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Assessing Environmental Impact on Phytoplankton Composition and Distribution in a Tropical River in Southern Nigeria

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ABSTRACT: *The influence of physico-chemical environmental variables on the distribution and composition of phytoplankton community of a tropical river in southern Nigeria was assessed between December 2009 and November 2010. The hypothesis tested was that shift from one station to another on the river's longitudinal gradient affect the physico-chemical variables and the phytoplankton assemblage and is modulated by the temporal rainfall changes. The databases obtained were subjected to canonical correspondence analysis (CCA). The result of the spatio-temporal interactions between the phytoplankton, and the physical and chemical variables indicated that species such as Peridium sp, Melosira moniliformis and Thalassiothrix nitzschiodes have highest abundance where dissolved oxygen is highest and ammonia and conductivity are at their lowest levels. Water level (depth) showed a positive relationship with Ulotrix sp and Ankistrodesmus sp, while biochemical oxygen demand had a correlation with Desmidium swartzi, Hyalotleca mucosa and Cosmarium amoerum. Current velocity, water level and total hydrocarbon explained 57.8% of the variation in the species matrix. This study is a contribution to the scarce data bank on some rivers in southern Nigeria, and will be very useful in formulating policies and regulatory framework for sustainable management of Mbo River.*

I. INTRODUCTION

Both the physic-chemical and biological studies integrating the overall state of health of a lotic system in contrast to the traditional physico-chemical parameters, which gives punctual and instantaneous information on the water quality of a given site (Karr *et. al*, 1986) is encouraged. While biological monitoring reflects the recent history of a system alteration, detected by the trend in the various biotic and abiotic components, the physico-chemical parameters pin-point a precise level of specific pollutants (Karr *et. al*, 1986; Rosenberg and Resh, 1993). Because of different approaches on assessing a systems environmental health, these two methods (physico-chemical and biological) are complementary and have been used in order to obtain a more holistic assessment on the environmental quality (Hughes and Gammon, 1987; Waite and Carpenter, 2000; Meador and Goldstein, 2003).

The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs (Shrestha *et al.* 2008). Therefore, the degree of water quality can be evaluated by characterizing the aquatic communities in the habitat (Wu and Suen, 1985). The relationship between community structure and environmental factors usually varies according to ecosystem type, group of organisms and spatial scale (WueLoucks, 1995).

Rivers are highly heterogeneous at spatial as well as temporal scales, and several investigators have documented this heterogeneity focusing on the physico-chemical and biotic dynamics of rivers. Due to their short life cycles, plankters respond quickly to environmental changes, therefore, their standing crop and species composition are more likely to indicate the status of the water in which they are found. They are also known to strongly influence certain non-biological aspects or physico-chemical attributes of the water (such as pH, colour, taste, dissolved oxygen concentration, and odour).

Several statistical assessment methods based on different organisms have been developed. The approach used in this study was the multivariate approach using canonical correspondence analysis (CCA). Identifying which environmental variables were most influential in determining community structure was the main aim in using CCA.

Presently, Mbo River is facing serious developmental interests by both the state government, (the proposed establishment of an international seaport at its mouth in Ibaka), and the oil companies that have newly discovered oil deposits within the river's catchment area. It is, therefore, important to monitor this water resource so as to characterize the physico-chemical and biological integrity/quality of this ecosystem to ensure the suitability of the river for the survival of aquatic population within the concept of the proposed developments.

II. MATERIALS AND METHOD

Study Area: Mbo River

Mbo River which is within the Niger Delta Zone of Nigeria is located within the tropical rainforest region characterized by tropical humid climate with distinct dry (November – March) and wet (April –October) seasons. It supports the local economic activities such as agriculture, fishery, eco-tourism and water supply for domestic use. The increasing urbanization and socio-economic activities have impacted on the ecosystem. The river suffers different impacts of anthropogenic activities along its extension. Non-point impact from the drainage due to surface runoff, washing and spillage from motorized boats, and direct defecation by rural dwellers constitute the main water quality/chemical problems, while loss of habitats as a result of harvesting of mangroves for firewood and riparian degradation constitute the physical problems.

