CORRELATIONS BETWEEN PHYSICO-CHEMICAL PARAMETERS AND RELATIVE FISH ABUNDANCE IN ANAMBRA RIVER BASIN, SOUTHERN NIGERIA.

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ABSTRACT

This study investigated the interaction between al parameters and fish abundance in Anambra River Basin. Both fish and water samples were collected between January and November, 2023. Fish samples were identified using keys and water analysis was done following standard protocols and procedures. Physico-chemical parameters and fish abundance vary across the space and time. Nine physiochemical parameters (Turbidity, DO, pH, Sal., EC, TSS, TDS, BOD and Col.) had a significant effect on the variability of the fish abundance among the 21 parameters investigated. Cyprinidae was found in the area of the River Basin with high concentration of TSS and DO. Bagridae was more in abundance in the area s with high concentration of BOD and low concentration of turbidity. Mochokidae and Mormyridae were more on the area of the River Basin where turbidity is high with low BOD. Channidae was found to be abundantly more in area with high concentration of EC and TSS. Clariidae and Characidae were found more abundance in area of the River Basin where the level of colour was high with low salinity. Cichldae family was found more in the area of the River basin with high concentration of salinity while the Malapteridae and Citharidae families were found more in areas with high concentration of TDS and pH and low BOD concentration. The environmental variables, such as pH, Total Suspended Solid (TSS), Total suspended solid (TDS), Dissolved oxygen(DO), and cations interdepend on one another and determine the fish community structure and abundant.

Keywords: *Correlation, physico-chemical, Fish abundance, River.*

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INTRODUCTION

In recent years there has been decline of these fishery which has been attributed to a wide range of causes among which is environmental degradation of the water bodies which significantly affects the physiochemical parameters of the river and consequently affect fish abundance (Odo*et al*., 2009). The physico-chemical parameter alters the fish community structure and population distribution. The changes in both the community structure and population distribution differ in space and time. Anthropogenic activities within and around aquatic ecosystem is capable of alliterating physico-chemical characteristics and or modification of physical habitat. Alterations of characteristics of habitat and physical habitat modification can lead to brief or long-lasting changes in the composition and population distribution of fish assemblages depending on the severity of the disturbance (Jianhua*et al.*, 2011). Over exploitation of water resources, over fishing, oil pollution, and the alteration of riparian environments are the mostly listed as the most important stressors that affect both community structure and population distribution of fish (Doadrio and Aldeguer, 2007).The consequences of anthropogenic activities and modification of physical habitats do not affect to population of fish but equally lead to low fish catch; thus crippled down to livelihood of fisher.

The spatial and temporal variations of the fish abundance and its relationship with physic-chemical parameters of Anambra River Basin are poorly documented. For sustainable manage and conserve, and to know their status of the fisheries, there is an urgent need to update the information on the spatial and temporal fish diversity, community structure and distribution patterns (Ngor*et al*., 2018). Therefore, the present study investigated the spatial and temporal variation of fish abundance with environmental correlates in Anambra River Basin.

Materials and Methods

Study Area

Anambra River Basin spatially lies between latitudes 6^0 00'N and 60 30'N and longitudes 6° 45'E and 7° 15'E. The river is at the South-Central region of Nigeria, close to the east of the Niger River into which it empties (Obiakor*et al.*, 2014). Anambra River is approximately 207.4 km to 210 km in length (Odo, 2004), rising from the Ankpa hills (ca. 305-610m above sea level) and discharging into River Niger at Onitsha (Odo, 2004]. The entire River basin drains an area of 14014km^2 (Odo, 2004).

The major fishing stations along this Anambra river basin includes the Ogurugu, Otuocha and Otu-Nsugbe fishing stations.

