was the reverse at Idoluwo (Rsq = 0.2109) and Ibiye (Rsq = 0.3498).

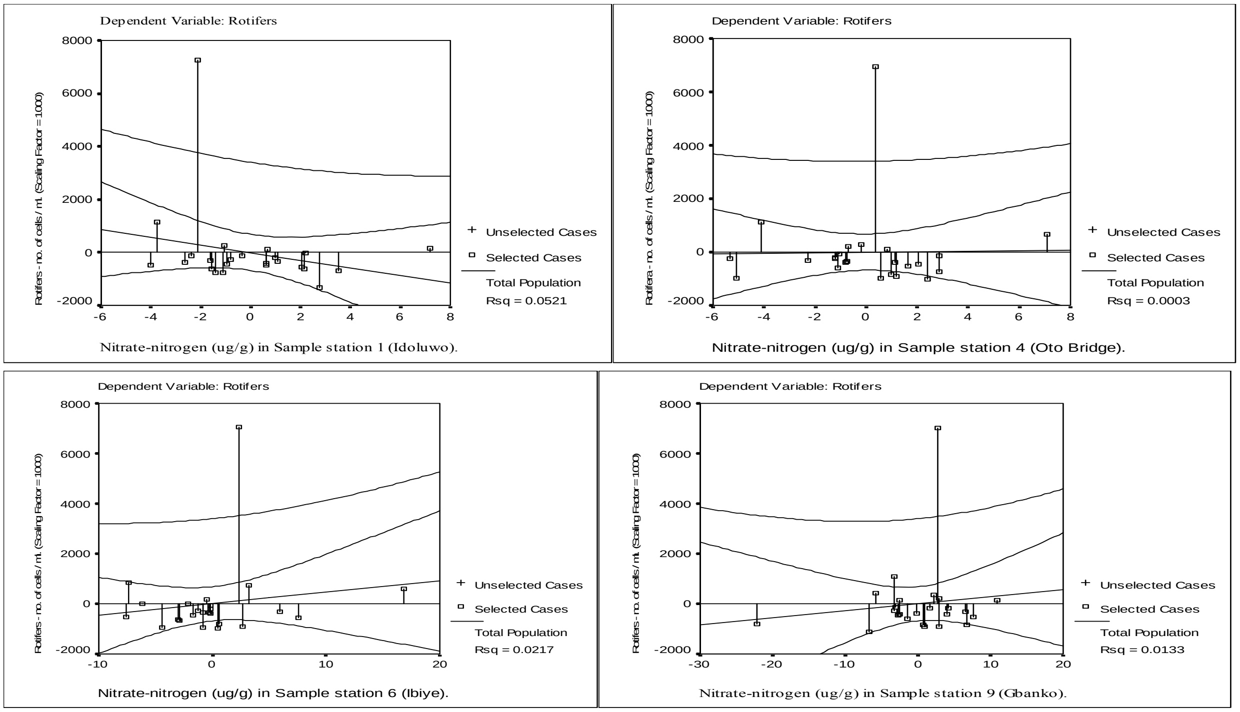


Figure.10: Partial regression plots showing the relationship between the Total population of Rotifers, and Nitrate-nitrogen (NO_3-N) at the Upstream, Midstream and Downstream portions of Ologe lagoon within the period of study.

