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Phytoplankton diversity and abundance of Oguta Lake and its trophic state

Original Article

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Abstract:

The abundance and composition of phytoplankton in Oguta Lake were studied. Oguta Lake is strategic as the largest natural lake in the Imo River Basin of South-Eastern Nigeria. A plankton net of 2-µm mesh size and 30 cm diameter was used to obtain the phytoplankton. Samplings were carried out according to study stations for one year. Phytoplankton samples collected were preserved in 4% formalin before laboratory analysis. Using a compound microscope, the phytoplankton were identified to species level using relevant taxonomic keys. 80 species of phytoplankton belonging to 29 taxonomic groups and three thousand seven hundred and twenty-two (3722) individuals were recorded. The different phyla recorded in order of abundance were Chlorophyta>Charophyta>Bacillariophyta>Euglenophyta>Cyanophyta>Chrysophyta>Xanthophyta>Rhodophyta. The four sampling stations located at Osemoto, Utu, Njaba, and Orashi had different relative abundances of 25.52%, 25.23%, 22.60%, and 26.65% of phytoplankton, respectively. August recorded the highest phytoplankton abundance of 16.36%, while the least abundance occurred in February (2.39%). *Stichococcus bacillaris* recorded the highest relative abundance in August (7.22%). Seasonal mean values of 19 species showed a significant difference at $p<0.05$, while 61 species showed no significant difference at $p>0.05$. Margalef's index of species richness, Simpson's index of species dominance, and Jaccard's similarity index showed minor variations among the study stations. The trophic state of Oguta Lake can be described as moderately eutrophic, as indicated by the presence of species belonging to the genera *Nitella*, *Chaetophora*, *Oscillatoria*, *Chlorella*, and *Ulothrix.*

Key words:
phytoplankton, diversity, abundance, moderately eutrophic, Oguta Lake

Apstrakt:

Diverzitet i brojnost fitoplanktona jezera Oguta i njegov trofički status

U ovom radu su ispitivani brojnost i sastav fitoplanktona u jezeru Oguta. Jezero Oguta ima strateški značaj kao najveće prirodno jezero u slivu reke Imo na jugoistoku Nigerije. Za uzorkovanje fitoplanktona korišćena je planktonska mreža dijametra 30 cm i prečnika okaca od 2 µm. Uzorci su prikupljani na istraživačkim stanicama tokom jedne godine. Za potrebe laboratorijske analize, prikupljeni fitoplankton čuvan je u 4% formalinu. Upotrebom svetlosnog mikroskopa fitoplankton je identifikovan do nivoa vrste pomoću relevantnih identifikacionih ključeva. Identifikovano je 80 vrsta fitoplanktona, raspoređenih u 29 taksonomskih grupa, sa ukupno 3722 jedinke. Zabeleženi su sledeći razdeli, navedeni prema zastupljenosti: Chlorophyta>Charophyta>Bacillariophyta>Euglenophyta>Cyanophyta>Chrysophyta>Xanthophyta>Rhodophyta. Četiri istraživačke stanice (Osemoto, Utu, Njaba i Orashi) imale su relativne zastupljenosti fitoplanktona od 25,52%, 25,23%, 22,60% i 26,65%, redom. Najveća brojnost fitoplanktona zabeležena je u avgustu (16,36%), dok je najmanja zabeležena u februaru (2,39%). Vrsta *Stichococcus bacillaris* imala je najveću relativnu zastupljenost u avgustu (7,22%). Srednje sezonske vrednosti za 19 vrsta pokazale su statistički značajnu razliku ($p<0.05$), dok za 61 vrstu nije bilo statistički značajne razlike ($p>0.05$). Margalef-ov indeks bogatstva vrsta, Simpson-ov indeks dominacije i Jaccard-ov indeks sličnosti pokazali su male varijacije među istraživačkim stanicama. U pogledu trofičkog statusa, jezero Oguta se može opisati kao umereno eutrofno, što potvrđuje prisustvo vrsta iz rodova *Nitella*, *Chaetophora*, *Oscillatoria*, *Chlorella* i *Ulothrix*.

Ključne reči:
fitoplankton, diverzitet, brojnost, umereno eutrofno, jezero Oguta

Introduction

Water bodies are known to support a wide array of aquatic organisms such as plankton, macroinvertebrates, nekton and aquatic macrophytes. Idowu (2004) reported that the biological aspect of water quality includes plankton, macroinvertebrates and nekton. The plankton is a mixed community of organisms consisting of plants and animals (Ugwu & Mgbenka, 2006). There are two forms of plankton – phytoplankton, which include photosynthetic protists, bacteria, and algae; and zooplankton, such as protozoa and tiny crustaceans (Audesirk et al., 2005). In aquatic ecosystems, phytoplankton is the foundation of the food web and the nutritional base for zooplankton and other vertebrates, shellfish, and finfish (Emmanuel & Onyema, 2007). The ecological significance played by phytoplankton in freshwater ecosystems cannot be overestimated. They provide dissolved oxygen used by most plants and animals to release energy during cellular respiration (Onyema, 2008). Generally, phytoplankton form a potential link in the trophic structure of inland waters. They also serve as indicator organisms of water quality, such as the degree of pollution and productivity (Hassan et al., 2010). The estimation of phytoplankton density, diversity, productivity, and trophic status of lakes is important not only for fisheries management but in other ecosystem studies (Offem et al., 2011).

Phytoplankton (singular - phytoplankter) are tiny, microscopic, free-floating, and drift with water currents. They exist in both freshwater and marine environments (Lindsey et al., 2010; Encyclopaedia Britannica, 2012). Like terrestrial plants, they use carbon dioxide, release oxygen, and convert minerals to a form that animals can use. They are responsible for 50 percent of all photosynthetic activity on Earth (Dimowo, 2013). Phytoplankton can be divided into two divisions, which include phototrophic bacteria, made up of purple sulphur bacteria and green sulphur bacteria, and algae such as Euglenophyta, Chrysophyta, Phaeophyta, Rhodophyta, Pyrrophyta, and Cyanophyta (Dimowo, 2013). Their composition and abundance are highly dependent on the availability of sunlight, carbon dioxide, and nutrients such as nitrate, phosphate, and silicate. These factors influence their density and distribution throughout the water column. Phytoplankton is an important primary producer; it is the basis of the whole autotrophic food web in the aquatic ecosystem (Anyinkeng et al., 2016). Muhammad et al. (2005) reported that the maximum phytoplankton production is obtained when the physicochemical factors are at an optimum level. The Bacillariophyta (diatoms), Chlorophyta (green algae), and Cyanobacteria make up the three major groups of phytoplankton in freshwater ecosystems, where they are a source of food to almost all aquatic life, either directly or indirectly. For example, in aquaculture, they serve as a food stock for zooplankton, which are in turn fed to fish larvae reared in fish hatcheries (Moncheva & Parr, 2010).