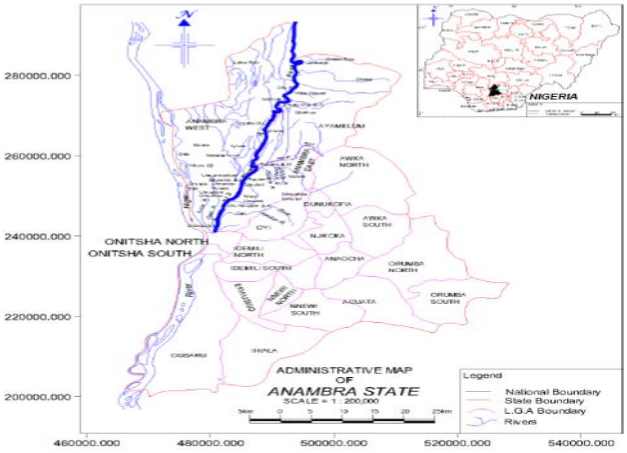

Figure1: Map of study area

Description of Study Sites

Ogurugu fishing Community

Ogurugu fishing Community (N06^O 47".285 and E 006^O 56".485)is upstream, located in Ogurugu Community in Uzo-uwanilocal Government, Enugu North, Enugu. Numerous anthropogenic activities such as laundry, swimming, fishing, extraction of drinking water, manual sand mining, and farming (rice, cassava), at flood plain, transportation of different goods and human being and lumbering. The surface was partially canopied with aquatic plants and the flow velocity was moderate.

Otuocha Fish Community

Otuocha Fish Community **(**N06^{O} 20''.307, E 006 ^{O} 50''.336) is located in Otuocha community in AguneriLocalGovernementArae of Anambra State. Otuocha fish landing is located about 210 km down stream of Ogurugu with big market along it bank Human activities observed include transportation of people with canoe, washing of different items, fishing, farming of rice, cassava and yam along its flood plain and extraction of water for irrigation during the dry season cropping

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Out-Nsugbe Fishing Community

Out-Nsugbe (N 06^{O} 16'' .713, E 006 ^{O} 48″.738) is located in Nsugbe at Anambra River floodplain. Out-Nsugbe is about 17 km downstream of Otuocha. Anthropogenic activities observed within and along the river are farming activities, mechanical dredging, fishing and transportation via canoe

Water Sample Collection

The water sample of the river stations were collected from January to November 2023 covering the dry and rainy seasons. The water samples for the analysis of the physiochemical parameter were collect 3 times in a month using the stratified random sampling approach. The strata include the first week of the month (between 1st -7th), middle of the month (between 12th -18th) and last week of the month (between 24th -30th). The average value from the three times collected in the month is recorded as the month's parameter value. All other parameters were determined in following standard protocols and procedures.

Fish Sample Collection and Identification: Fish samples from 10 local fisher-folks landing were utilized to characterize the abundance of each fish. Fish specimens was identified from monographs, description checklist and fish identification guide of Olaosebikan and Raji (1998), Idodo-Umeh (2003) and Fish Base databases (Froese and Pauly, 2017).

Data Analysis

Data collected were analyzed using PCA and CCA

Results and Discussion

Spatial and temporal variation of fish family Abundance

The spatio-temporal variations of *Mormyridae* are shown in table 2. The values ranged between 206 and 6,571 individual fish. The highest value was recorded in Otuocha (June 2023) while the lowest value was recorded in Otuocha (November, 2023). The spatio-temporal variations of *Mochokidae* are shown in table 2. The values ranged between 272 and 8,147 individual fish. The highest value was recorded in Otuocha (June 2023) while the lowest value was recorded in Otuocha (November, 2023). The spatio-temporal variations of *Claridae* are shown in table 2. The values ranged between 213 and 3,741 individual fish. The highest value was recorded in Otuocha (June 2023) while the lowest valuewas recorded in Otu-Nsugbe(August, 2023). The spatio-temporal variations of *Bagridae* are shown in table 1. The values ranged between 223 and 8,123 individual fish. The highest value was recorded in Otuocha (May, 2023) while the lowest valuewas recorded in station (July, 2023). The spatio-temporal variations of *Citharidae* are shown in table 2. The values ranged between 80 763 individual fish. The highest value was recorded in Otuocha (June 2019) while the lowest value was recorded in Otu-Nsugbe(May,2019). The spatio-temporal variations of *Characidae* are shown in table 1. The values ranged between 250 and 5,170 individual fish. The highest value was recorded in Otuocha (November, 2023) while the lowest valuewas recorded in station 3(July, 2023). The spatio-temporal variations of *Cyprinidae* are shown in table 2. The values ranged between 273 and 8,1862 individual fish. The highest value was recorded in Otuocha (October, 2023) while the lowest value was recorded in Ogurugu (August, 2023). The spatio-temporal variations of *Channidae* are shown in table 1. The values ranged between 269 and 6,276 individual fish. The highest value was recorded in Otuocha (October, 2023) while the lowest value was recorded in Ogurugu (October, 2023). The spatio-temporal variations of *Cichlidae* are shown in table 2. The values ranged between 213 and 7,681 individual fish. The highest value was recorded in Otuocha (October, 2023) while the lowest value was recorded in Ogurugu (July, 2023). The spatio-temporal variations of *Malapteridae*are shown in table 1. The values ranged between 287 and 5,982 individual fish. The highest value was recorded in Otuocha (February, 2023) while the lowest value was recorded in Otu-Nsugbe(May, 2023). The spatial and seasonal variation of fish abundance would guide fisher when(month) to go for fishing and fishing gears to employ for fishing with respect to the family of fish available with their catchability.

