Journal of Fisheries International 3 (3): 83-90, 2008
ISSN: 1817-3381

Phytoplankton of the Lower Reaches of Okpoka Creek, Port Harcourt, Nigeria

[1]O.A. Davies, [2]D.S. Abolude and [3]A.A.A. Ugwumba
[1]Department of Fisheries and Aquatic Environment,
Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria
[2]Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria
[3]Department of Zoology, University of Ibadan, Ibadan, Nigeria

Abstract: There has been no information on the phytoplankton community of the lower reaches of Okpoka Creek, Upper Bonny Estuary, Port Harcourt, Nigeria. This study was conducted to assess the species composition, diversity, abundance and distribution of phytoplankton. Phytoplankton and surface water samples were collected from May 2004 to April 2006 at mostly low tides from three stations according to standard methods. Phytoplankton was identified microscopically. Species diversity was calculated using standard indices. Surface water samples were analyzed for temperature, pH, transparency, dissolved oxygen, salinity, total dissolved solid, chloride, alkalinity, phosphate and ammonia. Phytoplankton community was made up of seven families: Bacillariophyceae (diatoms) were the most diversified and abundant algae with 26 genera and 63 species. *Melosira varians* (351 cell counts) was the dominant diatom. The examined physico-chemical parameters favoured the high abundance and population of phytoplankton in this creek.

Key words: Phytoplankton, species composition, abundance, physico-chemistry, okpoka creek, Nigeria

INTRODUCTION

Phytoplankton plays a significant role in the aquatic food chain. It is generally known that algae provide food directly or indirectly to aquatic fauna (Townsend *et al*., 2000; Miller, 2005; Conde *et al*., 2007). Phytoplankton communities are major producers of organic carbon in larger rivers, are a food source for planktonic consumers and may represents the primary oxygen source in many low gradient rivers (Wehr and Descy, 1998). According to Reynolds (2006), phytoplankton are responsive to excessive supplies of inorganic nutrients and may pose problems in long stretches of rivers with cultural eutrophication. They may also enhance water quality for humans in rivers affected by agricultural or industrial uses.

The knowledge of the algae in the aquatic environments could be useful in predicting the movement of herbivorous fishes (Ikusemiju and Olaniyan, 1977). They do not have control over their movement, thus they are good bio-indicator of pollution and pertubation in any aquatic ecosystem (Marine Biology Organization [MBO], 2007a). The use of organisms for monitoring pollution is based on the belief that natural, unpolluted environments are characterized by balanced biological conditions and contains a great diversity of plants and animal life with no one species dominating (Ruivo, 1972). A natural environment is composed of animals of all trophic levels. Passy (2007) used the distribution of diatoms to reflect the average biological condition of water bodies. The species composition, diversity, abundance and distribution of the phytoplankton are used to assess the biological integrity of the water body. They also, reflect the nutrient status of the environment. Diatoms favour nutrient rich environment particularly nitrates (Frankovich *et al*., 2006). Euglenoids have been implicated as biological indicator of pollution (Munawar, 1972).

Studies on the phytoplankton of the Niger Delta River System include those of Okpuruka (1986), Nwadiaro (1990), Erondu and Chindah (1991a, b), Chindah and Pudo (1991) and Chindah and Keremah (2001). There is no information on the phytoplankton of lower reaches of Okpoka Creek. These parts of Okpoka Creek are under various human activities and they contribute to the Rivers State fish resources. These human activities are boating, dredging, fishing, toileting, refuse dumping and domestic and industrial effluents discharges. This present study is aimed at providing information on the phytoplankton assemblage of these parts of Okpoka Creek.

Corresponding Author: O.A. Davies, Deparment of Fisheries and Aquatic Environment,
Rivers State University of Science and Technology, Nkpolu, Port Harcourt, Nigeria

MATERIALS AND METHODS

Study area: The Okpoka Creek is situated between longitudes 7°00"E and 7°15"N and latitudes 4°28"E and 4°40"N. It is a tributary of the Upper Bonny Estuary in the Niger Delta, South-South of Nigeria (Fig. 1). The Bonny Estuary is richly endowed with abundant aquatic resources (fin/shellfishes resources, other aquatic life). The area is prone to pollution resulting from industries located along its shore. The flushing action of the tidal flows contribute to moving of these pollutants down into the coastal zones of which the lower reaches of Okpoka Creek is one. The lower reaches of this Creek pass through the following communities: Abuloma, Ojimba, Oba-Kalio, Abam and George-ama. The vegetation is dominated by Nypa palm (*Nypa fructican*), red mangroves (*Rhizophora racemosa*) and white mangroves (*Avecennia nitida*) (Davies, 2008).

Sampling stations: A total of 3 stations were chosen at least 500 m apart along the main creek course. The sediments in these stations are sandy-loam (Davies, 2008).

