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Impact of Human Activities on the Distribution, Abundance and Diversity of Phytoplankton in the Calabar River System, Cross River State, Nigeria

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Abstract
The impact of human activities on the distribution, abundance and diversity of phytoplankton in the Calabar River System, Cross River State, Nigeria, was investigated for six months (March - August, 2015). Results were pooled for each of the seven stations: Tinapa, Export Free Trade Zone (EFTZ), Nigerian Ports Authority (NPA), Army Base and Nigerian National Petroleum Corporation (NNPC) Jetties, including Creek Town Entrance (CTE), where facilities such as recreational, oil, water transport, security, warehouse are located and vessel movements common, unlike Adiabo Bridge Head (ABH) area, which was used as control station, where such facilities are absent. Twenty-nine phytoplankton species belonging to five families (Bacillariophyceae, Cyanophyceae, Pyrophyceae, Chrysophyceae and Chlorophyceae) were recorded. Total of 588 Bacillariophyceae were encountered with 308 Cyanophyceae, 427 Pyrophyceae 286 Chrysophyceae and 362 Chlorophyceae. In general, the control station had more phytoplankton with 377 individuals, with 229 individuals at station 1, 203 at station 2, 243 at station 3, 225 at station 4, 222 at station 5 and 229 at station 6. Phytoplankton species such as Synura among the Chrysophyceae, and Microsterias among the Chlorophyceae were observed to occur at all the stations, while others were station-specific. Species abundance was observed to vary at each station and ranged from 20-25 with 20 at station 5, 21 at stations 3, 4 and 6 and 22 at stations 1 and 2, while the control station had the highest number of species with 25 individuals. Margalef's, Shannon-Wiener and Evenness indices were also observed to vary at each of the stations. These variations are discussed in relation to the impact of human activities on the phytoplankton community in the river system.

Keywords: Impact of Human Activities, Distribution, Abundance, Diversity, Phytoplankton, Calabar River System, Nigeria

Introduction
Phytoplankton forms a diverse group of marine and freshwater plants ranging from unicellular planktonic species which lack true roots, stems and leaves and do not produce flowers or seeds [1]. They are eukaryotic photosynthetic species that contain chlorophyll and also utilize solar energy to generate their chemical energy [2]. They are present throughout the lighted regions of all aquatic ecosystems (Mudflats, ponds, lakes, streams, seas and oceans) [3,4]. Phytoplankton is responsible for more than 95% of the photosynthetic activities in the world oceans [5]. This amounts to nearly ¾ of the world's primary production and nearly half of the oxygen in our atmosphere [1,6,7].

The distribution, abundance and diversity of these eukaryotic photosynthetic species may be affected to a large extent by human activities particularly the building of barriers, bridges and dams across river system [4,8,9]. The dredging of river system is also known to greatly impact on the communities of diverse groups of organism including phytoplankton [10]. These impact range from population inhibition of desirable species to explosion of undesirable ones as previously reported [11-14]. However, none of these studies has reported on the impact of human activities on the distribution, abundance and diversity of phytoplankton in the Calabar river system, Nigeria, which is the focus of the present investigation.

Materials and Methods
Study area
The Calabar River Nigeria is a major tributary of the Cross River Estuary in southern Nigeria, and a major sink of industrial and municipal wastes arising approximately activities. The river is located approximately between Latitude 4.960983^{0}N and Longitude 8307724^{0}E (Fig. 1) [15].

The river drains part of the Oban Hills in the Cross River National Park [16]. The geology of the river basin includes the pre-Cambrian Oban Massif, cretaceous sediments of the Calabar flank and the recent Niger Delta sedimentary basin. The basin is about 43km2 wide and 62km long with an area of 1,514km^2 [10].

