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Limnological properties and phytoplankton as indicator of pollution, Choba segment, New Calabar River, Port Harcourt Nigeria

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Abstract

The limnological properties and phytoplankton as pollution indicator was studied for three Months between February and April,2022. Water and phytoplankton samples were collected from three stations following standard method of APHA using 45µm mesh size plankton net and plastic bottles for phytoplankton and physicochemical variables respectively. The results showed that some of the physicochemical variables studied had their mean values, pH (6.23±0.69), dissolved oxygen (DO)(5.60±0.11 mg/l), electrical conductivity (EC)(280.00±7.0 µs/cm), sulphate (SO4) (83.00±1.00 mg/l) and turbidity(4.91±0.43 cm) within the permissible limits of WHO while others were above the limits. The results also showed that all the variables did not show significant difference spatially at $p<0.05$ except BOD, EC and NO_3. Most of the variables recorded the highest values in March except NO_3 with SO_4 and NO_3 recording the highest values in station 2. A total number of 31 species of phytoplankton belonging to the five taxonomic groups in the order, bacillariophyceae, cholorophyceae, cyanophyceae, chrysophyceae and xanthophyceae were identified. Phytoplankton species identified to be pollution indicator species were *Navicular sigma, Cyclotella combata, Cyclotella operculata, Spirogyra sp, Anabaena affinis, Anabaena flus-aqua, Microcystis pulvenca, and Oscillaria lacustris.* The total abundance of phytoplankton was highest in station 2 (1,508 Ind/ml) but lowest in station 1(1,144 Ind/ml). Considering the values of some of the physicochemical variables which were above the permissible limits of WHO and the occurrence of some pollution indicator species, Choba segment of the New Calabar River is considered to be at the verge of been threatened/polluted. Therefore, adequate measures should be put in place to regulate the anthropogenic activities in the area.

Keywords: Limnological Properties; Water Quality; Phytoplankton; Pollution Indicator Species; Port Harcourt

1. Introduction

Considering the significance of water to life, it is an indispensable natural resource globally which all life forms depend upon for survival (1). Several studies have shown that anthropogenic activities such as mining, agricultural activities, household waste production, urbanization and other industrial processes contributed to the pollution load of the aquatic ecosystems thus altering the limnological status and community structure of aquatic biota including micron-invertebrates (phytoplankton) and macroinvertebrates such as bivalves (2-5).

According to (6), plankton has been reported by researchers as the reflection of the hydro-environmental condition per time, hence acting as bio-diagnostic components that point to the health status of the aquatic ecosystem. (7) and (8) opined that phytoplankton serves as bio-indicators monitoring the array of water chemistry condition. (9) opined that phytoplantkton are micro-plants organisms without distinct roots, stems and leaves. (10) reported phytoplankton

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community to play vital role in aquatic ecosystems as bio-indicators and primary producers, providing for carbon fixation, oxygen and food production.

According to (11) phytoplankton species survive and develop in diverse aquatic habitats while different species are restricted to defined niche with respect to their physiological requirements and environmental limitations. Since water bodies serve as habitats to a variety to organisms, response to the stressors may vary among the producers and consumers. According to (12) phytoplankton community structure might change in line with the nutrient's status and other regulating factors, which may affect community in either way or could lead to general loss of biodiversity.

(13) opined that phytoplankton assemblages are generally, more sensitive to pollution than other assemblages. According to (14) phytoplankton are the best biological indicators of pollution in the aquatic environment. Water framework Directive (WFD) (2000/60EC, 15) disclosed that phytoplankton is one of the five biological quality elements (phytoplankton, macrophytes, phytobenthos, macro invertebrates and fish) requiring ecological status assessment in water surface. The quality and quantity of phytoplankton is a function in part of the nutrient load. Phytoplankton responds to low dissolved oxygen levels, high nutrient levels (eutrophication) and toxic contaminants. (16) opined that water quality assessment systems is a function of the number or diversity of taxa from different algal groups which are dominants and indicators species.

