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Original Article

Ecological Status of Opa Reservoir, Obafemi Awolowo University, Ile Ife, based on the Abundance and Diversity of its Planktonic Flora

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Abstract

A study investigating the spatial and temporal distribution, composition and abundance of plankton in Opa reservoir, Obafemi Awolowo University, Ile-Ife, Southwest Nigeria, was conducted over a period of an annual cycle. The study was undertaken with a view of providing a more recent catalogue of planktonic flora and possibly an update of the reservoir's trophic status. Quantitative net planktons were collected monthly from both the surface and bottom levels at three sampling stations established at the dam site (lacustrine), mid-lake (transition) and upper inflow (riverine) parts of the reservoir. The divisions recorded were Bacillariophyta > Cyanophyta > Chlorophyta > Euglenophyta > Myzozoa > Ochrophyta = Charophyta > Cryptophyta in order of abundance. Vertically, the highest occurrence of species was recorded at the lacustrine bottom station (71 species), while the least occurrence was observed in the transition bottom station (51 species). A total of sixteen plankton species showed significant seasonal variation in abundance during this study period, while only seven species had significant spatial variation ($p \leq 0.05$). Higher abundance was observed during the rainy season (170,797,350 Org/m^3 from seventy-two species) than dry season (5,138,400 Org/m^3 from forty-nine species). Notable bio-indicator plankton species recorded were *Anabaena circinalis, Anabaena flos-aquae, Microcystis* sp., *Aphanocapsa litoralis* and *Microcystis aeruginosa.* Some other pollution indicator species recorded were *Synedra ulna, Oscillatoria agardhii, Phacus* sp., *Surirella* sp., *Closterium* sp., *Aphanocapsa* sp. and *Euglena* sp. Hence, Opa reservoir is very rich in Bacillariophyta (diatoms), followed by Cyanophyta (blue-green) and Chlorophyta (green algae), which are known to characterize eutrophic lakes.

Keywords: bio-indicator species; phytoplankton; taxonomic composition; trophic status; water quality

Introduction

By the virtue of the position of phytoplankton at the base of the aquatic food web, they stand as the most important factor of production in the aquatic ecosystem (Moshood, 2009). Various ecological changes such as presence, absence, replacement or addition of species can also be monitored using the phytoplanktonic community as a potential tool (Codd, 1995). Therefore, the presence of phytoplankton in reservoirs goes a long way in determining the sustainability and productivity of most aquatic habitats. The growth significance and sustainability of any ecosystem is largely accounted for by the diversities of phytoplankton and their abundance. Both factors are equally related and do change as their interaction is influenced by the environment and population processes (Benedict and Gabriel, 2012).

Phytoplankton are known to be very important in estimation of the potential fish yield (Hecky and Kling, 1981), productivity (Park *et al.*, 2003), water quality (Walsh *et al.*, 2001), energy flow (Simciv, 2005), trophic status (Reynolds, 1999), and water management (Beyruth, 2000). Phytoplankton such as *Microcytis* sp., *Anabaena* sp., *Oscillatoria* sp. are known indicators of pollution while the presence and abundance of Chlorophyceae are indicative of the environment's suitability for fish production (Olasehinde and Abeke, 2012). The suitability of micro-algal components as bio-indicators of the water condition is because they confer more tolerance than many other biotas used for monitoring environmental changes (Nwankwo and Akinsoji, 1992).

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Adesakin *et al.* (2017) reported direct discharge of untreated municipal/industrial waste as well as run off from agricultural areas into Opa reservoir, with resultant significant effects on the reservoir's physicochemical parameters both temporally and spatially and this may possibly inflict a level of risk to the inhabiting aquatic biota. This, coupled with the fact that the last published record of plankton research carried out on Opa reservoir was that of Rotifers only by Akinbuwa and Adeniyi (1996), lead to the present study. The study seeks to determine the taxonomic composition, diversity and abundance of phytoplanktonic organisms of Opa reservoir with respect to spatial and temporal distribution, as well as to assess the water quality and trophic status of the reservoir with a view to determining the effects of the discharges.

Materials and Methods

Plant material

The study site, Opa reservoir (Fig. 1), is located between longitude 004°31'40"E to 004°32'45"E, and latitude 07°30'N to 07°31'N, within the Obafemi Awolowo University community, Ile-Ife, Southwest Nigeria (Fawole and Arawomo, 2000). The reservoir was established in 1978 by the impoundment of River Opa which sources from Oke-Opa, a set of hills on the Eastern side of the Ife/Ilesha road, Ile-Ife, Osun state (Akinbuwa and Adeniyi, 1996). A number of rivers, including Amuta, Esinmirin, Obudu and Opa unite to form the Opa River. The reservoir has a catchment basin of about 116 km^2 (Akinbuwa and Adeniyi, 1996). Its total surface area is 0.95 km^2, while the maximum capacity is about 675,000 m^3 with depth of 0.95 m and 6.4 m at littoral zone and open water respectively (Fawole and Arawomo, 2000). The dam wall made of gravel is about 0.28 km long and about 15 m from the foundation to the crest (Akinbuwa and Adeniyi, 1991). As expected of tropical shallow reservoirs, the water volume during the dry season reduces significantly, whereas in the rainy season, there is increased volume of water inflow resulting from floods leading to high turbidity and a general immersion of the vegetation on the shoreline. This seasonal fluctuation in the water discharge into the reservoir directly affects its water level.

Three sampling stations A, B and C were established on the reservoir denoting the lacustrine, transition and the riverine area of the reservoir along the horizontal axis respectively (Fig. 1). The station A is located at the dam-site just beside the wall, an area assumed to be the deepest part of the lake, station B is the middle of the lake, while the C station is towards the inflow into the lake. A permanent buoy (rubber float) was used to demarcate each of the three sampling stations for ease of subsequent recognition. The distances between the stations and the grid coordinate of each station was taken and recorded using the Global Positioning System (GPS) handheld receiver.