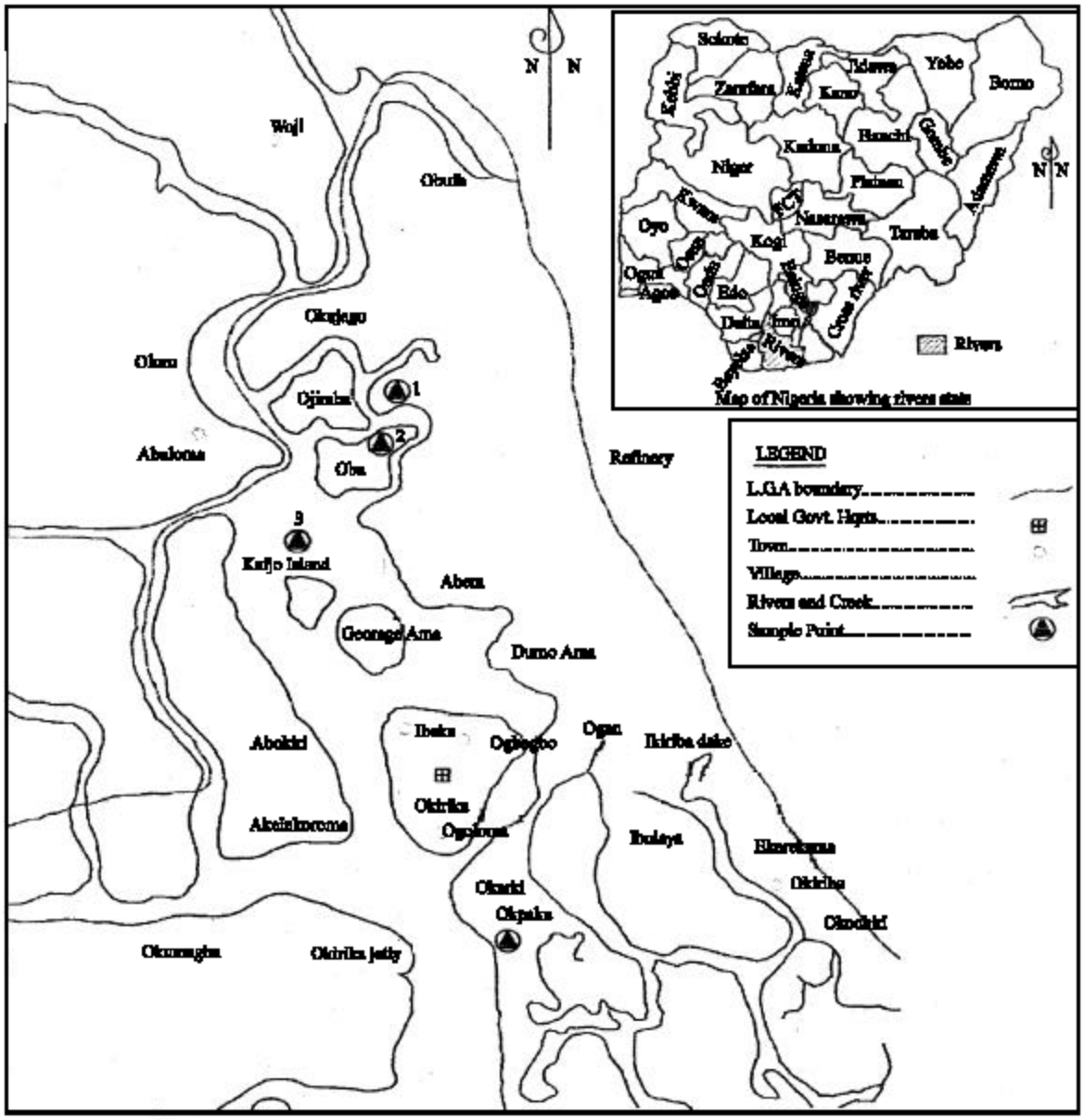

Fig. 1: Study area map

The stations are: Ojimba (upstream close to a dredging company in Abuloma), Oba and Kalio-ama (downstream close to Abuloma Jetty and Marine Base Sawmill Industry).

Phytoplankton sample collections and analyses: Samplings were done mostly during the low tides. Surface water samples were collected using sterilized one-litre wide mouth, plastic containers (APHA, 1985) at each station. The sample in the container was fixed with 10% formalin. Sedgwick-Rafter counting chamber and binocular compound microscope were used to enumerate the phytoplankton (standing crop). Identification of species was done by using descriptive keys of Mills (1932), Needham and Needham (1962) and Newell and Newell (1963). The diversity indices calculated were Margalef species diversity (H), Dominance, Shannon and Evenness.

