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Fish Community Structure in River Ossiomo, Niger Delta, Nigeria in Relation to Some Selected Environmental Variables

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In the past decade, it has been reported that water quality of rivers are deteriorating increasingly. In this study we examined the state of River Ossiomo to assess the current health of the river for a period of 24 months from April 2019 to March 2020, then July 2020 to May 2021 in three well marked out stations. The study was to determine the relationship between environmental variables and fish species assemblage in the river. From the results of the physico-chemical variables, the

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mean values of pollution indicating physico-chemical variables such as sulphate (1.26±0.32mg/l) and total suspended solids (TSS) (5.53±1.89mg/l) were higher in station 2. On the other hand, pH (5.94±0.48), DO (8.64±1.57mg/l), turbidity (7.48±7.63NTU), TDS (29.64±14.65mg/l) and phosphate (0.43±0.31mg/l) mean values were highest in station 1. Conductivity (70.87±26.42µS/cm) and nitrate (0.49±0.34mg/l) mean values were highest in station 3. Further, dissolved oxygen (DO) was higher in station 1, the reference station. The analysis of variance (ANOVA), we performed for the physico-chemical variables revealed that temperature, conductivity, DO, total dissolved solids (TDS), alkalinity, TSS, sulphate, phosphate and nitrate were significantly different among the three stations sampled (P<0.05), while pH, BOD and turbidity were not significant among the three stations sampled (P>0.05). The result of the principal component analysis showed that conductivity was positively associated with station 3, and temperature, TDS and alkalinity were negatively associated with stations 1 and 2. A total of 2,324 fish individuals belonging to 29 taxa were recorded in the entire study period. Station 1 harbours more fish species (1018), followed by station 2 (809), and we recorded the lowest number of fish individuals in station 3 (497). *Auchenoglanis occidentalis* was the most preponderant fish species probably occasioned by its level of adaptation to prevailing environmental conditions in the study river. The least abundant fish species was *Synodontis eupterus*.The canonical correspondence analysis we used in visualizing the relationship between fish species and physico-chemical variables showed that fish taxa such as *Distichodus brevipinni*, *Cteropoma kinsleyae, Tilapia zillii, Malapterarus electricus, Mormyrus engystoma,* and *Synodontis nigita* that were positively associated with pollution indicating physico-chemical variables were suggested as indicators for monitoring riverine health in the Niger Delta area of Nigeria. We recommend that more detailed studies should be carried out in River Ossiomo to confirm this result. However, this study serves as a baseline study in the present study area.

***Keywords**: Physico-chemical variables; indicator fish taxa; Auchenoglanis occidentalis; Synodontis nigita; River Ossiomo; Niger Delta; Nigeria.*

1. INTRODUCTION

In recent time, riverine systems in the Afrotropic, Nigeria not excluded have been reported to suffer from high level of pollution occasioned by increasing population, agricultural activities, industrialization and urbanization [1, 2]. Among the major stressors in riverine systems causing degradation, urbanization and industrialization is the major culprit [2-4]. Urbanization and industrialization results in storm-water return flow, sewage disposition, agricultural runoffs and effluent discharges [4]. Human activities are fast becoming a serious management issues for river managers, and if not tackled urgently, it could result to grave effects on riverine systems community structure and functionality [4].

In assessing the effects of human activities on rivers, various aquatic biota is employed (e.g. phytoplankton, zooplankton, macroinvertebrates and fishes [2, 5, 6]. Among the aquatic biota employed in assessing riverine systems health, fish species and taxa are rarely explored in monitoring the effects of human activities on riverine systems. Most fish species and taxa are nektonic while some are benthic in nature, hence their use as utility for monitoring riverine systems will benefit the science of biomonitoring which is still scarce in the Afrotropics [7]. Fish respond to perturbation differently, for instance, Victor and Tetteh [8] asserted that some of the Bagridae (e.g. *Chrysichthys nigrodigitatus*) respond negatively to environmental disturbance, but more recently, a contrary report on the level of tolerance of *Chrysichthys nigrodigitatus* was given by [9], and it was stated that *Chrysichthys nigrodigitatus* respond favourably to increase gradient of pollution. Due to the contrary view on the level of tolerance of various fish species, in this study, we explored the relationship between selected fish species and physico-chemical variables in River Ossiomo, in the Niger Delta area of Nigeria in a bid to point out fish species and taxa that can be used as indicators for monitoring riverine systems health in the Niger Delta area of Nigeria.

