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Phytoplankton Community of Upper Reaches of Orashi River, Rivers State, Nigeria

Davies, O.A.*, Otene, B.B. Amachree, D., Nwose, F.A.

Departrment of Fisheries and Aquatic Environment, Rivers State University, Nkpolu-Oroworukwu, Port Harcourt, Rivers State, Nigeria.

***Corresponding Author**

Abstract: *The Upper Reaches of Orashi River in Onelga Local Government Area of Rivers State, Nigeria accommodates different human activities such as dredging, fishing, bathing, washing, laundry to mention but a few. The study determined species composition, diversity, abundance and distribution of phytoplankton assemblages of the Upper Reaches of Orashi River. Also, it investigated the spatial and temporal variations of the phytoplankton of the Upper Reaches of Orashi River. Phytoplankton samples were collected monthly between April and June 2016 from three (3) sampling stations established along the River course according to standard method. The samples were identified microscopically. Data analyses were done using Statistical Package for Social Sciences (SPSS) for two-way analysis of variance at 0.05 level of significance and descriptive statistics. A total of 798 cell counts from 3 families (Bacillariophyceae, Chlorophyceae and Cyanophyceae) and 24 species dominated by diatoms (Bacillariophyta) were recorded. The species diversity indices (Margalef and Shannon) were identified. There were no significant spatial variation between Bacilliariophyta, Chlorophyta and Cyanophyta ($p<0.05$). Dominant species of phytoplankton were Gyrosigma sp (74 cell counts), Meridion circulare (71 cell counts) and Melosira varians (63 cell counts). The presence of dominant Bacillariophyceae indicates that this River is perturbed and organically polluted. Also, the recorded Melosira varians (Bacillariophyceae), Oscillatoria limosa and O. lacustris (Cyanophyceae) denotes nutrient enrichment of this River. Anthropogenic activities within and around this River should be controlled. Also, regular monitoring and evaluation of the study area is advocated.*

Keywords: *Microalgae, Assemblage, Anthropogenic Activities, Organic Pollution, Nutrient Enrichment, Orashi River, Niger Delta.*

INTRODUCTION

Phytoplankton are the plant plankton that is graded according to size, commonly used in aquaculture as food for larval fish and invertebrates (Frank and Snell, 2008). Most members of the phytoplankton are photoautotrophic organisms of the aquatic ecosystems while some are phagotrophic in nature. The growth and distribution of the phytoplankton depend on the carrying capacity of the environment and nutrients concentrations (Davies, Abowei and Tawari, 2009). Phytoplankton uses precursors such as light and carbon dioxide to manufacture their food via the process of photosynthesis. Phytoplankton community composition enhances the functioning of aquatic ecosystems.

In the aquatic ecosystem, the phytoplankton constitutes the foundation of the food webs and chains, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell fish and finfish

(Emmanuel, and Onyema, 2007). Phytoplankton communities are major producers of organic carbon in large rivers, a food source for planktonic consumers and may represent the primary oxygen source in low-gradient Rivers. They are widely used in biomonitoring of pollution (Davies, Abowei and Tawari, 2009). Their distributions, abundance and species diversity, species composition are used to assess the biological integrity of the water body (Townsend, Harper and Begon, 2000). Phytoplankton also reflects the nutrient status of the environment. They lack control over their movements thus they cannot escape pollution in the environment. Davies *et al.* (2015) and Davies (2018) reported that pollution affects the species composition, abundance, distribution, standing crop and chlorophyll concentration of phytoplankton.