As beneficial as phytoplankton are, they could also be harmful. Under certain conditions, such as pollution of water bodies with sewage and human excreta, certain harmful phytoplankton predominate and produce biotoxins which affect the taste and colour of water, impart a bad taste to fish, and harbour diseases, thereby causing massive fish kills. Examples of such harmful phytoplankton include: Cyanophyta (*Cyanobacteria*/blue green algae), which produce geosmin, a toxin that imparts a bad flavour on fish, especially bottom dwellers such as catfish and carp, and Rhodophyta, which causes red tides following massive fish kills (Babatunde et al., 2014).

The presence and abundance of phytoplankton in Nigerian water bodies have been analyzed and reported by some researchers, for example, in Onah Lake (Olele & Ekelemu, 2008), Egbe Reservoir (Edward & Ugwumba, 2010), Ejagham Lake, Ikot Okpora Lake, and Obubra Lake situated along the flood plain of Cross river (Offem et al., 2011). This study attempts to shed light on the current state of the phytoplankton community of Oguta Lake and its trophic state. Oguta Lake is strategically one of the most productive lake ecosystems in West Africa.

Materials and Methods

Study area

Oguta Lake (**Fig. 1**) is located between Latitude 5º 41'–5º 44' North of the Equator and Longitude 6º 56'–6º 45' East of Greenwich. This region is located within the equatorial rain forest belt with an average annual rainfall of 3,100 mm (Ahiarakwem & Onyekuru, 2011). Most parts of the shoreline are lined up by a community of bank macrophytes consisting of grasses such as *Panicum senegalense* and a sparse population of floating macrophytes such as *Pistia stratiotes*, *Azollia africana*, *Salvinnia auriculata*, *Ceraphyllum demersum*, *Ulyicularia inflexa*, and water lilies- *Nymphyaea lotus* and *N. macrantha.* Plant life is poor and restricted to the littoral zone (<1.5 m depth).

Four water bodies comprising Njaba, Awbana, Utu, and Orashi rivers are associated with Oguta Lake. The Njaba and Awbana discharge into the lake all year round, while the Utu stream flows in during the rainy season. The Orashi River flows past the lake in its southwestern portion. The total annual inflow from the rivers and streams is about 25,801.60 m^3 (Ahiarakwem, 2006; Umunnakwe,

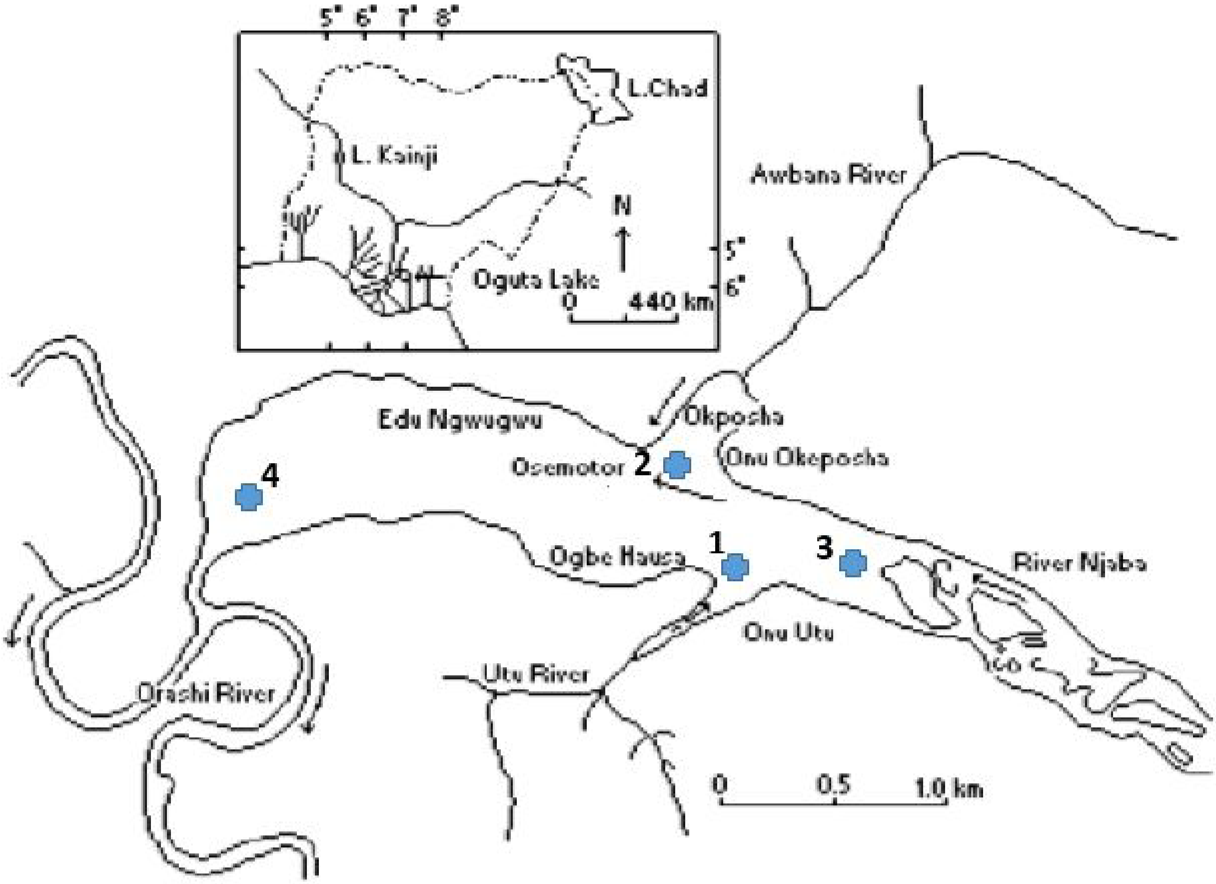

Fig. 1. Map of Oguta Lake showing sampling locations

2014). The rainy season (April - September) is marked by moderate temperature and high relative humidity, while October to March (dry season) has scanty rainfall, higher temperatures, and low relative humidity.

Sampling locations

Four sampling locations were designated within the lake. An area where the water is shallower and there is a reduced current was considered a suitable sample location.

1. Utu Station: This is located at a point where the Utu stream enters Oguta Lake. From this station, farm lands and human settlements could be observed. Utu station has a mean depth of 5.63±0.460 m.

2. Osemoto Station: This is located where Awbana River joins Oguta Lake. Anthropogenic activities like the processing of cassava and breadfruit, refuse disposal, and sewage disposal are predominant in this station. This station has a mean depth of 5.40±0.732 m.

3. Njaba Station: This is where the Njaba River joins Oguta Lake. Sand mining is done close to this station. The mean depth of this station is 5.42±0.681 m.

4. Orashi Station: Oguta Lake flows into the Orashi River at this station. A very serene environment and deeper than other stations, with an average depth of 6.27±0.630 m.

Phytoplankton sampling

Samples for phytoplankton analysis were collected by the hand trawling method. Sampling was done with a 2-µm mesh size plankton net and once a month between April 2017 and March 2018 to cover periods of rainy and dry seasons. Using a dug-out canoe (Uzoka et al., 2024), vertical haul and horizontal towing were made in each station, after which the content of the plankton net was put into a 120 ml plastic bottle. Preservation was done by adding a 4% formalin solution within 5 minutes of sample collection. The sample was then taken to the laboratory for identification and enumeration. After 48 hours and prior to identification, the sample was concentrated to 50 mL. Using a standard dropper, a drop of the sample was placed on a glass slide of a binocular compound microscope (AXL LABO 1.3 mega pixel) and covered with a cover slip. This was viewed for identification and enumeration. Phytoplankton were identified at magnifications of

10x, 40x, and 100x using suitable taxonomic keys by Edmonson (1959), Needham & Needham (1962), Whitford & Schumacher (1973).

