



Dynamics of the chlorophycean populations in a Lagoon bordered by heavy industry, Lagos, Southwest, Nigeria

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ABSTRACT

An investigation into the dynamics of the population of the green algae (Chlorophyceae) in Ologe lagoon was carried out from January, 2018 to December, 2019. The study covered identification, temporal abundance, spatial distribution and diversity of the (Green algae). These were correlated with variations in some physical and chemical parameters in the lagoon. Eleven sample stations, including Five villages (Idoluwo, Oto, Ibiye, Obele, and Gbanko) bordering the lagoon, were sampled using standard techniques. Data obtained were statistically analyzed using linear regression and hierarchical clustering. Thirteen (13) species of the Class Chlorophyceae were identified and there were positive, significant correlations between them and physical and chemical parameters (surface water temperature and conductivity). The presence of Organic Matter Content (OMC) showed, via partial regression plots, positive correlations at sample stations 2 (Rs_q = 0.038), 4 (Rs_q = 0.290), 6 (Rs_q = 0.095), 7(0.4392), 10 (Rs_q = 0.190) and 11 (Rs_q = 0.046). The population increased correspondingly with NO₃-N at Ibiye (Rs_q = 0.0218) and Gbanko (Rs_q = 0.0132). The relationship was positive with the concentration of phosphate-phosphorus (PO₄-P) at Ibiye (Rs_q = 0.2574). The population was indifferent to the concentration of PO₄-P at Oto (Rs_q = 0.0000), while it dropped with a corresponding increase in PO₄-P at Idoluwo (Rs_q = 0.1300) and Gbanko (Rs_q = 0.0228). Potassium(k) was observed to favor the green algae at Idoluwo (Rs_q = 0.2941). There was also a positive correlation with Sulphate-sulphur (SO₄-S) at Oto (Rs_q = 0.0957) and Gbanko (Rs_q = 0.4560). The hierarchical cluster analysis, revealed two main clusters with all the species except *Tribonema* occupying the first cluster (the richest), which is divided into eight sub-clusters. Meanwhile, the *Spirogyra* and *Selenastrum* species, displayed the greatest similarity or homogeneity, on the rescaled distance cluster. The green algae showed a polymictic distribution and had no prevalent species. The results revealed a narrow spectrum in diversity of Chlorophycean species which were patchy in spatial distribution, undergo seasonal perturbations and were highly influenced by nutrient imputes from bordering towns including Ibiye, Oto, Gbanko, Idoluwo, Agbara industrial estate and surrounding farmlands.

Keywords: Chlorophyceae, Nutrient, Cluster, Polymictic and Perturbations.

INTRODUCTION

Generally, physical, chemical and biological factors affect the quality and productivity of any impounded or natural aquatic habitat. Based on limnological data obtainable, ecological conditions of aquatic habitats can be evaluated and manipulated to increase fish production through pollution control and water quality management. Universally, some regions are known to be more productive than others. The problems posed by the distribution and seasonal succession of phytoplankton species are of interest, since such differences may have either positive or negative effects on the higher components of the food chain, especially fish, which are more often, of economic importance to man. The zooplankton which are the primary consumers in the aquatic habitats are dependent on the phytoplankton for survival as they in turn form the first live foods for fish fry. The populations of primary producers have been known to change in both number and composition with the passage of the seasons and, at each stage, there is a complex pattern of interplay between chemical and physical factors and plant and animal populations (Grenz *et al.*, 2000). It is without doubt that to understand the structure and functioning of an ecosystem, it is essential to know the different elements of which it is composed i.e. the distribution of organisms in space and time.

The multiple equilibria, periodicity and quasi-periodicity sometimes manifested by over-blooming of algae constitute a variety of problems to the communities surrounding aquatic habitats.

Problems associated with algal bloom conditions in relation to zooplankton and fish survival and their ultimate impact on the occupiers of the upper trophic levels (especially man) have generated considerable interest. Currently, there is still lack of knowledge and information on some Nigerian lakes and lagoons (e.g. Ologe lagoon), with regards to their limnology – water quality and pollution status, algology and general plankton status and consequently their potential for fish production. There is thus, no basis or platform from which to launch an efficient and/or effective management and development of Ologe lagoon as a resource.

STUDY AREA

Socio-economic Importance of Ologe Lagoon

Currently, the study area (Ologe lagoon, Figure 1) is mainly used for the purpose of artisanal fishery, waste disposal, sand mining, tourism and transportation. Fish farms are also located along the banks of the Ojo section of the Badagry Creeks, which brings in marine water from the Lagos harbor and also drains the fresh water from the lagoon. And just like the Lagos lagoon, it may be regarded as one of the large “septic tanks” in the region. The main anthropogenic pressure on the lagoon is industrial from the adjacent Agbara industrial estate. All the organic and industrial wastes / effluents (both partly treated and untreated) from its boundary towns/villages including the Agbara industrial estates are channeled into the lagoon as liquid effluents or dumped directly into it as solid wastes. Since 1996 the human populations in Ojo and Badagry local Government Areas (which borders the lagoon) have increased tremendously, increasing the demand for industrially manufactured products and creating a double-impact pressure of the consequently released domestic wastes on the recipient Ologe Lagoon catchment area.

The major environmental hazard on the lagoon is due to effluents from Agbara, which, is made up of a commercial area, three residential areas and three industrial areas. Over twenty factories belonging, to the food and beverages, pharmaceutical, breweries, metal finishing industries, cement companies chemical and pulp and paper companies presently occupy the industrial area. The effluents of these factories/industries are discharged into Ologe lagoon all year round after treatment with ACTi-rotor turbines which mechanically mixes the waste water collected in a massive concrete reservoir. It might therefore be an understatement to propose that, the domestic and industrial pollutants (organic and inorganic) may have an appreciable impact on the ecology of the lagoon system. More so, Ologe lagoon drains into the Atlantic Ocean (via the Badagry creek) through the Lagos harbor. It is therefore of great economic importance not only to Lagos state and Nigeria but to the entire West African sub-region as ecological catastrophes occurring upstream, could have grievous consequences downstream, if not checked.