Table 1: Spatio-temporal Distribution and Relative abundance of predominant fish family in Anambra RiverBasin

Fish family / Month	*Mormyridae*	*Mochokidae*	*Claridae*	*Bagridae*	*Citharidae*	*Characidae*	*Cyprinidae*	*Channidae*	*Cichlidae*	*Malapteridae*
Feb. Ogurugu	1963	5040	2520	573	1431	280	851	1123	1403	841
Otuocha	4041	7402	6390	4819	4072	1482	6143	5542	4631	5982
Otu-Nsugbe	1682	2528	231	1892	231	1076	1472	1872	1602	1452
Mar. Ogurugu	1400	4213	1462	840	1124	582	274	804	554	1023
Otuocha	2210	1487	2591	1421	365	1832	1110	7421	1121	1502
Otu-Nsugbe	823	621	401	1253	612	1190	1298	298	1870	1480
Apr. Ogurugu	794	1254	490	925	1490	541	319	621	893	1430
Ouocha	1092	5980	1102	1023	5481	2543	2942	1398	1780	798
Out-nsugbe	1472	1253	412	1040	398	245	612	801	428	631
May Ogurugu	307	809	527	613	835	592	3469	1013	1183	506
Otuocha	1853	736	1921	8123	1489	370	2214	380	4810	2254
Out-Nsugbe	1280	272	1798	478	229	632	417	642	678	287
Jun. Ogurugu	1120	561	1960	4280	265	849	912	1135	289	308
Otuocha	1456	2570	412	3321	7631	1458	3709	751	1123	2091
Otu-Nsugbe	206	821	234	1608	675	401	1056	441	246	453
Jul. Ogurugu	812	1940	1678	294	344	568	618	835	213	831
Otuocha	1103	2954	1852	365	1102	2124	1840	2231	1012	1480
Otu-Nsugbe	412	212	620	223	1450	250	1260	892	643	421
Aug. Ogurugu	1125	2208	491	254	80	1189	273	541	278	315
Otuocha	2267	3240	2547	2124	721	812	1942	342	1792	712
Otu-Nsugbe	581	842	213	623	416	1042	789	1420	842	609
Sep. Ogurugu	1680	392	582	272	310	297	826	567	1963	1128
Otuocha	3219	4809	2967	4412	261	4062	5134	2530	5932	3210
Otu-Nsugbe	1153	1241	2319	1465	662	239	425	892	2714	824
Oct. Ogurugu	2241	4760	1389	3648	570	1405	502	269	2504	1562
Otuocha	4390	7032	3741	5142	3421	3264	8862	6276	7681	4071
Otu-Nsugbe	2310	291	3568	2103	1886	413	1674	1254	3571	1909
Nov. Ogurugu	3920	5889	3080	4482	769	1245	1672	1023	1901	2219
Otuocha	6571	8147	435	5902	7032	5170	7362	5914	7023	5190
Otu-Nsugbe	3562	3361	2932	2310	2513	835	2301	1880	3142	1472

3.3.1 PCA Analysis and result

Table 8 presents the principal component analysis results of physico-chemical parameters in station1. The PCA analysis shows that the major principal components of the sample physiochemical parameters were EC, DO, COD. Na, K, Ca, Mg, P, Cl and NO_2 and correlated with one another. These physco-chemical parameters in the first principal component contributes to about 53% (0.5344*100%) of the variation of all the 21 sample physico-chemical parameters of the river in station