River Ossiomo is located in Edo State within the Niger Delta area of Nigeria, and it stretches to the border of Delta State, also within the Niger Delta area of Nigeria. The river suffers from numerous disturbances ranging from unplanned human settlements, storm water return flow from nearby farmlands and settlements, wastes from wood mill factory and the presence of oil flow station in some reaches of the river.

2. MATERIAL AND METHODS

2.1 The Study Area and Stations Description

The study was conducted along the stretch of River Ossiomo within the Niger Delta Region of Nigeria. River Ossiomo stretches over 275 kilometers, meandering within Delta and Edo States in Southern Nigeria. The river is supplied by tributaries of Ikpoba, Okhuaihe and Akhaianwan Rivers. River Ossiomo with confluence of Ogba River drains into the Benin River within Koko town in Delta State and empties into the Atlantic Ocean [10]. The river is important ecologically and socio-culturally as it provides ecosystem services to the riparian communities. Ecologically, the river supports a permanent discharged into the Benin River which empty into the ocean. The study area is characterized by two distinct seasons (dry and wet), with average annual temperature of 35°C [4]. The dry season spans from November to March while the wet season is from April to October with a peak of heavy rainfall in July [4,].

The study was carried out in three well-marked out stations for a period of 24 months from April 2019 to March 2020, then July 2020 to May 2021. Sampling was not carried out in April and May, 2020 due to logistics reasons. Stations were selected based on accessibility and the degree of human activities in the study area.

Station 1 is within the coordinate of 6°03'06.45" N and 5°40'52.72" E, and it is situated upstream of the river, and was selected to represent the reference or least impacted station, due to the presence of minimal human activities in the station.

Station 2 is within the coordinate of 5°58'16.86" N and 5°32'13.19" E and it is located within the Ossiomo industrial park in Ologbo, where the surrounding impacts include run-off from roads, wood mill and informal settlements, farm land and other agricultural practices.

Station 3 sits within the coordinate of 6°01'51.77" N, 5°29'45.81" E and it is further downstream of the river, with confluence of Rivers Ossiomo and Ogba. This station also suffers from the runoffs coming from the wood mill and informal settlements in station 2, though minimal compare to that of station 2.

2.2 Physico-chemical Variables Sampling and Analyses

Physico-chemical variables were measured at the three sampling stations over the study period. On each sampling occasion, sub-surface and mid-channel dissolved oxygen (DO), pH, conductivity, turbidity, temperature, total suspended solids (TSS) and total dissolved solid (TDS) were measured in-situ [11,12].