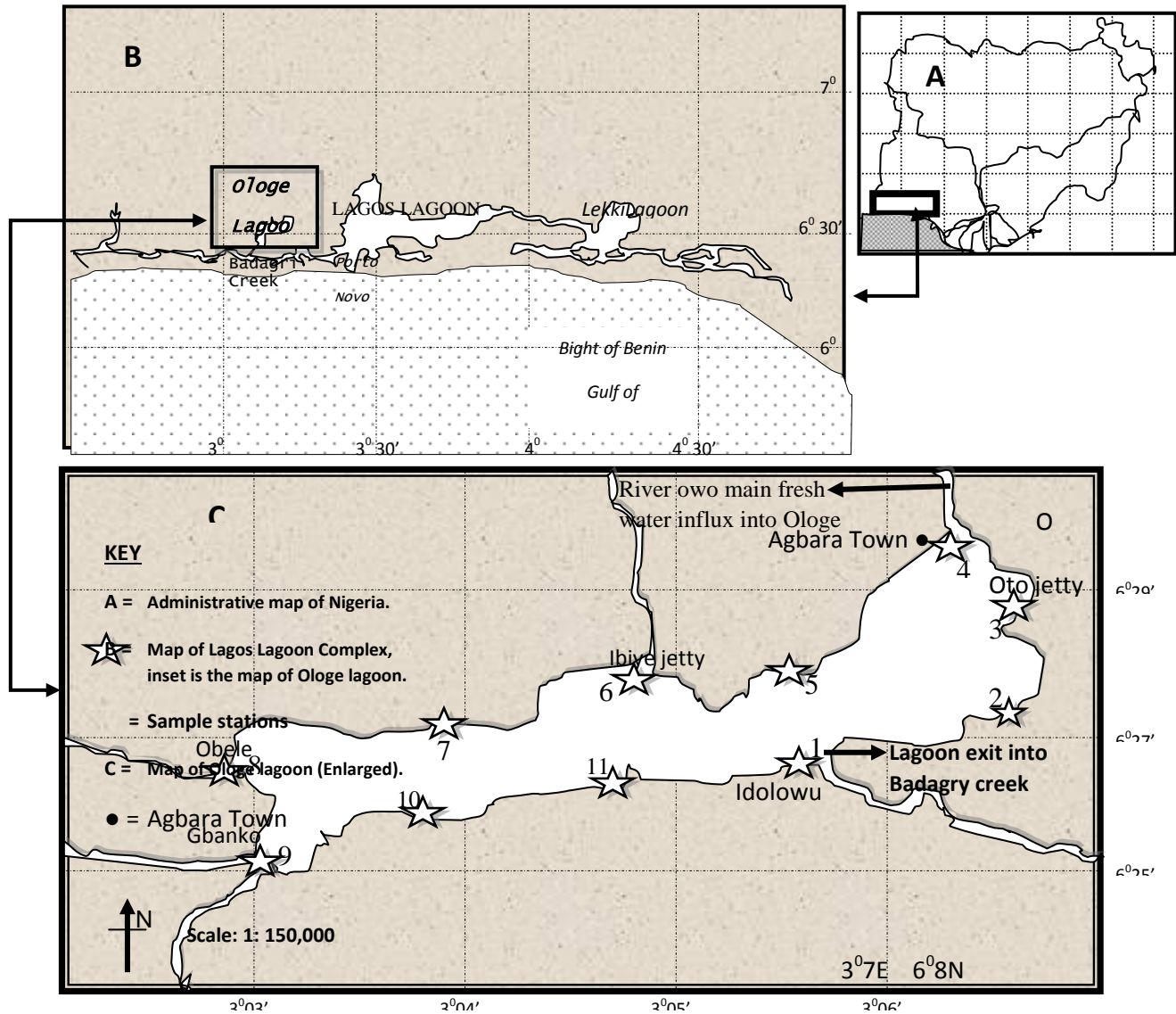


Figure 1: Map of Ologe Lagoon showing the sample stations

MATERIALS AND METHODS

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 (figure 1-C). Sampling of all marked stations 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 flora.

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.

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 including the small-celled phytoplankton 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 some time 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.

Sediment Sampling and Analysis

The Ologe lagoon sediments from four sample stations according to criteria prescribed by GEMS / Water Operational Guide (1977, 1988) on Global Water Quality Monitoring (Upstream-Oto Bridge, midstream-Ibiye, downstream- Idoluwo and Gbanko) were collected by the use of a Rigosha sediment sampler. They were stored in

well-labeled opaque polythene bags, according to sampling stations and kept in an ice chest.

One gram of the sediment was weighed out, dried on a filter paper and placed in an oven at 450°C for 8 hours to destroy the organic matter content (OMC). The digestion of the sediments was done according to: FAO / SIDA, (1983).

The samples were analyzed for, total nitrate-nitrogen, total phosphate-phosphorus, total sulphate-sulphur, potassium, mercury, copper, and iron. Their concentrations were determined by comparing their absorbance with those of factory prepared AAS standard solution using the Pyronicam SP 2900 Atomic Absorption Spectrophotometer. The Organic Matter Content (OMC) was later estimated as loss on ignition for all the sediment samples collected within the study period, using the equation below to calculate the concentration of Particulate Organic Matter (POM).

$$\text{POM } (\mu\text{g/g}) = \frac{\text{B}-\text{A} (1000\text{ml/L})}{\text{Sample Volume (ml)}}$$

Where B = Weight of filter + Residue (mg) before ignition.
And A = Weight of filter + Residue (mg) after ignition.

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 keys.