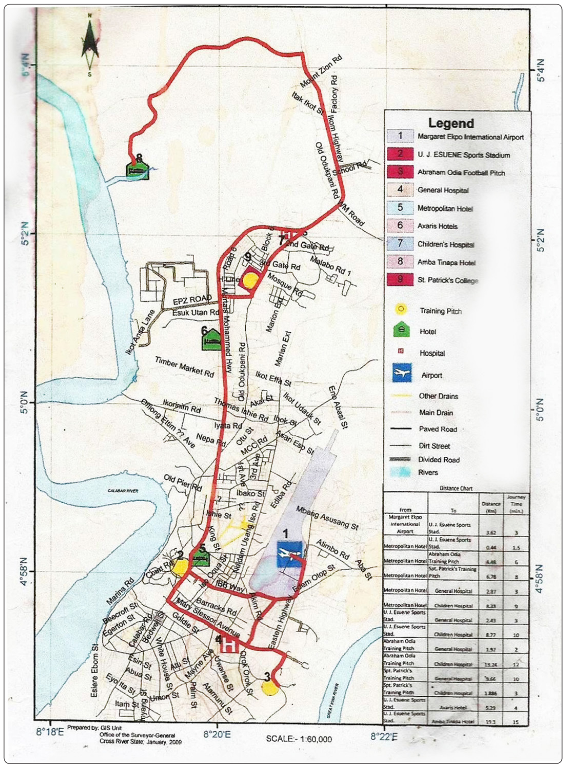

Figure 1: Map of Calabar River, Nigeria, showing sampling stations

The climate of the area and the hydrodynamics of the river system in relation to industrial activities has been described [15,16].

Collection of Samples

Seven locations were selected and geo-referenced accordingly (Table 1). Phytoplankton samples were collected below the river water surface following using a standard hydrobios plankton net of 55µm mesh of 18.0cm diameter [17]. The filtration method of known volume of the river water was employed following [18].

Table 1: Stations and GPS coordinates

Sampled stations	GPS coordinates
Stn 1 (Control point (Adiaba Bridge head)	050339.2N
	008180.2E
Stn 2 (opposite Tinapa)	050244.1N
	081816.2N
Stn 3 (opposite EPZ)	050144.0N
	008130.1E
Stn 4 (opposite NPA)	050053.9N
	0081844.5E
Stn 5 (Army Base)	050012.3N
	008184.0E
Stn 6 (Creek Town Entrance)	050060.9N
	0081753.9E
Stn 7 (opposite NNPC Jetty)	045851.8N
	0081910.7E

Source: Field sampling institu data (March-August, 2015)

The samples were preserved in 10% buffered formaldehyde solution following [19]. All samples were transported in plastic boxes to the Biological Oceanography Laboratory, Faculty of Oceanography, University of Calabar, Nigeria, for analysis.

Analysis of Samples

In the laboratory, 5ml of Lugol's iodine solution was added to each 100ml of phytoplankton sample and well stirred to mix using a glass rod and allowed to sediment. Samples were then observed under a inverted microscope of x10, x40 and x100 objectives, following [4]. The addition of Lugol's iodine solution to the samples enhanced the identification and enumeration of the phytoplankton cells. Identification was carried out to the lowest taxonomic level practicable following schemes provided [3,5,17,20].

Data Analysis

The data was analyzed empirically using numerical and relative abundance of each of the phytoplankton species in each of the families. Ecological indices such as Margalef's (species diversity) index (d), Shannon-wiener index (H) and Evenness index (E) were also determined [12,21,22].

Numerical and Relative Abundance

Numerical abundance of each of the phytoplankton species and family was determined by summation process [21]. The number of each phytoplankton species was added up to obtain the total number of all individuals (N) and used for the calculation of the relative abundance of each family using the equation:
$\% Ra=100 (n)/N$ [4] .
where:
% Ra=relative abundance
n = number of individual species
N = total number of all individuals per station

Margalef's (Species Diversity) Index, (d)

Margalef's index, d, which is independent on sample size is based on the relationship "S" and the total number of individuals observed (N), and is generally known to increase with increase in sample size [12,21].
The index is given by the formula:
$d = S-1/\ln N$ [12,21].
where;
S = total number of species
N = total number of individuals sampled,
And ɩn = the natural or Niperian logarithm ($\log_e$).
The values of Margalef's diversity index (d), obtained from any ecological survey, usually windows the pollution status of the area [11].

Shannon-Wiener index, H

This is sensitive to the number of species present and how evenly individuals are distributed in the sample [21].
and is given by the formula:

$$H = \frac{N \log N - fi \log fi}{N}$$

where:
N= total number of all individuals in the assemblage
fi= total number of individual species or group of species.

Evenness Index (E)

Evenness of the phytoplankton community was determined by dividing the observed diversity (H) by the maximum diversity (Hmax) of the phytoplankton at each station.