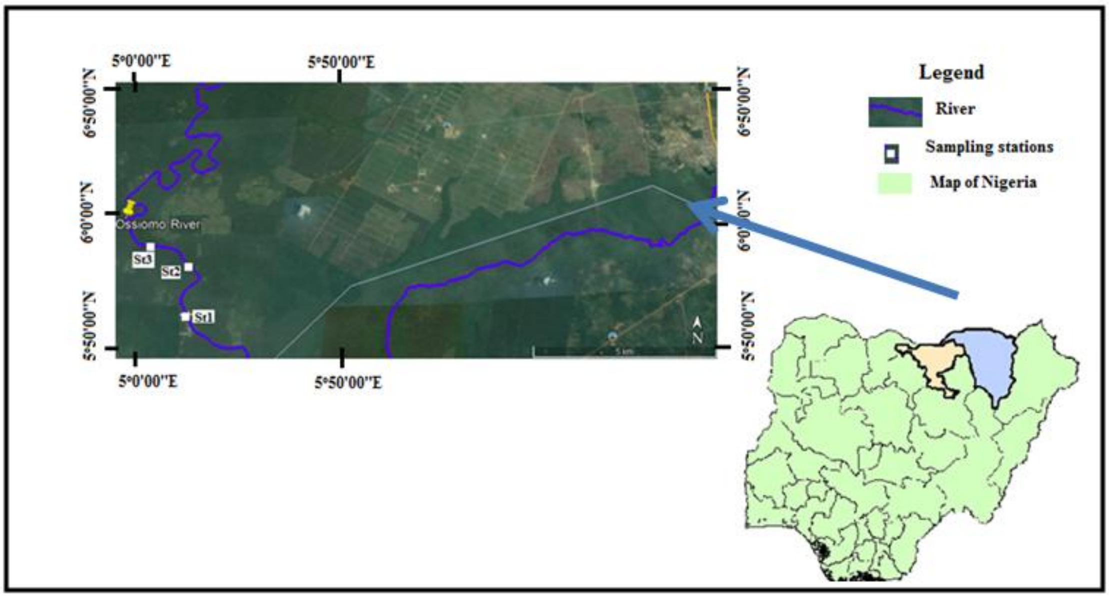

Fig. 1. Map of the study area showing the sampling stations

A portable dissolved oxygen meter (DO STARTER300D, ±1% made by OHAUS Corporation, USA) was used for the determination of DO while a Pocket-sized pH meter (pHep®, ± 0.1 made by HANNA LTD, England) was used in determining pH. TDS, TSS and conductivity were determined via a pocket-sized dissolved solids and conductivity meter with temperature compensation (TDS & EC hold, ±2% made by Griffin Company, USA). Turbidity was determined using turbidometer. To analyze for alkalinity, BOD, sulphate, phosphate and nitrate, separate water samples were collected on each station using sterile bottles of 50ml, and they were determined at the laboratory following APHA [13] methods.

2.3 Fish Sampling and Identification

Simultaneously, during physico-chemical variables analyses per station, fish samples were also collected. Fish sampling was done by fishermen who were contracted during the sampling exercise. The fishermen were briefed on the aim of the study before they embarked on the fishing exercise, and they were monitored closely to ensure they followed the appropriate procedures for fishing. Beach seine and cast nets were used for sampling of fish at each sampling station.

Identification of fish species were done at the laboratory using identification guides by [12] and [14]. After which enumeration of the fishes were done.

2.4 Data Analysis

The mean, standard deviation and range of physico-chemical variables were conducted on the Univariate function of PAST [15]. In determining the mean values differences of the physico-chemical variables, a one-way analysis of variance (ANOVA) was calculated using PAST [15]. Turkey pairwise analysis using honestly significant difference (HSD) was used to confirm station means of physico-chemical variables that differed in means.

The relationship between the sampled stations and physico-chemical variables was determined using principal component analysis (PCA). On the other hand, the relationship between physico-chemical variables and fish taxa among the sampled stations was determined using canonical correspondence analysis (CCA). In order to confirm the level of significance between the CCA first two axes, a Monte-Carlo permutation test at 999 permeations was conducted. PCA and CCA were constructed using PAST [15].

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Environmental variables

The mean, standard deviation and ranges of the physico-chemical variables in the study area is presented in Table 1 below. The temperature was lowest in station 2 (25.91$\pm$0.89^{o}C) and the highest was in station 1 (26.72$\pm$0.96^{o}C). BOD (1.24$\pm$0.68mg/l), alkalinity (48.30$\pm$11.36mg/l), TSS (5.53$\pm$1.89mg/l) and sulphate (1.26$\pm$0.32mg/l) mean values were lowest in station 2, while pH (5.94$\pm$0.48), DO (8.64$\pm$1.57mg/l), turbidity (7.48$\pm$7.63NTU), TDS (29.64$\pm$14.65mg/l) and phosphate (0.43$\pm$0.31mg/l) mean values were highest in station 1. Conductivity (70.87$\pm$26.42µS/cm) and nitrate (0.49$\pm$0.34mg/l) mean values were highest in station 3. The one-way ANOVA conducted revealed that temperature, conductivity, DO, TDS, alkalinity, TSS, sulphate, phosphate and nitrate were significantly different among the three stations sampled ($P<0.05$). On other hand, pH, BOD and turbidity were not significantly among the three stations sampled ($P>0.05$).