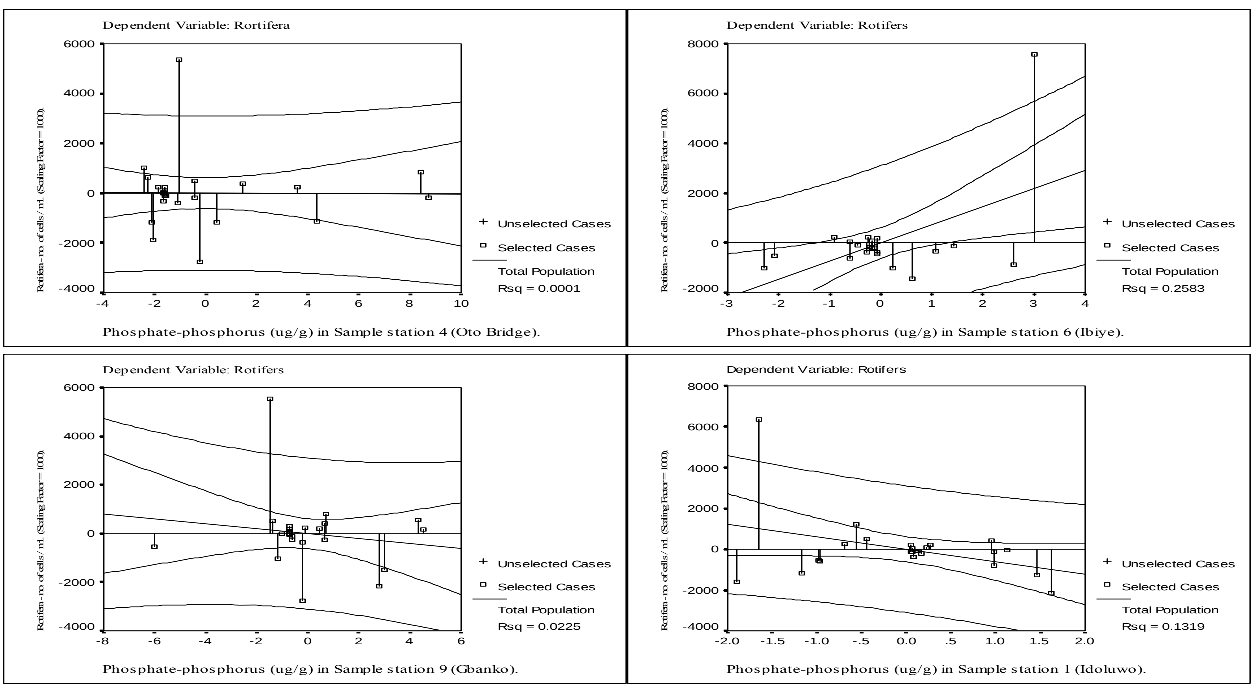


Figure.11: Partial regression plots showing the relationship between the Total population of Rotifers, and Phosphate-phosphorus (PO_4-P) at the Upstream, Midstream and Downstream portions of Ologe lagoon within the period of study.