Surface water sample collections for physico-chemistry parameters: One-litre sterilized containers were used to collect water samples for 10 physico-chemical parameters at each station namely, temperature, pH, salinity, transparency, Total Dissolved Solids (TDS), dissolved oxygen (DO), chloride, alkalinity, phosphate and ammonia. All the containers were kept in ice-chest box for laboratory analyses (APHA, 1985). Temperature, pH and DO were measured in-situ using mercury-in-glass thermometer (in Celsius), pH meter model Hanna H19812 and Winkler's method. Salinity was measured in the laboratory using salinity/conductivity meter Horiba-u:IOμ multimeter. Transparency was determined using a 20 cm diameter Secchi disc as described by Boyd (1981). TDS, chloride and alkalinity by titrimetric method (APHA, 1985). Phosphate and ammonia were determined by spectrophotometer method at various wavelengths (APHA, 1985).

Statistical analysis: Statistical Analysis System (SAS) (2003) and Microsoft Excel 2003 statistical packages were used to analyze the data for analysis of variance (ANOVA), Duncan, multiple range and Pearson Correlation Coefficient.

RESULTS

Phytoplankton composition: The phytoplankton of the lower reaches of Okpoka Creek was composed of seven families: Bacillariopyceae (diatoms), Chlorophyceae (green algae), Cyanophyceae (blue-green), Euglenophyceae (euglenoids), Chrysophyceae (golden algae), Pyrrophyceae (dinoflagellates) and Xanthophyceae (yellow-green). This study recorded 61 genera and 112 species of phytoplankton (Table 1). Diatoms were the dominant algae in terms of genera and species (26 genera and 63 species) while the golden algae the least (1 genera and 1 species). Station 3 had the maximum number of diatom species (53 species) but the maximum relative abundance of diatoms (35.2%) was recorded in Station 2. Chrysophyceae and Pyrrophyceae were absent in Stations 2 and 3. The dominant phytoplankton species were *Melosira varians* (diatoms), *Netrium digitus* (green algae), *Anabeana spiroides* (blue-green algae), *Euglena gracilis* (euglenoid), *Dinobryon sertularia* (golden algae), *Ceratium hirudinea* (dinoflagellate) and *Tribonema vulgare* (yellow-green).

Diatoms: Bacilliariophyceae recorded the maximum density (7166.80 No./mL) and the Euglenophyceae the minimum (96.46 No./mL).

The diatoms were the most diversified algae in the Lower Okpoka Creek. Margalef species diversity index ranged between 1.41±0.08 (Station 1) and 1.62±0.07 (Station 2). Station 2 tended to have the richest number of diatoms among the Stations (Table 2).

Melosira varians was the most abundant diatom (Table 3). It increased in number from Station 1 (351 cell counts) to Station 3 (421 cell counts). *Cyclotella comta* was the next abundant diatom. Station 2 (486 cell counts) recorded the highest number of *C. comta* and Station 1 (213 cell counts) the least. *Cosinodiscus lacustris* and *Navicula placentula* ranked third and fourth, respectively in abundance. The maximum of number of *C. lacustris* was observed in Station 1 (381 cell counts) and the minimum in Station 2 (289 cell counts). *N. placentula* ranged between 197 cell counts (Station 3) and 274 cell counts (Station 2). Station 2 had the maximum density of diatoms

Table 1: Phytoplankton composition of the lower reaches of Okpoka Creek

Phytoplankton families	Density (No./mL)	Relative abundance of species (%) S1	S2	S3	Total number of genera	Total number of species S1	S2	S3	Number of species
Bacillariophyceae	7166.8	32.2	35.2	32.6	26	63	46	49	53
Chlorophyceae	1672.97	27.7	39.8	32.6	22	28	18	20	19
Cyanophyceae	382.31	28.2	53.5	18.3	6	12	7	9	6
Euglenophyceae	96.46	64.1	5.1	30.8	2	4	3	2	2
Chrysophyceae	457.26	100	-	-	1	1	1	-	-
Pyrrophyceae	286.74	100	-	-	2	2	2	-	-
Xanthophyceae	1330.48	35.2	39	25.9	2	2	2	2	2
Total					61	112	79	83	82

S1-Station 1, S2-Station 2, -Absent, S3-Station 3, - Absent

Table 2: Variation of diversity indices of phytoplankton in relation to station in lower reaches of Okpoka Creek

