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Assessment of phytoplankton species composition, abundance and diversity within the itu bridge-end area of the lower cross river system, Nigeria

Job Bassey Etim

Abstract
This paper reports on the phytoplankton species composition, abundance and diversity within the Itu bridge-end area of the lower Cross River system, Nigeria, which was undertaken for nine months (February- October, 2018). Surface water samples were collected for phytoplankton studies by filtration method, using a-20L plastic bucket and a-55µm standard plankton net. Samples were concentrated to 10ml, stored in well-labeled plastic bottles and preserved in 4% buffered formaldehyde solution prior to laboratory analysis. Samples were analyzed by addition of 1-2 mls of Lugol's iodine solution which enhanced phytoplankton cell identification under an inverted microscope of x 10 and x 40 magnification using standard texts and atlases. Total of 57 phytoplankton species spread into 5 taxonomic families (Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae and Chrysophyceae) were identified. All identified species of the phytoplankton were those common in the tropical river system. A total of 36.34% of the phytoplankton were Bacillariophyceae, with 20.54% of Euglenophyceae, 20.38% of Cyanophyceae, 16.47% of Chlorophyceae and 6.27% of Chrysophyceae. There was a predominance of Melosira variance in the Bacillariophyceae, Anaena spiroides in the Cyanophyceae, Euglena gracilis in Euglenophyceae and Ceratium hirudinea in the Chrysophyceae. The complete absence of the genus Coscinodiscus in the Bacillariophyceae interplayed by the low ranges of the Margalef's index of (2.58 – 3.09) for Bacillariophyceae, (2.11 – 2.62) for Chlorophyceae, (1.44 – 1.86) for Cyanophyceae, (1.24 – 1.90) for Euglenophyceae and (0.79 – 1.18) for Chrysophyceae, and the high values (>1) of the Shannon-Wiener indices which ranged between 1.96 – 2.36 for Bacillariophyceae, 1.63 – 1.95 for Chlorophyceae, 1.73 – 2.05 for Cyanophyceae, 1.92 – 2.05 for Euglenophyceae and 1.34 – 1.60 for Chlorophyceae connote the Itu bridge-end area of the lower Cross River system to be under the threat of pollution. There was a significant relationship ($p<0.05$) between phytoplankton abundance and month of sampling. Based on the results of the study, proper management strategies of this area of the river system are outlined and recommended.

Keywords: Assessment, phytoplankton, species composition, abundance, diversity, ITU bridge-end area

1. Introduction
The productivity of any aquatic ecosystem depends on the amount of plankton present in the said water body (Davies *et al,* [16]. Prasad [48] is of the view that plankton is all organisms (Plants and animals) which live in water that have limited power of locomotion, largely move by means of flagella or other various mechanisms which alter their distribution by changes in buoyancy and are more or less passively drifted by waves and water currents. Odiete [40] and Davies *et al* [16] is of the view that plankton, typically phytoplankton growth and distribution depend on the carrying capacity of the environment and on the concentration of nutrients at both intracellular and extracellular levels Phytoplankton constitutes the most important components of the food chain in every water body Ajuonu *et al,* [4]; Job *et al,* [28]; Ekanem *et al,* [21]; Ada and Job, [1]. All other living organisms in water depend directly or indirectly on them for food Ajuonu *et al,* [4]. More than 95% of the photosynthetic activities in the world oceans are as a result of phytoplankton and nearly ¾ of the world's primary production and nearly ½ of the oxygen in our environment is released by phytoplankton Ekanem *et al,* [21]; Ada and Job, [1]. The distribution, abundance and diversity of phytoplankton have been reported to be influenced, to a large extent, by human activities particularly the building of barriers, bridges and dams across river systems Job *et al* [54]; Haslam [27]; Fenchel [26]; Ada and Job [1].