Table 3: Principal components of Physico-chemical parameters in Ogurugu

Principal Components 1	Principal Components 2	Principal Components 3
EC (0.30)	pH (-0.36)	BOD (0.45)
DO (0.29)	Sal (-0.34)	Cl (0.40)
COD (0.28)	Turb. (-0.34)	TDS (-0.32)
Na (0.28)	TSS (-0.31)	
K (0.28)	SO_4 (-0.34)	
Ca (0.30)	Col. (-0.22)	
Mg (0.30)	HCO_3 (-0.22)	
P (0.29)		
NO_2 (0.28)		

The physico-chemical parameters, pH, Sal, Turb, TSS, TDS, Col, HCO_3 and SO_4 were closely associated and correlated with one another, with their eigen values all negative. These physiochemical parameters contribute to about 32% (0.3172*100%) of the variation. The third component has BOD, Cl and TDS as its major physiochemical parameters. This third principal component presents a contrast between BOD, Cl and TDS. TDS was negatively correlated BOD and Cl (figure1).

The results show that EC, DO, Na, K, Ca, Mg and P make up the first three principal components. They are closely associated and positively correlated with one another. These physico-chemical parameters contribute to about 45% (0.4538*100%) of the variation of all the 21 sample physiochemical parameters of the river in Otuocha

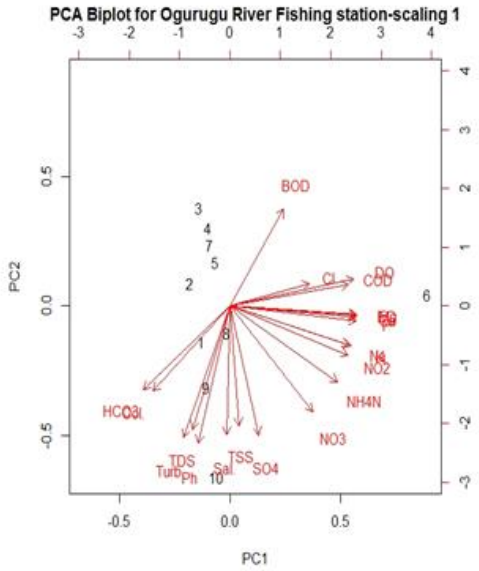


Figure 2. PCA plot in Ogurugu

Table 4: Principal component analysis result of the major principal components of the sample physiochemical parameters in Otuocha.

Principal Components 1	Principal Components 2	Principal Components 3
EC (0.32)	pH (0.31)	Col (0.38)
DO (0.32)	Sal (0.32)	TSS (0.45)
Na (0.29)	BOD (-0.32)	
K (0.29)	Cl (-0.34)	
Ca (0.31)	HCO_3 (- 0.23)	
Mg (0.32)	COD (-0.24)	
P (0.31)	NH_4N(0.24)	

The second components, NH_4N with COD and HCO_3, were negatively correlated. The result of PCA indicated that when NH_4N increases the values of both COD and HCO_3 decrease (fig 2). BOD was also negatively correlated with Salinity and pH; thus, directing that BOD decreases with any increase of Sal. orpH. The physico-chemical parameters in second principal component which explains approximately 28% of the variance of the original variables. The third component explains about 20% of the variation has Col and TSS as its major physiochemical parameters. There was no correlation relationship between two physiochemical parameters (Col and TSS) (Figure 2).

Table 5: presents the principal component analysis result of the physiochemical parameters for station 3. It shows that the first four principal components all have variances greater than one and together accounts for approximately 95.6% of the variance of the original variables hence they can be classified as the major principal components of the sample physiochemical parameters. The significant physiochemical parameters that makes up these four major principal components are shown in table 5. In the first component we have EC, DO, Na, K, Ca, Mg and COD as the significant physiochemical parameters and they contribute to about 39.5% (0.3953*100%) of the variation of all the 21 sample physiochemical parameters of the river in station 3. EC, Ca, Mg and Na are highly positively correlated. Same as NH_4N with P and COD with DO are also positively correlated (fig 3).