		Diversity indices			
Station	Phytoplankton class	Dominance	Evenness	Shannon	Margalef
1	*Bacillariophyceae*	0.18±0.01^{a}	0.41±0.01^{a}	0.78±0.03^{b}	1.41±0.08^{ab}
2		0.17±0.02^{a}	0.41±0.01^{a}	0.85±0.03^{a}	1.62±0.07^{a}
3		0.14±0.01^{b}	0.38±0.02^{a}	0.79±0.05^{a}	1.50±0.10^{ab}
1	*Chlorophyceae*	0.28±0.04^{a}	0.26±0.04^{a}	0.26±0.04^{a}	0.49±0.08^{a}
2		0.22±0.04^{a}	0.25±0.04^{a}	0.27±0.05^{a}	0.44±0.09
3		0.24±0.04^{a}	0.24±0.04^{a}	0.25±0.04^{b}	0.50±0.10^{a}
1	*Cyanophyceae*	0.15±0.07^{a}	0.12±0.06^{a}	0.13±0.05^{a}	0.24±0.13^{a}
2		0.16±0.07^{a}	0.12±0.05^{a}	0.11±0.05^{a}	0.27±0.14^{a}
3		0.14±0.09^{a}	0.13±0.08^{a}	0.09±0.06^{a}	0.30±0.21^{a}
1	*Euglenophyceae*	0.22±0.01^{a}	0.24±0.10^{b}	0.12±0.02^{b}	0.24±0.10^{b}
2		0.03±0.01^{a}	0.02±0.01^{b}	0.01±0.01^{b}	0.02±0.01^{b}
3		0.25±0.25^{a}	0.22±0.22^{a}	0.10±0.10^{a}	0.22±0.22^{a}
1	*Chrysophyceae*	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
2		-	-	-	-
3		-	-	-	-
1	*Pyrrophyceae*	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
2		-	-	-	-
3		-	-	-	-
1	*Xanthophyceae*	0.13±0.06^{a}	0.11±0.05^{a}	0.08±0.03^{a}	0.16±0.08^{a}
2		0.11±0.06^{a}	0.09±0.05^{a}	0.07±0.03^{a}	0.07±0.04^{a}
3		0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}	0.00±0.00^{b}

Means with the same letter in the same row are not significantly different (p>0.05)

(926.7 No./mL) and Station 1 the minimum (7274.08 No./mL) (Fig. 2).

Green algae: A total of 28 species of green algae were observed. *Netrium digitus* was the most abundant (756 cell counts) and followed by *Crucigenina retangularis* (158 cell counts) (Table 4). *N. digitus* increased downstream from Station 1 (187 cell counts) to Station 3 (290 cell counts) while the maximum number of *C. rectangularis* was recorded in Station 2 (73cell counts) and the minimum in Station 1 (33 cell counts). However, the highest density of green algae (1245.77 No./mL) was observed in Station 1 and the lowest (1171.24 No./mL) in Station 2 (Fig. 2).

Blue-green algae: *Anabeana spiroides* was the dominant blue-green algae (25 cell counts) and *Nodularia* species, the least (3 cell counts) (Table 5). *A. spiroides* decreased downstream, ranged between 3 cell counts (Station 3) and 12 cell counts (Station 1). Station 2 had the maximum density (485.50 No./mL) of blue-green algae and Station 3 the minimum (263.86 No./mL) (Fig.2).

Euglenoids, golden algae, dinoflagellates and yellow-green algae: The dominant euglenoid was *Euglena gracilis* (Table 5). The maximum *E. gracilis* (17 cell counts) was observed in Station 1 and the minimum (1 cell count) in Station 2. Station 3 (71.00 No./mL) recorded the highest density of euglenoids and Station 2 (47.38 No./mL), the least (Fig. 2). Only 1 species of golden algae was recorded. It was only present in Station 1 with density of 390.83 No./mL (Fig.3). Dinoflagellates were

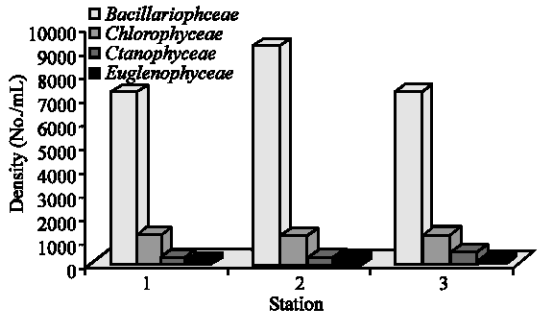

Fig. 2: Variation of Phytoplankton density in relation to station in Lower reaches in Okpoka Creek

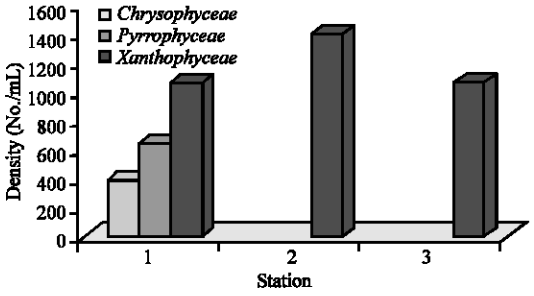

Fig. 3: Variation of Phytoplankton density in relation to station in Lower reaches in Okpoka Creek

absent in Stations 2 and 3. *Ceratium hirudinea* was the dominant species (16 cell counts). The density of dinoflagellates was 639.50 No./mL (Fig. 3). Two species of yellow-green algae were observed. *Tibonema vulgare* was the dominant species (554 cell counts). This species decreased downstream from 212 cell counts (Station 1)