Studies on phytoplankton species composition in the Nigerian river systems from available literature include those of Adebisi [2], Adekunle *et al* [3], Chinda and Braide [14], Chinda and Pudo [15], Egborge [20], Dimowo [17], Erondu and Chinda [24], Ogeechee *et al* [42], Okogwu and Ugwumba [44], Nwadiaro and Ezefill [38], Eyo *et al* [25], Akpan [7, 8, 9, 10], Ekeh and Sikoki [22], Eni *et al* [23], Kadiri and Omozusi [30], Akpan and Offem [6], Ekanem *et al* [21], Egbai and Job [19], Davies *et al* [16] and Ada and Job [1]. None of these studies reports on the phytoplankton of the Itu bridge-end area of the lower Cross River system, Nigeria, which the present paper is designed.

2. Materials and Methods

2.1 Study area

The study area is the lower Cross River system, a tropical freshwater fluvial system draining the rainforest belt of Akwa Ibom and the Cross River States, Nigeria King, [32]. There are two seasons in the area (dry) (November - March) and rainy (April - October). At Ayadehe, Itu bridge-end area, located at approximately 50 12'N, 70 59'E (Fig. 1) where samples for this study were collected, the river experiences tidal variations which are most pronounced in the dry season King, [32]. The river flow becomes unidirectional during the peak of rains (July - October), with the current velocity increasing from 0.4 - 0.6 ms-1 in the dry season to 0.7-1.5ms-1 during the rains King. [32]. The average depth has been reported by Etim and Brey [56] to be 4m in the dry season and 14 m in the Wet season. Water temperature of the study area according Etim and Enyenihi [57], varies between 22 °C and 30 °C. The river is hydro-dynamically relatively homogenous stretching about 25 km to the north and 25km to the South of Itu Etim and Enyenihi, [57]; Etim and Brey, [56]. The river is vertically homogenous in most physico-chemical parameters with annual variation in pH of 6.8-7.2, salinity, 0.2 - 0.60⁄00 and total hardness ranging between l0 – 20 mg CaC03L-1 King, [32].

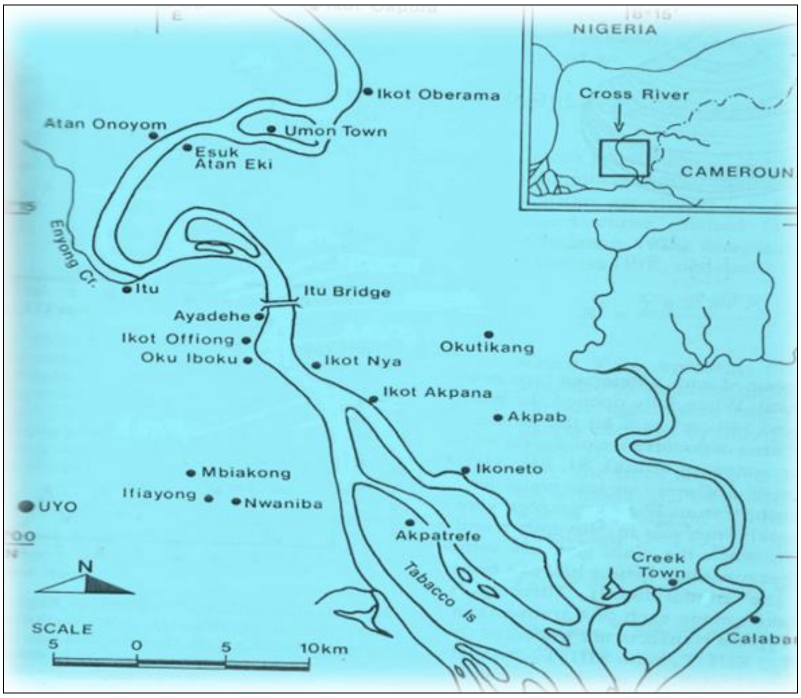

Fig 1: Map of the lower reaches of the cross river system, Nigeria, showing ITU bridge-end area where samples were collected. Adapted from Moses [36]

2.2 Collection of samples

Phytoplankton samples were collected within Itu bridge-end area of the Cross River system, Nigeria, by filtration method using a-20L bucket and a standard plankton net of 55µm mesh as recommended by Job *et al*. 2017. The 20L of surface water was filtered and concentrated to 10 ml and preserved in 4% buffered formaldehyde solution in properly labeled plastic sample bottles. Triplicate samples were collected during each month of sampling and pooled into a single sample. Filtered samples were stored in plastic boxes and transported to the Biological Oceanography Laboratory, University of Calabar, Nigeria, for analysis.