Residence of phytoplankton in aquatic ecosystems such as estuaries is related to nutrient availability which affects the abundance and distribution of zooplankton and other invertebrates (Davies, 2018). Quite a number of works have been conducted on the phytoplankton of the Niger Delta rivers (Davies, Abowei and Tawari, 2009; Davies et al., 2015; Davies et al., 2006; Davies et al., 2008; Abowei, Davies and Tawari, 2008; Davies, 2009; Davies and Otene, 2013; Davies and Ugwumba, 2013; Davies and Jaja, 2014; Yakubu et al., 2000). The previous documented studies carried out in the Orashi River to the best of my knowledge are on access to safe water supply and sanitation in Lower Orashi River Basin, Rivers State, Nigeria (Arokoyu and Ukpere, 2014), impact of water quality pertubation on the zooplankton community of Orashi River, South-South, Nigeria (Upadhi and Wokoma, 2017) and physico-chemical variables of the Upper Reaches of Orashi River, Niger Delta, Nigeria (Davies, Nwose and Teere, 2018) but there is little or no information on the phytoplankton community of the Upper Reaches of Orashi River. This study therefore aimed at providing viable and current information on the phytoplankton of the Upper Reaches of this River. This information may indicate if this River is rich in fin/shellfish species. In other words, the study also focused on studying the roles of human activities which influence the species composition, diversity, abundance and distribution of phytoplankton in this water body. The study determined species composition, diversity, abundance and distribution of phytoplankton assemblages. Also, the spatial and temporal variations of the phytoplankton of the Upper Reaches of Orashi River were investigated.

Materials and Methods

The Study Area

The study was carried out on the Upper Reaches of Orashi River Basin System, Niger Delta, Nigeria. The river basin starts from Ndoni- Onelga and stretches to the sea via Abonnema- Asalga (Fig. 1). The region lies in the southern fringe of the tropical rainforest belt. It is located between latitudes 4°32' and 5°23'N, and longitudes 6°24' and 6°59'E. It shares boundary with the following local governments areas: Ahoada East and Ogba/Egbema/Ndoni in the North; Akuku-Toru in the South; Degema and Asari-Toru at the South-South East; Ahoada East and Emohua in the Eastern flank; Yenagoa at the North-West, Brass and Ogbia (Kolo Creek Communities)

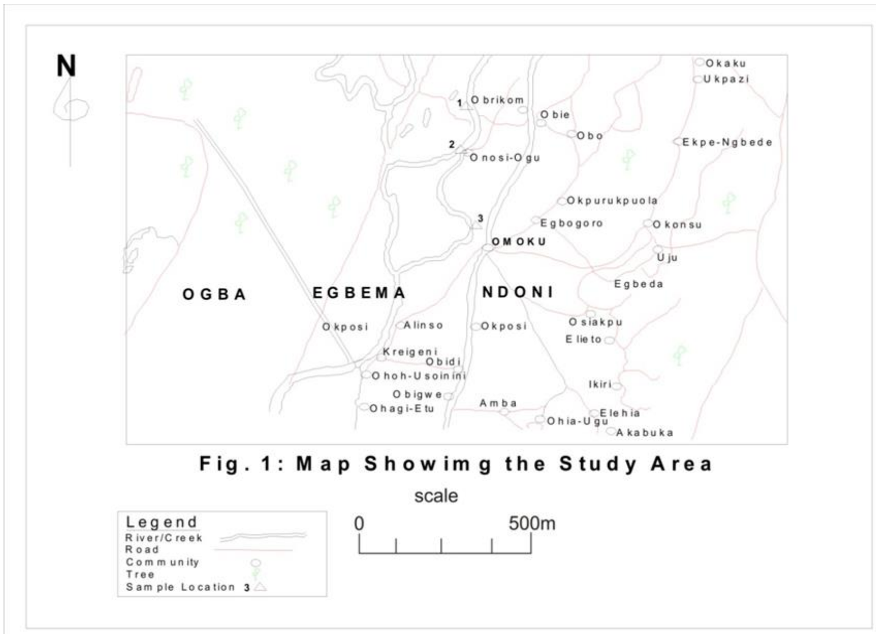

Figure 1: Study Area Map

Local Government Areas of Bayelsa State at its South-South West and West respectively. It is a low lying region between 0 to 55 meters above sea level. Its hydro-geologic profile is characterized by alluvial sedimentary strata composed chiefly by poorly leached loosed porous sandy to fertile loamy soils.