Anthropogenic activities within and outside the New Calabar River render the water unsafe for human consumption and also affect the organisms in the river. Despite these, there is a knowledge gap especially on the limnology of the New Calabar River. This study is therefore aimed at ascertaining the pollution level of the river by assessing the water quality and phytoplankton structure/diversity of the ecosystem.

2. Material and methods

2.1. Study Area

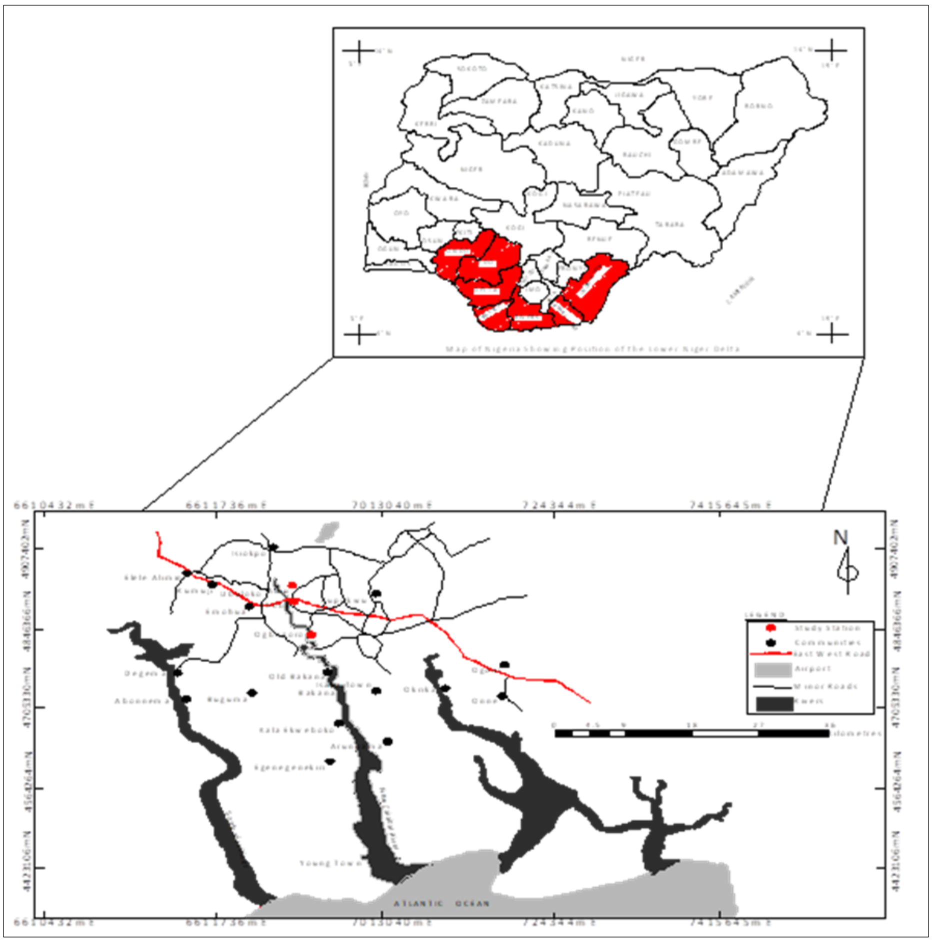

Figure 1 Map of the Study area showing the sampling station

The New Calabar River stretches across several communities from Iwofe through Ogbakiri, Ogbogoro Choba and Aluu and lies between longitude $006^0$53 530^0 56E and latitude 04^0 53' 1.9020'N in Choba River (Figure 1). This river is a fresh water type surrounded by residential communities, oil companies abbatoirs, manufacturing companies and transportation (17).

Sample collection, preparation and Laboratory Analysis, samples were collected from three geo-reference stations using GIS tools. Water samples were collected in amber bottles and clear plastic bottles to test for the physicochemical parameters, biological oxygen demand (BOD), sulphate (SO_4), sulphate(PO_4), nitrate(NO_3) electrical conductivity(EC), dissolved oxygen (DO), pH and temperature using standard method of (18). Phytoplankton samples were also collected using 45μm mesh size plankton net to provide a quantitative account of the microalgae. Collected samples were fixed with 2% formalin and transported to the laboratory for analysis where microalgae were sorted from samples, identified and classified into different taxa using the phytoplankton guide (ROPME) oceanographic cruise identification keys.