Table 3: Species composition of *Bacillariophyceae* of lower reaches of okpoka creek

Bacillariophyceae species	Cell counts S1	S2	S3	Total
Cyclotella comta	213	486	348	1047
C. meneghiniana	134	237	179	550
C. striata	47	81	57	185
C. operculata	147	123	148	418
*C. species**	147	15	193	355
Fragilaria intermedia	-	35	9	44
F. capucina	-	7	-	7
*F. species**	7	35	10	52
Epithermia zebra	-	-	8	8
Stauronesis acuta	8	18	-	26
S. parvula	4	2	-	6
S. species	24	-	23	47
Diatoma vulgare	7	48	3	58
*Rhizosolenia species**	-	-	7	7
Tabellaria fenestrata	14	35	95	144
Synedra ulna	605	205	140	950
S. acus	22	-	9	31
S. affinis	96	21	48	165
*S. species**	54	136	91	281
Cosinodiscus lacustris	381	289	372	1042
C. radiata	18	82	83	183
*C. species**	24	28	82	134
Amphora ovalis	94	56	38	188
Nitzschia sigma	291	142	303	736
N. bilobata	116	124	30	270
N. lanceolata	-	25	54	79
*N. species**	-	14	-	14
N. paradoxa	467	97	28	592
N. filiforms	23	27	-	50
Navicula gracilis	81	85	62	228
N. cuspidata	152	92	56	300
N. placentula	251	274	197	722
N. microcephala	14	100	72	186
N. bacillum	88	112	53	253
*N. species**	36	132	23	191
Melosira varians	351	391	421	1163
M. undulata	35	-	60	95
M. pusilla	56	75	-	131
M. distans	-	12	11	23
M. listans	164	199	54	417
M. gracilis	5	1	1	7
*M. species**	16	-	3	19
Cymbella cuspidata	1	20	-	21
C. lata	10	14	6	30
Surirella robusta	2	32	26	60
*S. species**	-	2	10	12
*Cymtopleura species**	4	-	-	4
Pinnularia viridis	8	11	-	19
P. horealis	7	5	31	43
P. major	-	18	-	18
*P. species**	37	29	13	79
Frustulia rhomboides	114	375	62	551
Gyrosigma acuminatum	108	207	177	492
*G. species**	34	122	68	224
G. attenuatum	-	-	23	23
G. paradoxa	-	-	36	36
Sphenodiscus astrae	16	137	67	220
*Bacillaria species**	-	-	23	23
*Biddulphia species**	-	-	4	4
Corethron hystix	-	-	2	2
*Cyclindrotheca species**	-	78	49	127
*Hydrosera species**	-	-	12	12
*Skeletonema species**	-	-	8	8
Total	4533	4891	3988	13412

-Absent, S1-Station 1 S/No -Serial number, S2-Station 2 S3-Station 3

Table 4: Species composition of *chlorophyceae* of lower reaches of okpoka creek

Chlorophyceae species	Cell counts S1	S2	S3	Total
Microspora villeana	2	112	-	114
Coelochaeta nitellarum	-	2	-	2
Mesotaenium species	3	5	-	8
Entransia dichloroplastes	-	3	-	3
Tetraedron tumidulum	42	17	53	112
*Tetmemorus species**	6	-	-	6
*Penium species**	8	-	-	8
Crucigenia rectangularis	33	73	52	158
C. fenetrata	74	10	50	134
Gonatozygon aculeatum	32	-	12	44
Staurastrum grande	-	31	-	31
Closeterium parvulum	13	1	4	18
C. gracile	5	13	2	20
C. kuetzingii	-	-	3	3
Cosmarium granatum	2	-	-	2
Cladophora glomerata	2	10	1	13
C. elegans	19	12	3	34
*Draparnaldia species**	-	-	1	1
Coelatrium micromium	1	1	4	6
C. recticulatum	7	12	13	32
Rhizoclonium hookeri	-	10	13	23
Netrium digitus	187	279	290	756
Closteridum lunula	7	4	3	14
*Ankistrodesmus species**	5	3	4	12
*Scenedesmus species**	-	4	3	7
*Cladophora species**	-	-	8	8
*Netrium species**	-	-	2	2
*Bulbochaeta species**	-	34	-	34
Total	448	636	521	1605

-Absent*- *- Unidentified, S/No-Serial number, S1-Station 1, S2-Station 2S3-Station 3