Sampling Stations

Water samples were collected from three sampling stations within the Upper Reaches of Orashi River and the Stations were located lengthwise along the River namely: Station 1 (Obiafu /Obrikom (OB/0B) Gas Plant Jetty), Station 2 (Onukpor water side at Omoku), and Station 3 (G.R.A water side at Omoku).

Duration of Study

Phytoplankton and surface water samples were collected once a month for three months between April and June 2016 at the three stations along the water course of the Upper Reaches of the River using AHPA (2005) method.

Field Collection of Phytoplankton

Phytoplankton samples were collected from sampling stations (Station 1, Station 2 and Station 3) in day light hours from (11.000 to 14.00 hours) using a 55 µm mesh size standard plankton net. The phytoplankton net was hauled horizontally against the water current for about 5 minutes and samples collected by the hauled net were transferred each time to one litre well labeled plastic containers with screw caps. Samples were preserved with 4% formaldehyde for microscopic analysis.

Laboratory Analysis of Phytoplankton

Five hundred (500) ml of each sample were allowed to stand for a minimum of 24 hours before decanting the supernatant. The supernatant was removed carefully until a 100 ml concentrated sample is taken. One (1) ml of sub-sample was collected from it and transferred into a Sedgwick–Rafter counting chamber using a stampel pipette. Five grids of the Sedgwick rafter were employed for identification and enumeration. Identification and enumeration were done under a binocular compound microscope with magnification 40 x 400. Three replicates of the sub-samples were analysed.

Phytoplankton Identification

Identification and characteristics of planktonic species was done by the descriptive keys by Needham and Needham (1962), Newell and Newell (1963), Han (1978) and Prescott (1982). Results were expressed in number of organisms per ml.

Calculation of Plankton Community Indices

The following formulae were used for the calculation of phytoplankton parameters:

i) Density of phytoplankton (Number of plankters per ml)

$$= (T)\frac{1000}{AN} \times \frac{Volume\ of\ concentrate\ (ml)}{AN\ Volume\ of\ sample\ (ml)}$$

(Boyd, 1982)

Where: T = Total number of plankters counted
A = area of grid in mm^2
N = number of grids employed
1,000 = area of counting chamber in mm^2

ii) Margalef Species diversity

$$H = \frac{S-1}{InN}$$

(Boyd, 1982)

Where S = the number of species (or other taxonomic group)
N = total number of phytoplankters

iii) Shannon's index of general diversity (H)'

$$H' = \frac{\log N - 1}{N \sum ni, \log ni}$$

(Cox, 1996)

Where: ni = total number number of individuals in each species
N = total number of individuals of all species

Nutrient parameters

Phosphate, nitrate and sulphate of the surface water samples were analyzed following AHPA (2005) method.

Data Analysis

Data obtained were analyzed for two-way analysis of variance (ANOVA) at 0.05 level of significance and descriptive statistics using Statistical Packages for Social Sciences (SPSS, 2006).

Results

Phytoplankton Composition, Abundance and Distribution

A total of 24 species (798 cell counts) of phytoplankton from 3 taxonomic groups, Bacillariophyta (12 species), Chlorophyta (7 species) and Cyanophyta (5 species) were recorded from the upper reaches of Orashi River. Spatially, the highest number of phytoplankton (312 cell counts) representing 39.10 % was observed in Station 1 while the lowest number 213 cell counts representing 26.69 % was recorded in Station 3 (Table 1). Spatially, the order of occurrence in increasing order was Station 1>Station 2 >Station 3. In all, the highest number of phytoplankton per individuals was observed in the month of June (268 cell counts) while the least (263 cell counts) were observed in May (Table 2). Bacillariophyceae had the highest value (168 cell counts) in the month of April while the lowest value (144 cell counts) was observed in May. The highest values of the class Chlorophyleae and Cyanophyceae (98 and 21 cell counts) were observed in May and the lowest (87 and 12 cell counts) in April.

