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Phytoplankton Assemblage along Gradients of the Imo River in Etche Local Government Area, Nigeria

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ABSTRACT

This study identified the phytoplankton assemblage of the increasingly in-stream sand-mined Imo River in Etche, southeastern Nigeria, as bioindicators of water quality. Plankton samples were collected once monthly for 24 months (March 2007-February 2009) with net of 55 µm mesh size that was hauled horizontally along the river course for 5 minutes at 7 sampling locations. Samples were later transferred to plastic containers and fixed/preserved in a 4 % formalin solution. In the laboratory, a wide-mouthed pipette was used to withdraw 1ml of the plankton subsample and to place it on a Sedge-wick rafter-counting chamber for direct microscopy observation. Standard keys were used for species identifications. The ANOVA, means plots, hierarchical cluster analysis (HCA), and the Margalef's species diversity index were used to analyze data. Phytoplankton comprised 43 genera and a mean density of 1859 cells/ml. The dominant phytoplankton was the Bacillariophyceae (53.25%), followed in order by Cyanophyceae (21.25%), Chlorophyceae (10.33%), Chrysophyceae (4.84%), Pyrrophyceae (4.57%), Xanthophyceae (3.39%) and Euglenophyceae (2.42%). Highest abundance was recorded in the reference sampling location 1 (527 cells/ml; 28.23%) and least abundance in location 6 (139 cells/ml; 7.45%). There was significant spatial heterogeneity in the plankton taxa [$F_{(20.94)} > F_{crit(3.94)}$] at $P<0.05$, and the diatoms and blue-green algae were most responsible for the observed inequality. The Chrysophyceans, Euglenophyceans, Cyanophyceans and Chlorophyceans formed the first and richest phytoplankton cluster. Comparatively low phytoplankton biotic diversity in the study could mostly be attributed to sand-mining-induced perturbations in water column, which exerted selective effects on the biological assemblage.

Keywords: Imo River, Etche, Phytoplankton, Biotic index, Sand mining, Spatial variations.

INTRODUCTION

There is a range of physical, chemical and biological components that affect water quality; some of which could provide a general indication of water pollution while others enable the direct tracking of pollution sources. These indicators include not only its physicochemical characteristics, but also aquatic organisms and biochemical techniques.

Sequel to this, many groups of organisms have been used as indicators of water quality and environmental changes in freshwater bodies, including algae, macrophytes, protozoa, fish, and other animals [1, 2]. Plankton, which are all those mixed group of tiny, living plants and animals that float, drift freely or feebly swim in water column independent of the shore and bottom [3] and occupy the base level of food chains (autotrophs) that lead up to

commercially important fisheries have severally been used as bioindicators of water quality [4]. Additionally, plankton communities play a major role in the biogeochemical cycles of many important elements such as the carbon cycle, nitrification, denitrification, remineralization and methanogenesis. These cycles bring about such processes as primary production and recycling. Plankton are ideal for theoretical and experimental population ecology due to their small sizes, short generation time and a relatively homogenous habits.

The Imo River is the most extensive of three rivers of Etche Local Government Area (LGA) in the Niger Delta region of Nigeria. The river serves for fisheries, domestic uses, as well as artisanal sand mining. Though a preliminary study on plankton checklist of the river in the neighbouring Oyigbo LGA was conducted by Zabbey et al. [5], none exist in the middle course of the river in the Etche LGA. As an attempt to close this gap, this study undertakes gradiential identification of phytoplankton assemblages, as fundamental indicators of environmental perturbations.

MATERIALS AND METHODS

2.1. Study Area

Etche is a subsistent agrarian ethnic group in Rivers State and is located within the eastern flank of the Niger Delta of Nigeria, between longitude 06˚ 05' and 07˚ 14'E and latitude 05˚ 08' and 04˚ 45' N (Fig. 1). The climate is typical of the tropical rainforest zone and rainfall is between 160-236cm; with about 300 rain days especially during March-November, per year. Temperature ranges between 24 and 38 ºC, and the predominant wind direction is Northerly winds, although there is a significant influence from the Southerly winds. High humidities of up to 90% is usually recorded during the wet season, while values as low as 40% could be recorded at the peak of the dry season [6]. However, some inhabitants also engage in petty trading, palm wine tapping, fishing, hunting and sand mining. In the neighborhoods of majority of the sampling locations are ongoing oil exploitation activities by the Shell Petroleum Development Company of Nigeria (SPDC), whose activities dates back to 1958 when crude oil was first discovered in the area.