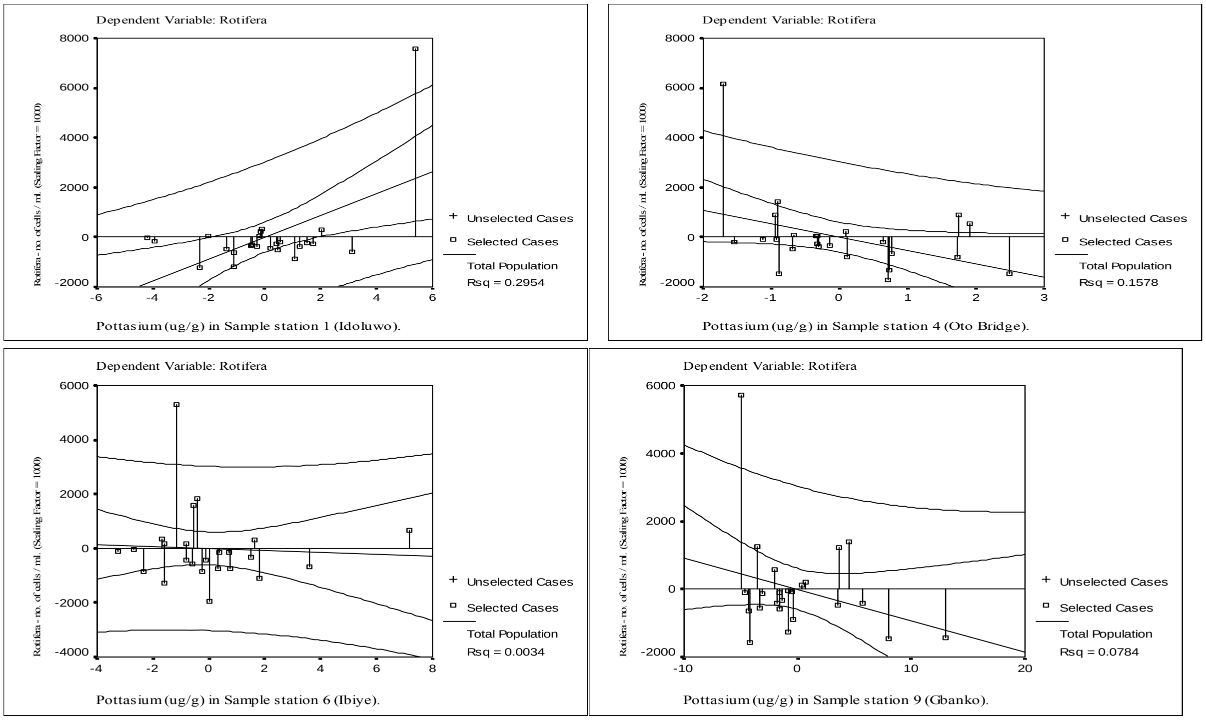


Figure.12: Partial regression plots showing the relationship between the Total population of Rotifers, and Potassium (K) at the Upstream, Midstream and Downstream portions of Ologe lagoon within the period of study.

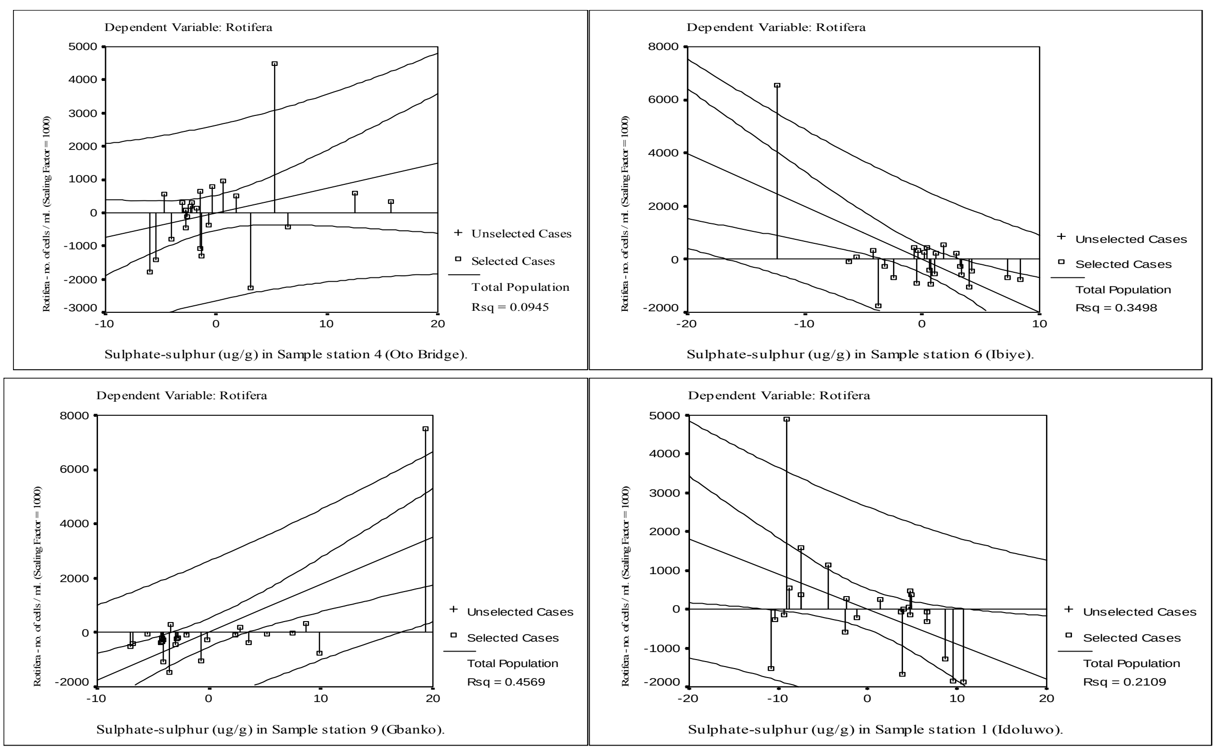


Figure.13: Partial regression plots showing the relationship between the Total population of Rotifers, and Sulphate - sulphur (SO_4-S) at the Upstream, Midstream and Downstream portions of Ologe lagoon within the period of study.

The partial regression plots showed that distribution of the organic matter content also had positive correlation at stations 2 (Rsq. = 0.035), 4 (Rsq. = 0.283), 6 (Rsq. = 0.085), 7 (Rsq. = 0.425), 10 (Rsq. = 0.185) and 11 (Rsq. = 0.043) (Figures 14, 15 & 16). The organic matter content increased with an increase in population of the rotifers at these sample stations.