The Bacillariophyceae species with the highest frequency of occurrence was *Gyrosigma sp.* (74 cell counts), followed by *Meridion circulare* (71 cell counts), *Melosira varians* (63 cell counts), *Cyclotella kutzingiana* (61 cell counts) and the least, *Tabellaria fenestrata* (7 cell counts) (Tables 1 and 2). Also, the Chlorophyceae species with the highest frequency of occurrence was *Volvox globator* (77 cell counts), followed by *Spirogyra sp.* (53 cell counts) and, the least, *Ulothrix sp.* (12 cell counts). For the Cyanophyceae species with the highest frequency of occurrence was *Rivularia planctonica* (17 cell counts), followed by *Oscillatoria lacustris* (13 cell counts) and, the least, *Anacystis aeruginosa* (5 cell counts).

Fig. 2 shows the spatial and temporal mean density of phytoplankton in the study area. The mean density of Bacillariophyceae was consistently higher in all the stations and months than any other taxonomic group followed by Chlorophyceae while the least was Cyanophyceae. There was no significant difference ($p>0.05$) between and within taxonomic groups spatially and temporally. Bacillariophyceae recorded the highest density (1.82 org/ml) in April (Station 1), while in the month of May and June the values were uniform (1.79 org/ml). In the month of May and June, Chlorophyceae had uniform highest density value of (1.30 org/ml) both in Station 1, while in April, Chlorophyceae recorded the lowest density of (0.80 org/ml) in Station 1. Cyanophyceae recorded the highest density (0.30 org/ml) in May and at Station 1, while in the month of April and June the values were uniform (0.20 org/ml) at Station 3.

Table 1: Spatial Variations of Phytoplankton in the Upper Reaches of Orashi River

	Taxa/Species	**Station**			
S/No.	**BACILLARIOPHYCEAE**	**1**	**2**	**3**	**Total**
1	*Cyclotella kutzingiana*	30	19	12	61
2	*Cyclotella glomerata*	24	10	4	38
3	*Melosira varians*	22	30	11	63
4	*Coscinodiscus lacustris*	12	14	4	30
5	*Tabellaria fenestrata*	2	1	4	7
6	*Diatoma vulgare*	6	5	4	15
7	*Meridion circulare*	23	29	19	71
8	*Gyrosigma sp.*	32	17	25	74
9	*Cymbella sp.*	9	4	3	16
10	*Synedra nana*	15	18	10	43
11	*Synedra pulchella*	9	16	14	39
12	*Bacillaria Paradoxa*	5	3	4	12
	Total	**189**	**166**	**114**	**469**
	CHLOROPHYCEAE				
1	*Volvox globator*	40	22	15	77
2	*Volvox aureus*	7	16	18	41
3	*Netrium digitus*	13	8	4	25
4	*Desmidium Optogonium*	15	18	11	44
5	*Spirogyra sp.*	14	19	20	53
6	*Ulothrix sp.*	6	4	2	12
7	*Closterium dianae*	8	4	13	25
	Total	**103**	**91**	**83**	**277**
	CYANOPHYCEAE				
1	*Oscillatoria Limosa*	3	2	3	8

2	*Oscillatoria Lacustris*	3	3	7	13
3	*Rivularia planctonica*	8	7	2	17
4	*Microcystis Puulvenea*	3	3	3	9
5	*Anacystis aeruginosa*	3	1	1	5
	Total	**20**	**16**	**16**	**52**
	Total No of Individuals	**312**	**273**	**213**	**798**
	Percentage Occurrence	39.10	34.21	26.69	100.00
	Total No of Species 24				

Table 2: Monthly Variations of Phytoplankton in the Upper Reaches of Orashi River