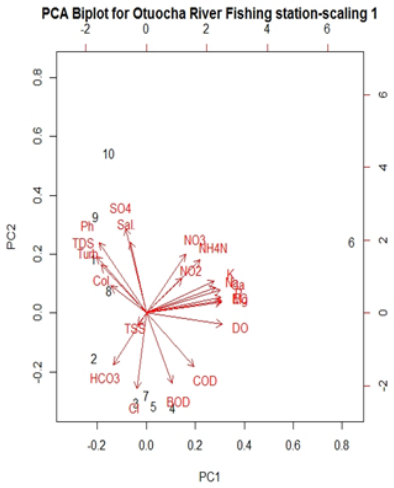


Figure 3. PCA plot in Otuocha

Table 5: Principal components of Physico-chemical parameters in Otu-Nsugbe of Anambra River

Principal Components 1 (Variance = 1.697)	Principal Components 2 (Variance = 1.590)	Principal Components 3 (Variance = 1.428)	Principal Components 4 (Variance = 1.054)
EC (0.34)	pH (-0.37)	Col (-0.35)	P (0.32)
DO (0.33)	SO_4 (-0.36)	Cl (-0.32)	NH_4N (0.29)
Na (0.34)	NO_3 (-0.32)		
K (0.30)	Turb (-0.31)		
Ca (0.34)	BOD (0.31)		
Mg (0.35)	NO_2 (-0.33)		
COD (0.23)			

The second components parameters (pH, Turb, NO_3, NO_2, and SO_4) contributed approximately 30.4% of the variance of the original variables, with their eigen values all negative. BOD was negatively correlated with pH, Turb, NO_3, NO_2, and SO_4 (figure 3). The third component explains 19.8% of the variance of the original variables and is associated with two physiochemical parameters Col and Cl. They both have negative eigen values and their arrows are adjacent to one another as seen in figure 3. Meanwhile the fourth component explains 5.9% of the variance of the original variables and is associated with two physiochemical parameters P and NH_4N. Figure 3 shows these two physiochemical parameters are negatively correlated as their arrows points in opposite directions to one another.

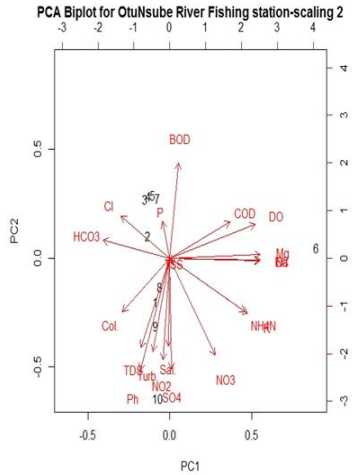


Figure 4. PCA plot in Out-Nsugbe

3.3.2 CCA Analysis and Results

Conical Component Analysis (CCA) was very successful as 100% (0.3515/0.3515 = 1.0000) of total variability of fish abundance was captured by the CCA in all the stations. The association between fish species with respect to their families and physiochemical parameters are shown (fig.4,5 and 6). A fish family closely associated to certain physiochemical parameters in the CCA biplot means that such fish family abundant increases in the area of the river with high concentration or level of such physiochemical parameter. All the CCA biplots in this study present nine physico-chemical parameters that had the significant effect on abundance of fish family in all the stations.

The CCA biplot in figure 4 presents these nine physiochemical parameters (Turbidity, DO, pH, Sal., EC, TSS, TDS, BOD and Col.) that had a significant effect on the variability of the fish abundance among the 21 parameters investigated. It also shows that the first axis of the plot is associated with increasing electrical conductivity (EC) while the second axis is associated with decreasing colour (Col). The analysis pointed out that EC happen to be the most significant physiochemical parameter that contributes to the variability of fish abundance of most families in the Ogurugu while Col., seems to be the least significant physiochemical parameter that contributes to the variability of abundance of most families of fish (fig.4).