2.3 Laboratory studies

In the laboratory, each sample was stained with 1-2 ml of Lugol's iodine solution and well-stirred to mix, using a glass rod and allowed to sediment as recommended by Ekanem *et al*. [21] and Ada and Job [1]. Samples were then observed under an inverted microscope (model: Olympus CH00545, Tokyo, Japan) of x 10 and x 40 objectives following Job *et al*. [28, 54]. The addition of Lugol's iodine solution to the samples enhanced phytoplankton cells identification and enumeration (Job *et al*. [28]; Ada and Job, [1]. Identification of phytoplankton was based on the schemes and descriptive keys of Needham and Needham [37], Whit ford & Schmachee [53], Patrick and Reiner [46], Kadiri [31] and Olaniyan [45]. Identification was carried out to the nearest possible taxon.

2.4 Data analysis

Data were analyzed empirically and ecologically.

2.4.1 Empirical data analysis

Individual species (n) of the phytoplankton in each sample was enumerated to find the total number of all individuals (N) in the family and used for the determination of the relative abundance (%Ra), using the formula:

$$(\%_{\mathrm{Ra}} = \frac{n(100)}{N} \quad \text{---------- Equation 1}$$

Where
n = number of individual species

And N = total number of all the individual species in the family (Job *et al*. [28], Job *et al*. [54]; Job and Ekpo [29], Egbai and Job, [19].

2.4.2 Ecological data analysis

2.4.3 Margalef's index (d)

This was based on Margalef's index (d) which windows the pollution index of the system where the study is being conducted in space and time Ali *et al*., [12]. Margalef's index (d) is given by the formula:

$$d = \frac{S-1}{InN} \text{ ---------Equation 2}$$

Where
S = total number of species
In = the natural or Nigerian logarithm (loge)
And N = total number of individual samples (Margalef, [34], [35]; Ogbeibu, [43]; Job *et al*., [54]; Job and Ekpo, [29]; Egbai & Job, [19]; by Ekanem *et al*., [21]; Ada and Job [1].

2.4.4 The shannon-wiener index (H)

This index is sensitive to the number of species present and how evenly the individuals are distributed in the sample (Shannon-Weaver, [49]; Ogbeibu, [43], Job *et al*., [54], and is given by the formula:

$$H = N\log N - \frac{\Sigma fi\log fi}{N} \text{ Equation 3}$$

Where
N = total number of all individuals, and fi = total number of individual species.

2.4.5 Statistical analysis

The distribution and abundance of the phytoplankton in relation to months of sampling were compared using the single factor analysis of variance (ANOVA) by Ranks (The kruskal-wallis test) at 0.05 level of significance SAS, [51].

3. Results

3.1 Species composition, species richness abundance and distribution

The species composition of the phytoplankton is presented in Table 1.

Table 1: Phytoplankton species composition within the Itu bridge-end area of the Cross River system, in Southern Nigeria (February – October, 2018).