	Taxa/Species				
S/No.	**BACILLARIOPHYCEAE**	**April**	**May**	**June**	**Total**
1	*Cyclotella Kutzingiana*	22	14	25	61
2	*Cyclotella glomerata*	15	7	16	38
3	*Melosira varians*	23	17	21	63
4	*Coscinodiscus lacustris*	10	9	11	30
5	*Tabellaria fenestrata*	3	1	3	7
6	*Diatoma vulgare*	5	3	7	15
7	*Meridion circulare*	27	22	22	71
8	*Gyrosigma sp.*	32	24	18	74
9	*Cymbella sp.*	3	7	6	16
10	*Synedra nana*	15	14	14	43
11	*Synedra pulchella*	12	16	11	39
12	*Bacillaria paradoxa*	0	10	2	12
	Total	**168**	**144**	**156**	**469**
	CHLOROPHYCEAE				
1	*Volvox globator*	27	26	24	77
2	*Volvox aureus*	14	14	13	41
3	*Netrium digitus*	8	10	7	25
4	*Desmidium optogonium*	17	12	15	44
5	*Spirogyra sp.*	18	14	21	53
6	*Ulothrix sp.*	3	7	2	12
7	*Closterium dianae*	0	15	10	25
	Total	**87**	**98**	**92**	**277**
	CYANOPHYCEAE				
1	*Oscillatoria limosa*	3	2	3	8
2	*Oscillatoria lacustris*	4	5	4	13
3	*Rivularia planctonica*	4r	5	8	17
4	*Microcystis Puulvenea*	1	4	5	9
5	*Anacystis aeruginosa*	0	5	0	5
	Total	**12**	**21**	**20**	**52**
	Total No of Individuals	**267**	**263**	**268**	**798**
	Percentage Occurrence	33.46	32.96	33.58	100.00
	Total No. of Species 24				

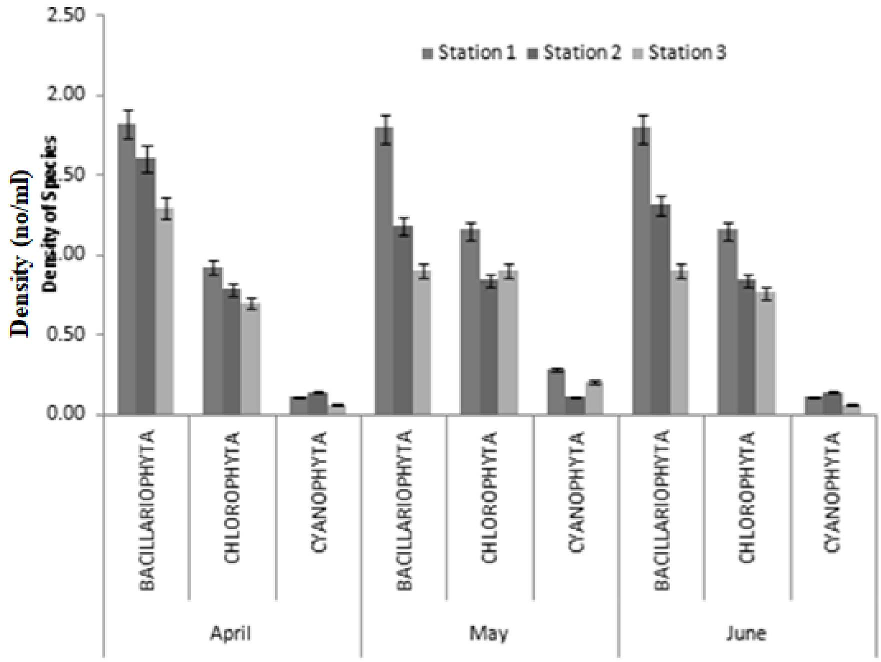

Figure 2: Spatial and temporal density of phytoplankton in Upper reaches of Orashi River

Species Indices

Figs. 3 and 4 show the Margalef and Shannon indices studied. Margalef index ranged from Stations 1 to 3 in all the phytoplankton taxonomic groups (Bacillariophyceae, Chlorophyceae and Cyanophyceae). Bacillarioplyceae ranged from 2.40 (Station 1) to 2.61 (Station 2) in April, Chlorophyceae ranged between 2.86 (Station 1) and 3.11 (Station 3), while Cyanophyceae ranged between 6.19 (Station 1) and 14.50 (Station 3). The overall mean values of (Margalef index) for the month of April were 7.49 = 0.105 (Bacillariophyceae), 8.97 = 0.125