Sample collection

Water samples were collected monthly from both the surface and bottom levels at the three sampling stations on the reservoir for a period of one year for phytoplankton analysis between October 2012 and November 2013. An improvised water sampler of 2.5 L capacity was used to take bottom water samples at required depths. Net plankton was sampled by pouring 20 litres of water through plankton net of 50 μm mesh size and the net planktonic contents was poured into a 30 ml sampling bottle and preserved with few drops of 5% formaldehyde and a drop of Lugol's solution for examination and identification. The preserved sub-sample containing plankton was examined in the laboratory using OMAX binocular light compound photo and their scaled pictures taken.

Planktonic population abundance was estimated based on the count records of the final concentrate volume of the

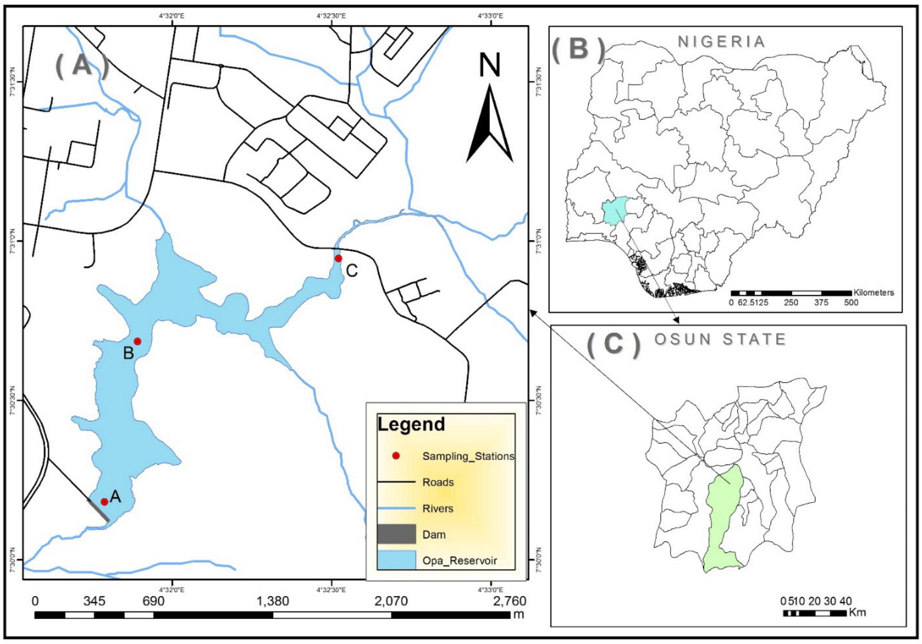

Fig. 1. Map of Opa Reservoir showing the investigated sampling stations (A); Nigeria (B); Osun State (C)

sub-sample with respect to the original volume of water filtered with plankton net and the result was then expressed in organisms per cubic metre of the original water sample.

Data analysis

Data collected were subjected to various descriptive and inferential analyses such as the means and standard deviations which gave the depiction of planktonic species abundance with respect to season and location. Analysis of variance was used to compare mean abundance of identified planktonic species, while correlation was used to show the relationship between different planktonic groups. Moreover, Principal Component Analysis (PCA) was used to reduce all interactions into components that also showed the relationship between recorded plankton species as applicable using SPSS Version 21 software (SPSS, 2012). Plankton community structure was determined using Species diversity indices (Shannon and Weaver, 1949), Dominance (Magurran, 2004), Species equitability or evenness (Pielou, 1966) and Species richness (Margalef, 1951; Menhinick, 1964).

Results

Species composition and occurrence

A total of eighty-two (82) species of phytoplankton were recorded belonging to fifty-five genera, forty-five families, thirty-two orders, twelve classes and eight divisions of algae as outlined below in Table 1 and summarized in Fig. 2. A total of 38 species occurred at all the three sampling stations at the surface and/or the bottom. These species include seven species of Cyanobacteria division (*Anabaena circinalis, Cylindrospermopsis raciborskii, Microcystis* sp., *Microcytis aeruginosa, Trachodesmium lacustre, Oscillatoria agardhii* and *Coelosphaerium* sp.). Others are seven species belonging to Chlorophyta (*Oedogonium* sp., *Pediastrum simplex, Pediastrum* sp., *P. duplex, Volvox aureus, Actinastrum hantzschii* and *Oocystis* sp.) and three species (*Euglena oxyuris, Euglena acus* and *Phacus longicauda*) representing Euglenophyta. Furthermore, species found only once throughout the sampling period and specific to a sampling station include *Anabaena flos-aquae, Chroococcus* sp., *Lyngbya* sp., *Cosmarium depressum, Cosmarium subcrenatum, Schizothrix lardacea, Aphanocapsa litoralis,* (Lacustrine)*; Melosira oamaruensis, Guarnardia flaccida, Thalasionema* sp., *Prasiola* sp., *Peridinopsis thompsonii, Trachelomonas caudata* (Transition) and *Melosira* sp. (Riverine).

Spatial variation

Phytoplankton total abundance ranged from 15,855,150 Org/m^3 at transition (surface) to 53,956,350 Org/m^3 at the lacustrine zone (surafce) of the reservoir. The recorded abundance as compared with zooplankton abundance recorded during the study period showed an average of 112 times (5.71-175.04 times) higher phytoplankton than the zooplankton recorded (Table 2).

The maximum mean abundance was also recorded at the lacustrine surface portion of the reservoir (963,506 Org/m^3) which had highest number of species (56 species) (Table 2). Horizontally, *Pediastrum* sp., *Actinastrum hantzschii* and *Dinophysis* sp. showed significant difference across zones ($p \leq 0.05$), while *Amphipleura jenneri, Pediastrum simplex, Pediastrum duplex* and *Volvox aureus* showed highly significant spatial difference ($p \leq 0.01$) (Table 3).