2.2. Data Analysis

The values obtained were subjected to different statistical tools for descriptive and inferential statistics. Spatial variations of the physicochemical parameters and phytoplankton calculated were determined using analysis of variance (ANOVA) with values considered significant at $p<0.05$ levels.

3. Results

The result of the limnological properties of the area studied are as presented on Table 1-3 below. Temperature value ranged between 29.50 and 30.00 ^{0}C with the mean value of 29.83±0.29 ^{0}C (Table1). Temperature value was higher (30.17±0.29 ^{0}C) in station 2 without significant different at $p<0.05$. Table 2).

pH values ranged from 6.00 to 6.69 with the mean value of 6.23± 0.39 (Table 1). pH values showed no significant variation at $p<0.05$ spatially and temporarily (ANOVA) and Duncan multiple range test. DO value ranged between 5.50 and 5.72 mg/l with the mean value of 5.00± 0.11 mg/l (Table 1). DO value was highest in station 3(5.73±0.13 mg/l) and April (5.70±0.17 mg/l) without significant different (Tables 2 and 3).

BOD value ranged between 10.5 and 11.5 mg/l with the mean value of 11.07± 0.5mg/l (Table 1). BOD values were significantly highest (11.87±58 mg/l) in station 1 than stations 2 and 3 at $p< 0.05$. Values were also highest in April (11.70±0.62 mg/l) (Table 3). Electrical conductivity (EC) ranged between 275 and 288 with the mean value of 280.0±7.00 μs/cm(Table 1). EC value was significantly higher in station 3 than stations 1 and 2 at $p<0.05$. EC value was highest (283.3±13.87us/cm) in march but lowest in April (277.3±12.01 us(cm).

The values of the nutrients (NO_3, SO_4 and PO_4) are as in Table 1-3. Only values showed significant difference with station 2 different from stations 1 and 3 while $S0_4$ and PO_4 showed no significant difference across the stations. NO_3 and $S0_4$ values were both highest in station 2 while PO_4 was highest in station 3. All the nutrient varied across the months.

Table 1 Mean Values of Physicochemical Parameters of the River across the Study Period

s/n	Parameters	Mean Values	Minimum-Maximum	WHO (2014)	EPA (2002)
1	Temp(0C)	29.83±0.29	29.5-30.0	25	NS
2	pH	6.23±6.69	6.00-6.69	6.5-8.5	6.5-8.5
3	DO(mg/l)	5.60±0.11	5.50-5.72	5	NS
3	BOD(mg/l)	11.07±0.51	10.5-11.50	10	NS
4	EC(μs/cm)	280.00±7.0	275-288	300	4.7-5.8
5	NO_3(mg/l)	18.43±0.86	17.50-19.20	10	10
6	SO_4(mg/l)	83.00±1.00	82-84	200	250
7	PO_4(mg/l)	0.53±0.09	0.43-0.60	0.5	0.5
8	Turb(cm)	4.91±0.43	4.30-5.50	5	5-25

NS: Not Stated. WHO- World Health Organization, EPA- Environmental Protection Agency

A total number of 31 species of phytoplankton belonging to the five taxonomic groups, bacillariophyceae (14 species) cholorophyceae (8 species), cyanophyceae (6-species), chrysophyceae (2species) and xanthophyceae(1 species) were identified (Table 4-5 and Figure 2) in the Choba segment of the new calabar River. Certain phytoplankton species identified generally known to be pollution indicator species were *Navicular sigma, Cyclotella combata, Cyclotella operculata, Spirogyra sp, Anabaena affinis, Anabaena flus-aqua, Microcystis pulvenca, and Oscillaria lacustris* (Table 4 and 5). The most dominant pollution indicators in this study were *Cyclotella combta*, (11255) *Cyclotella operculata* (916) cells/ml). The total abundance of phytoplankton (total count) per station was highest in station 2 (1,508 Ind/ml) followed by station 3 (1,366 Ind/ml) but lowest in station 1(1,144 Ind/ml). The highest abundance of phytoplankton (1530 cell/m) was recorded in March while the least (130Ind/ml) was recorded in May. In all a total of 4,018 ind/ml of phytoplankton was recorded consisting 2,780 cell/ml (69.19 %) of Bacillatiophycleae, 606 cell/ml (15.08 %) chlorophyceae, 527 ind/ml (13.12 %), 75 ind/ml (1.87 %) and 30 ind/ml (0.75 %) xanthophyceae (Figure 2).