Taxonomic list	Feb	March	April	May	June	July	August	Sept	Oct.
Bacillariophyceae (Diatoms)									
Synedra ulna	6	4	4	8	8	10	5	3	4
S. cyclopium	5	6	3	6	3	8	4	-	2
Melosira ambigua	10	-	7	9	5	8	7	4	3
M. distans var humilis	8	4	6	-	8	9	6	5	2
M. granulate	-	6	8	3	7	12	3	7	5
M. varians	79	87	74	83	95	85	38	27	43
Stephanoitiscus dubius	7	6	3	9	6	-	8	4	3
Amphora ovalis	11	9	7	7	5	22	-	9	18
Nitzschia sigma	4	6	8	3	4	12	2	5	9
N. filiformis	6	3	5	7	-	18	5	3	10
Fragilaria intermedia	9	11	7	6	9	31	-	7	28
Cyclotella cornta	13	19	15	14	21	13	12	10	8
C. strata	17	12	14	15	17	11	15	13	12
C. Operculata	9	16	10	3	11	6	-	9	4
Diatoma vulgane	21	10	12	18	11	9	15	7	6
Cosinodiscus radiate	11	18	14	17	15	11	9	11	9
Total abundance(N)	225	222	204	210	229	269	708	136	128
Number of species (S)	16	16	17	16	16	16	14	16	17
Chlorophyceae (Green algae)									
Closteridum lunula	5	3	7	3	-	5	6	-	9
Tetraedron tumidulum	-	7	11	-	9	16	3	5	13
Crucigenia Fenetreta	12	-	8	9	3	4	9	3	5
Closeterium gracile	11	5	7	16	3	-	9	3	6
Cos marium granatum	18	12	15	16	9	11	17	10	13
Cladophora elegans	-	9	6	6	-	4	5	-	8
Netrium digtus	6	-	9	8	12	9	4	3	5
Pleuretaenium indicum	9	5	-	7	-	6	-	7	11
P. tridentulum	6	4	3	3	2	-	3	9	-
P. ovatum	7	-	5	5	3	14	5	3	5
Closterium cornu	-	5	5	3	4	-	6	7	4
C. pronum	11	7	6	9	5	2	9	3	-
Spirogyna laza	16	13	19	10	9	18	13	11	17
S. reflexa	11	-	7	-	9	5	9	3	5
Total abundance(N)	112	70	108	95	68	94	98	67	101
Number of species (S)	11	10	13	12	11	11	13	12	12
Cyanophyceae (Blue-green algae)									
Merismopedia elegans	6	-	11	5	3	7	-	-	9

Oscillatoria probiscens	-	18	23	3	8	14	5	13	21
O. tenius	23	19	17	13	16	11	21	15	13
O. laciistrics	19	13	18	17	10	13	14	11	15
Anabaenan affinis	3	7	-	2	5	2	-	14	-
A. spiroides	31	43	35	28	41	27	29	40	33
A. arnoldii	11	13	9	19	16	7	9	11	6
Raphidiopsiss curvata	4	7	-	8	6	1	8	9	-
Crucigenia crucifera	-	6	8	8	-	9	3	5	11
Spirulina subsalsa	3	-	7	3		8	6	8	9
Total abundance (N)	100	126	128	106	109	99	95	126	117
Number of species	8	8	8	10	9	10	8	9	8
Euglenophyceae									
Trachelomonas superbus	6	-	7	7	3	5	5	3	9
T. volgensis	9	8	11	6	5	-	7	7	13
T. voivocina	5	9	-	-	o	7	3	7	7
Eutreptia viridis	6	8	-	4	6	3	3	-	4
Euglena acus		-	7	o	-	o	3	1	-
E. caudate	4	3	8	5	3	-	5	7	9
E. deses	6	5	_	-	4	2	7	6	3
E. rubra	-	6	5	3	9	-	5	7	8
Euglena viridis	7	11	4	9		3	-	13	7
E. gracilis	75	61	84	43	58	73	63	59	83
Trachelomona Africana	7	3	-	9	5	5	-	5	6
Total abundance (N)	125	114	126	89	96	99	101	115	149
Number of species (S)	9	9	7	9	9	8	9	10	10
Chrysophyceae									
Peridium cinetum	6	3	-	5	5	3	-	5	3
Dinobryon sociale	5	-	7	4	2	9	3	-	5
Dinobryon divergens	-	7	6	3	-	4	6	3	-
Dinobryon sertularia	6	9	11	5	7	8	5	11	9
Ceratium hirudinea	17	13	21	13	13	24	15	11	18
Total abundance (N)	34	32	45	30	27	48	29	30	35
Number of species (S)	4	4	12	5	4	5	4	4	4

Total of 57 phytoplankton species spread into 5 families was identified. These were Bacillariophyceae (17 species), Chlorophyceae (14 species), Cyanophyceae (10 species), Euglenophyceae (11 species) and Chrysophyceae (5 species). The Bacillariophyceae were the most diverse phytoplankton family followed by the Chlorophyceae, Euglenophyceae, Cyanophyceae and Chrysophyceae.