The enumeration of phytoplankton was carried out following the drop count method adapted from Verlecar & Desai (2004) and reported as units or organisms per drop. This was done by calculating the organism concentration per ml of sample.

Total organisms/mL = Total number of organisms per drop × Number of drops per mL.

Relative abundance of the phytoplankton species was calculated according to the following:

% abundance= (X/Total no of species) x 100

where X is number of species.

Statistical analysis

The collected data were subjected to statistical analysis. Means and bar chart presentations were done using MS Excel 2016. A student's t-test (independent samples t-test) was employed to ascertain significant differences at $p<0.05$ to compare seasonal differences. Biological indices, including Margalef's index (d), Simpson's index (1-D), and Jaccard's index (J) were used in the calculation of taxa richness, dominance, and similarity of study stations.

Results and discussion

Composition and abundance

The phytoplankton composition of Oguta Lake is presented in **Tab. 1** and **2**. **Tab. 1** shows the composition and abundance of phytoplankton species recorded in Oguta Lake. **Tab. 2** shows the spatial distribution of phytoplankton species recorded in Oguta Lake, while **Fig. 2** shows the temporal distribution of phytoplankton species. A total of 29 orders, 80 species, and three thousand seven hundred and twenty-two (3722) individuals were recorded.

The different phyla recorded include Chlorophyta, Charophyta, Cyanophyta, Euglenophyta, Chrysophyta, Baccillariophyta, Rhodophyta, and Xanthophyta. The Chlorophyta comprises 3 classes - Chlorophyceae, Ulvophyceae, and Trebouxiophyceae. The Chlorophyceae comprises 4 orders - Chaetophorales, Chlamydomonadales, Chaetopeltidales, and Sphaeropleales. Ulvophyceae is represented by only one order - Ulotrichales while the class Trebouxiophyceae is represented by 2 orders Prasiolales and Microthamniales. The relative abundance of Chaetophorales is 7.29% with 271 individuals; Chlamydomonadales is 7.12% with 265 individuals, Chaetopeltidales is 2.44% with 91 individuals, while Sphaeropleales is 15.76% with 587 individuals.

The Ulvophyceae recorded one order (Ulotrichales) and is represented by 2 species (*Ulothrix subtilissima* and *Protoderma viride*). The order Ulotrichales has a relative abundance of 1.93% with 72 individuals. The class Trebouxiophyceae is represented by 2 orders (Prasiolales and Microthamniales), each represented by one species – *Stichococcus bacillaris* and *Microthamnion* sp., respectively. Prasiolales has a relative abundance of 2.53% with 94 individuals while Microthamniales is 0.32% and 12 individuals.

The phylum Charophyta is composed of 3 classes - Zygnematophyceae, Coleochaetophyceae, and Charophyceae. Zygnematophyceae is represented by two orders – Desmidiales, and Zygnematales. The Desmidiales is represented by 12 species with a relative abundance of 17.89% and 666 individuals. The Zygnematales comprises four species with 8.19% abundance and 305 individuals. Coleochaetophyceae is represented by one species (*Coleochaete scutata*) with a relative abundance of 0.32% and 12 individuals. The class Charophyceae is also represented by one order, Charales, with one species, *Nitella furcata*. The relative abundance is 1.67% with 62 individuals.

The phylum Cyanophyta recorded only one class (Cyanophyceae) throughout the period of study. Three orders were recorded in this class, including Spirulinales, Nostocales, and Oscillatoriales. The order Spirulinales is represented by two species with 119 individuals. Its relative abundance is 3.2%. The order Nostocales recorded two species comprising 95 individuals. The relative abundance is 2.55%. The order Oscillatoriales recorded five species belonging to the family Oscillatoriaceae with 283 individuals and a relative abundance of 7.60%.

The phylum Euglenophyta is represented by one class Euglenophyceae. Two orders were recorded under this class - the Euglinales and Euglinida. A total of 10 species were recorded, 9 belonging to the family Euglenaceae under Euglinales, while one species (*Lepocinclis steinii*) was recorded under the family Phacidae of the order Euglenida. The order Euglenales recorded a total of 333 individuals with a relative abundance of 7.06%, while the order Euglenida is represented by 70 individuals with 1.88% relative abundance.

The phylum Chrysophyta recorded only one class-Chrysophyceae. Two orders were recorded under Chrysophyceae. The order Ochromonadales recorded 3 species with a 2.63% relative abundance and 98 individuals, while the order Isochrysidales recorded one species and two individuals with a relative abundance of 0.05%.

The Bacillariophyta recorded numerous species during the period of study. Three classes and nine orders were recorded. The classes include - Bacillar-

Table 1. Composition and abundance of phytoplankton in Oguta Lake

Phylum	Class	Order	Family	*Species*	No collected	% Total
Chlorophyta	Chlorophyceae	Chaetophorales	Chaetophoraceae	*Chaetophora elegans*	59	1.59
				Chaetophora incrassata	68	1.83
				Chaetophora pisciforms	31	0.83
				Protoderma viride	29	0.78
				Stigeoclonium carolinianum	42	1.13
				Stigeoclonium farctum	3	0.08
				Stigeoclonium aestivate	39	1.05
		Chlamydomonadales	Chlamydomonadaceae	*Chlamydomonas fenestratus*	30	0.81
				Chlamydomonas sp	21	0.56
			Volvocaceae	*Volvox dissipatrix*	185	4.97
			Phacotaceae	*Pteromonas angustus*	29	0.78
		Chaetopeltidales	Dicranochaetaecaeceae	*Dicranochaete remiforms*	91	2.44
		Sphaeropleales	Hydrodictyaceae	*Hydrodictyon reticulatum*	186	4.99
				Pediastrum simplex	4	0.11
			Selenastraceae	*Quadrigula chodati*	90	2.42
				Quadrigula lacustris	63	1.69
			Scenedesmaceae	*Coelastrum scabrum*	67	1.8
				Coelastrum shaericum	29	0.78
				Coelastrum microporum	82	2.2
			Microsporaceae	*Microspora stagnorum*	66	1.77
	Ulvophyceae	Ulotrichales	Ulotrichaceae	*Ulothrix subtilissima*	12	0.32
			Helicodictyaceae	*Protoderma viride*	60	1.61
	Trebouxiophyceae	Prasiolales	Prasiolaceae	*Stichococcus bacillaris*	94	2.53
		Microthamniales	Microthamniaceae	*Microthamnion sp*	12	0.32
Charophyta	Zygnematophyceae	Desmidiales	Desmidiaceae	*Staurastrum ornithopoda*	131	3.52
				Pleurotaenium trabecula	55	1.48
				Pleurotaenium granulatum	48	1.28