3.1.2 Correlation between environmental variables and stations

In correlating physico-chemical variables with stations sampled, we constructed a Principal Component Analysis (PCA) biplot. The result of the PCA showed that conductivity was positively associated with station 3, and temperature, TDS and alkalinity were negatively associated with stations 1 and 2 (Fig. 2). The eigenvalues of the first axes of the PCA were 2.98 and 0.012, respectively, while the total variance of the first two PCA axes were 99.39% and 0.41%, respectively revealing that axis 1 showed more variation in the correlation than station 2.

3.1.3 Fish species community structure

A total of 2,324 fish individuals were recorded in the entire study period (Table 2). The fish species collected in River Ossiomo belong to 29 taxa. Station 1 harbour more of fish species (1018), followed by station 2 (809), and station 3 (497) had the lowest fish individuals.

Table 1. Means, standard deviations and ranges (in parenthesis) values of physico-chemical variables in River Ossiomo, Niger Delta, Nigeria. F-values and P-values as revealed by one-way analysis of variance (ANOVA). Physico-chemical variables per station with the same superscript letters shows no significant differences (P>0.05) as revealed by Turkey Honestly Significant Difference

Variables	St1	St2	St3	F-value	P-value
Temperature (^{o}C)	26.72±0.96 (25.11-28.14)^{ab}	25.91±0.89 (24.12- 27.4)^{b}	26.18±0.94 (25.0-28.19- 2)^{ab}	2.28	0.0089
Conductivity (µS/cm)	60.06±22.08 (8.64- 96.62)^{a}	57.87±27.45 (23.18– 98.32)^{a}	70.87±26.42 (29.6-133.61)^{a}	2.20	0.0080
pH	5.94±0.48 (5.21-6.92)^{a}	5.75±0.47 (4.92-6.57)^{a}	5.64±0.40 (5.08-6.28)^{a}	0.76	0.82
DO (mg/l)	8.64±1.57 (5.06-11.82)^{ab}	6.89±1.65 (4.34-10.34)^{b}	6.20±1.12 (5.11-9.12)^{b}	1.78	0.049
BOD (mg/l)	1.24±0.68 (0.14-1.99)^{ab}	2.07±0.98 (0.31-4.14)^{b}	1.67±0.88 (0.23-3.32)^{ab}	1.44	0.15
Turbidity (NTU)	7.48±7.63 (1.01-28.57)^{a}	7.28±6.86 (3.19-3.1)^{b}	4.67±0.76 (3.27-5.93)^{a}	0.71	0.81
TDS(mg/l)	29.64±14.65 (12.61-67.14)^{a}	29.18±10.04 (17.18-48.91)^{a}	25.22±11.26 (6.84-47)^{a}	3.28	0.00030
Alkalinity (mg/l)	48.30±11.36 (27.14-62.41)^{a}	56.62±24.91 (21.19-91.14)^{a}	55.23±25.91 (23.12-96.94)^{a}	2.49	2.03E-08
TSS(mg/l)	5.39±1.21 (2.14-7.51)^{a}	5.53±1.89 (2.04-10.19)+	5.33±1.58 (3.02-7.61)^{a}	2.49	0.0042
Sulphate (mg/l)	1.26±0.32 (0.12-2.58)^{a}	1.75±0.74 (0.21-2.64)^{a}	1.44± 0.81 (0.24-3.21)^{a}	2.95	0.00089
Phosphate (mg/l)	0.43±0.31 (0.02-0.99)^{a}	0.41±0.21 (0.09-0.71)^{a}	0.37±0.22 (0.04-0.91)^{a}	2.19	0.012
Nitrate (mg/l)	0.37±0.21 (0.04-0.76)^{ab}	0.21±0.078 (0.1-0.99)^{b}	0.49±0.34 (0.06-0.99)^{ab}	1.67	0.068