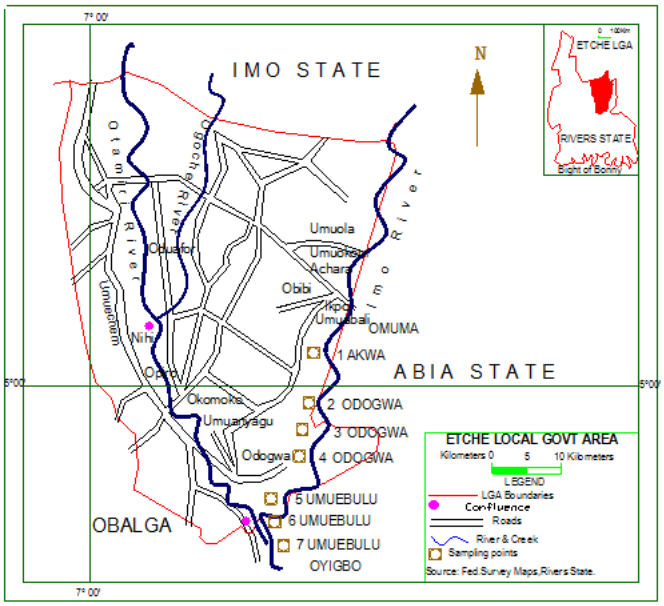

Fig. 1. Location map of Etche LGA showing the sampling locations on Imo River

2.2. Sampling Design and Locations

Sampling for plankton were done once monthly for 24 months (March 2007-February 2009) at 7 sampling locations within 08:00-18:00 hours on sampling days. Sand mining activities by local operators as well as other human activities such as washing of cloths and bathing were ongoing at all the sampling locations (SLs) (though sand mining only commenced during the second year in SL 1). SL 1 was situated upstream at Akwa community. SLs 2, 3, and 4 were situated about 1 km apart at Odogwa community, with SL 2 situated about 2 km from SL 1. SLs 5, 6,

and 7 were also situated about 1 km apart at Umuebulu community; with SL 5 situated about 3 km from SL 4. Odogwa and Umuebulu communities house oil and gas facilities belonging to the SPDC.

2.3. Sample Collection

Plankton net of 55µm mesh size was hauled horizontally along the river course for 5 minutes at each SL according to the methods of Grant [7] and Anene [8]. The resultant concentrated plankton samples were later transferred to plastic containers, fixed and preserved in a 4 % formalin solution according to Boney [9] and Anene [8] in the field.

2.4. Laboratory Analysis

In the laboratory, with the use of a wide-mouthed pipette, 1ml of the plankton subsample was withdrawn from the field samples that had been homogenized by inverting the containers few times, and placed on a Sedge-wick rafter-counting chamber and observed by direct microscopy. Keys provided by Whitford and Schumacher [10], Needham and Needham [11], Cole [12], Maosen [13], Jeje and Fernando [14, 15], Egborge [16], and APHA [17] were used for species identifications. Counts were made in triplicates and their averages taken and expressed as cells/ml of water.

2.5. Statistical Analyses

The MS Excel 2007 and SPSS Version 17.0 software packages were used in the analyses of data. Determination of spatial variance equality (homogeneity) in means of the plankton taxa was made with the single factor analysis of variance (ANOVA). Further plots of group means was made with means plots. The hierarchical cluster analysis (HCA) was used to explore and reveal natural groupings (or clusters) within the plankton assemblages that would otherwise not be apparent. Species diversity was determined with the Margalef's index (I) [18].