Charophyta	Zygnematophyceae	Desmidiales	Desmidiaceae	*Cosmarium trilobulatum*	66	1.77
				Cosmarium portianum	12	0.32
				Spondylosium sp	75	2.02
				Tetmemorus brebissonii	48	1.29
				Hyalotheca dissiliens	40	1.07
				Micrasterias radiata	42	1.13
				Micrasterias mahabuleshwarensis	46	1.24
			Peniaceae	*Penium margaritaceum*	68	1.83
			Gonatozygaceae	*Gonatozygon monotaenium*	35	0.94
		Zygnematales	Zygnemataceae	*Zygnema sterile*	25	0.67
				Spirogyra sp	185	4.97
			Mesotaeniaceae	*Netrium oblongum*	40	1.07
				Spirotaenia condensata	55	1.48
	Coleochaetophyceae	Coleochaetales	Coleochaetaceae	*Coleochaete scutata*	12	0.32
	Charophyceae	Charales	Characeae	*Nitella furcata*	62	1.67
Cyanophyta	Cyanophyceae	Spirulinales	Spirulinaceae	*Spirulina major*	51	1.37
				Spirulina subsalsa	68	1.83
		Nostocales	Nostaocaceae	*Anaebena confervoides*	45	1.21
			Tolypothrichaceae	*Tolypothrix tenuis*	50	1.34
		Oscillatoriales	Oscillatoriaceae	*Oscillatoria subtilissima*	91	2.44
				Oscillatoria amphibian	36	0.97
				Oscillatoria brevis	70	1.88
				Oscillatoria angustissima	79	2.12
				Symploca borealis	7	0.19
Euglenophyta	Euglenophyceae	Euglenales	Euglenaceae	*Phacus hispidula*	16	0.43
				Trachelomonas schauinslandi	7	0.19
				Trachelomonas rugulosa	57	1.53
				Trachelomonas acanthostoma	37	0.99
				Trachelomonas abrupta	23	0.62
				Trachelomonas armata	50	1.34

Euglenophyta	Euglenophyceae	Euglenales	Euglenaceae	*Trachelomonas volvocina*	52	1.4
				Euglena polymorpha	2	0.05
				Colacium vesiculosum	19	0.51
		Euglinida	Phacidae	*Lepocinclis steinii*	70	1.88
Chrysophyta	Chrysophyceae	Ochromonadales	Synuraceae	*Synura caroliniana*	12	0.32
			Ochromonadaceae	*Ochromonas mutabilis*	61	1.64
			Dinobryaceae	*Dinobryon sertularia*	25	0.67
		Isochrysidales	Derepyxidaceae	*Derepyxis dispar*	2	0.05
Bacillariophyta	Bacillariophyceae	Naviculales	Naviculaceae	*Navicula platystoma*	13	0.35
			Pinnulariaceae	*Pinnularia viridis*	13	0.35
		Surirellales	Surirellaceae	*Stenopterobia intermedi*	43	1.16
		Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia longiseta*	43	1.16
		Eunotiales	Eunotiaceae	*Eunotia pectinalis*	24	0.64
				Eunotia curvata	20	0.54
				Desmogonium rabenhorstianum	42	1.13
		Melosirales	Melosiraceae	*Melosira granulata*	45	1.21
		Cocconeidales	Cocconeidaceae	*Cocconeies plancentula*	37	0.99
		Cimbellales	Gomphonemateceae	*Gomphonema sphaerophorum*	22	0.59
				Gomphonema parvulum	35	0.94
	Mediophyceae	Stephanodiscales	Stephanodiscaceae	*Stephanodiscus dubis*	2	0.05
	Coscinodiscophyceae	Aterolamprales	Aterolampraceae	*Asteromphalus sp*	2	0.05
Rhodophyta	Compsopogonaphyceae	Compsopogonales	Compsopogonaceae	*Compsopogon coeruleus*	6	0.16
Xanthophyta	Xanthophyceae	Vaucheriales	Vaucheriaceae	*Vaucheria aversa*	8	0.22
Total					3722	100%

Table 2. Seasonal variation and abundance of phytoplankton at the study stations

Species	Osemoto	Utu	Njaba	Orashi	Total	Rainy season	Dry season
Chaetophora elegans	12 (1.26)	7 (0.75)	22 (2.62)	18 (1.81)	59	7.50±0.885*	2.33±1.116*
Chaetophora incrassata	21 (2.21)	19 (2.02)	16 (1.90)	12 (1.21)	68	8.50±2.391	2.83±1.352
Chaetophora pisciforme	9 (0.94)	0 (0.00)	14 (1.66)	8 (0.81)	31	3.83±1.701	1.33±1.333
Protoderma viride	8 (0.84)	6 (0.64)	5 (0.59)	10 (1.01)	29	1.83±0.703	3.00±1.065
Stigeoclonium carolinianum	13 (1.37)	10 (1.06)	19 (2.26)	0 (0.00)	42	4.00±1.065	3.00±0.966
Stigeoclonium farctum	0 (0.00)	3 (0.32)	0 (0.00)	0 (0.00)	3	0.00±0.000	0.50±0.500
Stigeoclonium aestivate	16 (1.68)	8 (0.85)	10 (1.19)	5 (0.50)	39	3.67±1.498	2.83±1.195
Chlamydomonas fenestratus	10 (1.05)	6 (0.64)	2 (0.24)	12 (1.21	30	3.00±1.265	2.00±1.033
Chlamydomonas sp	7 (0.74)	0 (0.00)	10 (1.19)	4 (0.40)	21	3.17±0.543*	0.33±0.211*
Volvox dissipatrix	14 (1.47)	33 (3.51)	93 (11.06)	45 (4.54)	185	20.67±2.836*	10.17±1.956*
Pteromonas angustus	7 (0.74)	8 (0.85)	6 (0.71)	8 (0.81)	29	3.17±0.792	1.67±0.843
Dicranochaete remiforms	13 (1.37)	30 (3.19)	15 (1.78)	33 (3.33)	91	10.67±2.741	4.50±1.668
Hydrodictyon reticulatum	63 (6.63)	40 (4.26)	38 (4.52)	45 (4.54)	186	20.17±5.224	10.83±3.458
Pediastrum simplex	4 (0.42)	0 (0.00)	0 (0.00)	0 (0.00)	4	0.67±0.494	0.00±0.000
Quadrigula chodati	22 (2.32)	15 (1.60)	13 (1.55)	40 (0.40)	90	8.83±2.587	6.17±2.023
Quadrigula lacustris	0 (0.00)	24 (2.56)	16 (1.90)	23 (2.32)	63	5.67±1.706	4.83±2.372
Coelastrum scabrum	10 (1.05)	12 (1.28)	27 (3.2)	18 (1.81)	67	7.17±1.078	4.00±1.826
Coelastrum shaericum	5 (0.53)	9 (0.96)	0 (0.00)	15 (1.51)	29	2.83±1.249	2.00±1.483
Coelastrum microporum	23 (2.42)	28 (2.98)	18 (2.14)	13 (1.31)	82	10.00±2.000	4.50±1.565
Microspora stagnorum	11 (1.16)	18 (1.92)	24 (2.85)	13 (1.31)	66	7.83±1.138	4.83±3.331
Ulothrix subtilissima	5 (0.53)	0 (0.00)	7 (0.83)	0 (0.00)	12	1.67±0.615	0.33±0.333
Protoderma viride	19 (2.00)	0 (0.00)	16 (1.90)	25 (2.52)	60	6.33±1.909	3.67±1.687
Stichococcus bacillaris	0 (0.00)	94 (10.01)	0 (0.00)	0 (0.00)	94	16.33±7.940	0.00±0.000
Microthamnion sp	7 (0.74)	0 (0.00)	0 (0.00)	5 (0.50)	12	1.17±0.543	0.83±0.307
Staurastrum ornithopoda	61 (6.42)	37 (3.94)	15 (1.78	18 (1.81)	131	10.83±2.688	11.00±3.173
Pleurotaenium trabecula	0 (0.00)	26 (2.77)	15 (1.78)	14 (1.41)	55	6.83±2.915	2.33±1.801
Pleurotaenium granulatum	5 (0.53)	17 (1.81)	18 (2.14)	8 (0.81)	48	6.00±1.966	2.00±0.816
Cosmarium trilobulatum	15 (1.59)	4 (0.43)	18 (2.14)	29 (2.92)	66	7.17±3.655	3.83±1.887