Note: stations with the same alphabet showed no significant difference in physico-chemical variables

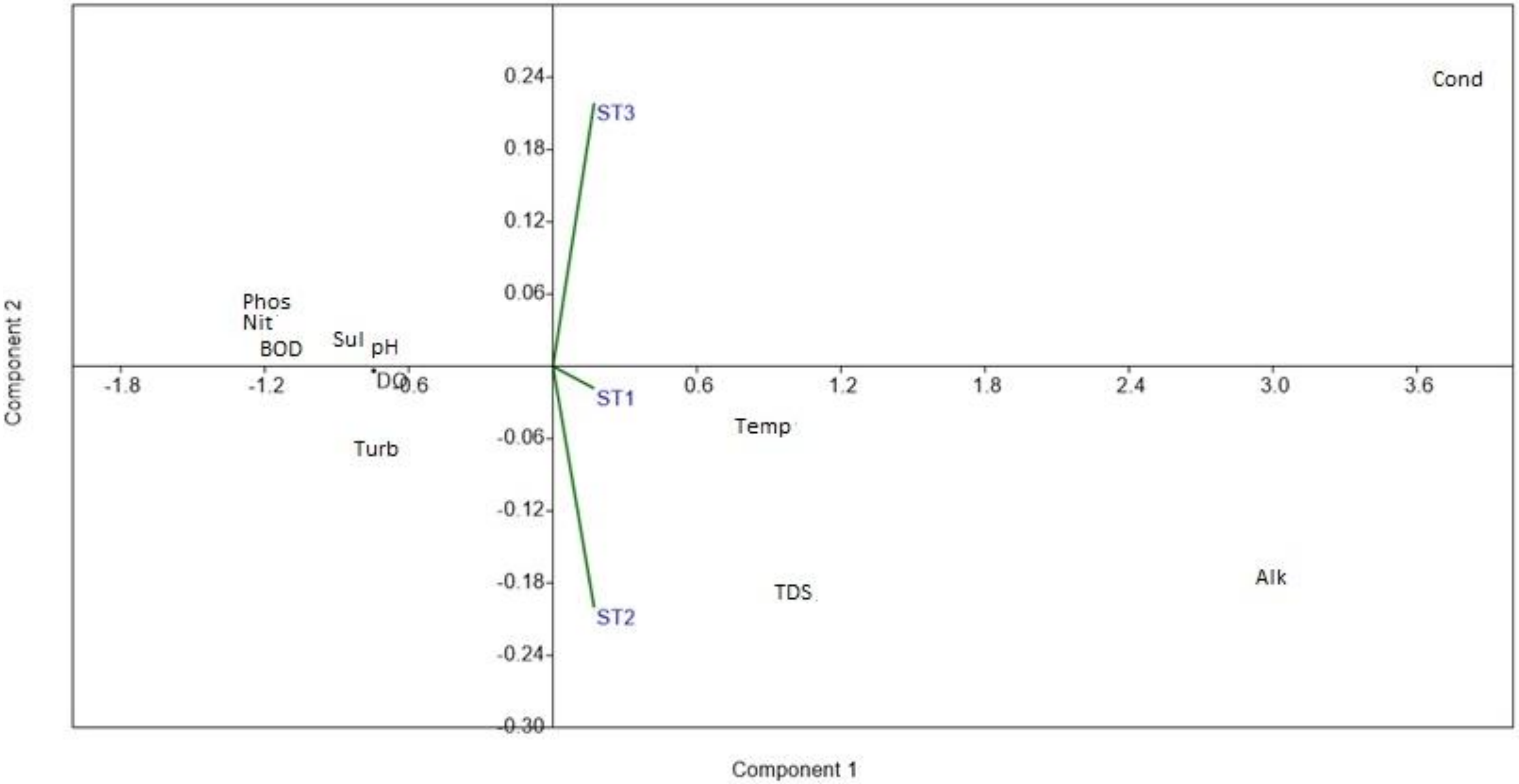

Fig. 2. Principal component analysis (PCA) showing the correlation between physico-chemical variables and sampled stations of River Ossiomo, Niger Delta, Nigeria