Phytoplankton 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 $1,000 \text{ mm}^2$. 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:

$$\text{Number of plankters per ml.} = \frac{\text{AN} \times \text{Volume of concentrate in ml.}}{\text{Volume of Sample in ml.}}$$

Where, T = total number of plankters counted, N = number of grids employed.

A = area of grids in mm²; 1,000 = area of counting chamber in mm²

Source: GEMS Water Operational Guide (1977).

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 ' $H' = -\sum_i^s p_i \log p_i$;

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

- (c) Simpson's Index (D) = An index of diversity based on the probability of picking two organisms at random that are different species; calculated as

$$D = 1 - \sum_{i=1}^s (P_i^2)$$

Where P_i = the proportion of individuals of species i in a community of "S" species.

- (d) Berger-Parker Dominance Index ' $d' = \frac{N_{\max}}{N_{\text{wt}}}$

Where N_{\max} = value of most abundant species and N_{wt} = 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 a proximity matrix. Here, the variables are known to be more strongly correlated when their values are closer to 1 or -1. An Absolute Similarity Matrix was then derived. A Dendrogram drawn from the matrix, 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 particular class. This hierarchical clustering is a measure of compactness or goodness of partition between groups of plankton.

RESULTS

A total of thirteen (13) green algal species were observed in Ologe lagoon within the period of study. The spatial preponderance of the green algae was lowest at the peak of the dry season in February, when a maximum of four species were noticed in station 8 (Obele) and only one or two in all other stations. The annual distribution of Green algae (figure 2) was cyclic, with most species occurring perennially except *Spirotamia* sp. (early dry season ephemeral), *Tetraspora* sp. (early rainy season ephemeral), *protococcus* sp. (rainy season annual) and *crucigenia* sp. (late rainy season/early dry season annual).

Some dominant species exhibited a prolonged positive acceleration phase, with the apex of the first oscillation occurring between July and August and the second between October and November. Although the population for others were lower, they mostly had three oscillations each, within the year, was cyclic, with most species occurring perennially except *Spirotamia* sp. (early dry season ephemeral), *Tetraspora* sp. (early rainy season ephemeral), *Protococcus* sp. (rainy season annual) and *Crucigenia* sp. (late rainy season/early dry season annual). Some dominant species exhibited a prolonged positive acceleration phase, with the apex of the first oscillation occurring between July and August and the second between October and November. Although the population for others was lower, they mostly had three oscillations each, within the year.

The most dominant green algal species in Ologe lagoon is *Ulothrix specie* (figure 3). Here, the percentage density of green algae in the lagoon, decreased in the order of *Ulothrix* sp. (19.8%), *Scenedesmusquadricauda* (16.7%), *Microspora* sp. (15.0%), *Tribonema* sp. (11.2%), *Crucigenia* sp. (9.2%), *Pediastrum* sp. (6.0%), *Scenedesmus acuminatus* (5.0%), *Selenastrum* sp. (4.5%), *Ankistrodesmus* sp. (4.4%), *Kirchneriella* sp. (3.7%) *Protococcus* sp. (2.4%) and *Tetraspora* sp. (2.2%).

Others, which were less than two percent, altogether made up 0.8% of the whole. The Shannon Weiner and Simpsons' diversity indices showed the *Ulothrix* species, which was richest, to be the most dominant of the Class

Chlorophyceae, closely followed by *Scenedesmus quadricauda* and *Microspora* species. The green algae also showed a polymictic distribution and had no prevalent species (Table 1).

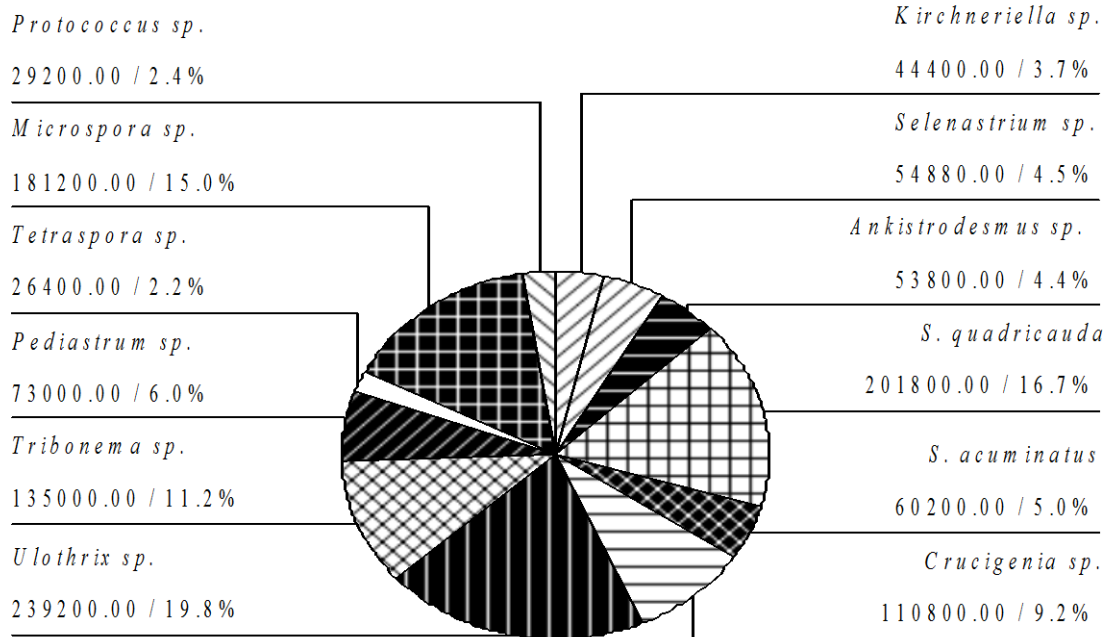
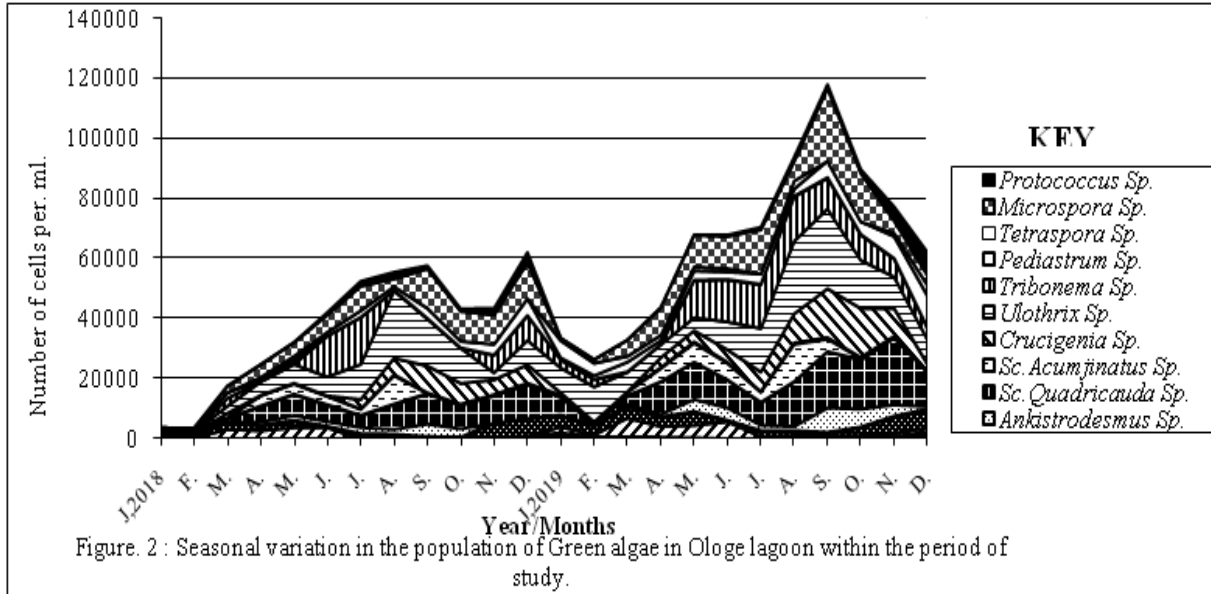