Cosmarium portianum	1 (0.11)	3 (0.32)	0 (0.00)	8 (0.81)	12	1.17±0.749	0.83±0.401
Spondylosium sp	13 (1.37)	21 (2.24)	13 (1.55)	28 (2.82)	75	8.00±1.461	4.50±1.857
Tetmemorus brebissonii	12 (1.26)	8 (0.85)	23 (2.73)	5 (0.50)	48	4.00±0.365	3.83±0.792
Hyalotheca dissiliens	5 (0.53)	11 (1.17)	24 (2.85)	0 (0.00)	40	4.83±0.654*	1.83±0.792*
Micrasterias radiata	12 (1.26)	0 (0.00)	14 (1.66)	16 (1.61)	42	5.50±1.928	1.50±0.806
Micrasterias mahabuleshwarensis	18 (1.89)	0 (0.00)	4 (0.48)	24 (2.42)	46	5.83±0.792*	1.83±1.108*
Peniun margaritaceum	28 (2.95)	18 (1.92)	0 (0.00)	22 (2.22)	68	8.67±2.565	2.67±2.290
Gonatozygon monotaenium	12 (1.26)	8 (0.85)	15 (1.78)	0 (0.00)	35	2.67±0.919	3.17±1.352
Zygnema sterile	10 (1.05)	7 (0.75)	0 (0.00)	8 (0.81)	25	2.83±1.376	1.33±0.715
Spirogyra sp	48 (5.05)	39 (4.15)	42 (4.99)	57 (5.75)	185	21.67±4.201	10.20±1.765
Netrium oblongum	14 (1.47)	8 (0.85)	12 (1.43)	6 (0.60)	40	4.67±0.843	2.00±0.894
Spirotaenia condensata	10 (1.05)	25 (2.66)	7 (0.83)	13 (1.31)	55	8.17±1.424*	1.00±0.516*
Coleochaete scutata	6 (0.63)	0 (0.00)	6 (0.71)	0 (0.00)	12	1,50±0.619	0.50±0.342
Nitella furcata	15 (1.58)	14 (1.49)	16 (1.90)	17 (1.71)	62	6.83±1.701	3.30±0.688
Spirulina major	14 (1.47)	8 (0.85)	17 (2.02)	12 (1.21)	51	6.17±0.477*	2.33±0.843*
Spirulina subsalsa	15 (1.58)	19 (2.02)	16 (1.90)	18 (1.81)	68	6.83±1.662	4.50±0.962
Symploca borealis	4 (0.42)	0 (0.00)	0 (0.00)	3 (0.30)	7	1.00±0.365	0.17±0.167
Anaebena confervoides	13 (1.37)	15 (1.60)	0 (0.00)	17 (1.71)	45	5.67±0.615*	1.83±0.276*
Tolypothrix tenuis	16 (1.68)	0 (0.00)	18 (2.14)	16 (1.61)	50	5.83±1.956	2.50±1.147
Oscillatoria subtilissima	22 (2.32)	21 (2.24)	16 (1.90)	32 (3.23)	91	9.67±1.498	5.50±1.857
Oscillatoria amphibian	15 (1.58)	9 (0.96)	0 (0.00)	12 (1.21)	36	4.17±0.872*	1.83±0.543*
Oscillatoria brevis	11 (1.16)	14 (1.49)	15 (1.78)	30 (3.02)	70	6.50±1.408	5.17±1.797
Oscillatoria angustissima	16 (1.68)	23 (2.45)	25 (2.97)	15 (1.51)	79	9.00±1.897*	2.50±0.957*
Phacus hispidula	3 (0.32)	9 (0.96)	0 (0.00)	4 (0.40)	16	2.00±0.683	0.67±0.333
Trachelomonas schauinslandi	0 (0.00)	0 (0.00)	0 (0.00)	7 (0.71)	7	1.00±0.365*	0.17±0.167*
Trachelomonas rugulosa	17 (1.79)	13 (1.38)	14 (1.66)	13 (1.31	57	7.00±1.461	2.50±0.847
Trachelomonas acanthostoma	9 (0.95)	0 (0.00)	13 (1.55)	15 (1.51)	37	5.83±1.014*	0.33±0.211*
Trachelomonas abrupta	6 (0.63)	11 (1.17)	4 (0.48)	2 (0.20)	23	3.17±0.401*	0.67±0.422*
Trachelomonas armata	24 (2.53)	19 (2.02)	0 (0.00)	7 (0.71)	50	6.83±0.792*	1.50±0.428*
Trachelomonas volvocina	30 (3.16)	0 (0.00)	0 (0.00)	22 (2.23)	52	7.00±1.915	1.67±1.054