RESULTS

3.1. Spatial Composition and Abundance

A total of 1859 cells/ml of phytoplankton, comprising of 7 taxa were counted during the study period. The centric and pennate diatoms (Bacillariophyceae) identified comprised a total of 990 cells/ml from 16 genera, making up the largest percentage of 53.25% of the phytoplankton. The most abundant genera encountered include *Melosira, Asterionella, Cyclotella, Navicula, Nitzschia* and *Diatoma* species (Appendix A). Euglenophyceae was the least abundant class of the phytoplankton encountered (45 cells/ml; 2.42%), with only *Trachelomonas lacustris, Phacus spp* and *Euglena variabilis* identified. Other taxa identified included the blue-green algae (Cyanophyceae) comprising 2 forms- colonial and filamentous forms and made up of 11 genera and totaling 395 cells/ml (21.25%), the green algae (Chlorophyceae) comprising 10.33% of the total phytoplankton abundance and totaled 192 cells/ml from 7 genera, the Chrysophyceae made up of 3 genera and comprised a total of 90 cells/ml (4.84%), the dinoflagellates (pyrrophyceae) which accounted for a total of 85 cells/ml (4.57%), and the Xanthophyceae which accounted for 3.39% (63 cells/ml) of total phytoplankton abundance.

The highest phytoplankton abundance was recorded in SL 1 (527cells/ml) while SL 6 recorded the least abundance of 139 cells/ml during the study period. These accounted for 28.23% and 7.45%, respectively of the total phytoplankton species identified. However, the locations ranked in the following order of abundance SL 1> SL 2> SL 7> SL 3> SL 5> SL 4> SL 6.

Twenty nine species of the bacillariophyceans were encountered during this study and SL 6 had the least abundance of 15 cells/ml. The order of spatial abundance of the diatoms is SL 1>SL 2>SL 7>SL 3>SL 5>SL 4>SL 6 (Fig. 2). The highest abundance of the cyanophyceans (142 cells/ml) was recorded in SL 1 while the least abundance (20 cells/ml) was recorded in SL 4 (Figure 2). The order of spatial abundance of the green algae (Chlorophyceae) is SL 1> SL 7> SL 2> SL 5> SL 4> SL 3> SL 6 (Fig. 2). SL 1 also yielded the highest abundance of the Chrysophycean species (26 cells/ml) while SL 6 yielded the least abundance of 2 cells/ml. The order of abundance by locations of the Chrysophyceans is SL 1> SL 7> SL 2&5> SL 3> SL 4> SL 6 (Figure 3). The spatial order of abundance of the euglenophycean plankter is SL 7> SL 3> SL 1&2> SL 6> SL 4> SL 5, with SL 1 showing the highest species abundance of 20 cells/ml, while the least abundance was recorded in SL 4 (5 cells/ml) (Fig. 3). SL 1 recorded the highest abundance of 21 cells/ml for the Xanthophyceans, while SL 4 recorded the least abundance of 3 cells/ml during the sampling period (Fig. 4).

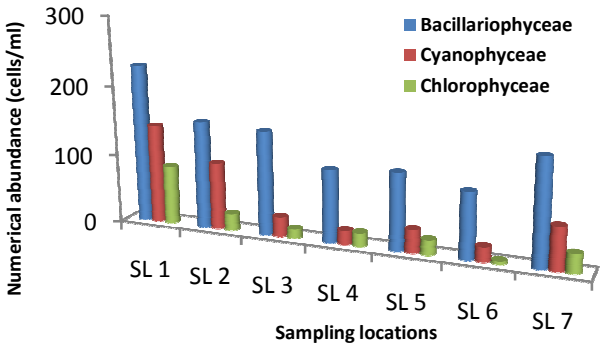

Fig. 2. Spatial variation in bacillariophycean, cyanophycean and chlorophycean densities of Imo River in Etche LGA

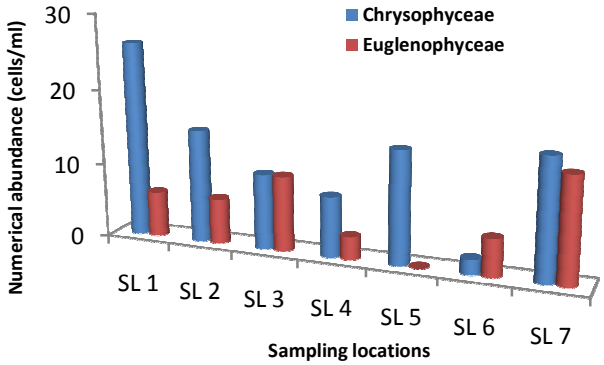

Fig. 3. Spatial variation in chrysophycean and euglenophycean densities of Imo River in Etche LGA