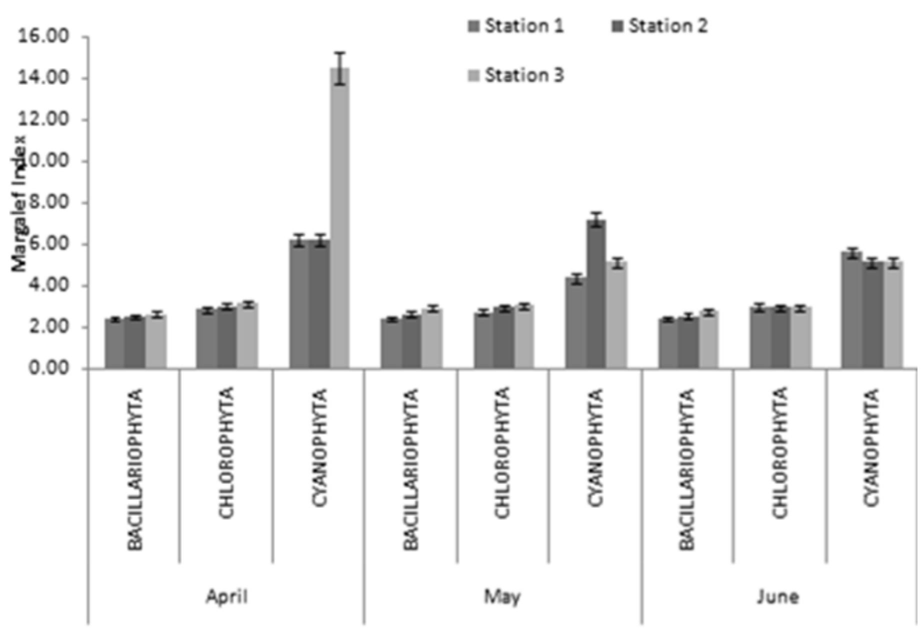

Figure 3: Spatial and temporal Margalef index of phytoplankton in Upper Reaches of Orashi River

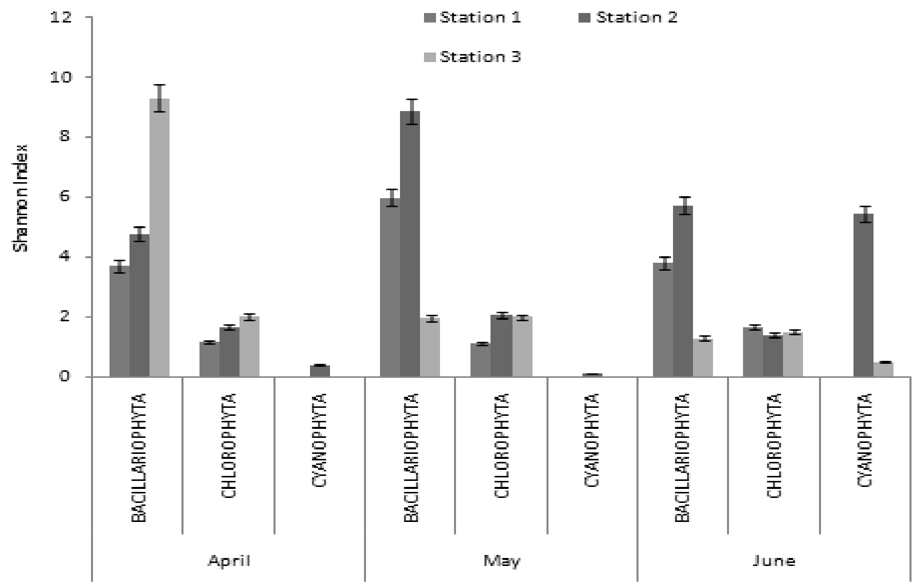

Figure 4: Spatial and temporal Shannon index of phytoplankton in Upper Reaches of Orashi River