Euglena polymorpha	0 (0.00)	0 (0.00)	2 (0.24)	0 (0.00)	2	0.33±0.333	0.00±0.000
Colacium vesiculosum	0 (0.00)	10 (1.06)	9 (1.07)	0 (0.00)	19	3.00±1.438	0.17±0.167
Lepocinclis steinii	26 (2.74)	15 (1.60)	5 (0.59)	24 (2.42)	70	8.00±2.394	3.67±1.978
Synura caroliniana	0 (0.00)	4 (0.43)	8 (0.95)	0 (0.00)	12	1.83±0.872	0.17±0.167
Ochromonas mutabilis	17 (1.79)	12 (1.28)	15 (1.78)	17 (1.71)	61	7.33±1.745	2.83±1.195
Dinobryon sertularia	3 (0.32)	11 (1.17)	7 (0.83)	4 (0.40	25	3.33±0.422*	0.83±0.401*
Derepyxis dispar	0 (0.00)	2 (0.21)	0 (0.00)	0 (0.00)	2	0.33±0.333	0.00±0.000
Navicula platystoma	6 (0.63)	0 (0.00)	7 (0.83)	0 (0.00)	13	1.83±0.654	0.33±0.211
Pinnularia viridis	6 (0.63)	5 (0.53)	0 (0.00)	2 (0.20)	13	1.50±0.342	0.67±0.333
Stenopterobia intermedia	16 (1.68)	10 (1.06)	0 (0.00)	17 (1.71)	43	4.33±1.022*	1.17±0.543*
Rhizosolenia longiseta	20 (2.11)	4 (0.43)	5 (0.59)	14 (1.41)	43	5.17±1.046	2.00±0.931
Eunotia pectinalis	14 (1.47)	6 (0.64)	0 (0.00)	4 (0.40)	24	3.33±1.145*	0.67±0.333*
Eunotia curvata	5 (0.53)	7 (0.75)	4 (0.48)	4 (0.40)	20	2.17±0.833	1.17±0.601
Desmogonium rabenhorstianum	8 (0.84)	10 (1.06)	12 (1.43)	12 (1.21)	42	5.17±0.946	1.83±1.276
Melosira granulata	9 (0.95)	13 (1.38)	8 (0.95)	15 (1.51)	45	5.17±1.922	2.33±1.282
Cocconeis plancentula	0 (0.00)	25 (2.66)	0 (0.00)	12 (1.21)	37	5.83±1.641*	0.33±0.333*
Gomphonema sphaerophorum	13 (1.37)	9 (0.96)	0 (0.00)	0 (0.00)	22	2.33±0.955	1.33±0.615
Gomphonema parvulum	6 (0.63)	9 (0.96)	8 (0.95)	12 (1.21)	35	4.33±0.422*	1.50±0.500*
Stephanodiscus dubis	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.20)	2	0.33±0.333	0.00±0.000
Asteromphalus sp.	0 (0.00)	2 (0.21)	0 (0.00)	0 (0.00)	2	0.33±0.333	0.00±0.000
Compsopogon coeruleus	2 (0.21)	0 (0.00)	0 (0.00)	4 (0.40	6	1.00±0.683	0.00±0.000
Vaucheria aversa	0 (0.00)	8 (0.85	0 (0.00)	0 (0.00)	8	1.33±1.333	0.00±0.000
Total	950 (100%)	939 (100%)	841 (100%)	992 (100%)	3722		

The numbers in parenthesis shows relative abundance (%) of the species
*Significant at *p*<0.5

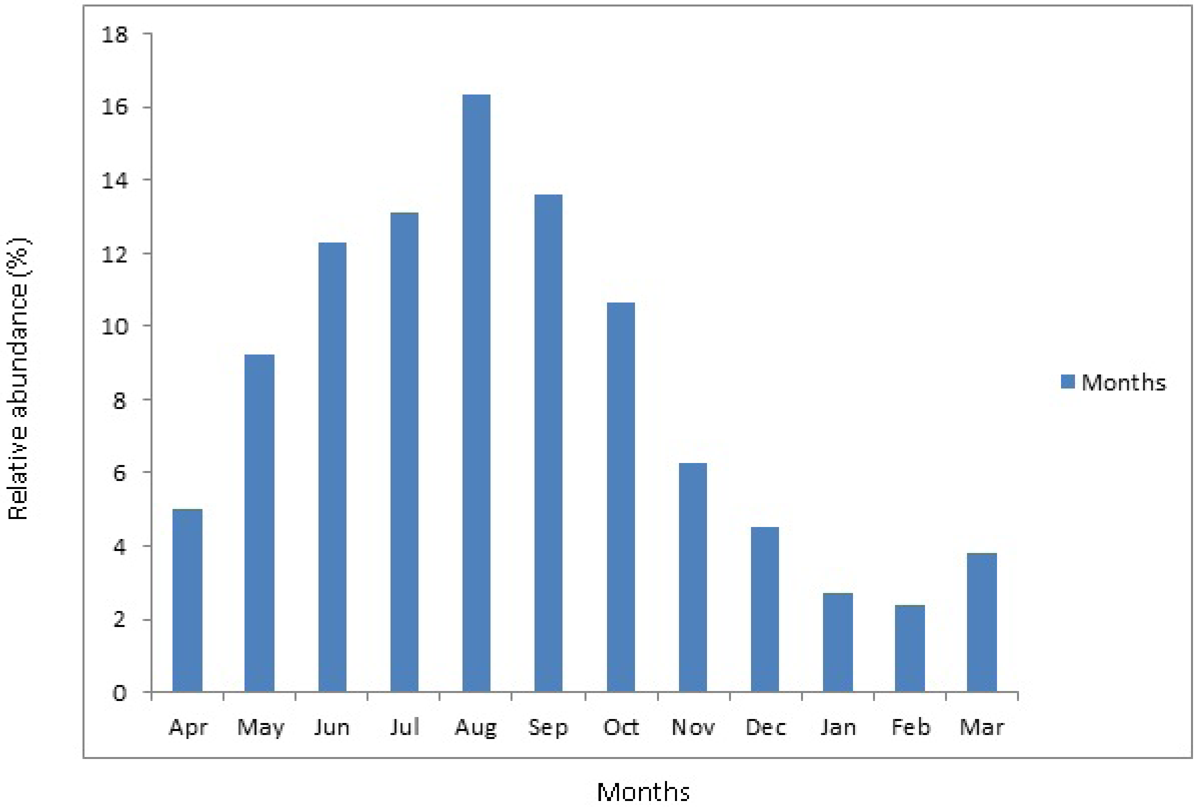

Fig. 2. Relative abundance (%) of phytoplankton species in different months

iophyceae, Mediophyceae, and Coscinodiscophyceae. The nine orders recorded are Naviculales, Surirellales, Rhizosoleniales, Eunotiales, Melosirales, Cocconeidales, Cimbellales, Stephanodiscales, and Aterolamprales. The order Stephanodiscales belongs to the class Mediophyceae, and Aterolamprales belongs to the class Coscinodiscophyceae. In contrast, the rest belong to the class Bacillariophyceae. 13 species were recorded under the phylum Bacillariophyta, the order Naviculales has 2 species, Eunotiales has 3 species, and Cimbellales has 2 species. In comparison, the rest were represented by one species each. The relative abundance of the order Naviculales is 0.7% with 26 individuals, Surirellales is 1.16% with 43 individuals, Rhizosoleniales is 1.16% with 43 individuals, Eunotiales has 2.31% relative abundance and 86 individuals, Melosirales is 1.21% with 45 individuals, Cocconeidales is 0.99% with 37 individuals, Cimbellales is 1.53% and 57 individuals, Stephanodiscales is 0.05% with 2 individuals. In comparison, Aterolamprales has a relative abundance of 0.05% with 2 individuals.

The phylum Rhodophyta recorded one class, Compsopogonophyceae, and an order, Compsopogonales. One species is represented in this phylum, and the relative abundance is 0.16% with 6 individuals. The phylum Xanthophyta, with relative abundance of 0.22% and 8 individuals is represented by one class Xanthophyceae, and an order Vaucheriales. *Vaucheria aversa* is the only species recorded in this phylum.