Table 5: Species composition of *Phytoplankton* of lower reaches of okpoka creek

Cyanophyceae species	Cell counts S1	S2	S3	Total
Anabeana affinis	3	3	2	8
A. arnoldii	-	6	3	9
A. spiroides	12	10	3	25
*A. species**	-	-	10	10
Anabaenopsis arnoldii	5	5	6	16
Raphidiopsis curvata	4	-	-	4
Rivularia species	11	12	-	23
Oscillatoria lacustris	1	8	2	11
O. tenius	-	20	-	20
*O. species**	4	-	-	4
Lynya major	-	9	-	9
*Nodularia species**	-	3	-	3
Total	40	76	26	142
Euglenophyceae species				
Trachelomonas africana	3	-	-	3
Euglena acus	5	-	-	5
E. viridis	-	1	2	3
E. gracilis	17	1	10	28
Total	25	2	12	39
Chrysophyceae species				
Dinobryon sertularia	33	-	-	33
Pyrophyceae species				
Peridinium cinctum	2	-	-	2
Ceratium hirudinea	16	-	-	16
Total	18	-	-	18
Xanthophyceae species				
Tribonema viride	33	82	27	142
T. vulgare	212	189	153	554
Total	245	271	180	696

Table 6: Physico-chemical parameters in relation to station in lower reaches of Okpoka Creek

Physico-chemical parameter	Station 1	2	3
Temperature (°C)	28.55±0.20[a]	28.60±0.20[a]	28.76±0.21[a]
pH	6.73±0.06[b]	6.83±0.06[a]	6.78±0.07[b]
Salinity (%)	12.62±0.71[a]	13.63±0.73[a]	14.83±0.83[a]
Transparency (m)	0.65±0.03[b]	0.65±0.03[b]	0.74±0.04[a]
Total dissolved solid (mg L^{-1})	13030±1120[b]	13850±1200[a]	14610±1220[a]
Dissolved oxygen (mg L^{-1})	5.13±0.29c	5.81±0.27[a]	5.55±0.32[b]
Chloride (mg L^{-1})	20246.09±1971.94[b]	18364.20±1333.31[c]	22676.39±1592.02[a]
Alkalinity (mg L^{-1})	90.97±3.80[a]	89.56±3.78[a]	96.57±3.44[a]
Phosphate (mg L^{-1})	0.96±0.20[b]	0.58±0.14[b]	0.49±0.09[b]
Ammonia (mg L^{-1})	0.15±0.02[a]	0.17±0.02[a]	0.18±0.02[a]

Means with the same letter in eth same row are not significantly different (p>0.05)

to 153 cell counts (Station 3). The highest density of yellow-green algae was observed in Station 2 (1405.79 No./mL) and the lowest in Station 8 (1061.31 No./mL) (Fig. 3).

Physico-chemical parameters: The recorded temperature ranged between 28.55°C (Station 1) and 28.76°C (Station 3).The minimum pH (6.73) in Station 1 and maximum pH (6.83) in Station 2. Salinity ranged from 12.62% (Station 1) to 14.83% (Station 3). The maximum transparency (0.74 m) was recorded in Station 3. Stations 1 and 2 had the same transparency (0.65m). Total dissolved solids (TDS) increased downstream; ranged between 13030 mg L^{-1} (Station 1) and 14610 mg L^{-1} (Station 3). The minimum dissolved oxygen (D0) (5.13 mg L^{-1}) was recorded in Station 1 and maximum (5.81 mg L^{-1}) in Station 2. The chloride level was high, ranging from 18364.20 mg L^{-1} (Station 2) to 22676.39 mg L^{-1} (Station 3). Station 2 had the minimum alkalinity level (89.56 mg L^{-1}) and Station 3 (96.57 mg L^{-1}) the maximum. The phosphate concentration was highest in Station 1 (0.96 mg L^{-1}) and lowest in Station 3 (0.49 mg L^{-1}). The minimum ammonia (0.15 mg L^{-1}) was recorded in Station 1 and maximum (0.18 mg L^{-1}) in Station 3 (Table 6).

The Pearson correlation revealed that temperature correlated positively with diatoms (r = 0.224), green algae (r = 0.084), blue-green algae (r = 0.042) and euglenoids (r = 0.158) but negatively with dinoflagellates (r = -0.206), golden algae (r=-0.276) and yellow-green algae (r =-0.682). Ammonia demonstrated positive correlations with diatoms (r = 0.037), blue-green algae (r = 0.448) and euglenoids (r = 0.040).

DISCUSSION

The lower reaches of Okpoka Creek is very rich in phytoplankton. The recorded 112 species from 61 genera were higher than the values reported for studies on other creeks of the Upper Bonny Estuary (Chindah and Keremah, 2001; Chindah and Braide, 2001). This might be attributed to favourable environmental factors such as moderately high water temperature and nutrients.