Abbreviations: *Temp (temperature), Cond (conductivity), DO (dissolved oxygen), BOD (biochemical oxygen demand), TDS (total dissolved solids), TSS (total suspended solids), Alk (alkalinity), Turb (turbidity), Phos (phosphate), Sul (sulphate) and Nitr (nitrate)*

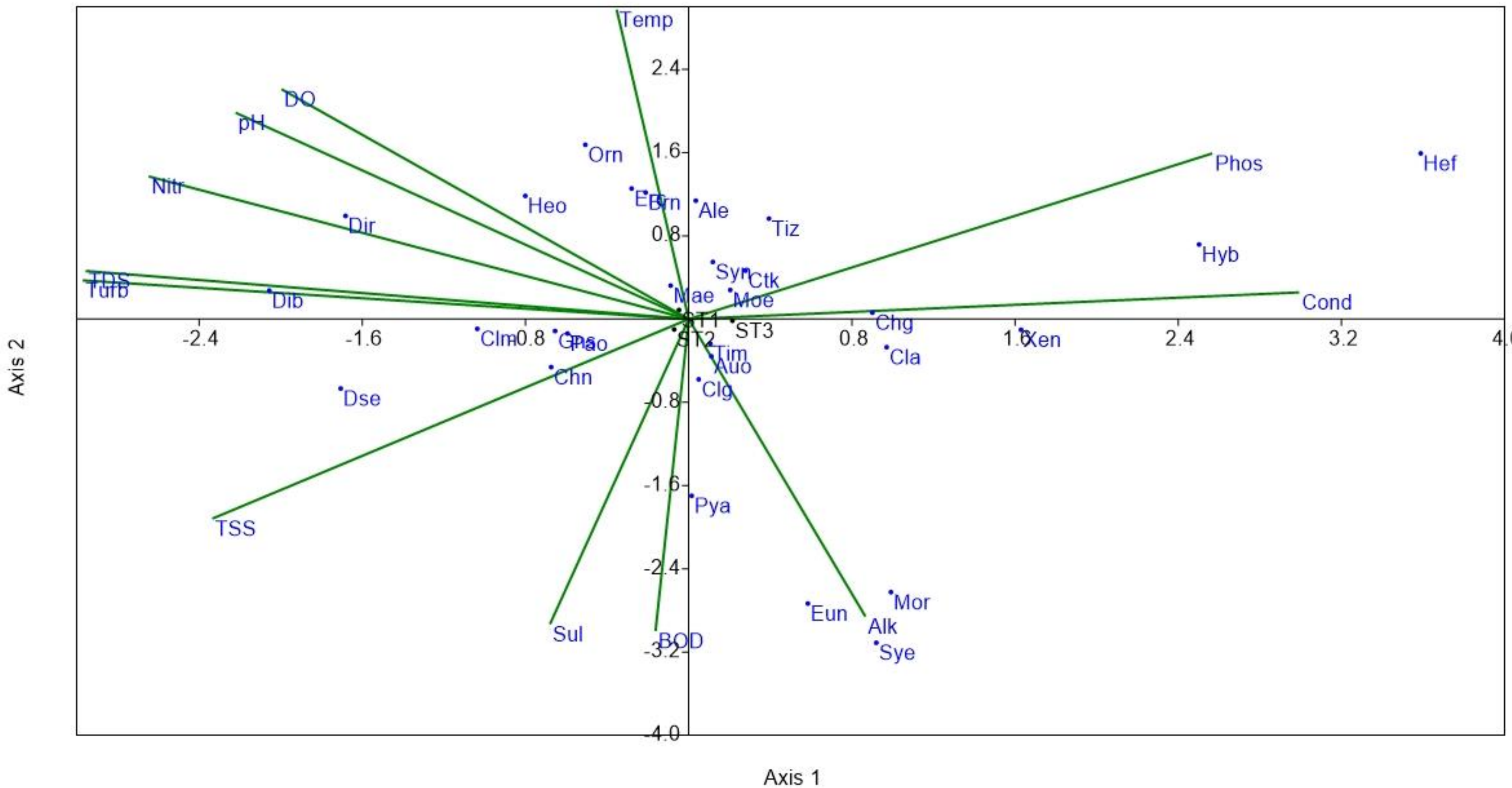

Fig. 3. Canonical correspondence analysis (CCA) triplot showing the relationship between environmental variables and fish species in the sampled stations of River Ossiomo, Niger Delta, Nigeria

Fish species code: *please refer to Table 2.*

Table 2. Fish community structure of River Ossiomo, Niger Delta, Nigeria

Fish species	Codes	ST 1	ST2	ST3
Cteropoma kinsleyae	Ctk	18	13	9
Auchenoglanis occidentalis	Auo	92	78	48
Chrysichthys nigrodigitatus	Chn	73	64	31
Parachanna obscura	Pao	69	57	29
Brycinus nurse	Brn	22	14	9
Alestes longipinnis	Ale	25	16	11
Chromidotilapia guentheri	Chg	43	33	26
Hemichromis fasciatus	Hef	25	12	22
Oreochromis niloticus	Orn	61	36	22
Tilapia mariae	Tim	35	29	18
Tilapia zilli	Tiz	49	32	24
Clarias macromystax	Clm	52	43	19
Clarias anguillaris	Cla	33	27	21
Clarias garipenus	Clg	78	69	41
Distichodus engycephalus	Dse	26	24	8
Distichodus brevipinnis	Dib	29	23	7
Distichodus rostratus	Dir	23	16	6
Hepsetus odoe	Heo	26	17	9
Malapterarus electricus	Mae	52	39	24
Synodontis eupterus	Sye	9	13	8
Synodontis nigita	Syn	21	15	10
Gnathonemius senegalensis	Gns	17	14	7
Hyperopisis bebe occidentalis	Hyb	19	12	15
Mormyrus rume	Mor	13	17	11