Seasonal variation

Higher abundance was observed during the rainy season (170,797,350 Org/m^3 from seventy-two species) than dry season (5,138,400 Org/m^3 from forty-nine species) (Table 2). The most abundant species during the dry season include *Guinardia flaccida, Cylindrospermopsis raciborskii, Oscillatoria agardhii, Perdiniopsis pernardii, Pediastrum simplex* and *Oedogonium* sp. (Table 3). Species showing highly significant seasonal difference ($p \leq 0.01$) include *Nitzschia* sp., *Pediastrum simplex, Pediastrum sp., Pediastrum duplex, Volvox aureus* and *Dinophysis* sp. While *Amphipleura jenneri, Surirella tenara, Chaetocerous subtilis, Anabaena circinalis, Microcystis aeruginosa, Ceratium inflatum, Euglena oxyuris* and *Trachelomonas caudata* all showed statistically signicant difference seasonally ($p \leq 0.05$) (Table 4).

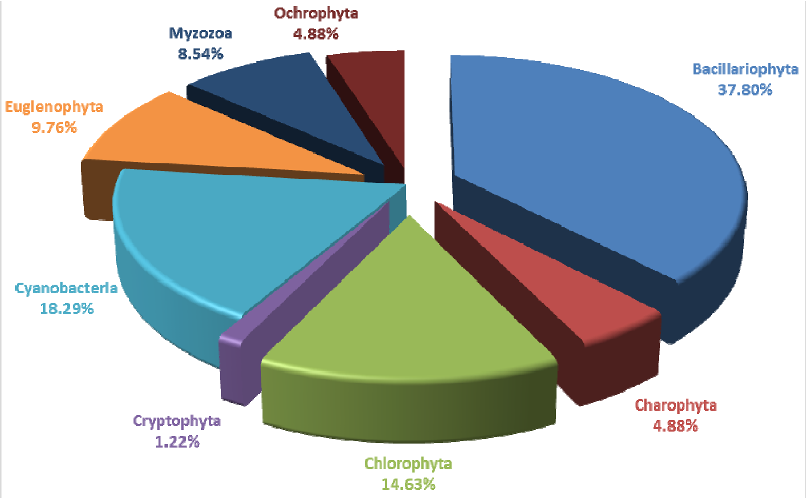

Fig. 2. Percentage composition of recorded phytoplankton taxa

Table 1. Outline classification and taxa composition of the phytoplankton flora

Division	Class	Subclass	Order	Family	Genus/Species
Cyanobacteria	Cyanophyceae	Nostocophycidae	Nostocales	Nostocaceae	*Anabaena circinalis*
					Anabaena flos-aquae
				Aphanizomenonaceae	*Cylindrospermopsis raciborskii*
		Oscillatoriophycidae	Chroococcales	Chroococcaceae	*Chroococcus* sp.
				Microcystaceae	*Microcystis* sp.
					Microcystis aerosonosa
			Oscillatoriales	Gloeotrichiaceae	*Gloeotrichia echinulata*
				Microcoleaceae	*Arthrospira* sp.
					Trachodesmium lacustre
				Oscillatoriaceae	*Oscillatoria agardhii*
					Lyngbya contorta
					Lyngbya sp.
		Synechococcophycideae	Pseudanabaenales	Schizotrichaceae	*Schizothrix lardacea*
			Synechococcales	Merismopediaceae	*Aphanocapsa litoralis*
				Coelosphaeriaceae	*Coelosphaerium* sp.
Chlorophyta	Chlorophyceae		Oedogoniales	Oedogoniaceae	*Oedogonium* sp.
			Sphaeropleales	Hydrodictyaceae	*Pediastrum duplex*
					Pediastrum simplex
					Pediastrum sp.
					Hydrodictyon reticulatum
			Chlamydomonadales	Volvocaceae	*Volvox globulus*
					Volvox aureus
	Trebouxiophyceae		Chlorelalles	Chlorellaceae	*Actinastrum hantzschii*
					Dictyosphaerium sp.
				Oocystaceae	*Oocystis crassa*
					Oocystis sp.
			Prasiolales	Prasiolaceae	*Prasiola* sp.
Euglenophyta	Euglenophyceae		Euglenales	Euglenaceae	*Euglena* sp.
					Euglena oxyuris
					Euglena viridis
					Euglena acus
					Trachelomonas sp.
					Trachelomonas caudata
				Phacaceae	*Phacus longicauda*
					Phacus pyrum
Myzozoa	Dinophyceae		Perdianiales	Perdiniaceae	*Peridinium* sp.
					Peridinium willei
					Peridinium cinctum
				Glenodiniaceae	*Peridiniopsis pernardii*
					Peridiniopsis thompsonii
			Gonyaulacales	Ceratiaceae	*Ceratium inflatum*
			Dinophysiales	Dinophysaceae	*Dinophysis* sp.
Cryptophyta	Cryptophyceae		Cryptomonadales	Cryptomonadaceae	*Cryptomonas ovata*
Ochrophyta	Synurophyceae		Synurales	Mallomonadaceae	*Mallomonas caudata*
			Desmidiales	Desmidiaceae	*Desmidium* sp.
					Cosmarium depressum
					Cosmarium subcrenatum
Charophyta	Conjugatophyceae		Zygnematales	Closteriaceae	*Closterium* sp.
					Closterium lanceolatum
				Zygnemataceae	*Spirogyra setiformis*
					Mougeotia boodlei
Bacillariophyta	Bacillariophyceae	Bacillariophycidae	Naviculales	Amphipleuraceae	*Amphipleura jenneri*
					Frustulia sp.
				Naviculaceae	*Navicula* sp. 1
					Navicula sp. 2
					Navicula sp. 3
				Pleurosigmataceae	*Pleurosigma* sp.
				Stauroneidaceae	*Stauroneis* sp.
				Pinnulariaceae	*Pinnularia viridis*
					Pinnularia sp.