This was represented by the formula:

$$E = \frac{H}{H_{max}}$$

as recommended by [12].

Results

Species Composition of the Phytoplankton

The checklist of the phytoplankton families and species is presented in Table 2. Total of 29 phytoplankton species belonging to five families were encountered. These were Bacillariophyceae, Cyanophyceae, Pyrophyceae (Cryptophyceae) and Chlorophyceae. At the control state (Adiabo-bridge beach), 131 (34.75%) of Bacillariophyceae, were identified, with 56 (24.45%) at station 1 (opposite Tinapa), 60 (29.56%) at station 2 (opposite EFTZ), 64 (26.34%) at station 3 (opposite NPA), 79 (33.78%) at station 4 (Army Base), 65 (29.28%) at station 5 (Creek Town entrance and), 58 (25.33%) at station 6 (opposite NNPC jetty).

Table 2: Major phytoplankton families/species identified at each of the sampled stations in the Calabar River, Cross River State, Nigeria (Pooled Data) (March - August, 2015)

S/N	Major phytoplankton families/species	Control station	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 7	Marginal Total
A	Bacillariophyceae	n*	n*	n*	n*	n*	n*	n*	n*	
1	Coscinodiscus excentricus	15	9	-	11	16	11	-	9	
2	Denticula thermalis	-	3	14	-	13	7	8	13	
3	Cyclotella stelligera	11	8	9	-	5	9	6	-	
4	C. comta	21	17	-	13	-	11	-	14	
5	Melosira granulata	13	-	11	7	-	-	9	6	
6	Biddlphia sp	16	4	7	-	13	11	10	13	
7	Surrirella Ovalis	-	3	5	11	7	-	5	-	
8	Gyrosigma sp	14	7	-	6	9	7	-	11	
9	Leptocylindricus danicus	10	-	4	-	5	3	8	-	
10	Naricula petersenii	17	5	3	7	-	6	3	5	
11	Skeletonema costatum	14	-	7	9	8	-	9	7	
Total abundance (N)		**131**	**56**	**60**	**64**	**76**	**65**	**58**	**78**	**588**
n* = the number of individual phytoplankton cells per liter										
B	Cyanophyceae	n*	n*	n*	n*	n*	n*	n*	n*	
1	Oscillatoria rubisceus	11	10	7	9	-	11	16	13	
2	Microcystis acrugiriosa	24	13	-	11	9	-	13	-	
3	Lyngbya contorta	16	-	13	-	11	8	-	11	
4	Anabaena spiroides	18	14	11	14	12	-	18	15	
Total abundance		**69**	**37**	**31**	**34**	**32**	**19**	**47**	**39**	**308**
C	Pyrrophyceae (Cryptophyceae)	n*	n*	n*	n*	n*	n*	n*	n*	
1	Crystochrysis sp	18	13	11	9	17	10	-	17	
2	Prorocentrum rotundata	19	21	13	18	13	-	19	-	
3	Piridium pellucidium	6	11	10	13	-	16	-	21	
4	Goyaulax digitale	-	13	-	-	14	-	17	13	
5	Rhodomonas sp	17	-	12	20	-	23	14	9	
Total abundance (N)		**60**	**58**	**46**	**60**	**44**	**49**	**50**	**60**	**427**
D	Chrysophyyceae	n*	n*	n*	n*	n*	n*	n*	n*	
1	Synura sp	16	11	9	13	12	16	12	9	
2	Asterionella sp	21	13	-	15	9	11	9	8	
3	Dinobryein bararium	10	-	6	-	7	-	8	-	
4	Crystochrysis sp	14	10	9	11	-	17	-	10	

Total abundance (N)		**61**	**34**	**24**	**39**	**28**	**44**	**29**	**27**	**286**
E	Chrlorophyceae	n*	n*	n*	n*	n*	n*	n*	n*	
1	Microsterias sp	12	9	13	13	10	16	13	15	
2	Closterium sp	10	-	11	16	-	11	10	11	
3	Botryocoecus boryanum	-	6	8	7	13	9	11	-	
4	Tetraspora lubrica	13	11	-	10	8	9	-	13	
5	Volvox aucus	21	18	10	-	14	-	11	-	
Total abundance (N)		**56**	**44**	**42**	**46**	**45**	**45**	**45**	**39**	**362**