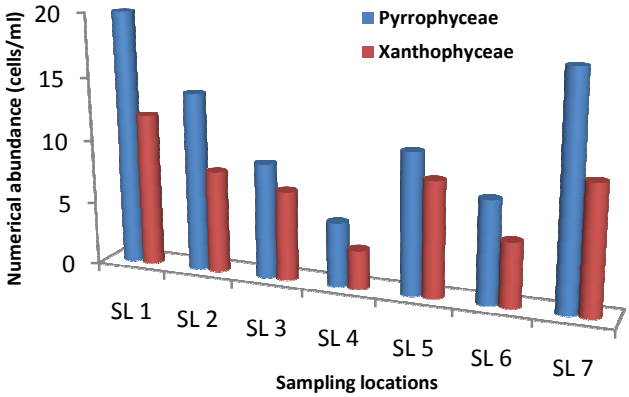

Fig. 4. Spatial variation in pyrrophycean and xanthophycean densities of Imo River in Etche LGA

The test of homogeneity in mean variance of the phytoplankton taxa revealed significant spatial inequality [$F_{(20.94)}>F_{crit(3.94)}$] at $P<0.05$. Further post-hoc means plots that utilized SL 2 as predictor variable revealed that the diatoms (154) and blue-green algae (96) were most responsible for the observed inequality across the locations (Figs. 5-10).

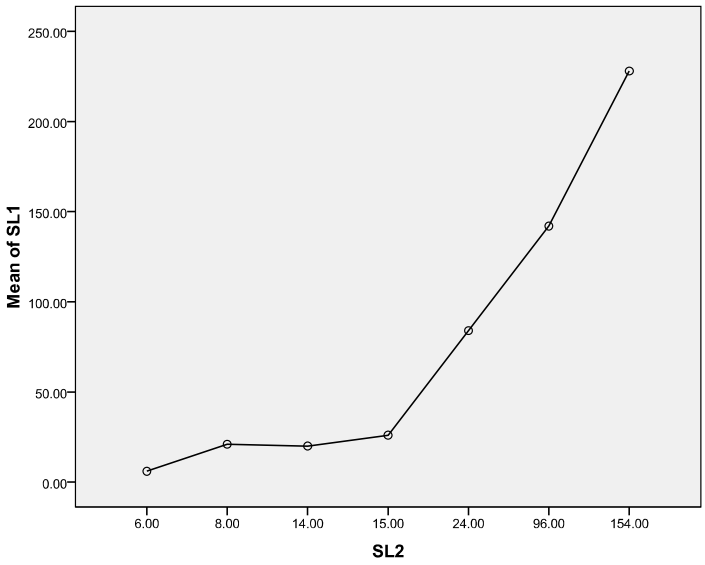

Fig. 5. Means plot of phytoplankton abundance between SL 2 and SL 1 in Imo River in ELGA

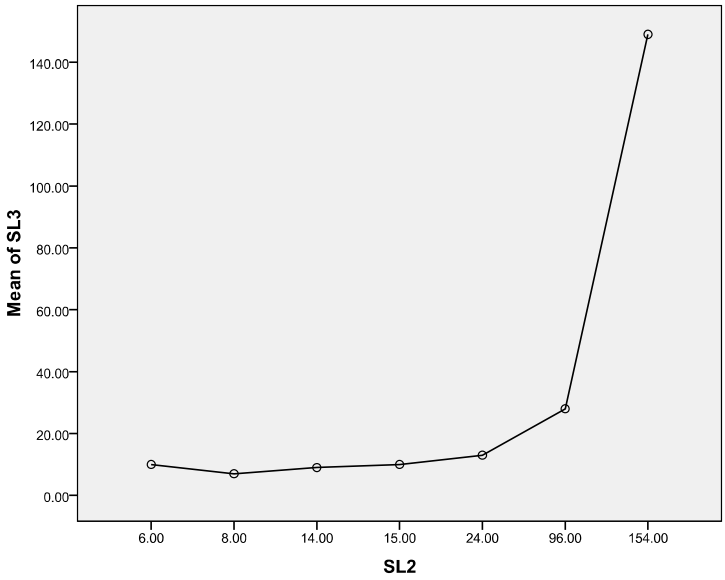

Fig. 6. Means plot of phytoplankton abundance between SL 2 and SL 3 in Imo River in ELGA

3.2. Biotic Diversity Index

Phytoplankton group diversity recorded Margalef's Index (I) range of 0.000-8.514; with SL 1 exhibiting overall highest phytoplankton mean diversity of 4.272 ± 2.100 (21.00%), while SL 6 exhibited least mean diversity of 1.808 ± 1.900 (9.00%) over the study period (Fig. 11). However, SLs 2, 3, 4, 5, and 7 recorded I values of 3.427, 2.836, 2.511, 2.487, and 3.398 respectively.