3.2 Ecological indices of the phytoplankton are presented in Table 1A.

Margalef's index ranged between 2.58 – 3.09 for Bacillariophyceae, 2.11 – 2.62 for Chlorophyceae, 1.44 – 1.86 for Cyanophyceae, 1.24 – 1.90 for Euglenophyceae and 0.79 – 1.18 for Chrysophyceae, interplayed also by the high values of the Shannon-wiener which ranged between 1.96 – 2.36 for Bacillariophyceae, 1.63 – 1.95 for Chlorophyceae, 1.73 – 2.05 for Cyanophyceae, 1.92 – 2.05 for Euglenophyceae and 1.34 – 1.60 for Chrysophycea.

Table 1(A): Summary of the ecological indices of the phytoplankton within the ITU bridge-end area of the cross river system, Nigeria (Feb-Oct, 2018).

Bacillariophyceae									
Total Abundance (N) $20L^{-1}$	Feb	March	April	May	June	July	Aug	Sept.	Oct.
	225	222	204	210	229	269	136	128	17
Number of species (S)	16	16	17	16	16	16	14	16	17
Margalef s Index (d)	2.58	2.78	3.00	2.81	2.76	2.68	2.64	3.09	3.11
Shannon -Wiener Index (H)	2.27	2.26	2.20	2.23	2.28	2.36	2.011	1.96	2.11
Chlorophyceae									
Total Abundance (N) $20L^{-1}$	Feb	March	April	May	June	July	Aug	Sept.	Oct.
	112	70	108	95	68	94	98	67	101
Number of species (S)	11	10	13	12	11	11	13	12	12
Margalef s Index (d)	2.11	2.11	2.56	2.42	2.37	2.20	2.62	2.62	2.38
Shannon-Wiener Index (H)	1.95	1.70	1.90	1.84	1.66	1.85	1.84	1.63	1.88
Cyanophyceae									
Ecological parameters	Feb	March	April	May	June	July	Aug	Sept.	Oct.
Total Abundance (N) $20L^{-1}$	100	126	128	106	109	99	95	126	17
Number of species (S)	8	8	8	10	9	10	8	9	9
Margalef s index (d)	1.52	1.44	1.44	1.92	1.70	1.96	1.54	1.65	1.47
Shannon -Wiener Index (Ei)	1.92	2.04	2.05	1.93	1.95	1.73	1.90	2.03	2.00
Euglenophyceae									
Total Abundance (N) $20L^{-1}$	Feb	March	April	May	June	July	Aug	Sept.	Oct.

	125	114	126	89	96	99	101	115	149
Number of species (S)	9	9	7	9	9	8	9	10	10
Margalef s Index (d)	1.44	1.69	1.24	1.78	1.72	1.52	1.73	1.90	1.80
Shannon-Wiener Index (El)	2.02	1.98	2.05	1.85	1.89	1.92	1.92	1.97	2.10
Chrysophyceae									
Total Abundance (N) $20L^{-1}$	Feb	March	April	May	June	July	Aug	Sept.	Oct.
	34	32	45	30	27	48	29	30	35
Number of species (S)	4	4	4	5	4	5	5	4	4
Margalef s Index (d)	0.85	0.87	0.79	1.18	0.91	1.03	1.19	0.88	0.84
Shannon -Wiener Index (H)	1.46	1.42	1.60	1.36	1.34	1.60	1.34	1.40	1.48

3.3 Abundance of the phytoplankton

In terms of abundance, Bacillariophyceae topped the list with 1794 cells/20L consisting of 36.34% of the phytoplankton population. This was followed by Euglenophyceae with 1014 cells/20L (20.54%), Cyanophyceae with 1006 cells/20L constituting 20.38% of the phytoplankton population. Chlorophyceae had 813 cells/20L forming of 16.47% of the population and Chrysophyceae with 310 cells/20L which formed 6.27% of the phytoplankton population (Table 1b).