(Chlorophyceae) and 26.60 = 4.792 (Cyanophyceae) (Fig. 3). The values increased from Bacilleriophyceae to Cyanophyceae. Shannon index increased from Station 1 to 3 and decreased from Bacillarophyceae to Cyanophyceae in April. Bacillanophyceae ranged from 3.72 (Station 1) to 9.33 (Station 3), Chlorophyceae ranged from 1.19 (Station 1) to 2.05 (Station 3) while Cyanophyceae ranged between 0.03 (Station 1) and 0.06 (Station 3) in the month of April (Fig. 4) temporally. Overall mean values ranged from Cyanophyceae 0.15 = 0.25 to Bacillariophyceae (5.94 = 2.98) in April. Others are as in (Fig. 4).

Nitrate values ranged between 0.40 mg/L (Station 3, June) and 0.84 mg/L (Station 1, April and June) with the overall mean of 0.54±0.19 mg/l during the present study (Table 3). Spatially and temporarily the phosphate value of 0.10 mg/L was uniform in all the stations and the three months during the study period with an overall mean of 0.10±0.0 mg/L. The sulphate levels recorded during sampling period from April to June ranged from 3.0 mg/L (Station 3, April) to 10.7 mg/L (Station 1, April) with overall mean of 5.72±3.57 mg/L.

Table 3: Spatial and temporal nutrient parameters of surface water from upper reaches of Orashi River

Parameter	**Month/Station**									**Mean±SD**	**Standard**
	April			**May**			**June**				
	1	2	3	1	2	3	1	2	3		
Nitrate (mg/L)	0.84	0.48	0.43	0.82	0.44	0.41	0.84	0.46	0.40	0.54±0.19	≤5 (McNeely et al.,1979)
Phosphate (mg/L)	0.10	0.10	0.10	0.05	0.10	0.10	0.10	0.10	0.10	0.1±0.00	0.1 (USEPA, 1976)
Sulphate (mg/L)	10.7	3.9	3.0	10.2	3.4	3.1	10.5	3.6	3.1	5.72±3.57	500 (USEPA, 1976)

Discussion

The observed number of species and families of phytoplankton dominated by Bacillariophyceae (diatoms) in the present study was low compared with some freshwater rivers in the Niger Delta and within Nigeria. Davies *et al*. (2009) reported eighty-four species from seven families of phytoplankton of Minichinda Stream, Rivers State, Nigeria; Abowei *et al*. (2008) observed five families, forty-three species and dominant diatoms of the phytoplankton of the Lower Sombreiro River, Niger Delta, Nigeria and Ikenweiwe *et al*. (2011) obtained four families of phytoplankton of Lekan-Are Lake, Ogun State, Nigeria. However, this present study recorded higher values of species than the work on phytoplankton of Oya Lake, Bayelsa State, Nigeria by Davies *et al*. (2015) that observed eleven species from three families, dominated by Chlorophyceae (blue-green algae) which could be attributed to difference in environmental factors and incessant crude oil spillages.

These results also differed from other studies on brackish water environments in the Niger Delta and Nigeria such as Davies *et al*. (2008) of seven families, 26 genera, 63 species and dominant diatoms of the Lower Reaches of Okpoka Creek, Niger Delta, Nigeria and Davies *et al*. (2009) of five families, one hundred and sixty-nine species and dominated by diatoms of the phytoplankton community of Elechi Creek, Niger Delta, Nigeria-a nutrient-polluted Tropical Creek. According to Guy (1992), the major factors influencing phytoplankton abundance are temperature, turbidity, light, nutrient availability, water current and chlorophyll 'a' grazing by zooplankton etc. The dominant Bacillariophyceae is a common phenomenon and feature of the open eutrophic water systems according to Townsend *et al*. (2000). The predominance of Bacillariophceae in Niger Delta waters observed was not only phytoplankton communities but also in periphyton communities (Nwankwo, 2004; Chindah, 2004). Therefore the dominance of diatoms in this study contradicts the statement that diatoms pre-dominate unpolluted natural lotic water bodies in the tropics (Davies, Abowei and Tawari, 2009). Dominance of Bacillariophyceae could be due to their ability to compete favourably with others for nutrients (Davies, Abowei and Tawari, 2009). It could also be an indication that the Upper Reaches of Orashi River is organically polluted according to Ruivo (1972) study that stated that organisms are used for monitoring pollution based on the belief that natural unpolluted environments are known by balanced biological conditions and contain a great diverse of plants and animals life with no one dominating.