n* = the number of individual phytoplankton cells per liter

Total of 69 (18.30%) Cyanophyceae were identified at the control station, with 37 (16.16%) at station 1, 31(15.27%) at station 2, 34(13.99%) at station 3, 32 (14.22%) at station 4, 19 (8.56%) at station 5 and 47 (20.52%) at station 6 (Table 3). Pyriophyceae (Cryptophyceae) contributed 60(15.92%) to the Phytoplankton population at the control station, with 58 (25.33%) at station 1, 46(22.66%) at station 2, 60(24.69%) at station 3, 44 (19.56%) at station 4, 49 (22.07%) at station 5 and 50 (21.83%) at station 6. Chrysophyceae had 61 individuals representing 16.18% of the Phytoplankton population at the control station, with 34 individuals (14.85%) at station 1, 24(11.82%) at station 2, 39(16.05%) at station 3, 28 (12.44%) at station 4, 44 (19.82%) at station 5 and 29 (12.66%) at station 6, while Chlorophyceae had 56 individuals at the control station and represented 14.85% of the phytoplankton population at the control station, with 44 individuals (19.21%) at station 1, 42(20.69%) at station 2, 46(18.93%) at station 3, 45(20.0%) at station 4, 45 (20.27%) at station 5 and 45 (19.65%) at station 6. (Table 3).

Table 3: Distribution of the Major Phytoplankton families at the different sampled stations during the period of study (March – August, 2015)

S/N	Phytoplanton families	Stn 1 (Control)		Stn 2		Stn 3		Stn4		Stn 5		Stn 6		Stn 7	
		(n)*	%n	n	% n	N	%n	n	%n	n	%n	n	%n	n	%n
1	Bacillariophyceae	131	34.75	56	24.45	60	29.56	64	26.34	76	33.78	65	29.28	58	25.33
2	Cyanophyceae	69	18.30	37	16.16	31	15.27	34	13.99	32	14.22	19	8.56	47	20.52
3	Pyrrophyceae (Cryptophyceae)	60	15.92	58	25.33	46	22.66	60	24.69	44	19.56	49	22.07	50	21.83
4	Chrysophyceae	61	16.18	34	14.85	24	11.82	39	16.05	28	12.44	44	19.82	29	12.66
5	Chlorophyceae	56	14.85	44	19.21	42	20.69	46	18.93	45	20.0	45	20.27	45	19.65
Total abundance (N) per station		377	100.0	229	100.0	203	100.0	243		225	100.0	222	100.0	229	99.99≈100
Total abundance of species (S) per station		25		22		22		21		21		20		21	
Margalef's index (d)		4.05		3.86		3.95		3.64		3.70		3.52		3.68	
Shannon-weiner index (H)		2.48		2.23		2.16		2.27		2.23		2.23		2.24	
Evenness index (E)		0.099		0.101		0.098		0.108		0.106		0.111		0.106	

n* = the number of individual phytoplankton families per liter
%n* = relative abundance of phytoplankton families per liter

The station-by-station distribution of the major phytoplankton families are illustrated in Figure 1a, while the relative abundance is shown respectively in Figures 1b-f. More Phytoplankton were encountered at the control station than at the other stations with the following pattern of distribution: control station with (377) individuals) > stations 3 with individuals 243> stations 1 and 6 with 229 individuals each > station 4 with 225 individuals > station 5 with 222 individuals > station 2 with 203 individuals (Table 3).

Ecological Indices

Margalef's index (d)

Margalef's diversity index was observed to range between 3.52-4.05 with a mean of 3.77. Highest value of (d) was recorded at the control station (Table 3).

Shannon-Weiner index (H)

Shannon-Weiner index was observed to range between 2.16-2.48 with a mean of 2.26 and fell within the acceptable range in community ecology (Table 3).

Evenness index (E)

Evenness index was observed to ranged between 0.098-0.111 with a mean of 0.104. The least evenness index value of 0.098 was recorded at station 2, while station 5 had the highest Evenness index value (Table 3).