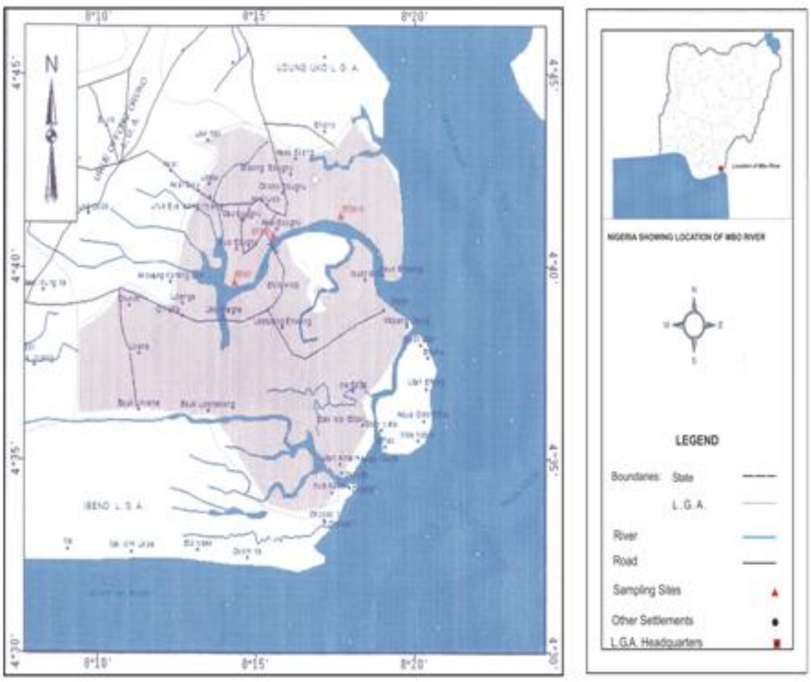

Fig. 1: **Mbo River showing Sampling Sites**
Source: Department of Geography & Regional Planning, University of Uyo, Uyo.

SAMPLING

Sampling was carried out fortnightly at the three established sites from December 2009 to November 2010 inclusive, during the mid morning hours between the hours of 8am and 11am.

Morphometric parameters were measured using appropriate procedures (Orth, 1983; Schlosser, 1982; Hanson, 1973; Bartram and Ballance, 1996). The chemical analysis of the waters was done using standard and analytical methods of water analysis (Bartram and Ballance, 1996; Trivedi and Goyal, 1986; APHA-AWWA-WPCF, 2005; USEPA, 1979).

Water samples were collected from the three study stations at regular and specific time intervals, since physico-chemical and biological features of lotic systems could vary with time. At each sampling location, the surface water samples (in three replicates) were collected at the middle of the river and stored in clean polythene bottles that were prewashed with nitric acid and thoroughly rinsed with deionized water (Bartram and Ballance, 1996). Water samples (1,000ml) were collected from approximately 20cm below the water surface mid-stream at each sample site in new, clean 1liter polyethene sample bottles, clearly and permanently labeled. The sample was fixed with approximately 5ml of 4% formaldehyde solution and taken to the laboratory for analysis. The sample bottles for plankton were allowed to stand (sedimentation) for 48 hours before decanting the supernatant leaving an aliquot of known volume (10ml). The concentrated samples were homogenized before 1ml of sub-sample from the original stock was collected with sample pipette (Onuoha, 2009). The pipette content was transferred unto a Sedgewick – Rafter counting chamber for species enumeration at a microscope magnification of 400_x using the synopsis of Mills (1932), Durand and Leveque (1980), Screenivas and Dulthie (1993), Newell and Newell (1977), Egborge (1973); APHA (2005); Onuoha (2007 and 2009).

Qualitative estimation of plankton was made using a 30cm square mouthed 70mm mesh bolting silk net (Griffin) and collections were made in triplicate. Plankton samples for qualitative analysis were obtained by placing the net below the water surface (20cm) and the net towed for 5 minutes until a sufficient quantity of plankton was collected.