			Bacillariales	Bacillariaceae	*Nitzschia sigma*
					Nitzschia sp.
					Bacillaria sp.
					Bacillaria paradoxa
			Cocconeidales	Cocconeidaceae	*Cocconeis pediculus*
			Surirellales	Surirellaceae	*Surirella tenara*
					Surirella minuta
		Eunotiophycidae	Eunotiales	Eunotiaceae	*Eunotia formica*
	Coscinodiscophyceae	Melosirophycidae	Melosirales	Melosiraceae	*Melosira oamaruensis*
					Melosira sp.
				Coscinodiscaceae	*Hyalodiscus* sp.
					Hyalodiscus radiatus
			Rhizosoleniales	Rhizosoleniaceae	*Rhizosolenia* sp.
					Guinardia flaccida
	Fragilariophyceae		Fragilariales	Fragilariaceae	*Fragilaria capucina*
			Licmophorales	Ulnariaceae	*Synedra ulna*
			Thalassionematales	Thalassionemataceae	*Thalassionema* sp.
					Thalassionema nitzschioides
	Mediophyceae	Chaetocerotophycidae	Chaetocerotales	Chaetocerotaceae	*Chaetocerous subtilis*
		Thalassiosirophycidae	Leptocylindrales	Leptocylindraceae	*Leptocylindrus danicus*
					Leptocylindrus minimus
			Thalassiosirales	Stephanodiscaceae	*Stephanodiscus* sp.

Table 2. Spatial and temporal abundance distribution of phytoplankton species

Organisms	Temporal		Spatial					
			Lacustrine		Transition		Riverine	
	Dry season	Wet season	Surface	Bottom	Surface	Bottom	Surface	Bottom
			Cyanobacteria					
Anabaena circinalis	730,050	38,550	173,700	30,000	113,850	405,750	24,450	20,850
Anabaena flos-aquae	0	150	0	150	0	0	0	0
Cylindrospermopsis raciborskii	75,600	3,709,650	1,349,100	717,000	1,086,900	155,400	36,750	440,100
Chroococcus sp.	150	0	0	150	0	0	0	0
Microcystis sp.	44,400	41,700	24,450	3,900	24,900	5,100	26,250	1,500
Microcystis aeruginosa	12,900	1,050	2,250	0	7,500	150	3,150	900
Gloeotrichia echinulata	0	600	300	0	0	0	150	150
Arthrospira sp.	1,050	300	1,050	150	0	0	0	150
Trachodesmium lacustra	1,950	1,350	1,050	150	600	600	600	300
Oscillatoria agardhii	1,052,100	12,399,150	5,510,550	766,500	96,600	6,589,950	185,700	301,950
Lyngbya contorta	0	450	0	150	0	0	300	0
Lyngbya sp.	0	150	0	150	0	0	0	0
Schizothrix lardacea	0	150	150	0	0	0	0	0
Aphanocapsa litoralis	0	150	0	150	0	0	0	0
Coelosphaerium sp.	3,000	3,150	3,450	150	300	0	2,100	150
			Chlorophyta					
Oedogonium sp.	31,200	269,100	12,300	170,850	450	103,500	0	13,200
Pediastrum simplex	303,600	188,100	171,900	96,600	106,800	28,200	75,150	13,050
Pediastrum sp.	110,850	52,650	56,400	30,150	30,150	27,900	14,100	4,800
Pediastrum duplex	52,650	22,050	47,550	4,800	13,650	450	7,500	750
Hydrodictyon reticulatum	0	300	0	150	0	0	0	150
Volvox globulus	0	1,800	750	0	0	0	1,050	0
Volvox aureus	5,100	150	750	150	450	0	2,100	1,800
Actinastrum hantzschii	4,950	450	300	150	1,200	3,450	150	150
Dictyosphaerium sp.	0	750	450	0	300	0	0	0
Oocystis crassa	4,500	0	4,200	0	0	0	300	0
Oocystis sp.	900	21,300	1,350	750	7,050	0	5,850	7,200
Prasiola sp.	0	300	0	300	0	0	0	0
			Euglenophyta					
Euglena sp.	600	2,850	450	900	900	600	0	600
Euglena oxyuris	16,350	4,350	1,800	9,150	1,050	450	0	8,250
Euglena sp.	750	0	0	600	0	0	150	0
Euglena acus	36,300	92,550	25,650	26,400	30,900	2,700	28,500	14,700