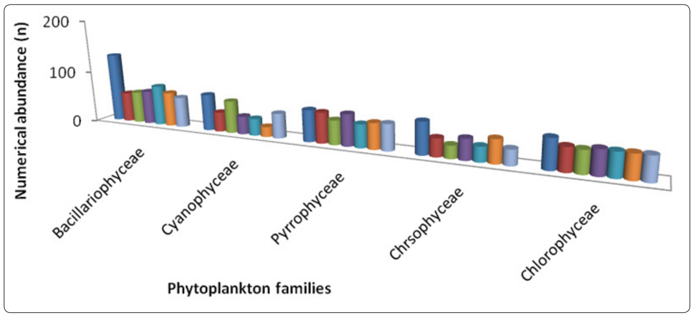

Figure 1a: Station-by-station distribution of phytoplankton families at the different sampled stations in the Calabar River, Nigeria during the period of study (March - August, 2015)

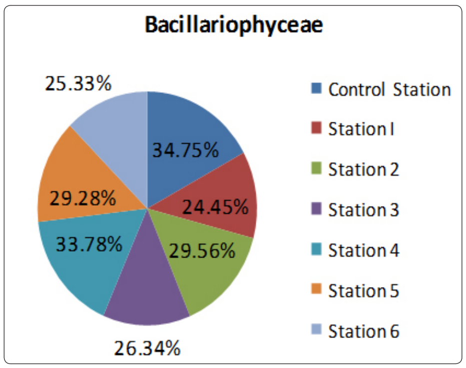

Figure 1b: Relative distribution of Bacillariophyceae at each of the sampled stations in the Calabar River, Nigeria, during the period of study

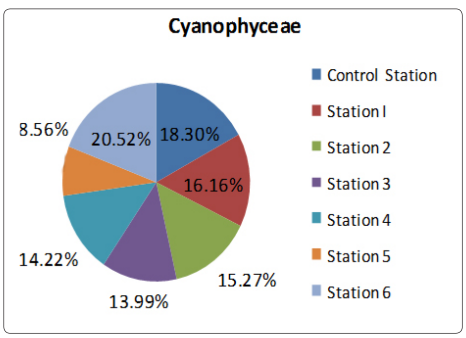

Figure 1c: Relative distribution of Cyanophyceae at each of the sampled stations in the Calabar River, Nigeria, during the period of study

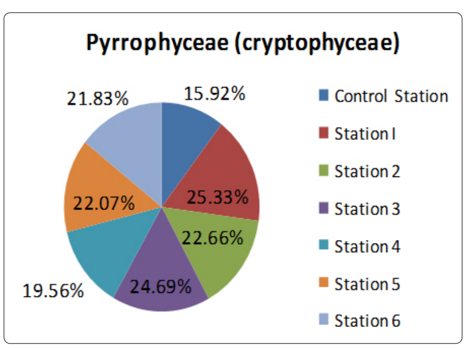

Figure 1d: Relative distribution of Pyrrophyceae (Cryptophyceae) at each of the sampled stations in the Calabar River, Nigeria, during the period of study

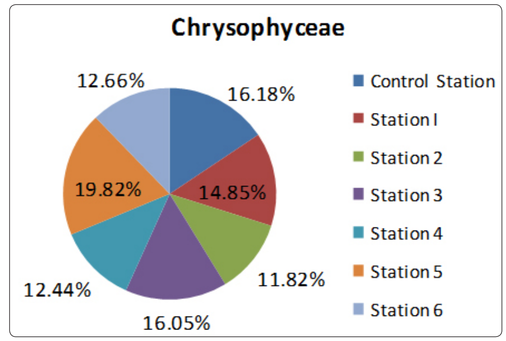

Figure 1e: Relative distribution of Chrysophyceae at each of the sampled stations in the Calabar River, Nigeria, during the period of study

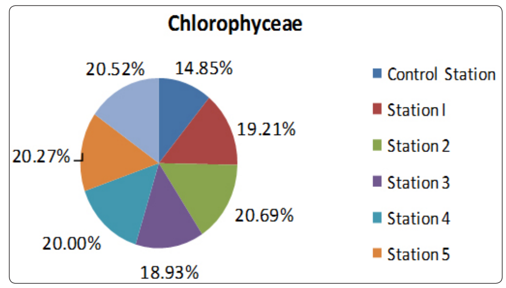

Figure 1f: Relative distribution of Chlorophyceae at each of the sampled stations in the Calabar River, Nigeria, during the period of study

Discussion

From the results of the present study, it is clear that most of the species of the phytoplankton species were station-specific in the Calabar river. The prevailing local conditions in a particular section and/or area of a river system would usually preclude major changes in the occurrence, distribution and abundance of a particular group of organisms or species group causing them to be abundant at one station, be station-specific or absent at others [15,23-28].