For quantitative estimation of plankton 100cm^3 of surface water was filtered through the plankton net, Khan *et al.*, 1983; Khan and Ejike (1984). One percent (1%) Lugol's iodine solution was added to the plankton sample to fix the phytoplankton component (Akpan *et al.,* 1994). Samples were fixed immediately for zooplankton with 4% hexamine buffered formalin to preserve the organisms. Sample was then concentrated by centrifuging and adjusting to 10ml. All organisms were identified and enumerated using a light compound microscope.

III. RESULTS

PHYSICO-CHEMICAL PARAMETERS

The results of the analyses are presented in Tables 1 - 2 and Figs. 2.

Water transparency displayed marked differences among stations. This variable is dependent on suspended sediment. Water transparency in Station I is higher because of the reduction in current velocity as the river nears the sea.

The distribution of conductivity at sampled stations appeared to be more related to the liquid conductivity, which expresses a positive correlation between conductivity and temperature (Vannote *et al*, 1980). However, difference in conductivity among the stations sampled in this study may be due to leaching of the riverside because of floods.

Table 1: The spatial variation in the physico-chemical parameters of Mbo River

Station	Water level	Current Vel	Color	Air temp	Dissolved O_2	BOD	Alkalinity	pH	Water temp	Conductivity	Transparency
I	5.66a	50.89a	56.12a	30.95a	7.70a	2.80a	24.24a	6.75a	28.13a	166.1a	58.58a
II	3.81a	49.67a	52.89c	30.81b	7.40a	2.85a	24.09a	6.76a	28.13a	165.5a	55.31a
III	5.41a	39.57a	58.39a	30.67a	7.40a	2.82a	25.59a	6.73a	27.53a	165.4a	53.26a
LSD	0.02	0.07	0.08	0.03	0.17	0.08	0.61	0.04	0.16	0.16	0.05
P	<0.0001	<0.0001	<0.0001	0.0003	0.01	0.52	0.01	0.3	0.005	<0.0001	<0.0001

Station	COD	NO_3-N	NO_2-N	PO_4-P	SO_4	NH_4-N	Sulphate	THC	TSS	TDS	TS
I	2.59a	318.08a	2.03a	52.66a	5.25a	1.55a	7.55a	3.62a	0.719a	0.99a	1.70a
II	2.55a	309a	20.64a	54.01a	4.25a	1.55a	6.56a	2.80a	0.71a	0.92a	1.67a
III	2.56a	308.2a	1.99a	54.15a	4.21a	1.55a	7.68a	2.68a	0.70a	0.95a	1.65a
LSD	0.02	2.12	0.69	0.31	2.69	0.06	0.15	0.12	0.004	0.009	0.01
P	0.04	0.07	<0.0001	<0.0001	0.21	0.65	0.002	<0.0001	0.32	<0.0001	0.03

* Means with same letters are not significant

Table 2: Means and Standard Deviation of Physico-Chemical Parameters of Mbo Rive

	STATION 1	STATION 2	STATION 3
Parameters			
Water Level (m)	5.66±6.83	3.81±0.71	50.41±0.92
Current velocity ($CmSec^{-1}$)	50.89±3.20	49.67±6.85	39.51±2.03
Color (NTU)	56.12±4.89	52.89±4.57	58.39±5.16
Air Temperature (^{0}C)	30.95±2.16	30.81±1.65	30.67±1.97
Dissolved Oxygen (mgL^{-1})	7.70±0.61	7.40±0.57	7.40±0.72
Biochemical Oxygen Demand(mgL^{-1})	2.80±0.36	2.85±0.28	2.82±0.25
Alkalinity(mgL^{-1})	24.24±3.23	24.09±4.53	25.58±3.84
pH	6.75±0.07	6.76±0.18	6.73±0.18
Water Temperature (^{0}C)	28.13±1.34	28.13±1.23	27.53±0.92
Conductivity (□ Scm^{-1})	166.12±5.20	165.46±5.09	165.37±4.85
Transparency (cm)	58.58±5.18	65.31±30.96	53.26±0.70
Chemical Oxygen Demand (mgL^{-1})	2.59±0.13	2.55±0.12	2.56±0.13
Nitrate-Nitrogen (□ gl^{1})	318.08±9.12	309.33±15.95	308.20±17.17
Nitrite-Nitrogen(□gl^{-1})	2.03±0.08	20.64±62.96	1.99±0.17
Phosphate-Phosphorus(□ gl^{1})	52.66±2.79	54.01±2.66	54.15±2.69
Sulphate (mgL^{-1})	5.85±7.98	4.25±0.26	4.21±0.24
NH_4 - N(□ gl^{1})	1.53±0.49	1.55±0.48	1.55±0.46
Sulphate (mgL^{-1})	7.53±0.60	6.56±2.47	7.68±0.59
Total hydrocarbon(mgL^{-1})	3.62±1.18	2.80±0.21	2.66±0.23
Total Suspended Solids (mgL^{-1})	0.71±0.21	0.71±0.21	0.70±0.21
Total Dissolved Solids(mgL^{-1})	0.99±0.28	0.92±0.30	0.95±0.29
Total Suspended Solids(mgL^{-1})	1.7±0.08	1.67±0.08	1.65±0.09