Trachelomonas sp.	1,800	0	0	0	150	0	1,650	0
T. caudata	0	150	0	150	0	0	0	0
Phacus longicauda	4,350	33,750	11,850	6,900	15,150	300	3,600	300
Phacus pyrum	0	7,500	900	0	6,300	0	300	0
Myzozoa								
Peridinium sp.	3,900	208,050	57,450	96,450	18,000	2,850	35,400	1,800
Peridinium willei	0	3,450	1,950	150	1,,200	0	0	150
Peridinium cinctum	0	32,850	18,000	7,350	6300	450	600	150
Peridiniopsis pernardii	714,150	5,266,200	1,034,550	1,608,150	3,337,350	0	0	300
Peridiniopsis thompsonii	0	150	0	0	0	0	150	0
Ceratium inflatum	1,350	0	0	0	0	450	300	600
Dinophysis sp.	99,450	51,450	30,300	24,150	20,100	12,900	25,800	37,650
Cryptophyta								
Cryptomonas ovata	22,950	100,500	17,250	12,900	8,100	9,150	69,750	6,300
Ochrophyta								
Mallomonas caudata	0	450	0	300	150	0	0	0
Desmidium sp.	5,100	145,200	25,200	4,800	300	120,000	0	0
Cosmarium depressum	0	300	0	300	0	0	0	0
Cosmarium subcrenatum	0	150	0	150	0	0	0	0
Charophyta								
Closterium sp.	0	300	150	0	150	0	0	0
C. lanceolatum	600	450	450	0	150	450	0	0
Spirogyra setformis	0	1,200	0	750	0	0	150	300
Mougeotia boodlei	0	14,554,200	580,650	13,431,300	48,450	144,300	15,750	333,750
Bacillariophyta								
Amphipleura jenneri	750	0	300	450	0	0	0	0
Frustulia sp.	0	150	150	0	0	0	0	0
Navicula sp. 1	600	1,800	150	1,500	150	450	0	150
Navicula sp. 2	150	150	0	0	0	0	150	150
Navicula sp. 3	0	150	0	0	0	0	150	0
Pleurosigma sp.	0	3,150	0	1,650	0	1,500	0	0
Stauroneis sp.	300	150	0	0	0	0	0	450
Pinnularia viridis	150	10,200	8,700	0	1,500	150	0	0
Pinnularia sp.	0	150	0	150	0	0	0	0
Nitzschia sigma	750	450	150	150	450	150	0	300
Nitzschia sp.	2,100	600	450	600	0	300	0	1,350
Bacillaria sp.	0	300	300	0	0	0	0	0
Bacillaria paradoxa	0	5,400	1,350	3,450	300	0	0	300
Cocconeis pediculus	300	300	150	0	300	0	0	150
Surirella tenara	3,150	0	150	0	0	300	600	2,100
Surirella minuta	300	2,400	300	2400	0	0	0	0
Eunotia formica	2,250	412,350	34,950	55,500	10,650	206,250	2,250	105,000
Melosira oamaruensis	300	300	0	0	300	0	0	300
Melosira sp.	0	150	0	0	0	0	150	0
Hyalodiscus sp.	0	450	0	0	0	0	450	0
Hyalodiscus radiatus	300	450	300	0	0	0	150	300
Rhizosolenia sp.	0	1,200	150	750	0	0	300	0
Guinardia flaccida	1,750,650	132,891,000	44,681,700	17,239,800	10,782,150	10,293,300	19,633,650	32,011,050
Fragilaria capucina	0	7,500	450	600	150	5,700	150	450
Synedra ulna	0	1,350	150	0	150	900	0	150
Thalassionema sp.	21,900	0	21,450	0	450	0	0	0
Thalassionema nitzschioides	450	0	0	0	0	0	0	450
Chaetocerous subtilis	1,200	39,900	10,500	7,200	9,000	3,150	9,450	1,800
Leptocylindrus danicus	9,750	109,350	17,250	19,800	43,800	3,000	26,550	8,700
L. minimus	450	0	0	0	0	300	0	150
Stephanodiscus sp.	0	48,450	8,700	5,100	20,400	300	8,700	5,250
Number of species identified	49	72	56	54	47	38	43	49
Mean	104,865	2,372,185	963,506	636,897	337,344	477,126	470,941	680,623
Total Abundance	5,138,400	170,797,350	53,956,350	34,392,450	15,855,150	18,130,800	20,250,450	33,350,550
Zooplankton Abundance (Bolawa, 2016)	900,600	1,219,300	308,250	222,300	644,700	70,650	570,250	303,750
Ratio of Phytoplankton to Zooplankton	5.71	140.08	175.04	154.71	24.59	256.63	35.51	109.80

Table 3. ANOVA statistics showing significant spatial variations in phytoplankton species abundance

	Lacustrine	Transition	Riverine	ANOVA	
Organisms	Mean ± SD (Ind/L)	Mean ± SD (Ind/L)	Mean ± SD (Ind/L)	F Ratio	p
Pediastrum sp.	3,606.25±6,397.151	2,418.75±4,673.882	787.50±1,154.504	3.698*	0.031
Actinastrum hantzschii	18.75±67.264	193.75±735.485	12.50±42.349	3.165*	0.049
Dinophysis sp.	2,268.75±2,668.407	1,375.00±1,993.740	2,643.75±3,151.029	3.404*	0.040
Amphipleura jenneri	31.25±98.701	0	0	5.376**	0.007
Pediastrum simplex	11,187.50±13,079.383	5,625.00±7,601.959	3,675.00±7,153.382	7.342**	0.001
Pediastrum duplex	2,181.25±3,739.676	587.50±1,358.248	343.75±957.387	13.184**	0.000
Volvox aureus	37.50±127.048	18.75±67.264	162.50±356.386	9.095**	0.000

** Highly Significant
*Significant

Table 4. ANOVA statistics showing significant seasonal variation among phytoplankton species

Organisms	Dry season	Wet season	ANOVA	
	Mean ± SD	Mean ± SD	F ratio	p
Amphipleura jenneri	250±141.42	0	4.881*	0.030
Surirella tenara	630±743.37	0	4.452*	0.038
Chaetocerous subtilis	400±187.08	2,216.667±1,660.23	6.485*	0.013
Leptocylindrus danicus	886.363636±1,362.00	2,865.789±4,228.21	5.112*	0.027
Anabaena circinalis	48,670±100,770.99	3,255±6,032.18	5.913*	0.018
Microcystis aeruginosa	2,580±2,581.39	525±375	4.924*	0.030
Ceratium inflatum	450±122.47	0	6.146*	0.016
Euglena oxyuris	2,335.71429±1,958.81	862.5±920.85	6.437*	0.013
Trichocerca caudata	0	150±0	4.242*	0.043
Nitzschia sp.	350±70.71	200±70.71	8.889**	0.004
Pediastrum simplex	13,800±13,943.03	4,518.75±5,455.77	14.349**	0.000
Pediastrum sp.	5,834.21053±7,575.24	1,755±1,935	10.125**	0.002
Pediastrum duplex	3,510±4,028.95	1,073.684±1,740.64	8.754**	0.004
Volvox aureus	510±380.66	150±0	16.430**	0.000
Oocystis sp.	300±122.47	777.7778±839.68	7.031**	0.010
Dinophysis sp.	4,735.71429±3,453.75	1,172.093±947.17	29.942**	0.000

** Highly Significant
*Significant

Diversity

The species richness recorded in the rainy season was higher than that of the dry season. Simpson's index shows a higher diversity in the dry season than wet and this agrees with the Hill's second diversity, which measured the number of very abundant species to be higher in the dry season than the wet season. Similarly, Shannon's index supports a slightly increase in the number of species and more evenness of distribution in the dry season than the wet. This is more revealed by a higher number of abundant species as Hill's first diversity index (Table 5).