Eutrophication resulting from anthropogenic activities has been considered to be undoubtedly one of the factors stimulating particularly, phytoplankton growth, since it involves the enrichment of a water mass with inorganic and organic nutrients supporting plant growth [26]. Nutrient enrichment as a result of authropogenic activity occurs in estuaries, coastal waters, river systems and creeks [3,26].

The phytoplankton abundance was higher at the control station than the other stations. The variations observed in the distribution, abundance and diversity of the phytoplankton, might be link with the varying degrees of the effects of the impact of human activities at each of the sampled stations. The results of the present study corroborate with [4,10,29].

The Calabar River is generally bordered by mangrove ecosystem with Nypa palm existing alongside other plants and shrubs [30]. The harvesting of the mangrove trees and Nypa palm for their various economic uses disrupts the ecological balance of the ecosystem thereby additionally impacting on the phytoplankton community. Mangrove-bordered aquatic ecosystems are known to import substantial amounts of organic matter from the mangrove [30]. The major part of this appears in the estuarine/ brackish water environment as detritus. This detritus is fed upon by suspendedfeeders [31,32]. Furthermore, the breaking down of the organic matter sets plants nutrients free, so that there may be considerable phytoplankton growth and distribution (provided that the water is not too turbid to allow solar radiation) for zooplankton to graze on [5,7,17,28]. There is rich food resource and suspended materials in mangrove-bordered aquatic systems for enhanced primary productivity [1,31,32]. This nourishing suspension might have given rise to the observed spatial distribution of the organisms during the period of investigation. Also, the appearance of some species and the disappearance of others might also have been attributed to the interplay of biochemical factors in the milieu of the organisms [1,18,33-35].

Considering the ecological index values of phytoplankton of between 3.52-4.05 for Margalef's index (d), 2.16-2.48 for Shannon-wiener index and 0.098-0.111 for Evenness index, the sampled stations in the Calabar River could be considered ecologically influenced by human activities.

In general ecological terms, Margalef's index values ranging between 1 and 3 indicate moderately polluted environment, while values greater than 3 indicate clean environment and values less than 1 are known to characterize heavily polluted conditions, while the range of values of the Shannon-wiener index between 2.17- 2.61 calculated for any aquatic system in relationship to community ecology usually shows that the species or group of species under investigation is/are evenly distributed or not under a threat of poor distribution, though there may be a reduction in population as a results of the interplay of predation and effect of anthropogenic activities [2,4,11,33,36]. Phytoplankton is the keystone of primary production in any aquatic ecosystem. Zooplankton and other fish species feed on the phytoplankton. If the population of the phytoplankton is affected, then the classic food web suffers drastically causing a reduction in fish yield which the riverine population depends on for their protein source and income generation.

Summary and Conclusions

The results of the investigations conducted on the impact of human activities on the distribution, abundance and diversity of phytoplankton revealed that though the is rich food resource arising from mangrove leaf litter, the tendency is that the phytoplankton community maybe affected by heavy human activity as observed at Tinapa, Export Free Trade Zone (EFTZ), Nigerian Ports Authority (NPA), Army Base and Nigerian National Petroleum Corporation (NNPC) Jetties, including Creek Town Entrance (CTE) where human activities were common, unlike the Adiabo Bridge Head (ABH), where facilities that likely to encourage human activities were absent.

Phytoplankton species such as Synura among the Chrysophyceae, and Microsterias among the Chlorophyceae were observed to occur at all the stations, while others were station-specific. Species abundance was observed to vary at each station and ranged from 20-25 with 20 at station 5, 21 at stations 3, 4 and 6 and 22 at stations 1 and 2, while the control station had the highest number of species with 25 individuals. Margalef’s, Shannon-Wiener and Evenness indices were also observed to vary at each of the stations [37].

The control station had more phytoplankton individuals than the other station. This was an indication that stations where human activities were heavy, phytoplankton population was reduced. Reduced phytoplankton population may mean reduced primary productivity and hence low fish yields and catches by the artisanal fisheries which are common in the Calabar river system. This phenomenon is likely to affect the source of cheap protein and income of the people in the area. However, if good science is applied to human activities in the area, a sustainable/ecologically balanced condition will prevail in the river system.

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