Spatial species variation and abundance

The phytoplankton species recorded in Oguta Lake showed variations at the study stations. The four sampling stations of Osemoto, Utu, Njaba, and Orashi had different relative abundances of 25.52%, 25.23%, 22.60%, and 26.65%, respectively (**Fig. 3**). A total of 80 phytoplankton species and 3722 individuals were recorded during the study period, showing that 67 species comprising 950 individuals were recorded in Osemoto. Sixty-two species and 939 individuals were recorded in the Utu study station. Njaba station recorded 55 species and 841 individuals, while 64 species and 992 individuals represent Orashi. Altogether, the Osemoto study station recorded the highest number of species, while the highest number of individuals was recorded in the Orashi study station.

Temporal species variation

The phytoplankton species varied in relation to the months. August produced the highest relative abundance, 16.36%, followed by September (13.62%), while the least abundance occurred in February (2.39%). The other months had varying

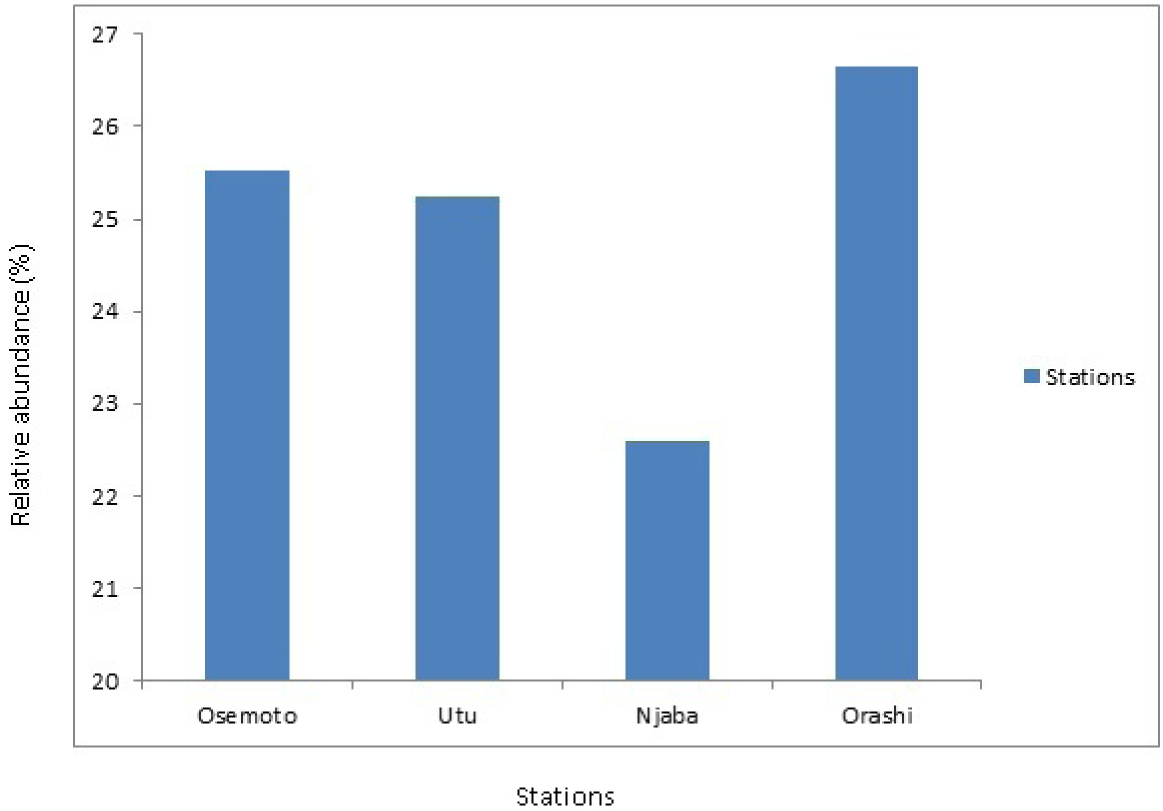

Fig. 3. Relative abundance (%) of phytoplankton species in the investigated stations

degrees of abundance.

Spatial phytoplankton diversity, dominance, and similarity

The phytoplankton diversity and dominance indices determined for the study stations are presented in **Tab. 3**. The Osemoto study station had the highest Margalef richness index of 22.1648, followed by the Utu study station (21.5292), while the lowest richness (18.4628) was at the Njaba study station. The Simpson dominance index was highest in the Orashi study station (0.9771), followed by the Osemoto study station (0.9765), while it was the least at the Njaba study station (0.9694). The Jaccard similarity index (**Tab. 4**) showed high similarity among the study stations. Utu and Osemoto shared a similarity index of 67.53%, Njaba and Osemoto's similarity index was 69.44%, while Orashi and Osemoto's similarity index was 81.94%. On the other hand, the Njaba and Utu similarity index was 60.27%, Orashi and Utu gave a value of 68%, while Orashi and Njaba showed a similarity of 63.01%.

Discussion

In the study of the phytoplankton composition of Oguta Lake, 80 species were recorded. The different phyla recorded include Chlorophyta (24 species), Charophyta (18 species), Bacillariophyta (13 species), Euglenophyta (10 species), Cyanophyta (9 species), Chrysophyta (4 species), Rhodophyta (1 species), and Xanthophyta (1 species). Following the species occurrence, the dominant taxa are the Chlor ophyta>Charophyta>Bacillariophyta>Euglenophyta >Cyanophyta. Anyinkeng et al. (2016) also recorded five taxa (Bacillariophyta>Cha rophyta>Chlorophyta>Cya nobacteria>Euglenophyta) as dominant in freshwater bodies in Buea municipality. Sorayya et al. (2011) and Wladyslawa *et al.* (2007) reported Chlorophyta, Bacillariophyta, Cyanobacteria

Table 3. Phytoplankton diversity and dominance at the study stations in Oguta Lake

	STATIONS			
	Osemoto	**Utu**	**Njaba**	**Orashi**
Number of species	67	65	55	64
Number of individuals	950	939	841	992
Margalef's index (D)	221,648	215,292	184,628	210,245
Simpson's index (1-D)	0.9765	0.9719	0.9694	0.9771

Table 4. Phytoplankton similarity coefficients of pairs of study stations in Oguta Lake

STATIONS	JACCARD INDEX			
	Osemoto	Utu	Njaba	Orashi
Osemoto	100%			
Utu	67.53%	100%		
Njaba	69.44%	60.27%	100%	
Orashi	81.94%	68%	63.01%	100%

and Dinophyta as dominant in freshwater communities. Similarly, Laskar & Gupta (2009) recorded 34 phytoplankton taxa belonging to Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae, in Chatla floodplain lake.

The most abundant genera sampled in this study were *Volvox, Quadrigula, Stichococcus, Staurastrum, Spirogyra*, and *Oscillatoria* which are mostly Chlorophyta, Charophyta, and Cyanophyta. These species may have the competitive ability, resilience, and competence to produce extracellular substances that inhibit or eliminate other algal species (Chindah et al., 2007). It may also be due to the constant addition of nutrients, particularly through nitrate and phosphate fertilizers used in the surrounding farms. Władysława et al. (2007) have attributed phytoplankton abundance to increased nutrient loads, especially in the blue-green algae (Cyanophyta). According to Oben et al. (2006), these groups of algae are known to fix nitrogen, causing eutrophication in water bodies. Blue-green algae produce toxins that can pose a health risk to humans and other animals when exposed to them in large quantities (Oben et al., 2006).