Figure. 3: Relative density of Green Algae in Ologe lagoon within the Period of study.

Table 1: Some indices of diversity of the Green Algae in Ologe lagoon within the period of study.

Green Algae	Sum of ni = N	Pi = ni/N	SHANNON WEAVER DIVERSITY INDEX (Pi log ₂ Pi)	SIMPSON'S DIVERSITY INDEX (Y=SUM Pi ²)
<i>Spirotamia Sp.</i>	9,800.00	0.00803	-0.0559	6.5E-05
<i>Kirchneriella Sp.</i>	44,400.00	0.0364	-0.174	0.00133
<i>Selenastrum Sp.</i>	54,880.00	0.045	-0.2013	0.00202
<i>Ankistrodesmus Sp.</i>	53,800.00	0.04411	-0.1986	0.00195
<i>Sc.Quadricauda Sp.</i>	201,800.00	0.16545	-0.4294	0.02737
<i>Sc.Acuminatus Sp.</i>	60,200.00	0.04936	-0.2142	0.00244
<i>Crucigenia Sp.</i>	110,800.00	0.09084	-0.3144	0.00825
<i>Ulothrix Sp.</i>	239,200.00	0.19612	-0.4609	0.03846
<i>Tribonema Sp.</i>	135,000.00	0.11068	-0.3515	0.01225
<i>Pediastrum Sp.</i>	73,000.00	0.05985	-0.2431	0.00358
<i>Tetraspora Sp.</i>	26,400.00	0.02165	-0.1197	0.00047
<i>Microspora Sp.</i>	181,200.00	0.14856	-0.4087	0.02207
<i>Protococcus Sp.</i>	29,200.00	0.02394	-0.1289	0.00057
	1,219,680.00	1	-3.3007	0.12083
			3.3007*	0.87917**
RICHNESS INDEX D = (S-1) / LOG N	EQUITABILITY / EVENNESS OF DISTRIBUTION; E = H/LOG ₂ S		BERGER-PARKER DOMINANCE INDEX "d" = (Nmax / Nwt)	
1.97166	0.89179		0.19612	

* = -SUM (Pi log₂ Pi)** =1-SUM Pi²

The Pearson's correlation coefficient ("r" values) between total Green Algae and some physical and chemical parameters showed negative correlations for transparency (-0.068), air temperature (-0.349), surface water temperature (-0.246), bottom water temperature (-0.243), bottom water dissolved oxygen (-0.096), pH (-0.327), conductivity (-0.113) and rainfall (-0.024) with a high level of significance for transparency (0.753), bottom water dissolved oxygen (0.657), conductivity (0.598), and rainfall (0.994) respectively (Table,2).

Only salinity (r = 0.041) with high level of significance (0.851) and surface water dissolved oxygen (r = 0.299)

with low level of significance (0.156), were positively correlated with Green algae.

The linear regression plots (Figure4) confirmed that, the total population of Green algae only increased with an increase in value of surface water temperature and conductivity. The total population of Green algae had a near neutral (zero correlation) with the surface water dissolved oxygen and therefore does not significantly increase or decrease with a change in the level of the SDO.

Table 2: Correlation coefficient ‘r’ values of the Total Green Algae and some physical and chemical 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 Green algae / Transparency	-0.068	0.060	-0.319	0.753
Total Green algae / Salinity	0.041	0.096	0.190	0.851
Total Green algae / Air temperature	-0.349	0.073	-1.747	0.095
Total Green algae / Surface water temperature	-0.246	0.135	-1.193	0.246
Total Green algae / Bottom water temperature	-0.243	0.111	-1.175	0.252
Total Green algae / Surface water Dissolved Oxygen	0.299	0.154	1.467	0.156
Total Green algae / Bottom water Dissolved Oxygen	-0.096	0.063	-0.450	0.657
Total Green algae / Depth	-0.002	0.061	-0.008	0.994
Total Green algae / pH	-0.327	0.136	-1.625	0.118
Total Green algae / Conductivity	-0.113	0.053	-0.536	0.598
Total Green algae / Rainfall	-0.024	0.236	-0.072	0.994

a – Not assuming the null hypothesis

b – Using the asymptotic standard error assuming the null hypothesis

c - Based on normal approximation.