Mormyrus engystoma	Moe	20	15	10
Papyrocranus afax	Pya	22	24	13
Xenomystus nigri	Xen	18	14	13
Erpetoichthys calabaricus	Erc	30	19	12
Eutropius niloticus	Eun	18	24	14
Total		**1018**	**809**	**497**

Auchenoglanis occidentalis was the most preponderant fish species with 92, 78 and 48 individuals, respectively, followed by *Auchenoglanis occidentalis* with 73, 64 and 31 individuals in stations 1, 2 and 3, respectively (Table 2). The least abundant fish species was *Synodontis eupterus* with 9, 13 and 8 individuals in stations 1, 2 and 3 respectively (Table 2).

3.1.3 Relationship between fish species and environmental variables

The CCA Axes 1 and 2 explained 64.47% and 35.53% of the ordination respectively. Axes 1 and 2 eigenvalues were 0.012 and 0.0068 respectively. Monte-Carlo permutation test performed revealed that there were no significant differences in the first two axes of the CCA correlation with fish species and physico-chemical variables (P>0.05). Nitrate, TDS and turbidity were positively correlated with *Distichodus brevipinnis*, while phosphate and conductivity were positively correlated with *Cteropoma kinsleyae, Tilapia zillii, Malapterarus electricus, Mormyrus engystoma, Synodontis nigita (*Fig. 3*).* On the other hand, TSS was negatively correlated with *Chrysichthys nigrodigitatus* and *Distichodus engycephalus* (Fig. 3). Alkalinity was positively correlated with *Eutropius niloticus*, *Mormyrus rume* and *Synodontis eupterus* (Fig. 3).