Spatially, however, the maximum richness occurred in the lacustrine surface station, while the lowest occurred in the riverine surface.

The highest diversity occurred in the lacustrine bottom as revealed by both Simpson's and Shannon's indices. The station with the most evenly distributed species is the riverine bottom (Table 5).

Species association

Principal Component Analysis (PCA) based on correlation analysis, was used to reduce the component factors to those with most influence (Table 6). Twenty-eight factors were found to have an Eigen value greater than 1, that is the strongest correlation between the components and the original set of flexible quantities accounting for a cumulative variance of 87.70 but only five were selected.

Component 1 with the highest total variance of 7.56% and maximum Eigen value of 6.28 showed strongest loading (0.881) for abundance of *Bacillaria paradoxa*. Other species that had strong positive loadings within component 1 were *Anabaena flos-aquae*, *Peridinium* sp., *Cosmarium depressum* and *C. subcrenatum*. Seventeen species showed positive correlation within the first component with seven of them having high or moderate loading. Component 2 showed positive correlation for twenty species recorded, which was the highest number of positive correlations recorded (Table 6).

Table 5. Spatial and temporal diversity of phytoplankton species

		Temporal		Spatial					
				Lacustrine		Transition		Riverine	
		Dry season	Wet season	surface	bottom	surface	bottom	surface	bottom
Richness Index	R1	3.11	3.64	3.26	3.11	2.71	2.63	2.49	2.77
Simpson's Index	λ	0.21	0.61	0.70	0.41	0.51	0.45	0.83	0.91
Hill's 2nd diversity	N2	4.79	1.64	1.43	2.46	1.96	2.20	1.20	1.10
Shannon's index	H'	1.95	0.89	0.71	1.14	1.03	1.02	0.43	0.27
Hill's 1st diversity	N1	7.03	2.44	2.03	3.14	2.79	2.77	1.54	1.31
Evenness Index 1	E4	0.68	0.67	0.71	0.78	0.70	0.79	0.78	0.84
Evenness Index 2	E5	0.63	0.45	0.42	0.68	0.54	0.68	0.37	0.31

Table 6. Principal component analysis for the phytoplankton species based on abundance

	1	2	3	4	5
Eigen value	6.28	5.94	5.51	5.34	4.61
Total % variance	7.56	7.16	6.643	6.435	5.555
Cumulative variance	7.56	14.72	21.36	27.80	33.35
Amphipleura jenneri		.310*			
Frustulia sp	.447*				
Navicula sp 1				.523**	.360*
Navicula sp 2			.711**		
Pleurosigma sp				.489	.359
Stauroneis sp		.254*	.650**		.254*
Pinnularia viridis	.398*			.290*	
Nitzschia sp		.405*			
Bacillaria sp	.447*				
Bacillaria paradoxa	.881**				
Surirella tenara		.323*	.739**		.258*
Surirella minuta			.256*	.604**	.424*
Melosira oamaruensis			.544**		
Melosira sp			.290*		
Hyalodiscus radiatus			.500**		
Rhizosolenia sp	.736**				.383*
Thalassionema sp		.631**		.435*	.254*
Leptocylindrus danicus	.436*		.263*	.269*	
Stephanodiscus sp	.513**				
Pediastrum simplex	.418*	.605**			
Pediastrum sp		.472*			
Pediastrum duplex	.308*	.555**		.355*	
Volvox globulus	.414*		.348*		
Volvox aureus		.381*	.633**		
Actinastrum hantzschii		.347*	.251*		
Oocystis crassa		.633**		.429*	.255*
Anabaena circinalis		.406*	.264*		
Anabaena flos-aquae	.777***				.397*
Microcystis sp	.310*	.374*			
Arthrospira sp	.291*	.598**		.359*	.299*
Trachodesmium lacustre		.539**		.292*	
Schizothrix lardacea	.447*				
Coelosphaerium sp		.386*		.288*	
Peridinium sp	.870***				
Peridinium cinctum				.433*	
Peridiniopsis pernardii			.254*	.494*	.349*
Peridiniopsis thompsonii			.290*		
Ceratium inflatum		.402*	.702*		
Dinophysis sp		.558**	.357*		
Cosmarium depressum	.777***				.397*
Cosmarium subcrenatum	.777***				.397*
C. lanceolatum		.431*		.361*	
Spirogyra setformis			.324*	.546*	.326*
Euglena sp			.557**	.291*	.397*
Euglena acus				.556**	
T. caudata		.385*			
Phacus pyrum			.290*	.583**	

Note: PC loadings < 0.25 are omitted *Weak loading (0.25 – 0.50) **Moderate loading (0.50 - 0.75) ***Strong loading (> 0.75) (Yao *et al*., 2014)

Discussion

The study found that Bacillariophyta, Chlorophyta and Cyanophyta dominated the net phytoplankton of Opa Reservoir, which is in agreement with records of other studies on African tropical reservoirs, especially Nigerian reservoirs (Adeniyi, 1978; Bwalla *et al*., 2010; Edward and Ugwumba, 2010; Offem *et al*., 2011; and Atobatele, 2013). The record of the family Bacillariophyceae as most abundant is similar to the record of Abowei *et al.* (2012) (Koluama area) as well as Ogamba *et al.* (2004) (Elechi creek complex), both of Niger Delta, Nigeria; Emmanuel and Onyema, (2007) (a tropical creek in South western Nigeria); Abowei *et al.* (2008) (Lower Sobreiro river of the Niger Delta); Zabbey *et al*. (2008) (Imo river); Davies *et al.* (2009) (Elechi creek, Niger Delta); Achionye-Nzeh and Isimaikaye, 2010 (Ilorin reservoir) and Nkwoji *et al.* (2010) (Lagos lagoon, Nigeria), followed by Cyanobacteria and Chlorophyta, which were more copious in the wet season.