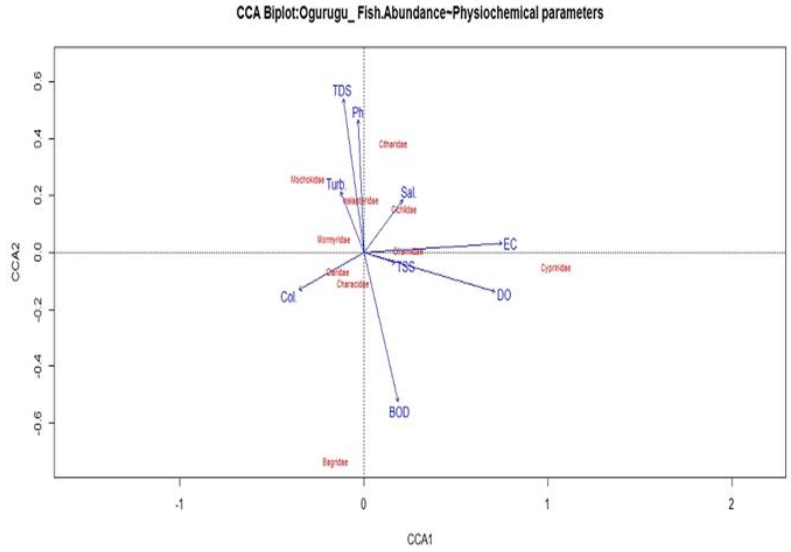
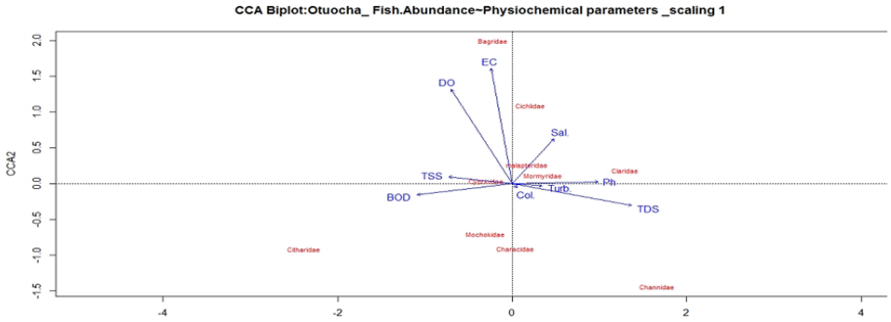


Figure 5: CCA plot in Ogurugu

The CCA biplot that fish species in the family of *Cyprinidae* is associated with TSS and DO and likely to be found abundant in an area of the river with high concentration of TSS and DO. For the species family *Bagridae*, they are seen to be associated to areas with high concentration of and BOD and low level of turbidity while species families *Mochokidae* and *Mornyridae* on the other hand are likely to be abundant in river areas with high level of turbidity and low concentration of biochemical oxygen demand. Fish species in the family of *Channidae* is seen to be likely abundant in areas and the season with high electrical conductivity and total suspended solid (TSS). Fish species in the families of *Claridae* and *Characidae* are likely to be found more in areas of the river and the season with high concentrations colour and low concentration of Salinity. For species family of *Cichlidae*are likely abundant in areas of the river and season with high concentrations of Salinity and the families of *Malapteridae* and *Citharidae* are seen to be abundant in areas in the river and season with high concentration of TDS and high pH level with low concentration of BOD. The CCA biplot, also presents nine physiochemical parameters that had significant effect on the variability of the fish abundance in Otuocha. It is observed from the Biplot that the first axis is associated with increasing salinity while the second axis is associated with decreasing BOD. The analysis pointed out that salinity happen to be the most significant physiochemical parameter that contributes to the variability of fish abundance of most families in the Ogurugu while BOD seems to be the least significant physiochemical parameter that contributes to the variability of abundance of most species families.

The CCA biplot, also presents nine physiochemical parameters that had significant effect on the variability of the fish abundance in Otuocha. It is observed from the Biplot that the first axis is associated with increasing salinity while the second axis is associated with decreasing BOD. The analysis pointed out that salinity happen to be the

most significant physiochemical parameter that contributes to the variability of fish abundance of most families in the Ogurugu while BOD seems to be the least significant physiochemical parameter that contributes to the variability of abundance of most species families.



Salinity, the most significant parameter, accounts for about 37.2% (0.1016/0.263*100) of the constrained variability of fish abundance while biological oxygen demand on the other hand contributes about 0.2% of constrained variability of the fish abundance of the species families.

The CCA biplot, revealed that the family of *Bagridae* is associated with EC and DO.*Bagridae* are likely to be in abundant in the season and the areas of the river with high concentrations of DO and EC. *Cichlidae*and *malapteridae*, they are seen to be abundant in areas in the river with high concentration of Sal., just like in Ogurugu. Families of *Claridae*, is pointed out to be more in abundance in areas in the river with high hydrogen ion concentration (pH level) with low concentration of biochemical oxygen demand (BOD) just like in Ogurugu. Specie family *Cyprinidae* is in abundant in areas of the river and the season with high level of TSS and low turbidity while family *Mormyridae* on the other hand is abundant in with high turbidity and low level of total suspended solids (TSS). Fish species family *Citharidae*, *Mochokidae*, *Characidae* and *Channidae* are seen to be in abundance in distant areas in the river from other species families with no significantly high level of any of the physiochemical parameters.