Table 2 Monthly Mean Values of Physicochemical Parameters of the Study Area

Stations	Temp	pH	DO	BOD	EC	NO3	SO4	PO4
Feb	29.83±0.29	6.23±0.09	5.60±0.11	11.07±0.51	280.0±7.0	18.43±0.86	83.0±1.00	0.53±0.09
March	29.83±0.76	6.33±0.29	5.67±0.15	11.57±0.60	283.3±13.67	18.10±1.35	83.33±2.08	0.63±0.06
April	29.50±1.00	6.27±0.25	5.70±0.17	11.70±0.62	277.3±12.0	16.77±1.32	86.67±3.22	0.68±0.03

Table 3 Spatial Mean Value of Physicochemical Parameters in the Study Area

Stations	Temp (0C)	pH	DO (mg/l	BOD(mg/l	EC (µs/cm)	NO_3	SO4 (mg/l	PO4 (mg/l
Station 1	29.50±1.00^a	6.33±0.35^a	5.57±0.13^a	11.87±15.28^a	278.33±15.28^b	16.93±1.53^b	85.00±3.46^a	0.58±0.12^a
Station 2	30.17±0.29^a	6.17±0.29^a	5.67±0.15^a	11.30±0.72^b	278.0±10.0^b	18.87±0.56^a	83.33±3.055^a	0.60±0.07^a
Station 3	29.50±0.50^a	6.33±0.06^a	5.72±0.13^a	11.17±0.29^b	284.3±6.42^a	17.50±1.00^c	85.67±3.51^a	0.67±0.58^a

Table 4 Spatial values (Abundance(cell/ml)) of Phytoplankton in the Study

S/N	Bacillariophyceae	ST 1	ST2	ST3	Total	%
1	**Melosira granulate*	12	4	17	33	0.82
2	**Melosira radiance*	1	15	13	29	0.72
3	*Achiathes gradilina*	60	90	75	225	5.60
4	*Asterionella formosa*	8	12	7	27	0.67
5	*Amphora ornate*	17	24	14	55	1.37
6	**Navicula sigma*	14	16	10	40	0.99
7	*Amphora ovalic*	26	27	19	72	1.79
8	**Cyclotella operculatea*	260	385	271	916	22.80
9	**Cyclotella combat*	295	360	400	1055	26.26
10	*Synedis salliness*	22	19	101	142	3.53
11	*Slephlian allaususioc*	22	29	19	70	1.74
12	*Tatrillan lustrate*	10	5	16	31	0.77
13	*Bacillaria paradoxa*	14	20	15	49	1.22
14	*Gyreceriopha species*	23	7	6	36	0.90