There were negative correlations at sample stations 1 (Rsq. = 0.108), 3 (Rsq. = 0.069), 5 (Rsq. = 0.133), 8 (Rsq. = 0.253) and 9 (Rsq. = 0.092); where the organic matter content decreased with an increase in the population of Rotifers.

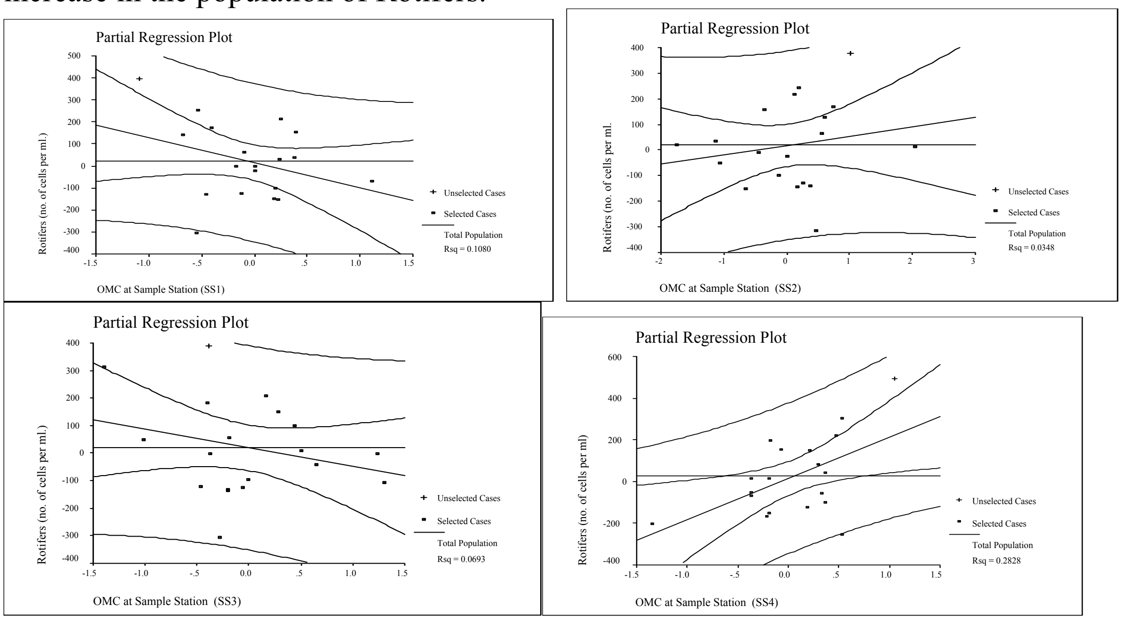


Figure.14: Partial regression plots showing the relationship (Correlative Distribution) between the population of Rotifers, and the Organic Matter Content (OMC) in SS_1 SS_2, SS_3 & SS_4 within, the period of study.