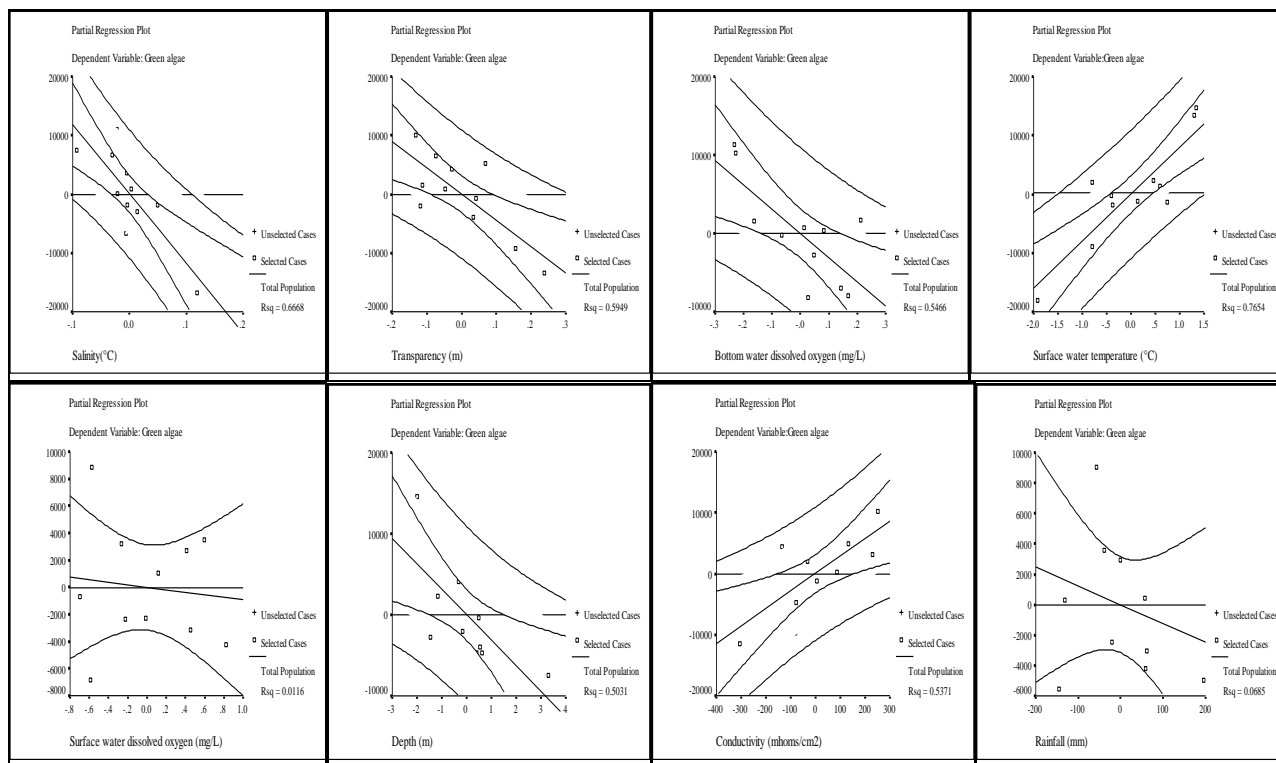


Figure 4: Partial regression plots showing the relationship between the populations of Green Algae, Transparency, Salinity, Bottom Water Dissolved Oxygen and Surface Water TemperatureSurface water Dissolved Oxygen, Depth, Conductivityand Rainfall within the period of study.

The Class Chlorophyceae (green algae) increased in population correspondingly with $\text{NO}_3\text{-N}$ at Ibiye ($R_{sq} = 0.0218$) and Gbanko ($R_{sq} = 0.0132$). The correlation was negative at Idoluwo ($R_{sq} = 0.0542$) and zero or neutral ($R_{sq} = 0.0003$) at Oto (Figure 5).

The chlorophyceae only had a positive relationship with the concentration of $\text{PO}_4\text{-P}$ at Ibiye ($R_{sq} = 0.2574$). The population of green algae was indifferent to the concentration of $\text{PO}_4\text{-P}$, (Figure 5) at Oto ($R_{sq} = 0.0000$), while the green algae dropped in population with a

corresponding increase in $\text{PO}_4\text{-P}$ at Idoluwo ($R_{sq} = 0.1300$) and Gbanko ($R_{sq} = 0.0228$).

The concentration of potassium was observed to favor the green algae at Idoluwo ($R_{sq} = 0.2941$) whereas the correlation was negative (Figure 5) at Oto ($R_{sq} = 0.1586$), Ibiye ($R_{sq} = 0.0028$) and Gbanko ($R_{sq} = 0.0782$). The green algae positively correlated with $\text{SO}_4\text{-S}$ at Oto ($R_{sq} = 0.0957$) and Gbanko ($R_{sq} = 0.4560$) while the correlation was negative at Idoluwo and Ibiye (Figure 5).