One of the factors that is likely to play an important role in determining phytoplankton community productive levels is nutrients availability; nitrogen, phosphorus and sulphate (Yamamuro *et al*., 1993). High temperature and nutrients (phosphate and ammonia) increased the photosynthetic activities of the phytoplankton thus increasing their population. The recorded pH, transparency, total dissolved solid, dissolved oxygen, chloride, alkalinity favoured the growth and reproduction of the phytoplankton (Boney, 1983; Reynolds, 2006). The high phosphate and ammonia were attributed to natural and anthropogenic sources (domestic and industrial).

The recorded diatoms dominance is in accordance with the reports of Nwankwo (1996), Nwankwo and Kasumu-Iginla (1997), Nwankwo (1998) and Chindah and Braide (2004). The dominance of phytoplankton community by diatoms in this study confirms the statement that diatoms predominate unpolluted natural lotic water bodies in the tropics (Guzkowska and Gasse, 1990; Pan *et al*., 1996). However, the differences in the community structure despite the dominance by diatoms is mainly due to the importance assumed by Chlorophyceae, Cyanophyceae and Euglenophyceae in the phytoplankton community. Chrysophyceae being the least algae could be due to their inefficiency to compete for nutrients (Boney, 1983).

The diatoms population tended to increase downstream and this could be attributed to salinity gradient. Salinity is one of the major factors influencing algal zonation and distribution within estuaries, both in terms of range of values and rate of changes (Rendall and Wilkinson, 1986). Also, it could be due to increased ammonia level downstream. Passy (2007) reported that diatoms distribution is associated with a downstream increase in nutrient level and organic pollution. Diatoms favour nutrient rich environments particularly nitrate (Frankovich *et al*., 2006; Marine

Biology Organization [MBO], 2007b). This finding is in agreement with the present study of high nutrients levels of phosphate and ammonia. The distribution of diatoms reflect the average ecological conditions of aquatic environment (Passy *et al*., 2004).

The high abundance of diatoms in this study might possibly be explained by the positive correlations that existed among diatoms, temperature and ammonia. The observed dominant *M. varians*, *Anabeana spiroides*, *Euglena gracilis* and *Ceratium hirudinea* indicated high nutrient status of the lower reaches of Okpoka Creek (Nwankwo and Amuda, 1993). These dominant species and high TDS indicated organic pollution from anthropogenic sources. The recorded TDS was above the permissible limits of 1, 001-10, 000 mg L^{-1} for brackish water (McNeely *et al*., 1979).

REFERENCES

American Public Health Association (APHA), 1985. Standard Method for the Examination of Water and Wastewater. A.P.H.A. 16th Edn. Washington D.C.: McGraw-Hill.

Boney, A.D., 1983. Phytoplankton. 4th Edn. London: Edward Arnold Publishers Limited.

Boyd, C.E., 1981.Water Quality in Warmwater Fishpond. 2nd Edn. Alabama: Craftmaster.

Chindah, A.C. and S.A. Braide, 2001. Crude oil spill and the phytoplankton community of a swamp forest stream. Afr. J. Environ. Stud., 2 (1): 1-8.

Chindah, A.C. and S.A. Braide, 2004. The physico-chemical quality and phytoplankton community of tropical waters. A case of 4 Biotopes in the Lower Bonny River, Niger Delta, Nigeria. Caderno dé Pésquisa Sér Bio. Santa Cruz da Sul, 16 (2): 7-35.

Chindah, A.C. and R.I. Keremah, 2001. Physico-chemistry and phytoplankton of a brackish water fish pond of the Bonny Estuary Nigeria. Afr. J. Environ. Stud., 2 (2): 63-67.

Chindah, A.C. and J. Pudo, 1991. A preliminary checklist of algae found in plankton of Bonny River in Niger Delta, Nigeria. Fragment Flore Geobotanica, 36 (1): 112-126.

Conde, D., S. Bonilla, L. Aubriot, R. de León and W. Pintos, 2007. Relative contribution of planktonic and benthic microalgae production in an eutrophic coastal lagoon of South America. J. Limnol., 78: 207-212.

Davies, O.A., 2008. Physico-chemical, parameters, plankton, epiphyton and finfish assemblages in Okpoka Creek, Niger Delta, Nigeria. Ph.D Thesis (Unpublished), pp: 310.

Erondu, E.S. and A.C. Chindah, 1991a. Variation in the physico-chemical features and phytoplankton of the New Calabar River at Aluu, Rivers State, Nigeria. Nigeria Institute of Marine and Oceanography Research Technical Paper, 75: 1-18.

Erondu, E.S. and A.C. Chindah, 1991b. Physico-chemical and phytoplankton changes in a tidal freshwater station of the New Calabar River, South Eastern, Nigeria. Environ. Ecol., 9 (3): 565-570.