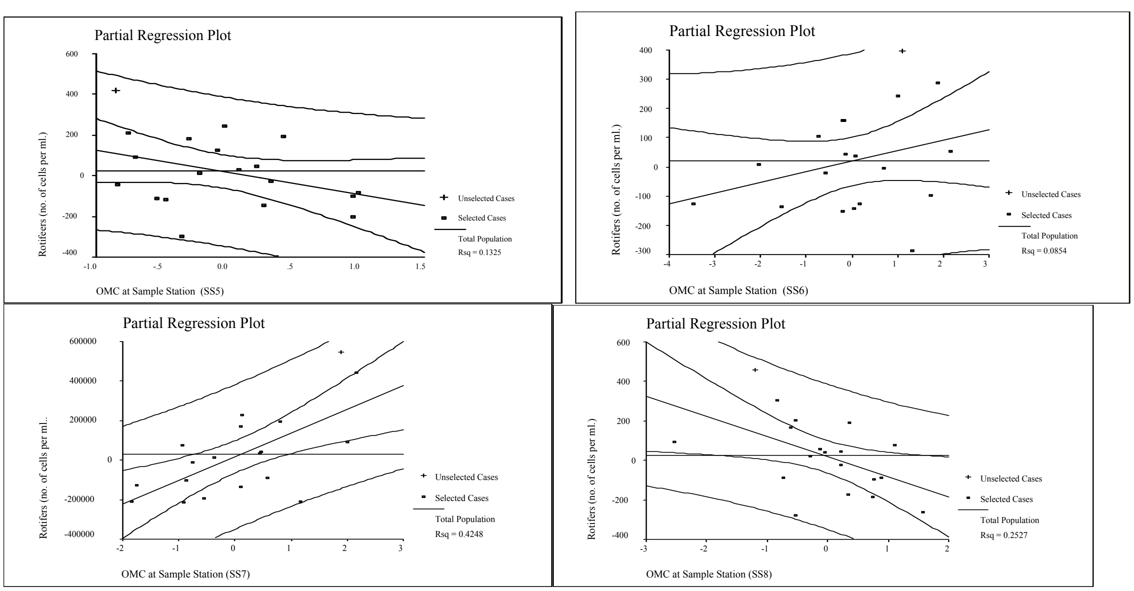


Figure.15: Partial regression plots showing the relationship (Correlative Distribution) between the population of Rotifers, and the Organic Matter Content (OMC) in SS_5 SS_6, SS_7 & SS_8 within, the period of study.

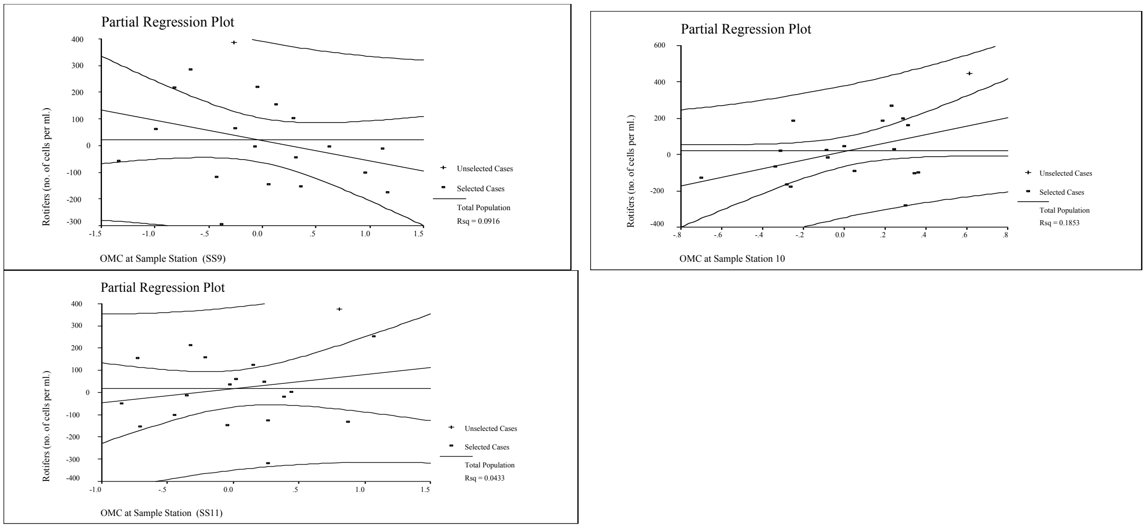


Figure.16: Partial regression plots showing the relationship (Correlative Distribution) between the population of Rotifers, and the Organic Matter Content (OMC) in SS9 SS10 & SS11 within, the period of study.

DIVERSITY INDECES

The *keratella* species was the richest (2.684) rotiferal group in the lagoon while the poorest was the *Proales species* (4.611). All other indices of diversity showed that the *keratela* species were the most dominant and more evenly distributed rotifer population in the Lagoon (Table 2).