The CCA biplot of Ogurugu, revealed that only nine physiochemical parameters had a significant effect on the variability of the fish abundance which is the same like in other stations.

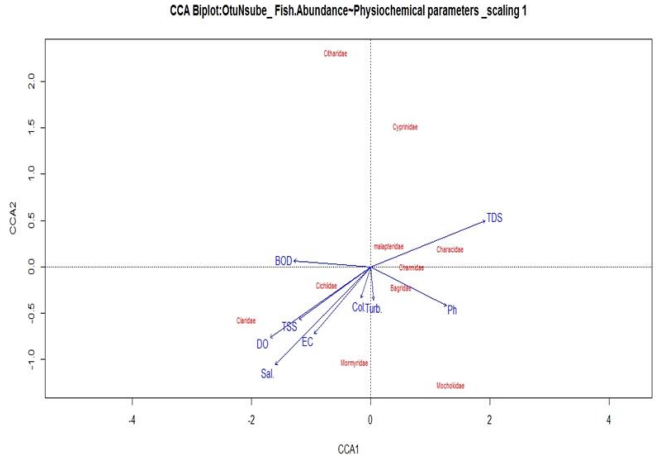


Figure 6. CCA Biplot for Otu-Nsube fishing station

It is observed from the Biplot that the first axis is associated with increasing TDS while the second axis is associated with decreasing biological oxygen demand. The analysis pointed out that TDS happen to be the most significant physiochemical parameter that contributes meaningfully to the variability of fish abundance of most families in the Otu-Nsugbewhile BOD seems to be the least significant physiochemical parameter that contributes to the variability of abundance of most species families. The biplot also shows that species in families of *Characidae* and *Malapteridae* are likely abundant in areas of the river with high concentrations of Total dissolved

solids (TDS) with low concentrations of DO and total TSS. On the other hands, fish species in the families of *Cichlidae* and *Claridae* seem likely to be found in areas with high concentrations of DO and TSS, EC and salinity with low concentrations of Total dissolved solids (TDS). Fish species in the family of *Bagridae* and *Channidae* are likely found in abundance with high hydrogen ion concentration (pH level). Species in the family of *Mormyridae* is seen to be likely found in areas with high turbidity(Turb.) and colour (Col). *Mochokidae*, *Citharidae* and *Cyprinidae* are seen to be likely found more in abundance in distant areas in the river from other species families with no significantly high level of any of the physiochemical parameters.

3.3.4 Discussion

The analysis showed that out of the twenty physiochemical parameters considered in this work, same nine physiochemical parameters had significant effect on the variability of the fish abundance in the three stations. So there is no difference significant in the parameters across the three stations. This is similar to the result obtained in Agali and Edema (2016) where the physiochemical parameters considered depicted no difference in their effect on fish abundance across three stations considered. With respect to fish abundance across the three stations, family of *Mochokidae* and *Bagridae* were the most and second to the most abundance families respectively in this present study. *Odo et al*(2009) reported family of *Mochokidae* as the second most dominant family in the Anambra river basin while in Agali and Edema (2016) reported family of *Bagridae* as the second most dominant fish family in Obueyinomo River located in Edo State, Nigeria. From the CCA biplot, electrical conductivity (EC) happens to be the most significant physiochemical parameter that contributes to the variability of fish abundance for most species families in t Ogurugu while salinity happens to be the most significant physiochemical parameter that contributes to the variability of fish abundance of most species families in station2. In Otu-Nsugbeon the other hand, TDS happens to be the most significant physiochemical parameter that contributes to the variability of fish abundance of most species families. In Lomeli (2011) salinity, DO and pH were the most significant physiochemical parameters on fish abundance in the Humboldt Bay in California. Prasad *et al*. (2020) indicated that dissolved oxygen (DO), pH, hardness, and water temperature are the pivotal environmental parameters to determine fish community structure in the Seti Gandaki River, Tanahu, Nepal

Conclusion

Both season and water quality parameters do affect the abundance of fish families. Only nine physiochemical parameters (Turbidity, DO, pH, Sal., EC, TSS, TDS, BOD and Col.) had a significant effect on the variability of the fish abundance based on Principal Component Analysis (PCA).

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Conflicts of interest

The authors hereby state that this research work and manuscript production complied with ethical standards and none of the authors have any potential conflict of interest. We further declare that this research was not funded by any agency.

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