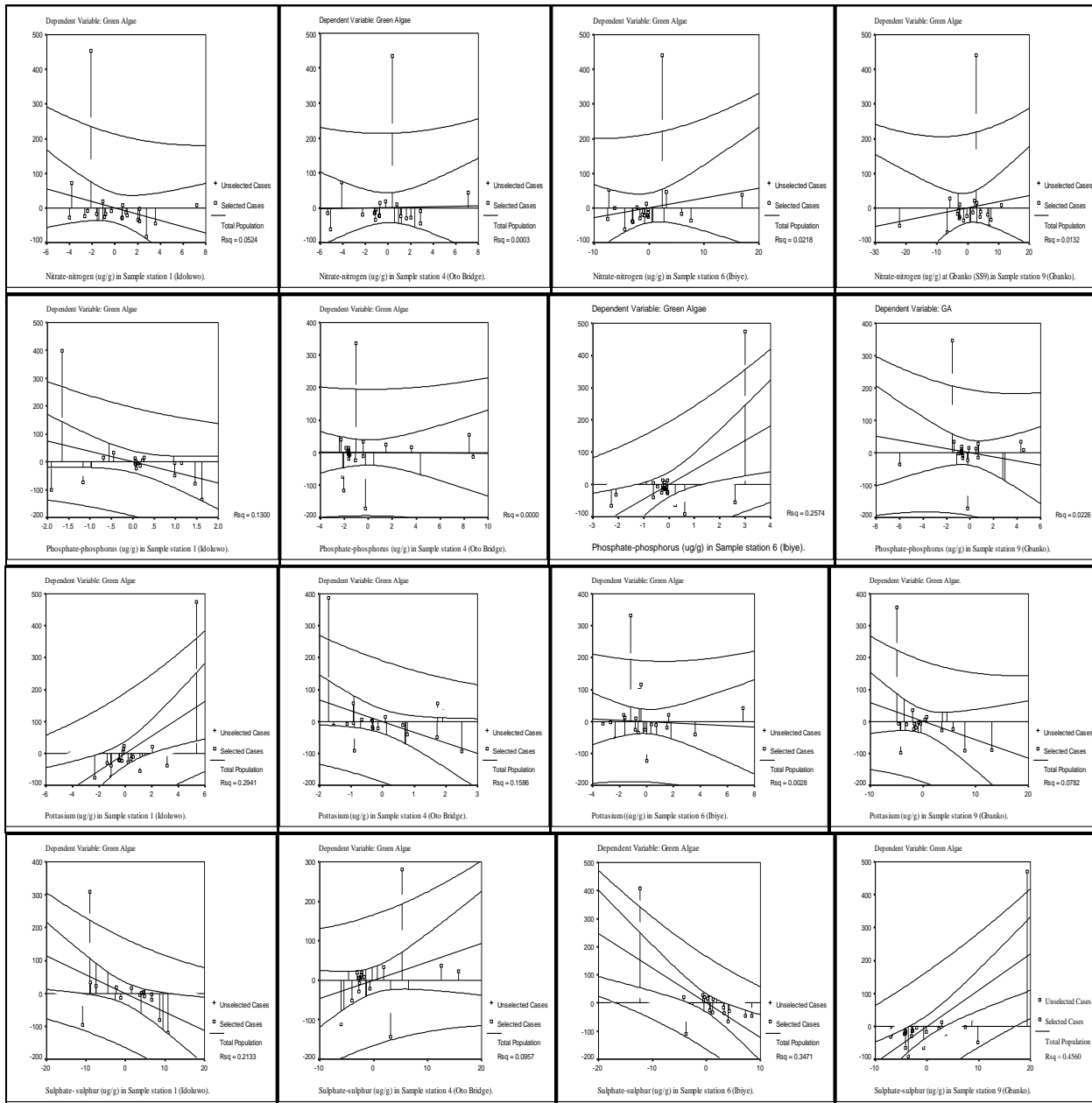


Figure 5: Partial regression plots showing the relationship between the Total population of Green Algae, and Nitrate-nitrogen ($\text{NO}_3\text{-N}$), Phosphate-phosphorus ($\text{PO}_4\text{-P}$), Potassium (K) and Sulphate-sulphur ($\text{SO}_4\text{-S}$) at the Upstream, Midstream and Downstream portions of Ologe lagoon within the period of study.

The presence of OMC as a result of the abundance of the green algae in Ologe lagoon within the period of study showed, via partial regression plots, a positive correlation at sample stations 2 (Rsq = 0.038), 4 (Rsq = 0.290), 6 (Rsq = 0.095), 10 (Rsq = 0.190) and 11 (Rsq = 0.046). The negative correlations at stations 1 (Rsq = 0.114), 3

(Rsq = 0.078), 5 (Rsq = 0.129), 8 (Rsq = 0.258) and 9 (Rsq = 0.100) - (Figure 6) showed a decline in the distribution of OMC at these stations with an increase in the population of the green algae within the period of study.