Table 2: Some indices of diversity for the Rotifers in Ologe lagoon within the period of study

Rotifers	Sum of ni	Pi	SHANNON WEAVER DIVERSITY INDEX	SIMPSON'S DIVERSITY INDEX	RICHNESS INDEX	BERGER-PARKER DOMINANCE INDEX	EQUITABILITY (EVENNESS OF DISTRIBUTION
Platyias Sp.	6,800.00	0.0217	-0.1199	0.0005	3.130	15.882	0.096
Kellicotia Sp.	40,800.00	0.1302	-0.3829	0.0169	2.603	2.647	0.308
Testudinela Sp.	1,400.00	0.0045	-0.0349	0.0000	3.814	77.142	0.028
Tricocerca Sp.	**81,800.00**	**0.2610**	**-0.5058**	**0.0681**	**2.442**	**1.320**	**0.408**
Euchlanis Sp.	6,200.00	0.0198	-0.1120	0.0004	3.164	17.419	0.090
Lecane Sp.	15,400.00	0.0491	-0.2136	0.0024	2.866	7.012	0.172
Keratela Sp.	**108,000.00**	**0.3446**	**-0.5297**	**0.1188**	**2.384**	**1.000**	**0.427**
Brachionus Sp.	36,000.00	0.1149	-0.3586	0.0132	2.633	3.000	0.289
Proales Sp.	**400.00**	**0.0013**	**-0.0123**	**0.0000**	**4.611**	**270.000**	**0.009**
Lindia Sp.	4,600.00	0.0147	-0.0894	0.0002	3.276	23.478	0.072
Asplanchna Sp.	7,600.00	0.0243	-0.1301	0.0006	3.092	14.210	0.105
Cupelopagis Sp.	1,800.00	0.0057	-0.0428	0.0000	3.686	60.000	0.035
Ascomorpha Sp.	2,600.00	0.0083	-0.0574	0.0001	3.514	41.538	0.046
TOTAL	313,400.00	1.000	-2.589	0.221			
			2.589*	**0.779****			

* = *-SUM (Pi $\log_2$ Pi)*, * = *1-SUM Pi^2*, Sum of ni = N , Pi = ni/N, SHANNON WEAVER DIVERSITY INDEX (Pi $\log_2$Pi) SIMPSON'S DIVERSITY INDEX (Y=SUM Pi^2), RICHNESS INDEX (d = (S-1) / LOG N, BERGER-PARKER DOMINANCE INDEX =Nmax/ Nwt, EQUITABILITY (EVENNESS OF DISTRIBUTION; E = H/LOG_2S.

Although the *Keratella* specie had a spatial dominance and stronger presence in the Rotiferal class, it was absent in August while, the *Lecane sp*., which was most closely related to *Keratella sp*., had very low similarities, at re-scaled distances, on the proximity or cluster scale. However, intra-species proximity was the same on the proximity scale for *A. volvolicola, Eosphora sp, Balatro sp, Lindia sp and Pleurotrocha sp* but was respectively lower for *Asplancna and Argonotholca and Lecane and Keratella species* (Table 3).

Table.3: Proximity Matrix for the Rotifers in Ologe lagoon within the period of study, with a measure of intervals, using Pearson's Correlation Coefficient.

Observations	*Platyi*	*Kellic*	*Testud*	*Tricoc*	*Euch*	*Leca*	*Kerate*	*Brac*	*Proal*	*Lindi*	*Aspla*	*Asco*	*Epipha*	*Balatr*	*Trocho*	*Pleuro*	*Eosph*	*Polya*	*Argono*
Platyias sp.	0.00																		
Kellicotia sp.	0.32	0.00																	
Testudinella sp.	0.47	**0.55**	0.00																
Tricocerca sp.	0.66	0.15	0.12	0.00															
Euchlanis sp.	0.41	0.38	0.45	**0.54**	0.00														
Lecane sp.	0.28	0.16	0.28	0.09	0.32	0.00													
Keratella sp.	0.18	0.37	0.15	0.17	0.34	**0.88**	0.00												
Brachionus sp.	0.32	0.20	0.17	0.29	0.42	0.02	0.01	0.00											
Proales sp.	0.16	0.38	0.09	0.09	0.18	**0.56**	**0.69**	0.11	0.00										
Lindia sp.	**0.67**	0.18	0.18	**0.79**	0.05	0.09	0.22	**0.61**	0.18	0.00									
Asplanchna sp.	0.24	0.25	0.14	0.29	0.65	0.12	0.30	0.37	0.14	0.07	0.00								
Ascomopha	**0.80**	0.01	0.13	**0.85**	0.18	0.13	0.12	0.45	0.13	**0.88**	0.19	0.00							
Epiphanes sp.	0.46	0.29	0.20	0.61	0.06	0.05	0.26	**0.64**	0.20	**0.93**	0.04	**0.64**	0.00						
Balatro sp.	0.70	0.04	0.13	0.83	0.20	0.10	0.15	0.37	0.13	0.82	0.21	**0.94**	**0.59**	0.00					
Trochosphaera	**0.79**	0.03	0.09	**0.70**	0.13	0.14	0.06	0.48	0.09	**0.79**	0.14	**0.89**	**0.59**	**0.67**	0.00				
Pleurotrocha	**0.65**	0.14	0.19	**0.81**	0.08	0.09	0.23	**0.56**	0.19	**0.98**	0.09	**0.89**	**0.89**	**0.89**	**0.71**	0.00			
Eosphora sp.	**0.78**	0.03	0.13	**0.85**	0.19	0.12	0.14	0.42	0.13	**0.87**	0.20	**0.99**	**0.63**	**0.98**	**0.82**	**0.90**	0.00		
Plyarthra sp.	0.29	**0.50**	0.17	0.06	0.01	0.05	0.31	0.30	0.17	0.20	**0.57**	0.23	**0.50**	0.25	0.17	0.15	0.24	.000	
Argonotholca	0.16	0.09	0.09	0.32	**0.76**	0.14	0.22	**0.54**	0.09	0.18	**0.93**	0.13	0.20	0.13	0.09	0.19	0.13	.023	0.00