CANONICAL CORRESPONDENCE ANALYSIS (CCA)

The first three of the CCA axes cumulatively explained 57.8% of the variation in the species matrix (Table 3). Axis 1 explained the highest proportion of the variance with 35.1% while axes 2 and 3 explained quite less 12.1% and 10.6%, respectively. Axis I is highly correlated with several environmental variables such as, current velocity (-0.65), water level (0.63), total hydrocarbon (-0.64), Nitrate-nitrogen (-0.36), total solids (-0.39) and dissolved oxygen (-0.35). Axis 2 is correlated with Eindex (r=0.54), water level (0.38) and current velocity (-0.32). The key variable explaining community variance along Axis 3 was biochemical oxygen demand (0.30). This indicates that variation along this axis may be due to this parameter and probably other environmental variables not measured.

Table 3: CCA Summary Statistics and Correlations of Phytoplankton Density with Physico-chemical Data

Summary Status	**Axis 1**	**Axis 2**	**Axis 3**
Eigenvalue	0.77	0.26	0.23
Cumulative variance explained	35.1	47.2	57.8
Pearson Correlation (Species Environment)	0.95	0.97	0.91
Axis Correlations (ter Break, 1986)	**Axis 1**	**Axis 2**	**Axis 3**
Water level (m)	0.63	0.38	-0.11
Current velocity (CmSec^{-1})	-0.65	-0.32	0.21
Color (NTU)	0.13	0.16	-0.29
Air temperature (^{0}C)	-0.18	-0.19	-0.13
Dissolved oxygen (mgl^{-1})	-0.35	0.17	0.03
Biochemical O_2 Demand(mgl^{-1})	0.24	0.01	0.30
Alkalinity (mgl^{-1})	0.28	0.13	0.04
Ph	-0.16	-0.01	0.01
Water Temperature (^{0}C)	-0.18	-0.09	0.26
Conductivity (□ Scm^{-1})	0.02	-0.15	0.03
Transparency (cm)	-0.15	-0.19	0.01
Chemical O_2 Demand(mgl^{-1})	0.06	0.03	0.10
Nitrate-Nitrogen(□ gl^{1})	-0.36	-0.00	-0.07
Nitrite – Nitrogen(□ gl^{1})	-0.24	-0.06	0.11
Phosphate-Phosphorus(□ gl^{1})	0.09	0.02	0.07
Sulphate(mgl^{-1})	0.06	0.27	-0.28
NH_4 – N(□ gl^{1})	-0.06	0.06	0.11
Sulphite(mgl^{-1})	-0.01	0.17	-0.11
Total Hydrocarbon(mgl^{-1})	-0.64	0.17	-0.13
Total Dissolved Solids(mgl^{-1})	-0.13	0.03	-0.02
Total Solids(mgl^{-1})	-0.39	-0.02s	0.06
Rainfall	0.20	-0.07	-0.27
SO_3(mgl^{-1})	0.19	0.12	0.12
Total Suspended Solids	-0.02	0.04	-0.04