Table l (b): Numerical and Relative abundance of the major phytoplankton families during the period of study (Feb – Oct., 2018). (Pooled data)

Major phytoplankton families	Abundance (Numerical and relative)
Bacillariophyceae	1794 (36.34)*
Chlorophyceae	813 (16.47)*
Cyanophyceae	1006 (20.38)*
Euglenophyceae	1014 (20.54)*
Chrysophyceae	310 (6.27)*
Overall Abundance (N)	4937 (100.0)*

*Numbers in parenthesis represent relative abundance (%)

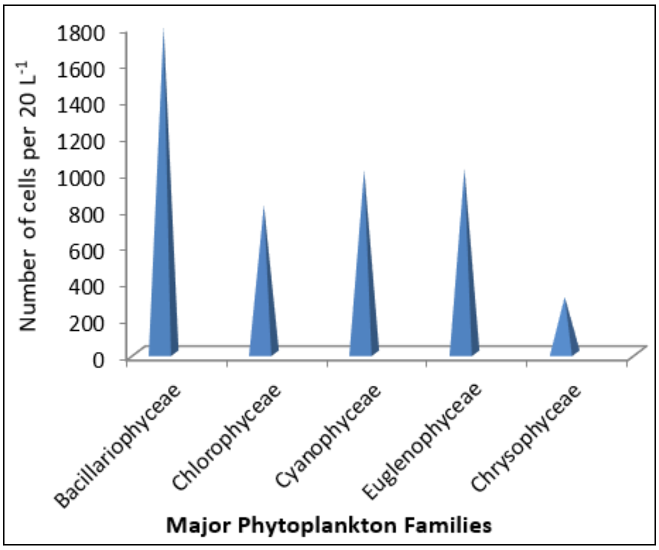

Fig 2: Numerical abundance of the major phytoplankton families

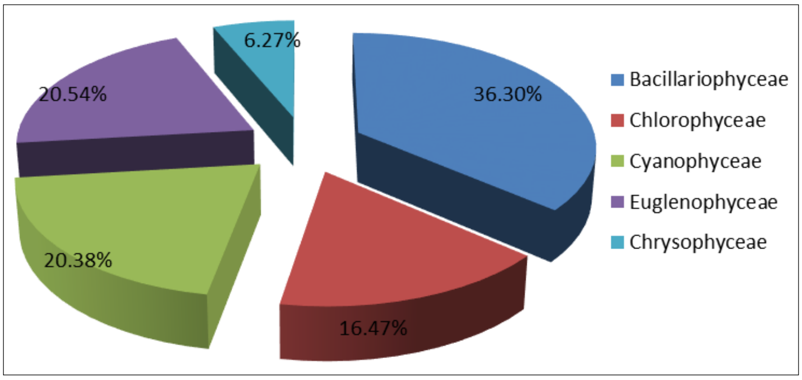

Fig 2(a): Relative abundance of the major Phytoplankton families

4. Discussion

The Bacillariophyceae (Diatoms), though were the most abundant phytoplankton in all the months of the study did not permit the drawing of conclusions that the river system is not under the threat of pollution. Basically, in a tropical unpolluted lotic aquatic system, the abundant of diatoms indicates clean water (Uttah *et al*., [52]; Davies *et al*., [16]; Offem *et al*, [41]; Dimowo [17], Job *et al*., [54], Egbai & Job, [19]. The absence or presence of certain species of phytoplankton in aquatic ecosystem usually signifies the ecological stability or otherwise of the system (Singh and Singh [50]; Uttah *et al*., [52]; Egbai and Job, [19]; Ekanem *et al*, [21]; Ada and Job, [1].

In this study, the phytoplankton genus such as Coscinodiscus, which is known to always be the predominant and abundant diatom in an unpolluted water system was completely absent in the samples during the study, which was interplayed by the predominance of Melosira varians (Bacillariophyceae), Anabaena spiroides (Cyanophyceae), Euglena gracilis (Euglenophyceae), Ceratium hirudinea (Chrysophyceae) in the samples, have strong ecological implication and this is a strong indication that, that section of the river system is under pollution threat. Many species of freshwater algae may proliferate quite intensively in eutrophic (i.e nutrient-rich) waters Uttah *et al*;, [52], though they may not form dense surface scums or "blooms" as do some Cyan bacteria (Uttah *et al*., [52], Mann, [33]; Castro & Huber, [13]. However, when certain species of phytoplankton becomes abundant, or absent, there is a defined ecological status of the system (Ali *et al*., [11-12]; Margalef [34-35].