The maximum phytoplanktonic abundance, recorded in the lacustrine zone, might be due to stability of certain environmental variables in this zone as a result of reduced water current, restricted movement and higher transparency (Salem, 2011; Adedeji *et al*., 2015). The lowest abundance in spite of high species richness recorded in April 2013, a period towards the first peak of the rainy season, could possibly be an effect of the washing away of many individual phytoplankton through flooding and their dislodging from littoral vegetation hence species enrichment (Adeniyi and Adedeji, 2007). The observed irregular variation in phytoplankton distribution from surface to bottom across the three sampling stations could be as a result of high mixing and nutrient re-cycling in the reservoir column during the rainy season (Ugwumba and Ugwumba, 1993; Adedeji *et al*., 2015). The higher planktonic composition recorded during the rainy season may furthermore be due to an increase in ionic dilution during this period as well as an increase in nutrient inflow and introduction of organic matter (Adedeji *et al*., 2015).

Generally, phytoplankton has been identified to be important in bio-monitoring of trophic status as well as water quality (Townsend *et al*., 2000; Davies *et al*., 2009; Achionye-Nzeh and Isimaikaye, 2010; Offem *et al*., 2011). Notable bio-indicator phytoplankton species recorded were *Anabaena circinalis, A. flos-aquae, Microcystis* sp., *Aphanocapsa litoralis* and *Microcystis aeruginosa,* which have been reported to produce algal toxins such as microcystin, that is a hepatotoxin and can cause serious illness in both humans and some other mammals (WHO, 2009; Ugwumba *et al*., 2013). These species were noted to be significantly in abundance during the present study. Other pollution indicator species that were recorded in this study include *oscillatoria agardhii, Phacus* sp., *Surirella* sp., *Closterium* sp., *Aphanocapsa* sp. and *Euglena* sp. suggesting the likelihood of pollution in the reservoir (Ugwumba *et al.,* 2013). Moreover, high percentage of Chlorophyceae and Cyanobacteria in a water-body, as obtained from this study, with Cyanobacteria being the second most represented taxa, is a clear indication of eutrophication (Taub, 1984; Olasehinde and Abeke, 2012). The elevated abundance of these species might have resulted from the quick increase in the supplied nutrients to the reservoir from several anthropogenic activities from the basin catchment area (Jaji *et al*., 2007).

Conclusions

Opa Reservoir is rich in phytoplankton, which are mostly members of Bacillariophyta (diatoms), Cyanobacteria (blue-green) and Chlorophyceae (green algae) often recorded in eutrophic lakes. As the hereby study revealed, very high abundance of the algae, recorded as compared to zooplankton abundance resulting from the increase in nutrients through continual inflow and seasonal changes, could lead to the lake deterioration with time. The lake should be therefore monitored closely.

References

Abowei JFN, Tawari CC, Hart AI, Garricks DU (2008). Fin fish species composition, abundance and distribution in the lower Sombreiro River, Niger Delta, Nigeria. International Journal of Tropical Agriculture and Food Systems 2(1):46-43.

Abowei JFN, Ezekiel EN, Hansen U (2012). Effects of water pollution on phytoplankton species composition in Koluama Area, Niger Delta Area, Nigeria. International Journal of Fisheries and Aquatic Sciences 1(2):134-139.

Achionye-Nzeh CG, Isimaikaiye A (2010). Fauna and flora composition and water quality of a reservoir in Ilorin, Nigeria. International Journal of Lakes and Rivers 3(1):7-15.

Adedeji AA, Komolafe OO, Akinrele OA, Adeleke O (2015). Water quality and plankton biota of Osinmo reservoir, Osun state, South-west Nigeria, Zoology and Ecology 25(2):145-153.

Adeniyi IF (1978). Studies on the physicochemical factors and planktonic algae of Lake Kainji, Nigeria. PhD Thesis. University of Ife, Ile-Ife.

Adeniyi IF, Adedeji AA (2007). The Rotifera fauna of Gongola River basin, Northeast Nigeria. Ife Journal of Science 9(1):1-16.

Adesakin TA, Adedeji AA, Aduwo AI, Taiwo YF (2017). Effect of discharges from re-channeled rivers and municipal runoff on water quality of Opa reservoir, Ile-Ife, Southwest Nigeria. African Journal of Environmental Science and Technology 11(1):56-70.

Akinbuwa O, Adeniyi IF (1991). The Rotifera fauna of Opa reservoir, Ile-Ife, Nigeria. Journal of African Zoology 105(5):383-391.

Akinbuwa O, Adeniyi IF (1996). Seasonal variation, distribution and interrelationships of Rotifers in Opa Reservoir, Nigeria. African Journal of Ecology 34:351-363.

Atobatele OE (2013). Pelagic phytoplankton succession pattern in a tropical freshwater reservoir (Aiba Reservoir, Iwo, Osun state, Nigeria). Bioremediation, Biodiversity and Bioavailability 7(1): 81-84.

Benedict OO, Gabriel UI (2012). Distribution and dynamics of a tropical waterfalls ecosystem. International Journal of Ecosystem 2(1):28-37.

Beyruth Z (2000). Periodic disturbances, trophic gradient and phytoplankton characteristics related to cyanobacterial growth in Guarapiranga reservoir. Sao Paulo State, Brazil. Hydrobiologia 424(1):51-60.

Bolawa OP (2016). A study of the spatial and temporal diversity and abundance of planktonic flora and fauna of Opa Reservoir, Ile Ife, Southwest, Nigeria. MSc Thesis. Department of Zoology, Obafemi Awolowo University, Ile-Ife, Osun state, Nigeria.