3.3. Hierarchical Cluster Analysis (HCA)

The HCA using the complete linkage classification revealed coefficient column showing 3 major clusters occurring between stages 18 and 19, 20 and 21, and 22 and 23. The dendrogram (Fig. 12) confirms the three main clusters, with Chrysophyceae, Euglenophyceae, Cyanophyceae and Chlorophyceae belonging to the first cluster, Pyrrophyceae and Xanthophyceae belonging to the second, and Bacillariophyceae belonging to the third cluster. This indicates a richer species abundance and diversity in the first cluster and single diversity in the third cluster.

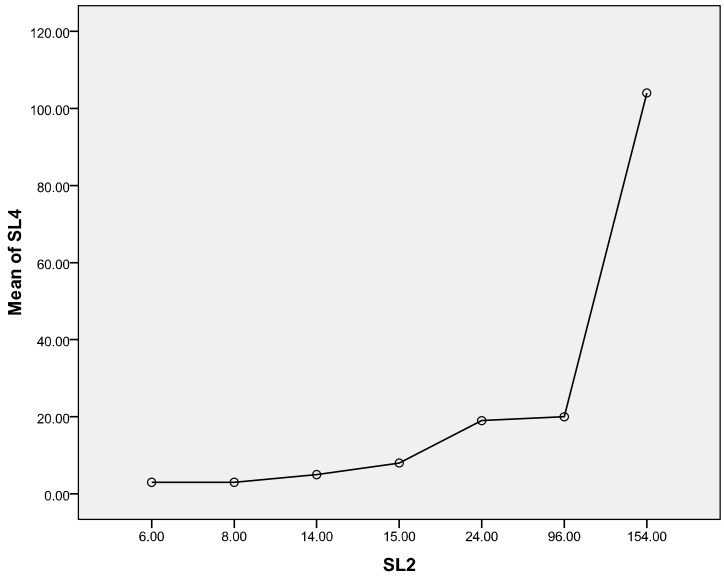

Fig. 7. Means plot of phytoplankton abundance between SL 2 and SL 4 in Imo River in ELGA

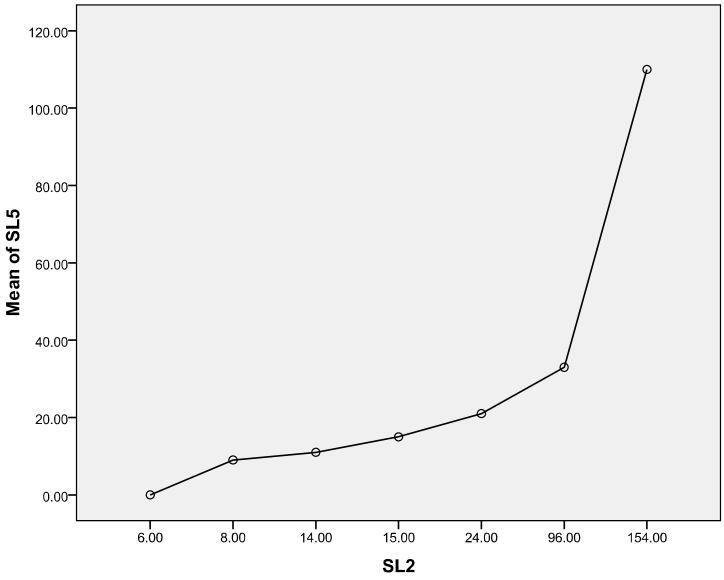

Fig. 8. Means plot of phytoplankton abundance between SL 2 and SL 5 in Imo River in ELGA