The rotiferal clustering (Figure 17) evinced two main groups with the first, having seven sub-clusters. The closest associates on the proximity scale (*Ascomorpha volvolicola. / Eosphora sp. / Balatro sp and Lindia sp. /Pleurotrocha sp*.) exhibited a very high degree of association being very scanty throughout the year. They individually made up less than one percent of the total rotifers in Ologe lagoon.

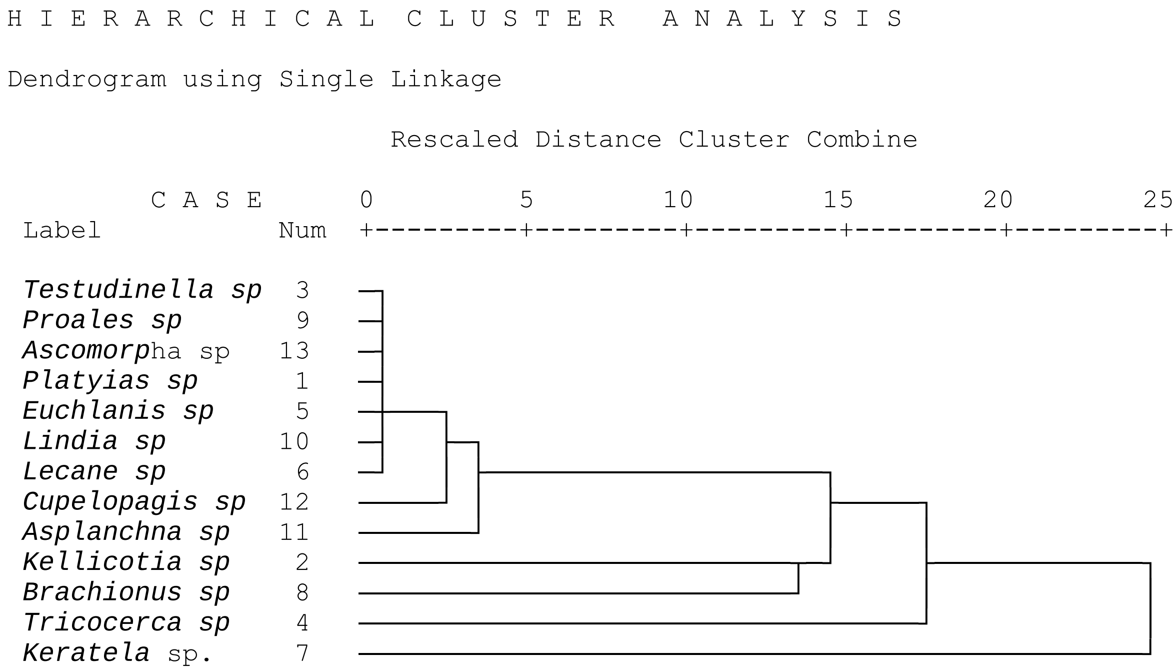


Figure.17: Dendrogram showing the hierarchical cluster analysis for Rotifers (using single linkage between groups) in Ologe lagoon, within the period of study.