	Total	785	1013	982	2780	69.19
	Percentage	19.54	36.44	35.32	100.00	
	Chlorophyceae					
1	**Spirogyra species*	25	10	25	60	1.49
2	*Volvox globator*	15	10	29	54	1.34
3	*Astidesmus horkerii*	35	26	20	81	2.02
4	*Cloterium diance*	28	22	19	69	1.72
5	*Anabaena spiroides*	27	34	28	89	2.22
6	*Desmidium species*	8	43	25	76	1.89
7	*Netrium digitalus*	19	51	30	84	2.09
8	*Crusigenila species*	27	27	23	77	1.92
	Total	184	223	199	606	15.08
	Percentage	30.36	36.80	32.84	100.00	
	Cyanophyceae					
1	**Anabaena affinis*	6	32	10	48	1.20
2	**Anabaena flus aqua*	30	43	29	102	2.54
3	**Microcystis pulvenca*	30	36	25	91	2.26
4	**Oscilarlorrin laculstris*	25	50	50	125	3.11
5	*Dactilococcopsis species*	19	45	31	95	2.36
6	*Rivilania species*	21	35	10	61	1.52
	Total	131	241	155	527	13.16
	Percentage	24.86	45.73	29.41	100.00	
	Chrysophyceae					
1	*Dinobryon species*	14	10	8	32	0.79
2	*Chromulina ovali*	19	10	14	43	1.07
	Total	33	20	22	75	1.87
	Percentage	44.00	26.67	29.33	100.00	
	Xanthophyceae					
1	*Tribonema species*	11	11	8	30	0.75
	Total	11	11	8	30	0.75
	Percentage	36.67	36.67	26.67	100.00	
	Grand Total	1144	1508	`1366	4018	100.00
	Percentage	28.47	37.53	34.00	100.00	

Note: Phytoplankton species asterisked are the pollution indicator species

Table 5 Monthly values (Abundance(Ind/ml)) of Phytoplankton in the Study Area

S/N	Bacillariophyceae	March	April	May	Total	%
1	**Melosira granulate*	10	14	9	33	0.82
2	**Melosira radiance*	7	13	12	32	0.72
3	*Achiathes gradilina*	45	70	110	225	5.60
4	*Asterionella formosa*	6	11	10	27	0.67
5	*Amphora ornate*	21	24	10	55	1.37
6	**Navicula sigma*	20	11	9	40	0.99
7	*Amphora ovalic*	25	15	32	72	1.79
8	**Cyclotella operculatea*	445	220	251	916	22.80
9	**Cyclotella combat*	350	325	380	1055	26.26
10	*Synedis salliness*	106	12	24	142	3.53
11	*Slephlian allaususioc*	17	26	22	65	1.74
12	*Tatrillan lustrate*	14	3	14	31	0.77
13	*Bacillaria paradoxa*	25	10	14	49	1.22
14	*Gyreceriopha species*	15	6	15	36	0.90
	Total	1106	760	912	2780	69.19
	Percentage	27.53	18.91	22.70	100.00	
	Chlorophyceae					
1	**Spirogyra species*	15	25	20	60	1.49
2	*Volvox globator*	18	25	11	54	1.34
3	*Astidesmus horkerii*	28	35	18	81	2.02
4	*Cloterium diance*	17	23	29	69	1.72
5	*Anabaena spiroides*	28	30	31	89	2.22
6	*Desmidium species*	20	25	31	76	1.89
7	*Netrium digitalus*	36	28	36	100	2.09
8	*Crusigenila species*	11	28	38	77	1.92
	Total	173	219	214	606	15.08
	Percentage	28.55	36.14	35.31	100.00	
	Cyanophyceae					
1	**Anabaena affinis*	20	13	15	48	1.20
2	**Anabaena flus aqua*	55	18	29	102	2.54
3	**Microcystis pulvenca*	30	35	26	91	2.26
4	**Oscilarlorrin laculstris*	70	30	25	125	3.11
5	*Dactilococcopsis species*	30	30	35	95	2.36
6	*Rivilania species*	21	25	20	66	1.52
	Total	226	151	150	527	13.16

	Percentage	43.00	28.65	28.46	100.00	
	Chrysophyceae					
1	*Dinobryon species*	6	16	10	32	0.79
2	*Chromulina ovali*	11	23	9	42	1.07
	Total	17	39	19	75	1.87
	Percentage	22.67	52.00	25.33	100.00	
	Xanthophyceae					
1	*Tribonema species*	7	14	9	30	0.75
	Total	7	14	9	30	0.75
	Percentage	23.33	43.66	30.00	100.00	
	Grand Total	1530	1183	1305	4018	100.00
	Percentage	38.08	29.44	32.48	100.00	