3.2 Discussion

Physico-chemical variables were examined to determine the level of degradation going on in River Ossiomo in the Niger Delta area of Nigeria. Higher concentration of pollution indicating physico-chemical variables such as BOD, turbidity, sulphate and nitrate were noticed in station 2, the heavily polluted stations. For instance, BOD, turbidity, sulphate and nitrate were proportionately higher in station 2 confirming the level of degradation posed by the presence of the wood mill factory and unplanned human settlement in the station. The result is in consonance with earlier report by [16], who reported higher concentration of physico-chemical variables in sites close to communities and mining sites. Further, [2] also affirmed the deleterious effect of pollutants coming from nearby by industrial sites as the major cause of poor water quality most especially in the Niger Delta area of Nigeria. This may be due to the presence of oil exploration outlets and other industrial outlets. Edegbene et al. [4] accentuated the effect of urbanization on the water quality of riverine systems within the Niger Delta area of Nigeria. They asserted that runoff from nearby farm lands and unplanned settlements are the major culprit affecting the ecological balance of rivers in the Niger Delta area of Nigeria.

Confirming the less human impact occurring in station 1, the dissolved oxygen (DO) concentration of station 1 was relatively higher than the other two stations. Overall, the DO concentrations in the three stations were within the maximum limit set by World Health Organization [17] and Standard Organization of Nigeria [18]. The principal component analysis (PCA) used to visualize the relationship between sampled stations and physico-chemical variables showed that the stations were delineated based on their level of degradation. For instance, temperature, TDS and alkalinity were negatively associated with station 1, the less impacted station.

A total of 2,324 belonging to 29 taxa were recorded during the study period. Similarly, Muhammad and Saminu [19] recorded 24 taxa in a riverine system in Northern Nigeria. Also, Arimoro et al. [20] recorded 47 taxa in a water body in the Niger Delta area of Nigeria. *Auchenoglanis occidentalis* was the most preponderant taxa in the study river, and immediately followed by *Chrysichthys nigrodigitatus* both in the family Bagridae. Station 2 harbours more of these taxa of fish in the study area. Recently, Edegbene [9] had asserted that Bagridae over the time in Nigeria riverine systems had developed adaptive radiation which enables them to adapt to impact arising from pollution [9]. Contrary to the results of the present study, Arimoro et al. [20] recorded only two taxa of Bagridae unlike in the present study. Victor and Tetteh [8] reported that environmental perturbation affects the pattern of distribution of most taxa of Bagridae most especially *Chrysichthys nigrodigitatus*. However, this was contrary to our result of *Chrysichthys nigrodigitatus* in the present study, further confirming the earlier assertion by [9] that maybe some taxa of Bagridae have developed adaptive mechanisms to withstand pollution.

Our CCA visualization showed that some group fish taxa can be suggested as biological indicators of pollution. For instance, *Distichodus brevipinni*, *Cteropoma kinsleyae, Tilapia zilli, Malapterarus electricus, Mormyrus engystoma, Synodontis nigita* were positively associated with pollution indicating physico-chemical variables, hence they can be said to adapt favourably in a deteriorating riverine systems.

4. CONCLUSION

In this study, we examined the relationship between physico-chemical variables and fish species. We found out that the assemblages of fish taxa in River Ossiomo was patterned by physico-chemical variables, as the river is fast deteriorating due to the presence of wood mill factory and unplanned settlements within the catchments of the study area. Some fish species such as *Tilapia zillii, Malapterarus electricus, Mormyrus engystoma* were suggested as indicators to monitor the ecological health of River Ossiomo, and this can be extended to other rivers within the Niger Delta area of Nigeria. To confirm the present result, we recommend that more detailed studies should be carried out along the stretch of the river.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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