For instance the low ranges of Margalef's index interplayed with the absent of Coscinodiscus in the phytoplankton, a species which is usually abundant in an unpolluted water coupled with the presence of species such as Melosira variance, Anabaena spiroides, Euglena gracilis and Ceratium hirudinea in the water column is also an additional evidence that the river system is under the threat of pollution. The species composition of the phytoplankton are however those common in tropical river systems Dimowo, [17], Eyo *et al*., [25], Ada &Job, [1] and Ekanem *et al*., [21].

As reported by Ali *et al* [12], and Margalef [34-35]. Margalef's index values of between1-3 indicate moderately polluted water with values less than 1 indicating the heavily polluted environment, while values greater than 3 window clean water. The ranges of the Margalef's indices obtained for the phytoplankton are clear indications that the system is threatened by pollution, which may be as a result of anthropogenic activities going on within the area. The high values of the Shannon -Wiener indices obtained in all the monthly may also be linked to unfavorable ecological conditions which may have interplayed with the environmental components of the milieu, thereby interfering with the growth of the phytoplankton. In an unpolluted environment, Shannon-Wiener index is known to range between 0-1 (Ogbeibu, [43], while values higher than this range signify poor diversity Peet, [47]. Similar observations were made by Dimowo [17], Offem *et al*., [41] and Uttah *et al*., [52] on other Nigerian rivers under threat of pollution.

5. Conclusion and recommendation

The results of the assessment of phytoplankton species composition, abundance and diversity within the Itu bridge-end area of the lower Cross River system, Nigeria, revealed the occurrence of 57 phytoplankton species spread into 5 families, namely: Bacillariophyceae (17 species), Chlorophyceae (14 species), Cyanophyceae (10 species), Euglenophyceae (11 species) and Chrysophyceae (5 species). The Bacillariophyceae were the most diverse phytoplankton family followed by the Chlorophyceae, Euglenophyceae, Cyanophyceae and Chrysophyceae. Margalef's indices were low with high Shannon-wiener indices. Some species of the phytoplankton showed predominance. Notably Melosira variance in the Bacillariophyceae, Anaena spiroides in the Cyanophyceae, Euglena gracilis in Euglenophyceae and Ceratium hirudinea in the Chrysophyceae. Complete absence of the genus Coscinodiscus in the Bacillariophyceae was observed. This additionally portrayed the Itu bridge-end area of the lower Cross River system as an environment under the threat of pollution. The low ranges of the Margalef's index (2.58 – 3.09) for Bacillariophyceae, (2.11 – 2.62) for Chlorophyceae, (1.44 – 1.86) for Cyanophyceae, (1.24 – 1.90) for Euglenophyceae and (0.79 – 1.18) for Chrysophyceae, interplayed also by high values of the Shannon-wiener indices which ranged between 1.96 – 2.36 for Bacillariophyceae, 1.63 – 1.95 for Chlorophyceae, 1.73 – 2.05 for Cyanophyceae, 1.92 – 2.05 for Euglenophyceae and 1.34 – 1.60 for Chlorophyceae further connotes the Itu bridge-end area of the lower Cross River system to be under the threat of pollution. Based on the foregoing, it is strongly recommended that the inhabitants of the area and users of this section of the Cross River system ensure proper handling and disposal of wastes generated from their daily activities. The area is a major link road between Calabar in Cross River State and other states in Nigeria. Travelers are usually observed to stop-by to purchase both fin and shell fishes which provide a cheap source of protein, as this area of the Cross River system is a good source of food fish notably, silver catfish (Chrysichthys nigrodigitatus) and the bivalve (Egeria radiata) including other fish species Moses [36].

According to Dugbeon *et al* [18], Job *et al* [55], Job *et al* [54] and Job & Ekpo [29], the conservation and proper management of water ecosystem is critical to the entire mankind, as long as biodiversity constitutes valuable natural resources in economic, cultural, aesthetic, scientific and educational terms. It is in view of this that the results of the present study are expected to serve as a background database for future reference in the management of this area of the Cross River system, Nigeria.

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