Note: Phytoplankton species asterisked are the pollution indicator species

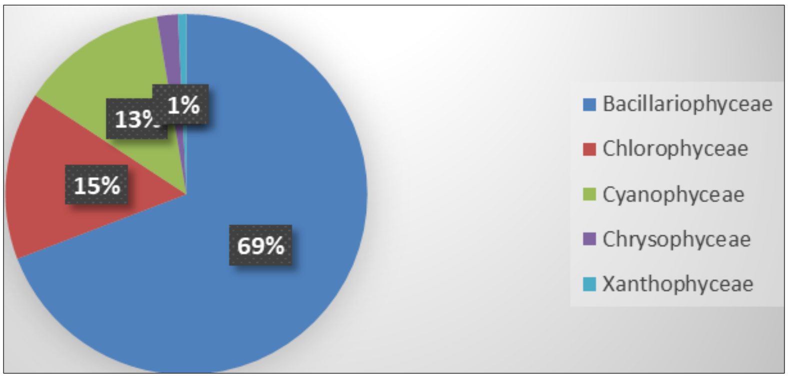

Figure 2 Percentage Composition of Phytoplankton Per Taxa

4. Discussion

It is expected that rivers need to have a healthy ecosystem as well as good water quality status so as to provide the services such as drinking, industrial use, agriculture, transportation and recreation (19-20).

Water temperature is considered as a critical factor influencing biotic and abiotic processes which are capable of affecting the quantum of dissolved matter, organic/inorganic pollutants, nutrients, micro bacterial concentrations, fish and invertebrates' behaviour in the aquatic environment (21). The observed temperature range is in line with the finding of (22) in Sombreiro river. This value is also in tandem with the range (29.30± 0.60 – 29.8± 0.3 ^{0}c and 27.30 – 32.1 ^{0}C) reported by (23) for Douglas and stumps creeks in Akwa Ibom state and (24) in Amadi creek in Rivers state. It was reported that at higher water temperature, water holds less dissolved oxygen which affect fish respiration and metabolism thius causing stress and high mortality rate (25).The observed non-significant difference across the stations could be attributed to similarity in climate and anthropogenic activities.

The observed pH range is though acidic but still within the acceptable range (6.0 and 9.0) required for culturing tropical fish species though may not tolerate a sudden change within the range as opined by (26) and (27). This result is contrary to the range (4.3 -6.3) reported by (28) in Eme river South East Nigeria. This pH is contrary to the acidic to alkaline condition (5.80-8.20) reported by 29) from selected fish ponds at Sunyani, Ghana which was attributed to high rate of decomposition of organic matter in the water. The observed non-significant difference in pH across the stations could be attributed to similarly in anthropogenic activities in the areas.

DO range in this study is within the permissible limit of (27) but below the limit (6 mg/l) permissible by (30) for aquatic life. Fluctuation in DO concentration as noticed in this study could be attributed to variation in anthropogenic activities from the surrounding into the areas. The observed higher concentration of DO in station 3 than other stations could be due to low rate of decomposition of organic matter resulting from low anthropogenic activities in the station. The DO concentration in this study is higher than the mean (4.43± 0.15 mg/l) reported by (31) in Ibuya river. The higher DO concentration in station 3 could also be attributed to low number of phytoplankton hence low respiratory activities in the area. (32) opined that DO content of a river is usually influenced by the decomposition of organic matter inputs from the increased runoffs after rain especially after a period of dryness.

The mean value of BOD obtained in this study exceeded the permissible limit of 3.0mg/l by (30). The observed high BOD across the stations in this study might have resulted from discharge of organic and inorganic pollutants through runoffs from the surrounding anthropogenic activities as opined by (32-33). (34) considered BOD as an indicator of organic pollution in a river. (35) as reported in (22) in Sombriero river opined that high BOD value usually reflect corresponding decrease in DO value.

The mean values of the nutrient (NO_3, SO_4 and PO_4) exceeded the permissible limits of (30) that permit productivity in the aquatic ecosystem except SO_4 which was below the limit. The high concentration of NO_3 and PO_4 in station 2 could be attributed to introduction or influx of organic and inorganic matter due to anthropogenic activities including runoffs laden with fertilizers and pesticides as observed by (36). The observed fluctuations in physicochemical parameters were influenced by the environmental factors and anthropogenic inputs.