Frankovich, T.A., E.E. Gaiser, J.C. Zieman and A.H. Wachnicka, 2006. Spatial and temporal distributions of epiphytic diatoms growing on Thalassia testudinum Banks ex Köñig: Relationships to water quality. Hydrobiologia, 569: 259-271.

Guzkowska, M.A.J. and F. Gasse, 1990. Diatoms indicators of water in some English urban lakes. Freshwater Biol., 23: 233-250.

Ikusemiju, K. and C.I.O. Olaniyan, 1977. The food and feeding habit of the catfishes, Claris walkeri, *C. filamentous* (Boulonger) in the Lekki Lagoon, Nigeria. J. Fish Biol., 10: 105-112.

Marine Biology Organization (MBO), 2007a. Zooplankton. http://www.marine.bio.com/oceans/zooplankton.asp-62k.

McNeely, R.N., V.P. Neimanis and L. Dwyer, 1979. Water quality sourcebook. A guide to water quality parameters. Ottawa:Inland waters directorate, water quality branch.

Mill, F.W., 1932. Some diatoms from Warri River, Southern Nigeria. J. Royal Microbes, 583: 382-395.

Miller, J.G., 2005. The flow of energy: Primary production to higher trophic levels. http://www/limno. fcien.edu.uy/reseach/rochabst.html.

Munawar, M., 1972. Ecological studies of euglenoids in certain polluted and unpolluted environments. Hydrobiologia, 39 (3): 307-320.

Needham, J.G. and P.R. Needham, 1962. A Guide to the Study of Freshwater Biology. 2nd Edn. San Francisco: Holden-Day, Inc.

Newell, G.E. and R.C. Newell, 1963. Marine Plankton. A Practical Guide. 1st Edn. London: Hutchinson Publishing Limited.

Nwadiaro, C.S., 1990. Ichthyofauna of Lake Oguta, a shallow lake in South-Eastern Nigeria. Arch. Hydrobiol., 115: 463-475.

Nwankwo, DI. and K.A. Kasumu-Iginla, 1997. Contributions to the diatom flora of Nigeria 11 Tube-dwelling pinnate diatoms from Lagos Moles. Nig. J. Bot., 10: 61-69.

Nwankwo, D.I., 1996. Phytoplankton diversity and succession in Lagos Lagoon, Nigeria. Arch. Hydrobiol., 135 (4): 529-542.

Nwankwo, D.I., 1998. Seasonal changes in phytoplankton composition and diversity in the Epe lagoon, Nigeria. Acta Hydrobiol., 40 (2): 83-92.

Nwankwo, D.I. and S.A. Amuda, 1993. Periphytic diatoms on three floating aquatic macrophytes in a polluted south-west Nigerian Creek. Int. J. Ecol. Environ. Sci., 19: 10-10.

Okpuruka, D.U., 1986. Tidal and semi-lunar variations in the surface phytoplankton of a Port Harcourt mangrove creek. Proceedings of the workshop on Nigeria wetlands. Akpata, T.V.I. and D.U.U. Okali, (Eds.). Lagos, pp: 1-183.

Pan, V., R.J. Stevenson, B.H. Hill, A.T. Herlihy and G.B. Collins, 1996. Using Diatoms as indicators of ecological conditions in lotic systems-A regional assessment. J. North Am. Benthol. Soc., 15: 481-495.

Passy, S.I., 2007. Diatom ecological guilds display distinct and predictable behaviour along nutrient and disturbance gradients in running waters. Aquatic Bot., 86: 171-178.

Passy, S.I., R.W. Bode, D.M. Carlson and M.A. Novak, 2004. Comparative Environmental Assessment in the studies of benthic diatom, macroinvertebrate and fish communities. Int. Rev. Hydrobiol., 89 (2): 121-138.

Rendall, D.A. and M. Wilkinson, 1986. Environmental torelance of the estuarine diatoms Melosira nummuloides (Dilw) Agric. J. Experimental Mar. Biol. Ecol., 102: 133-151.

Reynold, C.S., 2006. The Ecology of Phytoplankton. 1st Edn. New York: Cambridge.

Ruivo, M.R., 1972. Marine Pollution and Sea Life. 1st Edn. England: Fishing News (Books).

SAS, 2003. Statistical Analysis System. User's Guide SAS/STA-t version. 8th Edn., SAS, Institute, Inc. Cary, N.C., US.

Townsend, C.R., J.L. Harper and M. Begon, 2000. Essentials of Ecology. 3rd Edn. London: Blackwell Science.

Wehr, J.D. and J.P. Descy, 1998. Use of phytoplankton in large river management. J. Psychol., 34 (5): 741-749.

Yamamuro, M., I. Kioke and H. Iizuumi, 1993. Partitioning of Nitrogen stock in the vicinity of a Fijian seagrass bed dominated by Syingodium iosettifolum (Ascherson) Dandy. Aust. J. Mar. Freshwater Resour., 44:101-115.