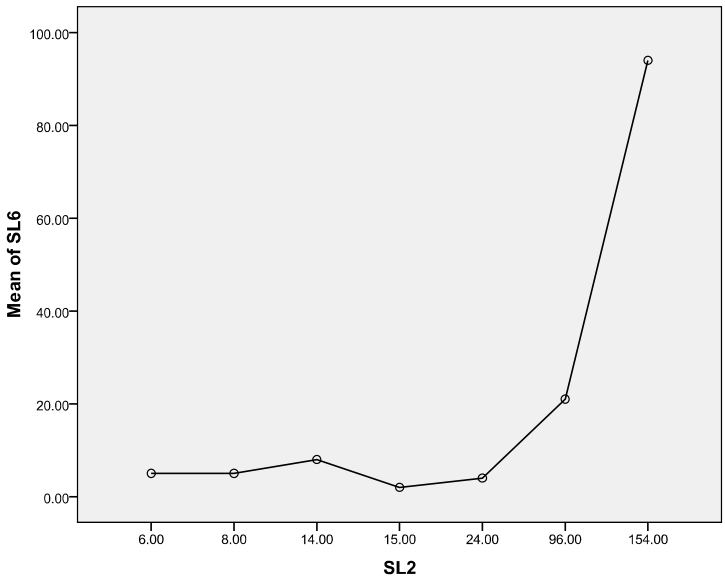

Fig. 9. Means plot of phytoplankton abundance between SL 2 and SL 6 in Imo River in ELGA

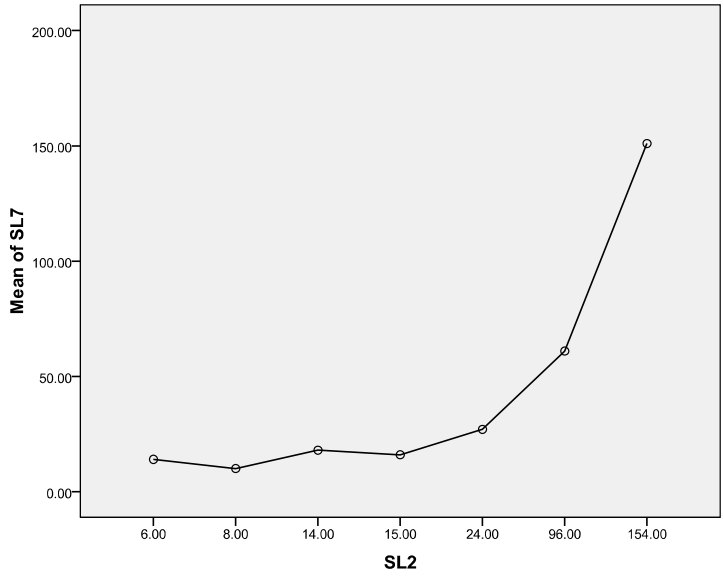

Fig. 10. Means plot of phytoplankton abundance between SL 2 and SL 7 in Imo River in ELGA