The results of this study is comparable to the findings of other researches such as 56 species reported by (37) in the new Calabar River, 43 species by (38) in the loewer Sombriero river, 34 and 20 species reported by (39) from Nkissa and Orashi rivers respectively. However, this result is contrary to the findings of (40) who reported 140 species belonging to 7 classes in Sombreiro river, 198 species reported by (41) in the Ntawoba creek and 169 species reported by (42) in Elechi creek. This is also contrary to the 12 species and 3 families reported by (17) in the New Calabar River. (43) reported 23 species of phytoplankton belonging to two taxonomic groups, diatoms and dinoflagellate in a coastal river in Ondo state Nigeria. Dominance by bacillariophyceae was also reported in Ikpa river by (44), Idumayo river by (12) all in southeast Nigeria but contrary to (45) where cyanophyceae dominated. The dominance of the phytoplankton group by bacillariophyceae in this study is a common feature of fresh and brackish water systems (Rivers and creeks) especially in the Niger delta and in Nigeria in general as opined by (38) and (46). The dominance of phytoplankton by the bacillariophyceae confirms the assertion that diatoms pre-dominate unpolluted natural lotic water bodies in the tropics ((47). The dominance of bacillariophyceae in this study in contrary to the dominance by cyanophyceae reported by (48-50). The dominance of phytoplankton by the bacillariophyceae in this study is contrary to the finding of (51) who opined that high relative abundance of cyanophyceae (blue-green algae) and its presence either in colonial or filamentous form may be indicative of the influence of organic pollution of the water body. (28) observed *Melosira granulata* and *Planktosphaeria gelatinosa* which is contrary to the *Cyclotella combta* and *Cyclotella granulate* dominating in this study. The observed composition of phytoplankton dominated by cosmopolitan and pollution tolerant species such as *Navicula sigma, Cyclotella combta, Cyclotella of opercullata, Spirogyra species, Anabaena affinis, Anabaena flus-aqua Microcystis pulvenca* and *Oscullaria lacustris* is an indication that the New Calabar River is eutrophic /polluted. This therefore confirms the assertion that phytoplankton species have been used as indicator of organic pollution (12,52-55).

Growth and development of chlorophyceae is influenced by environmental factors such as transparency, water temperature, dissolved oxygen, pH and nutrients such as NO_3, PO_4 and S04 (56-57) while low level of DO and BOD, nitrate and PO_4 enhance the growth of diatoms/ bacillariophyceae (58). The observed variation in abundance across the stations and months could be attributed to difference in anthropogenic activities climate change. The higher abundance of phytoplankton in station 2 than other stations (1 and 4) could be attributed to high organic wastes, agricultural runoffs and other anthropogenic activities in the area. The presence of *Microcystis species* is an indication that the water needs to be controlled since it was a member of cyanophyceae categorized as toxic plankton (59-60). (61-63) opined that plankton abundance and diversity can be used as indicator of water fertility. (64) also reported *Microcystis aeruginosa*, *Oscillatoria limnosa* and *Anabaena species* among the pollution indicator species in the pond of Darbhanaga Bihar, India. The dominance of the Cyclotella species in this study is similar to that reported by (45) in the upper Barataria estuary, Louisiana. (65) referred *Microcystis aeruginosa* as an indication of moderate organic pollution while *Oscillatoria limnosa* as a reflection of heavy organic pollutions in fresh to brackish water situations.

5. Conclusion

The impact of anthropogenic activities on the aquatic system could be assessed by the water quality status and the diversity of phytoplankton therein. In this study some limnological variables in some stations were above the permissible limits of some water standard and some phytoplankton considered as pollution indicator species were recorded. The recorded low diversity of species of phytoplankton families depicts that the New Calabar River is at the verge of pollution. It is therefore advisable that there should be restriction of some anthropogenic activities in the area to avoid further discharge of harmful wastes into the area.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest among the authors.

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