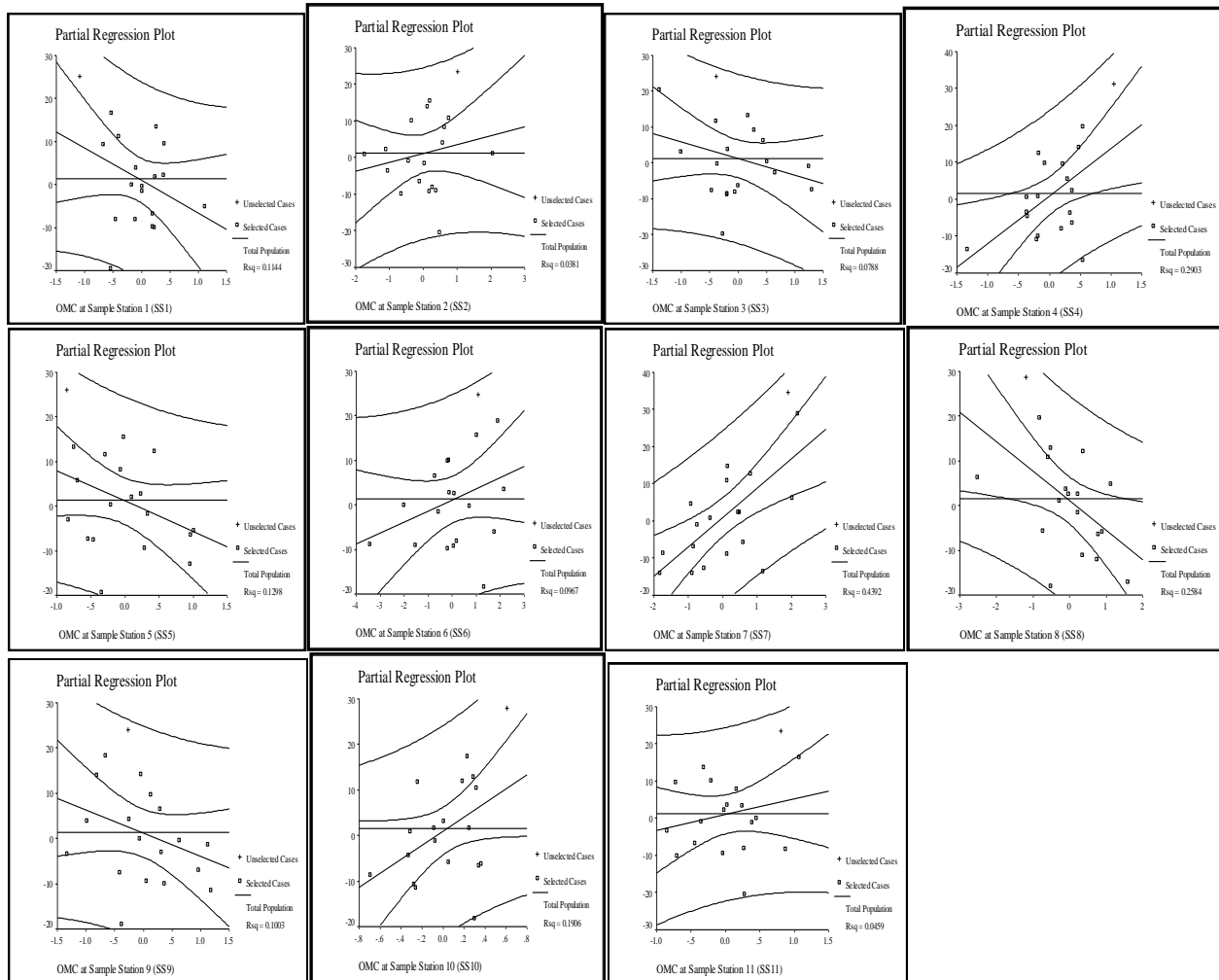


Figure 6: Partial regression plots showing the relationship (Correlative Distribution) between the population of Green Algae, and the Organic Matter Content (OMC) in all sample stations within, the period of study.

The hierarchical cluster analysis for green algae in Ologe lagoon (Figure 7), revealed two main clusters with all the species except *Tribonema sp.* occupying the first cluster (the richest), which is divided into eight sub-clusters. Meanwhile, the *Ankistrodesmus sp.*, *Ulothrix sp.* and *Scenedesmus acuminatus* exhibited the greatest

homogeneity on the scale. The closest associates on the distance scale were *Spirogyra sp.* / *Selenastrum sp.*, *Pediastrum sp.* / *Microspora sp.*, *Ankistrodesmus sp.* / *Ulothrix sp.*, and *S. acuminatus* / *Tetraspora sp.*, displaying their similarity or homogeneity, in a decreasing order.

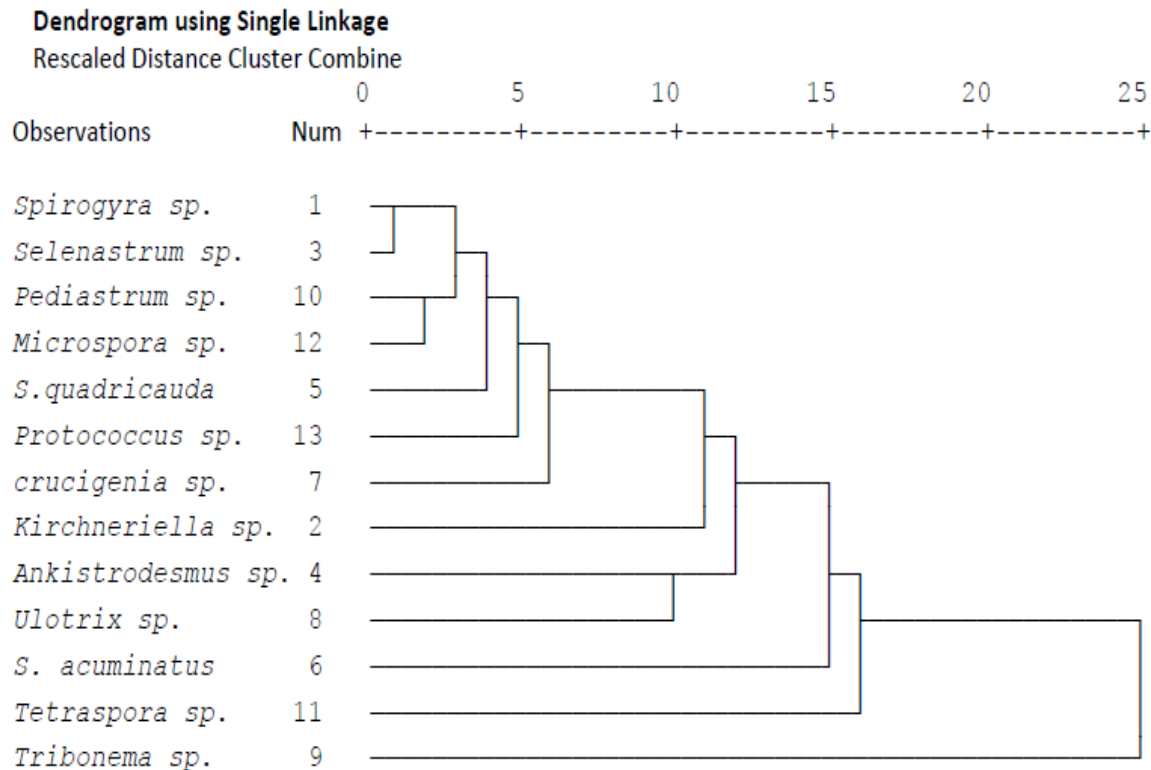


Figure. 7: Dendrogram showing the hierarchical cluster analysis for green algae (using single linkage between groups) in Ologe lagoon, within the period of study.