DISCUSSION

The total population of Rotifers had a near neutral (zero correlation) with the surface water dissolved oxygen and therefore does not significantly vary with a change in the level of the SDO. This is in line with the postulation by Weithoff et al, 2000, on the effect of water column mixing on bacteria, phytoplankton and rotifers under different levels of herbivory in a shallow eutrophic lake.

The environmental parameters are assumed to be perturbed by white noise characterized by a Gaussian distribution with mean zero and unit spectral density (Tapaswi et al, 1999). The Gause's hypothesis states that "two species with the same ecological requirements cannot coexist in the same place indefinitely; that is they cannot form steady state populations if they occupy the same niche". This assertion is in agreement with Therriault (2002) on temporal patterns of diversity, abundance and evenness for invertebrate communities from coastal freshwater and brackish water rock pools. It was implied that some temporal changes in community matrix could be linked to temporal changes in environmental variables. In this study, a significant increase in salinity corresponded to an increase in species richness, likely due to an increase in marine fauna. Similarly, changes in abundance and evenness corresponded to changes in temperature, dissolved oxygen, and pH. In addition, physicochemical variables used in this study were shown to affect the Rotifer community metrics. (The only high significant value for positive correlation was between Total Rotifers and salinity {$r = 0.844$}. The correlation was also positive with surface water dissolved oxygen {$r = 0.155$} but with low level of significance. Most relationships between community matrix and environmental variables were negative with the exception of Simpson's diversity index for which positive relationships were found. This may indicate that, as lagoon conditions become less favorable, a few species flourish and dominate the community (Therriault, 2002). The distribution was polymictic.

CONCLUSION

The results herein, show that Ologe lagoon is;
- a tropical, shallow, eutrophic and predominantly fresh water aquatic habitat with salinity increasing downstream.
- The lagoon is endowed with a broad diversity of rotiferal species, which showed patchiness in spatial distribution. The assemblage of Rotifers had high spatial coverage, low density, low temporal occurrence but high diversity.
- It under-goes seasonal perturbations which were made manifest by the sigmoid and irruptive distribution of the rotiferal species.
- The diverse rotiferal populations were highly influenced by nutrient inputs from the Agbara industrial estates and surrounding farm lands.
- The most significant nutrient imputes into the lagoon are dissolved inorganic nitrates, sulphates, phosphates and pottasium.
- Clusters by squared euclidan distances using single linkage between groups, showed some species proximities and/or similarities, indicating great similarity in ecological demands between and among species for survival, thus showing a great potential for increased biological diversity.
- The main biotopes of Ologe lagoon include the upstream River Owoh-Ologe lagoon ecotone and the mid- and downstream sectors including the Badagry creek-Ologe lagoon ecotone.

RECOMMENDATION

The Lagos state government recognizes that the harvesting of fisheries resources is an important and reasonable use of Ologe lagoon and consistent with use of the lagoon heritage Area. However, it also acknowledges that industrial activities affect both target and non-target species and their habitats and consequently has the potential for producing adverse ecological effects in both the fished areas and the catchment of the lagoon system as a whole. The Authority (Lagos State Environmental Protection Agency, LASEPA) is working to ensure that all industrial activities in Lagos State including the Ologe Lagoon catchment area are discharging, at least, partially treated effluents into River Owoh, the main fresh water supply into Ologe Lagoon. The results of this Thesis have shown that the Ologe Lagoon Heritage Area is ecologically unstable and requires consistent monitoring of the myriad of effluents discharged into it. Therefore, through collaboration with fisheries management agencies and stakeholders, the Lagos State Government should seek to:

- Minimize ecological impact through the restriction, cessation or mandatory adoption of new technologies of those industrial activities that can be judged, using the best available information, to be significantly damaging to the biotopes around Ologe Lagoon.
- Ensure that adequate monitoring and assessment are undertaken to determine the impacts of industrial activities, the status of phyto- and zooplankton species and the ecosystem on which they depend.
- Undertake and sponsor research designed to quantify the ecological impact of industrial activities adjudged to be ecologically damaging to the lagoon and the health of the fishes, through the bloom of Harmful algal Species.

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