Bwalla RL, Ovie SI, Ajayi O, Haruna A (2010). Preliminary study on the limnology and plankton abundance in relation to fish production in some NIFFR Reservoirs. Report Opinion 2(6):7.

Codd GA (1995). Cyanobacterial toxins: Occurrence, properties and biological significance. Water Science and Technology 32:149-156.

Davies OA, Abowei JFN, Tawari CC (2009). Phytoplankton community of Elechi Creek, Niger Delta, Nigeria: A nutrient polluted tropical creek. American Journal of Applied Science 6(6):1143-1152.

Edward JB, Ugwumba AAA (2010). Development trends and evaluation of Egbe reservoir water nutrient status in Ekiti State, Nigeria. Journal of Life Sciences 4(1):26.

Emmanuel BE, Onyema IC (2007). The plankton and fishes of a tropical creek in south western Nigeria. Turkish Journal of Fisheries and Aquatic Science 7:105-113.

Fawole OO, Arawomo GAO (2000). Fecundity of *Sarotherodon galilaeus* (Pisces: Cichlidae) in the Opa reservoir, Ile-Ife, Nigeria. Revista de Biología Tropical 48(1):201-204.

Hecky RE, Kling HJ (1981). The phytoplankton and protozooplankton of the euphotic zone of Lake Tangayinka: Species composition, biomass, chlorophyll content and spatio-temporal distribution. Limnology and Oceanography 26:548-564.

Jaji MO, Bamgbose O, Odukoya OO, Arowolo TA (2007). Water quality assessment of Ogun River, Southwest Nigeria. Environmental Monitoring and Assessment 133(1-3):473-482

Magurran AE (2004). Measuring biological diversity. 2nd edition Oxford, U.K: Blackwell Science Ltd.

Margalef R (1951). Diversidad de especies en las comunidales naturales. [Diversity of species natural areas]. Public Institute of Applied Biology 9:5-27.

Menhinick EF (1964). A comparison of some species-individuals diversity indices applied to samples of field insects. Ecology 45:859-861.

Moshood KM (2009). Phytoplankton assemblage of a small, shallow, tropical African reservoir. International Journal of Tropical Biology 57(4):1009-1025.

Nkwoji JA, Onyema IC, Igbo JK (2010). Wet season spatial occurrence of phytoplankton and zooplankton in Lagos Lagoon, Nigeria. Scientific World Journal 5(5):7-14.

Nwankwo DI, Akinsoji A (1992). Epiphyte community of water hyacinth, *Eichhornia crassipes* (MART) Solms in coastal waters of South Western Nigeria. Archiv fur Hydrobiologie 124(4):501-511.

Offem BO, Ayotunde EO, Ikpi GU, Ada FB, Ochang SN (2011). Plankton-based assessment of the trophic state of three tropical Lakes. Journal of Environmental Protection 2:304-315.

Ogamba EN, Chinda AC, Ekweozor IKE, Onwuteaka JN (2004). Water quality and phytoplankton distribution in Elechi Creek Complex of the Niger-Delta. Journal of Nigerian Environmental Society 1(2):121-130.

Olasehinde KF, Abeke AA (2012). Limnological features of Ikere Gorge Reservoir, Iseyin south-western Nigeria: Plankton composition and abundance. Journal of Biology and Environmental Sciences 2(6):20-31.

Park S, Brett MT, Oshell ET, Goldman CR (2003). Seston food quality and *Daphnia* production efficiencies in an oligo-mesotrophic Subalpine lake. Aquatic Ecology 37:123-136.

Pielou EC (1966). The measurement of diversity in different types of biological collections. Journal of Theoretic Biology 13:131-144.

Reynolds CS (1999). Non-determinism to probability, or N:P in the community ecology of phytoplankton: Nutrient ratios. Archiv für Hydrobiologie 146:23-35.

Salem TA (2011). Variation in phytoplankton along different zones of Aswan High Dam Reservoir. Egypt Journal of Aquatic biology and Fishery 15:87-104.

Shannon CE, Weaver W (1949). The mathematical theory of communication. Urban University, Illinois Press, Illinois.

Simciv T (2005). The role of plankton, zoobenthos, and sediment in organic matter degradation in oligotrophic and eutrophic mountain lakes. Hydrobiologia 532:69-79.

SPSS (Statistical Package for Social Sciences) (2012). Statistical Package for the Social Sciences Base 21 for Windows. Chicago, IL: SPSS

Taub DM (1984). Primate Paternalism. Burkhuys Publishers. New York, USA.

Townsend CR, Harper JD, Begon M (2000). Essentials of ecology. 3rd edition, Blackwell Science, London, UK.

Ugwumba AAA, Anago IJ, Esenowo IK (2013). The physicochemistry and plankton diversity of Awba Reservoir University of Ibadan, Ibadan Nigeria. Research Journal of Environmental and Earth Sciences 5(11):638-644.

Ugwumba AO, Ugwumba AAA (1993). A study of the physico-chemical hydrology and plankton of awba Lake in Ibadan, Nigeria. Fish Academic Communication 1:20-39.

Walsh CJ, Sharpe AK, Breen PF, Sonneman JA (2001). Effects of urbanization on streams of the Melbourne region, Victoria, Australia. I. Benthic maroinvertebrates communities. Freshwater Biology 46:535-551.

WHO (2009). World Health Organization Annual Report. International Standards for drinking water, WHO Geneva, 1st Edition.

Yao H, Qian X, Gao H, Wang Y, Xia B (2014). Seasonal and spatial variations in heavy metals in two typical Chinese Rivers: Concentrations, environmental risks and possible sources. International Journal on Environmental Resource and Public Health 11:11860-11878.

Zabbey N, Sikoki FD, Erondu J (2008). Plankton assemblages and environmental gradients in the middle reach of the Imo River, Niger Delta, Nigeria. African Journal of Aquatic Science 33(2):241-248.