Chlorophyta and Bacillariophyta were among the abundant phytoplankton algal groups recorded. This is because they are adapted to a wide range of physicochemical parameters. Most of the phytoplankton species encountered here were dominated by Bacillariophyceae and Chlorophyceae and appeared to be normal inhabitants of natural lakes, ponds, streams, and artificial impoundments in the tropics and subtropics (Aneni & Hassan, 2003; Olaleye & Adedeji, 2005; Periyanayagi et al., 2007). Arimoro et al. (2008) reported that in the Orogodo River in Nigeria, phytoplankton were in the order of Bacillariophyceae>Chlorophyceae>Cyanophyceae>Euglenophyceae. Bellinger & Siegee (2010) also reported that diatoms (Bacillariophyta) abundance is a characteristic feature of a eutrophic environment while Ajuonu et al. (2011) have shown that the qualitative and quantitative dominance of diatoms in an aquatic ecosystem is a significant indicator of water quality and environmental condition as they are adapted to a wide range of physicochemical parameters. Sverdrup et al. (2003) and Onyema et al. (2008) reported that diatoms and dinoflagellates are important components of photosynthetic organisms and form the basis of the aquatic food chain, with the dinoflagellates being second in importance to the diatoms as basic food producers in the plankton community. The presence of the blue-green algae, as one of the most abundant genera, indicates that the water is not potable except after proper treatment. The blue-green algal bloom gives a dark green paint-like appearance in water, indicating eutrophication.

The Chlorophyta is the most abundant algal group in this study. This finding agrees with most authors who reported that the phytoplankton community in freshwater is mostly chlorophyta, cyanophyta, and diatoms (Sorayya et al., 2011). Similar studies by Ayodele & Ajani (1999) showed that green and blue-green algae dominate most tropical African lakes. Adeyemi (2012) discovered that Chlorophyta were the most dominant and accounted for approximately 79% within the phytoplankton community of Ajeko stream, followed by Bacillariophyta (17%), Euglenophyta (2%), and Cryptophyta (2%). The availability of these planktonic algae could be attributed to the physicochemical parameters, which are within tolerable limits (Adeyemi, 2012) and influence the growth and survival of this phytoplankton (Adeyemi, 2011).

Cyanophyta, also known as blue-green algae, Cyanobacteria, and Myxophyceae (Dimowo, 2013), in this study, surpassed the Chrysophyta, while the Chrysophyta surpassed the Rhodophyta in terms of number of species. The dominance of Cyanophyta has been observed by several authors, among whom were Sekadende et al. (2004), who observed Cyanophyta dominance in the Lake Victoria basin; Ogato (2007), who observed dominance of Cyanophyta in Lake Bishoftu; Deng et al. (2007), who reported dominance of Cyanobacteria in summer and autumn in Lake Chaohu; Shakila & Natarajan (2012) who also observed dominance in the Temple Pond of Thiruporur, Chennai. Cyanophyta occurrence in great abundance suggests eutrophication, and this may have a negative effect on the water quality (Suzie, 2015). Similar observations were made by Babatunde et al. (2014). The abundance of Cyanophyta observed may have been caused by the presence of pollutants in the water due to anthropogenic activities around Oguta Lake's banks.

The Euglenophyta was dominated by species of the Euglenaceae (*Trachelomonas*) and one species of Phacidae (*Lepocinclis steinii*). According to Yusuf (2020), the presence of *Phacus* sp. directly indicates the beginning of pollution load because this species is generally considered a dominant and tolerant genus of polluted ponds. Synuraceae, Ochromonadaceae, Dinobryaceae, and Derepyxidaceae are families of the Chrysophyta group recorded. Other groups of the algal species were found at a relatively low abundance. The Rhodophyta and Xanthophyta, each contributing less than one percent relative abundance, are an attestation of the fact that the environment was conducive for their proliferation. The observed low occurrence of the Rhodophyta and Xanthophyta is corroborated by the study of Kadiri (2006), while the low occurrence of Chrysophyta indicates the oligotrophic nature of the water (Bellinger et al., 2010; Ewebiyi et al., 2015).

The presence of some species like *Nitella*, *Chlorella*, *Ulothrix*, and *Microcystis sp.* indicates nutrient eutrophication (Bellinger & Siegee, 2010), while *Cosmarium sp.* are indicators of an oligotrophic environment. According to Sorayya et al. (2011), *Staurastrum*, *Cosmarium, Closterium*, and *Pediastrum* (desmid species) and some micro-green algae *Scenedesmus, Chlamydomonas,* and *Chlorella* are generally common and diverse in oligotrophic lakes and ponds, and thus are considered as indicator species for oligotrophic systems and for monitoring water quality (Coesel, 2001). This could result from the different rivers associated with Oguta Lake and corresponds to differences in phytoplankton structure and biomass at the different sampling stations.

The highest abundance of phytoplankton species was observed in Orashi station. This could be attributed to a conducive environmental condition for their growth (Rajagopal et al., 2010). Carvalho et al. (2010) stated that a high density of phytoplankton could be associated with favourable environmental conditions, and also, lower activities of grazers and predators (Ghosh et al., 2012). Uneven distribution of phytoplankton was also observed across sampling stations. Ewebiyi et al. (2015) thought that the distribution of phytoplankton within aquatic ecosystems was directly correlated with water quality, while changes in phytoplankton structure and biomass greatly affect the aquatic ecosystem functions, including shifts in nutrient cycles and or food web (Pearly & Peierls, 2008).

The seasonal occurrence, composition, and abundance of phytoplankton in this study show a higher wet season occurrence than the dry season, although the variation in seasonal mean values of many species did not show a significant difference at $p > 0.05$. Sekadende et al. (2004) and Suzie (2015) recorded the same observation where phytoplankton density was higher during the rainy season than the dry season. On the other hand, Yusuf (2020) recorded a higher dry season phytoplankton density than the wet season. Similar findings were observed by Onyema (2008) in Iyagbe Lagoon.

Conclusion

The present study has provided a new understanding of the phytoplankton diversity and abundance, and to a large extent, the trophic state of Oguta Lake. The phytoplankton structure of Oguta Lake shows 29 taxonomic orders and three thousand seven hundred and twenty-two (3722) individuals. A total of 80 species were recorded. The different phyla recorded in order of abundance were Chlorophyta>Charophyta> Bacillariophyta>Euglenophyta>Cyanophyta>Chrysophyta>Xanthophyta>Rhodophyta. Oguta Lake showed an appreciable phytoplankton density compared to other lentic waters in Nigeria. The presence of some species, such as *Nitella, Chaetophora, Oscillatoria, Chlorella,* and *Ulothrix,* indicates the eutrophic state of Oguta Lake, although a few generally common and diverse oligotrophic species were recorded. Oguta Lake is considered one of the most productive lake ecosystems in West Africa. It therefore requires constant monitoring and implementation of measures that will discourage the perturbation of this lake, such as strong management policies.

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