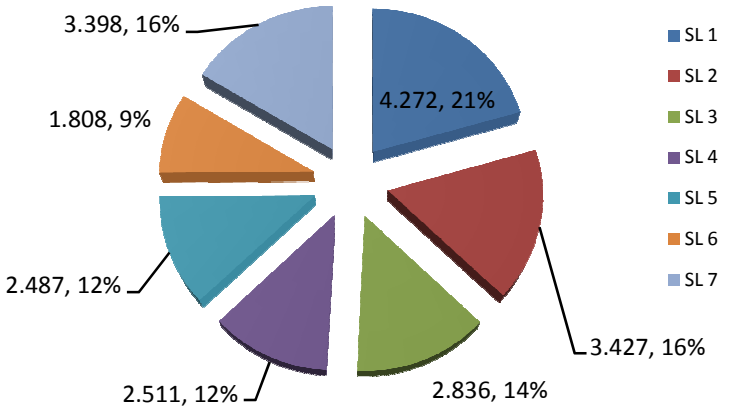

Fig. 11. Mean spatial diversity of phytoplankton of Imo River in Etche LGA

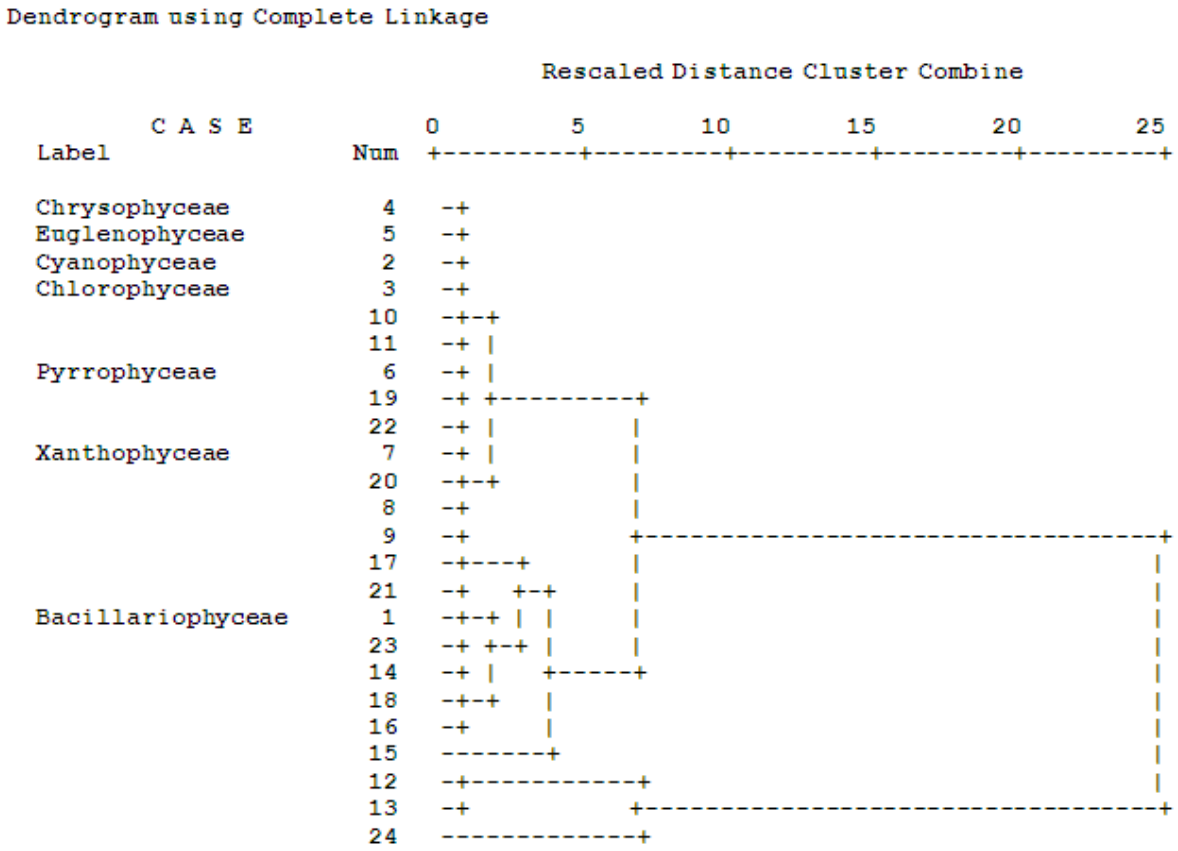

Fig. 12. Dendrogram showing hierarchical clustering of phytoplankton of Imo River in Etche LGA

DISCUSSION

4.1. Distribution of Plankton taxa

Two broad groups of phytoplankton- the stable and oscillating genera were observed in this study. According to Kilham and Hecky [19], the stable genera could be regarded as k-selected, because they were made up of individuals able to exploit various microhabitats offered.

SL 1, the upstream control location that recorded the highest species abundance also experienced less human activities (sand mining commenced here only in the second year of study) than the rest of the locations due to its location in the more pristine, rural community- Akwa. The other locations were situated in urban areas where more anthropogenic activities were ongoing. This less human interference may have encouraged stability and growth of more plankton species in SL 1.

4.2. Biotic Diversity

Generally, biotic diversity was low, especially when compared with the works of Zabbey et al. [5] on the segment of the same river in Oyigbo LGA and Ogamba et al. [20] in Elechi Creek Complex, all in the Niger Delta of Nigeria. Whereas Zabbey et al. [5] recorded a mean phytoplankton Margalef's diversity of up to 5.395, the current study recorded a mean Margalef's value of 2.963 only during the study period. This paucity could again be attributed to perturbations in water quality, especially from sand mining activities, which exerted selective effects on biological assemblages [21, 22]. Zabbey et al. [5] have also identified sand mining as being responsible for low plankton abundance and diversity in the Imo River, even as Tamuno [23] had also identified sand mining as exerting deleterious effects on plankton community composition elsewhere in the Niger Delta area. The dominance in diversity by the diatoms in this study conforms to several other works by hydrobiologists such as Imevbore [24], Holden and Green [25], Egborge [26], Adebisi [27], IPS [28], Chindah and Pudo [29], Erondu and Chindah [30] and Oduwole [31].