P (first axis) = 0.02; P (all axes) = 0.005

Each of the three axes explained a statistically significant and high proportion of the species-environment relationship (r=0.95, r=0.97 and r=0.91 for axes I, 2 and 3 respectively). The analysis was stable with low Monte Carlo correlation proportions. On the CCA ordination diagram of the first and second canonical axes (Fig. 2), sites are generally clumped together to the right of Axis I (2nd Quadrant) and the lower section of Axis 2 (3rd Quadrant). Sites S_{26} to S_{36} appear clustered together on the ordination diagram. These are sites with highest rise in water levels and highest recordings of alkalinity, biochemical oxygen demand and Color. The most influenced sites are site S_{26} and S_{34} which the farthest sites along the vector arrow projection on the biplot, while Site S_{32} shows intermediate influence by these variables. On the third Quadrant (+), some sites appear clumped together. Such sites include sites S_{13} to S_{22} and site S_{24}. These are sites which are most impacted by rainfall which is the variables with greatest influence in determining the concentration of NH_4 and conductivity as recorded. Sites are generally spread along the left side of the biplot (Quadrants 4 and 1). In Quadrant 4, Current velocity is the most influential variable determining the distribution of phytoplankton species. Sites S_8 and S_2 are most influenced by water temperature, NO_3, NO_2 and pH and an intermediate level of current velocity.

From the biplot (Fig. 2), water level, total alkalinity, biochemical oxygen demand, chemical oxygen demand, color and Phosphates are positively correlated with each other and negatively correlated with current velocity, water temperature, nitrate-nitrogen, nitrite-nitrogen, air temperature and pH. On the other hand, rainfall, NH_4 and conductivity are correlated positively with each other and show a negative correlation with total hydrocarbon, dissolved oxygen, sulphate and total dissolved solids.