The high abundance of phytoplankton in Station 1 above other stations could be attributed to difference in environmental factors such as nutrient values (nitrate, phosphate and sulphate) and low rate of grazing by zooplankton. The two indices of species diversity (Margalef's species richness and Shannon's diversity index) used in this study showed minimal variation throughout the period of study. The ranges of Margalef's index observed for the various phytoplankton classes, Bacillariophycere, Cholorophyceae and Cyanophyceae are typical of eutrophic water as reported by Roberto *et al*. (1998).

The observed *Melosira varians*, *Oscillatoria limosa* and *O. lacustris* denotes nutrient enrichment of the Upper Reaches of Orashi River according to Zargarad and Ghosh (2006) and Ganai and Parveed (2014). Those studies stated that excessive growth of certain algal genera namely *Scenedesnus*, *Anabaena*, *Oscillatoria* and *Melosira* indicate nutrient enrichment of aquatic bodies. The harmful algal bloom-forming genera (*Melosira*, *Synedra* and *Oscillatoria*) observed in this present study were also reported in some aquatic environments in the Niger Delta (Davies, Abowei and Tawari, 2009; Davies et al., 2008; Davies et al., 2015; Davies et al., 2014; Roberto, Torres – Orozco and Zanatta, 1998).

The obtained nitrate values in this study were more than the ≤5 mg/L (Guy, 1992) expected to be found in natural surface water. The fluctuation in values of nitrate across the stations and months could be attributed to high human excrement and industrial discharged. The high nitrate value in Station 1 in April and June could be linked to anthropogenic inputs. The phosphate values in this study fell within the set standard of USEPA (Nwankwo, 2004) of 0.1 mg/L for open waters. The values were slightly uniform across the stations and months, observed phosphate could be linked to utilization by photoautotrophs to synthesize chlorophyll 'a' for primary productivity in the aquatic ecosystem. According to Davies *et al.* (2009), phosphate is the most limiting nutrient to primary productivity in aquatic ecosystem whose deficiency affects algal metabolism, growth and photosynthetic activity but excess could cause eutrophication. The observed phosphate values were favourable to the observed phytoplankton. The obtained sulphate values showed that Upper Reaches of Orashi River is a fresh water environment. The sulphate mean values recorded during the present study period were lower than the values (377.60-1231 mg/L) reported by Davies *et al.* (2009) in Elechi Creek, Rivers State but similar to the observation of 2.07 mg/L of Minichinda Stream, Rivers State by Davies *et al.* (2009). However, the values were within the permissible value (500 mg/L) of USEPA (Chindah, 2004).

Conclusion and Recommendation

The presence of dominant Bacillariophyceae indicates that this River is perturbed and organically polluted. Also, the recorded *Melosira varians* (Bacillariophyceae), *Oscillatoria limosa* and *O. lacustris* (Cyanophyceae) denotes nutrient enrichment of this River and the level of vulnerability of this river to environmental factors or stress. In addition, three harmful algal bloom-forming genera (*Melosira*, *Synedra* and *Oscillatoria*) were recorded. Based on the results, the followings are recommended:

1. There should be proper monitoring of the activities of people living at the bank of the River to ensure that they comply with environmental laws.
2. Companies, sited close to the bank of the River not complying with the environmental rules and regulations should be sanctioned.
3. There should be surveillance on regular bases to ensure that the issues of threat could be averted.
4. Effluents from companies and residents should be treated before discharged into the river or recycled into useful materials or resources.

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