4.3. Hierarchical Cluster Analysis

The HCA as an exploratory tool designed to reveal natural groupings within a data set that would otherwise not be apparent revealed clusters that did not depend on numerical nor commonly assumed criteria. Belgrano et al. [32] stated that although non-linear density-dependence has been widely emphasized in population dynamics studies, the existence of non-linear exogenous forces have been less explored. They proposed that the formulation of population dynamics models should include both non-linear endogenous and exogenous responses for a better understanding of the effects of natural systems. The clustering of Chrysophyceae, Euglenophyceae, Cyanophyceae and Chlorophyceae together, and Bacillariophyceae separately must have utilized these exogenous criteria other than numerical abundances. This reveals that there are latent relationships existing between the plankton groups, which otherwise were not exposed by numerical abundance and diversity alone.

CONCLUSION

Phytoplankton species identified were spatially dominated by the bacillariophyceans (diatoms), with the least qualitative groups encountered as pyrrophyceans and xanthophyceans, and the least quantitative as euglenophyceans. Sampling location 1 recorded the highest phytoplankton abundance due to its relatively pristine disposition, while location 6 recorded the least phytoplankton abundance due to more anthropogenic activities there. Plankton abundance and diversity compared lowly with some other lotic water bodies in the Niger Delta area of Nigeria.

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Appendix A. List of phytoplankton divisions and species identified in Imo River in Etche LGA (March 2007-February 2009)

Bacillariophyceae
Asterionella formosa Hassal
Achnanthes gracillina Her.
Bacillaria paradoxa Gmel.
Cyclotella kutzingiana Thwaites
C. meneghiniana Kūtz.
C. operculata (A.g.)
Cymbella afinis Kūtz.
Diatoma elongatum Agadh.
D. spp.
Fragilaria capucina Desm.
Gomphonema parvulum (Kūtz.)
Gyrosigma attenuatum (Kūtz.)
Melosira spp
M. varians C.A. Ag.
M. pusilla
Navicula cuspidate
N. dicephala (Ehr.)
N. gracilis Ehr.
Nitzschia ricta Hantsch.
N. filiformis (W. Smith)
N. closterium W. Smith
N. gracilis Hantsch
Pinularia viridis (Nitzsch)
P. divergens Kutz.
P. appendiculata Clev.
Stauroneis anceps Her.
Synedra ulna (Nitzch) Her.
Tabellaria binalis (Her.)
T. fenestrata Kūtz.
Cyanophyceae
Anabaena spiroides Kleb
Aphanizomenon flos-aquae (L.) Ralfs.
Dactylococcopsis acicularis Lemm.
Gloeocapsa spp
Gomphosphaeria lacustris Chod.
Lyngbya limnetica Lemm.
Microcystis aeruginosa (Kūtz.)
Oscillatoria tenuis Ag.
Phormidium spp
P. mucicola Hub-Pestalozzi et Naum
Raphidiopsis curvata Fritsch et Rich.
Rivularia planctonella Elenk.
Chlorophyceae
Closterium gracile Bréb.
C. parvulum Nãg
C. kuetzingii Bréb.
Cosmarium spp
C. circulare Reinsch.
Chlamydomonas spp
Microsterias thomasiana Arch.
Spirogyra spp
Ulothrix spp
Volvox globator (L.) Her
Chrysophyceae
Dinobryon divergens Imh.
Mallomonas caudate Conrad**.**
Rhizosolenia eriensis H.L. Smith
Euglenophyceae
Euglena gracilis Klebs.
Phacus spp
Trachelomonas lacustris Drez.
Pyrrophyceae (Dinoflagellata)
Cryptomonas erosa Ehr
Gymnodinium aeruginosum Stein.
Xanthophyceae
Tribonema vulgare Pasch.
T. utriculosum (Heering)