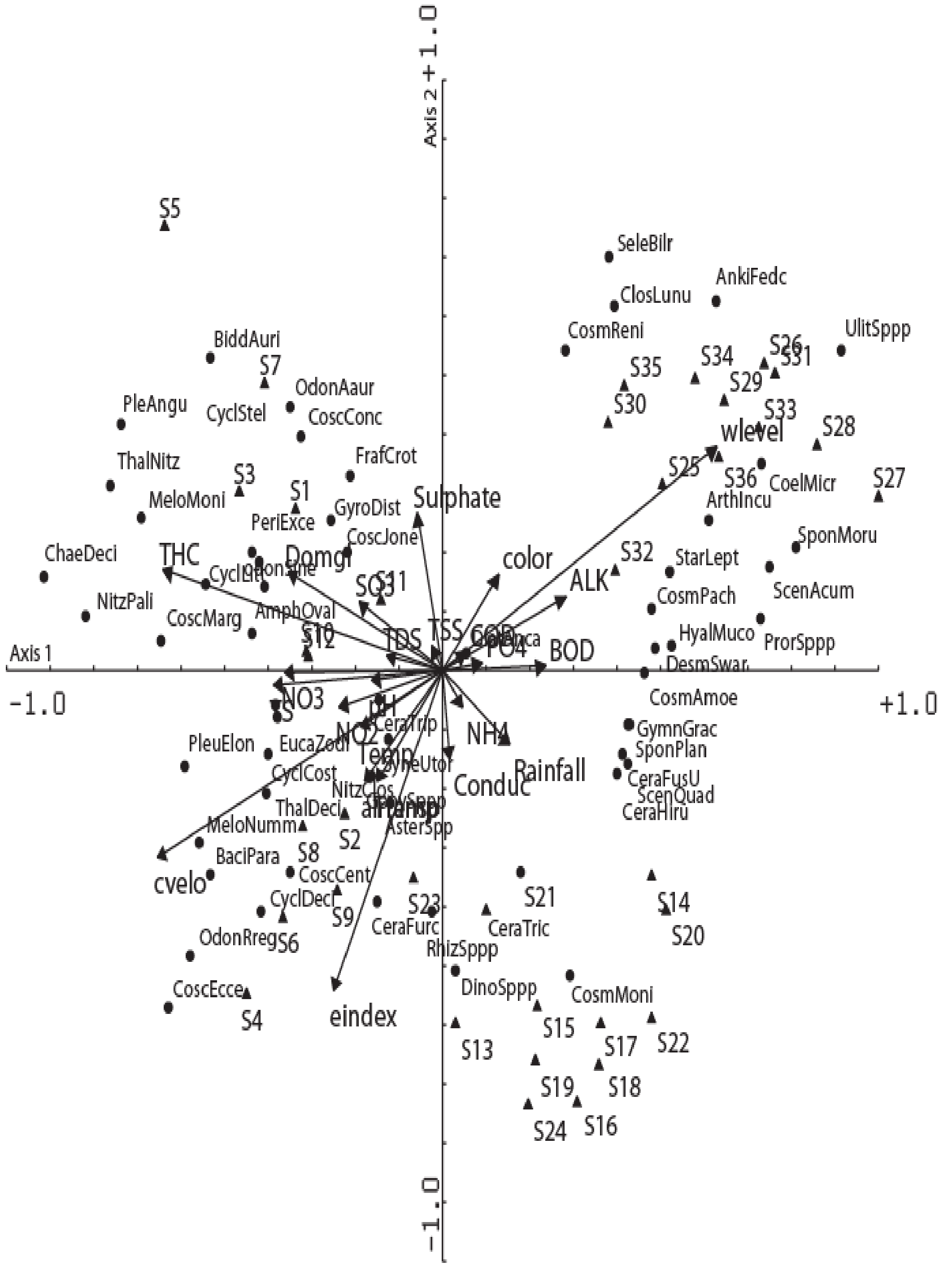

Fig. 2: CCA biplots scores showing the relationship between the environmental variables and phytoplankton assemblages at the three sites. The sites and months are represented by (▲) and species by (●)

The Canonical correspondence analysis (CCA) of the entire relative abundance of Phytoplankton community data revealed that several environmental variables were closely correlated with species matrix (Fig. 2). Species like *Ulotrix* sp and *Ankistrodesmus* sp increase in abundance with increasing rise in water level and decreasing (slow) currents. Other species still favoured by rise in water level include *Coelastrium microporum*, *Arthrodesmus incus* and *Spondylosium moruloforme*. Other physico-chemical variables determining the distribution and abundance of phytoplankton species in this quadrant include, alkalinity, color and biochemical oxygen demand. Species like *Staurastrum leptocladium* and *Cosmarium pachyderma* have highest abundances with an intermediate rise in water level. Above named species also prefer slow current for maximum abundance. Other species in this quadrant like *Selenastrum bibraiarium*. *Closteridium lunulla* and *Cosmarium reiniforme* are closely correlated with a high rise in color intensity especially in Sites S_{30} and S_{35}. *Desmidium swartzi*, *Hyalotteca mucosa*, *Cosmarium amoerum* and *Prorocentrum sp* have their highest abundance with an increase in biochemical oxygen demand and are closely related to each other and this is indicated by their clustering together. In the third quadrant (+), species are those most influenced by an increase in rainfall which is the most determining factor of the species abundance here. Other variables like NH_4 and conductivity are closely related and their increase results invariably in an increase in the abundance of species like *Ceratium trichoceros*, *Ceratium fusus*, *Spondylosum planum* and *Gymnodinium gracile*.

Increase in the speed of the current results in an increase in the abundance of *Baciliaria paradosca*, *Coscinodiscus eccentricus*, *Odontella aurita*. *Melosira nummuloids* and *Pleunosigma elongatum* therefore, these species do well in fast current. Species like *Thalassiosera decipiens*, *Cyclcotella costatum* and *Eucampia zodiacus* occur where the flow of current is intermediate. Also the abundance of those species is also influenced by an increase in water temperature, nitrite-nitrogen, air temperature, pH and nitrate-nitrogen. From the biplot also it could be assessed that an increase in the concentration of total hydrocarbons (THC) leads to an increase in the abundance of *Chaetoceros decipiens*, *Nitzschia closterium*, *Melosira moniliformis*, and *Thalassiothrix nitzschiodes*, *Amphora ovalis*, and *Cosmarium moniliforme* abundance is highest where total hydrocarbon (THC) is at an intermediate level. Organisms like *Peridium sp*, *Melosira moniliformis*, *Thalassiothrix nitzschiodes* and *Pleurosigma angulation* have highest abundance with increase in dissolved oxygen. Other species affected by an increase in dissolved oxygen, sulphite and sulphate include *Gyrosigma distortum*, *Cosanodiscus jonesianus*, *Coscinodiscus concinnus*, *Odontella aurita*, *Fragillaria crotonensis* and *Biddaulphia aurita*. These species have lowest abundance where NH_4 and conductivity are highest.
Species clusters around certain sites indicate their high abundance at those sites (Fig. 2).