DISCUSSION

While recognizing the fact that phytoplankton crop and primary production are closely related, this work has largely considered, on the one hand, factors affecting photosynthetic rate (temperature, transparency of water and nutrient concentration. Incident lights, length of day, stabilization of water column and /or flow rate were not measured. However, factors concerning the size of standing crop including, cell number, and floristic composition were considered. Spatial preponderance of green algae in Ologe lagoon was lowest in February, when a maximum of four species were noticed in station 8 (Obele) and only one or two in all other stations. The annual distribution of Green algae was cyclic, with most species occurring perennially except *Spirotamia sp.* (early dry season ephemeral), *Tetraspora sp.* (early rainy season ephemeral), *Protococcus sp.* (rainy season annual) and *Crucigenia sp.* (late rainy season/early dry season annual). Some dominant species exhibited a prolonged positive acceleration phase, with the apex of the first oscillation occurring between July and August and the second between October and November of the study period. Although the population for others was lower, they mostly had three oscillations each, within the

year. The most dominant green algal species in Ologe lagoon is the *Ulotrix* species. The green algae also showed a polymictic distribution and had no prevalent species. The linear regression plots confirmed that, the total population of Green algae only increased with an increase in value of surface water temperature and conductivity. The total population of Green algae had a near neutral (zero correlation) with the surface water dissolved oxygen and therefore does not significantly increase or decrease with a change in the level of the SDO. The Class Chlorophyceae (green algae) increased in population correspondingly with $\text{NO}_3\text{-N}$ at Ibiye ($\text{Rs}q = 0.0218$) and Gbanko ($\text{Rs}q = 0.0132$). The correlation was negative at Idoluwo ($\text{Rs}q = 0.0542$) and zero or neutral ($\text{Rs}q = 0.0003$) at Oto. The chlorophyceae only had a positive relationship with the concentration of $\text{PO}_4\text{-P}$ at Ibiye ($\text{Rs}q = 0.2574$). The population of green algae was indifferent to the concentration of $\text{PO}_4\text{-P}$, at Oto ($\text{Rs}q = 0.0000$), while the green algae dropped in population with a corresponding increase in $\text{PO}_4\text{-P}$ at Idoluwo ($\text{Rs}q = 0.1300$) and Gbanko ($\text{Rs}q = 0.0228$). These observations coincided with the report of Michael *et al* (1988) that phosphorus availability has been closely linked to primary production rates and accelerated eutrophication in the great lakes.

The concentration of potassium was observed to favor the green algae at Idoluwo ($R_{sq} = 0.2941$) whereas the correlation was negative at Oto ($R_{sq} = 0.1586$), Ibiye ($R_{sq} = 0.0028$) and Gbanko ($R_{sq} = 0.0782$). The green algae were positively correlated with SO_4-S at Oto ($R_{sq} = 0.0957$) and Gbanko ($R_{sq} = 0.4560$) while the correlation was negative at Idoluwo and Ibiye. These results agreed with the assertions of Duarte *et al* (2000), that gross production was very closely related to combined enrichments with phosphorus and nitrogen probably forced by the relatively high additions of nutrients. Jarvinen *et al* (1997) also contended that consistently low primary production after the combined addition of phosphorus and glucose suggest that in the presence of a labile organic carbon source, epilimnetic bacteria were superior to algae in the uptake of phosphorus. The green algae were a commonly occurring assemblage with low diversity and low densities, characterized by long duration of occurrence,

CONCLUSION

The results herein, show that Ologe lagoon;

- Is a tropical, shallow and eutrophic aquatic habitat.
- Had Chlorophyceae which showed patchiness in spatial distribution.
- Under-goes seasonal perturbations which were made manifest by the sigmoidal distribution of the planktonic species.
- The diverse planktonic populations were highly influenced by nutrient and metal inputs from the Agbara industrial estates and surrounding farm lands.
- The most significant nutrient and metal imputes into the lagoon are dissolved inorganic nitrates, sulphates, phosphates and potassium. During the rainy season, phosphates were taken up by the algae, which apparently lowered the concentration to such a great extent. Due to internal recycling and water turbulence, the phosphate appeared to have stayed longer in the epilimnion than the silt itself. However, the dry season phosphate concentrations appeared to be higher when it is often expected that most silts would arrive from the hinterland and the phosphate concentration in the lagoon would be controlled by the sinking clay.
- 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 Ologe lagoon –Badagry Creek ecotone at Idoluwo.

RECOMMENDATION

The Lagos State Government of Nigeria, 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 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.

Establish a system of protected areas that are representative of the complex range of ecological communities found in the Ologe Lagoon Catchment Area.

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.

Ensure that ecologically sustainable industrial activities are managed in a way that is maintained in perpetuity.

Ensure understanding of and compliance with the management regimes in the Ologe Lagoon through public information and education programs and the adoption of satellite monitoring and communications technology.

Form a specialist Management Advisory Committee to develop a Fisheries Management Plan with an objective of sustainability. The Lagos State Government and the Fisheries Agencies should collaborate in management programs to assess the effects of industrial activities on Fisheries as a whole, to minimize these impacts on the lagoon community.

Know the importance of, and the need for, linking population dynamics processes at the ecosystem level, thus reflecting a macro-ecological perspective of coastal-marine ecological systems.

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