IV. DISCUSSION

The Canonical Correspondence Analysis conducted on the entire phytoplankton community singled out current velocity, water level and biochemical oxygen demand as the main environmental factors influencing phytoplankton distribution and abundance. The negative correlation (r=-0.65) with current velocity in this study is supported by a number of authors in plankton study (Wetzel, 2011; Newel & Newel 1963) who observed that plankton have little or no ability to withstand currents and therefore fast currents lead to a reduction in the density of plankton in space and time. Water level invariably affects the distribution and abundance of phytoplankton. From the CCA, a slight increase in water level resulted in a corresponding increase in the total phytoplankton. This is assumed to be due to a reduction in BOD and COD (main polluting factors) as the water level increases and also an increase in DO which is vital for phytoplankton production. The observed negative correlation in the CCA of phytoplankton and BOD also indicates BOD in the river influence abundance and distribution.

V. CONCLUSION

The main aim of this work was to study the physico-chemical and biological attributes of Mbo River and to see whether these traits show differences in contrasting stations and seasons so as to assess the hydrobiological status of the river system. The results of this study reveals that diverse floral and faunal species are under pressure from anthropogenic activities especially oil exploration as shown by the canonical correspondence analysis (CCA) of all the biological factors examined. The CCA on phytoplankton, zooplankton and benthic macroinvertebrates, identified total hydrocarbons (which is associated with petroleum products) as the main factor affecting the distribution and abundance of these organisms in the river.

The location of Mbo River in the rainforest of Nigeria places the river under direct impact by seasonal rainfall which was shown in this study to be the major factors driving the physical and chemical attributes of the river and the biological abundance and distribution, thus the hydrobiological state of the river. This study also proved the hypothesis that different landuses affects the physico-chemical and biological parameters of the river and results in temporal and seasonal variations in these factors.

The disturbances to the river particularly coming from the agricultural and petroleum sector were found to affect the biological attributes of Mbo River with certainty, and thus, more careful approaches to lower and limit the adverse impact of these pollutional factors must be encouraged to practice.

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BIOGRAPHY

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Mandu Essien-Ibok(Ph.D) was born in Calabar on June 17th, 1969. She acquired B.Sc(Fisheries) in 1998 and M.Sc (Fisheries/Hydrobiology) in 2008 both from the University of Uyo, Uyo. Mandu Essien-Ibok holds a Ph.D Hydrobiology/Fisheries (2012) from Michael Okpara University of Agriculture, Umudike, Nigeria. She got into the University of Uyo as Graduate Assistant in the Department of Fisheries and Aquaculture and presently holds the position of Lecturer II. Her publications include 1) Seasonality in the Physical and Chemical Characteristics of Mbo River, Akwa Ibom State, Nigeria. Nigerian Journal of Agriculture, Food and Environment. Vol 3, 2010. 2) Macroinvertebrate Composition Structure of a tropical rainforest pond in uyo, Nigeria. International Journal of Chemical, Environmental and Pharmaceutical Research. Vol 15, 2011. She is currently researching on characterizing the estuaries in Akwa Ibom State using bioassessment methods and was previously researching on Hydrobiology and Water Quality of Mbo River, Akwa Ibom State, South East Nigeria. Dr (Mrs) Essien-Ibok is a member of the following societies: Fisheries Society of Nigeria (FISON), Nigerian Biological Conservation Society (NBSC), Association for Aquatic Sciences of Nigeria (AASN), , Association for Promoting African Girls in Engineering,Science and Technology Education (APAGESTE), International network of Women in Science and Engineering (INWES).

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