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RESEARCH

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Planktonic flora and fauna of Opa Reservoir wetlands, Obafemi Awolowo University, Ile-Ife, Nigeria

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Abstract

Background: Wetlands are transition zones between aquatic and terrestrial environments of Opa Reservoir Obafemi Awolowo University, Ile-Ife, Nigeria, threatened by increase in agricultural practices and urbanization within the catchment area. A critical appraisal of the current ecological integrity of the wetlands using planktonic composition and community structure which are formidable to sustaining wetlands is essential, hence this study.

Result: A total of 104 plankton species comprises of 68 species of phytoplankton and 36 species of zooplankton were recorded from the wetlands. In each sampled location and during the sampling period, Bacillariophyta had the highest occurrence among the phytoplankton, while Rotifera recorded the highest occurrence among the zooplankton. Generally, *Synedra ulna* and copepod (cyclopoid) Nauplius, respectively, were the most common phytoplankton and zooplankton recorded during the period of study. Analyses also showed that the phytoplankton had a higher species occurrence and abundance (65.3% and 98.18%, respectively) than the zooplankton (34.6% and 1.82%, respectively). Diversity indices (Shannon–Wiener, Margalef, and Simpson) analyses of both plankton groups revealed that the wetlands were generally polluted.

Conclusion: The study concluded that the ability of the wetlands to support and maintain a balanced adaptive community of plankton with species composition and diversity is being eroded due to anthropogenic activities in the wetland areas. This could have some ecological and socioeconomic implications considering the fact that they are intrinsically a part of the adjoining reservoir which provides many ecosystem services.

Keywords: Diversity, Community structure, Phytoplankton, Zooplankton, Opa reservoir, Wetlands

Background

Wetlands a marshy, fen, peatland or water area, whether natural or artificial, permanent or temporary, with water that is stationary or flowing, which may be fresh, brackish, or salty, with a depth at low tide not exceed six meters, have provided a wide range of ecosystem services for humankind in all continents (Junk, 2002; Millennium Ecosystem Assessment, 2005). They are characterized by a large number of ecological niches and harbour a significant percentage of world's biological diversity. Wetlands are among the most productive ecosystems in the world comparable to rainforests and coral reefs (Thomas and Deviprasad, 2007). They host a considerable biological diversity including planktonic assemblage, which makes them one of the most productive life-supporting systems in the world (WWF, 1999). Vegetative matters that release by wetlands into rivers also help to boost fish trophic plasticity in the rivers and lakes (Orie, 2017). Values associated with biological productivity of wetlands also include water quality and flood control, erosion

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control, community structure and wild life support, recreation, and esthetics (Leck et al., 2012).

However, various anthropogenic activities or human-induced stress such as burgeoning human population, rapid urbanization, deforestation, siltation, overharvesting, domestic and industrial wastes, and introduction of invasive alien species have contributed to the decline of the quality and quantity of wetlands (Fonge et al., 2012). Consequently, these direct and indirect drivers of wetland degradation are changing their ecosystem functions and undermine their capacity to sustain ecosystem services in their respective basins (Millennium Ecosystem Assessment, 2005; Ribaudo et al., 2001).

Plankton which are primary producers that contribute immensely to water body productivity and food web chain are one of the formidable community structure that sustains wetlands (WWF, 1999). They are also serve as bioindicators of water quality because they respond very quickly to changes in environmental stress and this could result in changes in their composition and community structure (Akindele & Adeniyi, 2013a; Dalu et al., 2014; Harley et al., 2006; Wu et al., 2012). Thus, the composition and community structure of plankton are useful in assessing the biological integrity and functioning of wetland ecosystem (Akindele & Adeniyi, 2013b; Brettum & Andersen, 2005).

Studies of wetland assessment in Nigeria have identified habitat changes caused by anthropogenic activities as the major contributing factor to alteration of wetland characteristics. However, Opa Reservoir wetland in Obafemi Awolowo University, Ile-Ife, which provides a wide range of ecosystem services such as habitat for a wide range of animals, flood control, water abstraction for irrigation, and provision of potable water receives little or no attention to its fair share of habitat degradation and decline in biodiversity due to deforestation, increase in cultivated lands, and construction of structures. In view of the importance of Opa Reservoir wetlands which are being threatened by various human-induced stressors, a critical appraisal of the current ecological integrity of the wetlands using planktonic composition and community structure is essential, hence this study.

Methods

The study area

The study was carried out on the wetlands of Opa Reservoir, Obafemi Awolowo University, Ile-Ife, Southwestern, Nigeria. The reservoir has a catchment area of about 116 km^2 and extends from longitude 004° 31′ E to 004° 32′ E and latitude 07° 30′ N to 07° 31′ (Komolafe & Arawomo, 2001). The reservoir, which was impounded in 1978, takes its source from Oke Opa hills (Akinbuwa & Adeniyi, 1996) and has a surface area of 0.95 km^2 with the maximum capacity of about 675 m^3 at impoundment (Komolafe & Arawomo, 2001). However, the reservoir was recently reported to have shrunk in size due to siltation and aquatic weed infestations (Adesakin et al., 2017). The catchment area is characterized by annual dry and wet seasons with the wet season extending from April to September while the dry season extends from October to March (Komolafe & Arawomo, 2001). The mean annual rainfall over the catchment area ranges from 1000 to 1237 mm while the average temperature had a peak of 28.8 °C in February and about 24.5 °C in August (Bayowa et al., 2011).

Selection of the sampling points

Random selection of the proposed sampling locations was done using ecological assessments survey design, commonly applied in a variety of research fields (Levin, 2006). Six sampling locations were established in the Opa Reservoir wetlands. The established sampling points were denoted as Sites A, B, C, D, E, and F (Fig. 1). The coordinates of the sampling points were established using a handheld Global Positioning System (GPS) for subsequent samplings. The characteristics of the sampled sites are shown in Table 1.

Sample collection

Plankton samples were collected by straining 30 L of water collected from each sampling site with a plankton net (45 µm mesh size) and concentrating it to 100 ml. The plankton samples were preserved *in-situ* with 5% formalin to ensure the integrity of the samples.

Laboratory analyses

Further laboratory analysis was carried out on 1.5 mL concentrate plankton sample in a Sedgewick Rafter counting chamber viewed under an Olympus compound light microscope at scanning power (× 40) and low power (× 100). Each observed plankton was enumerated, and their scaled photomicrograph was taken. Identification of the recorded plankton species was based on phytoplankton and zooplankton guides such as American Public Health Association (1998), Kutikova (2002), Victor (2002), and Opute and Kadiri (2013), in addition to other works of Akinbuwa (1999), Fernando (2002), Suthers and Rissik (2009), Bellinger and Sigee (2010), and Ekhator et al. (2014). The species diversity, abundance, and evenness were determined using appropriate indices. The abundance of each plankton taxon per unit volume of the water was estimated based on count records obtained. The abundance of each species was determined by the following equation:

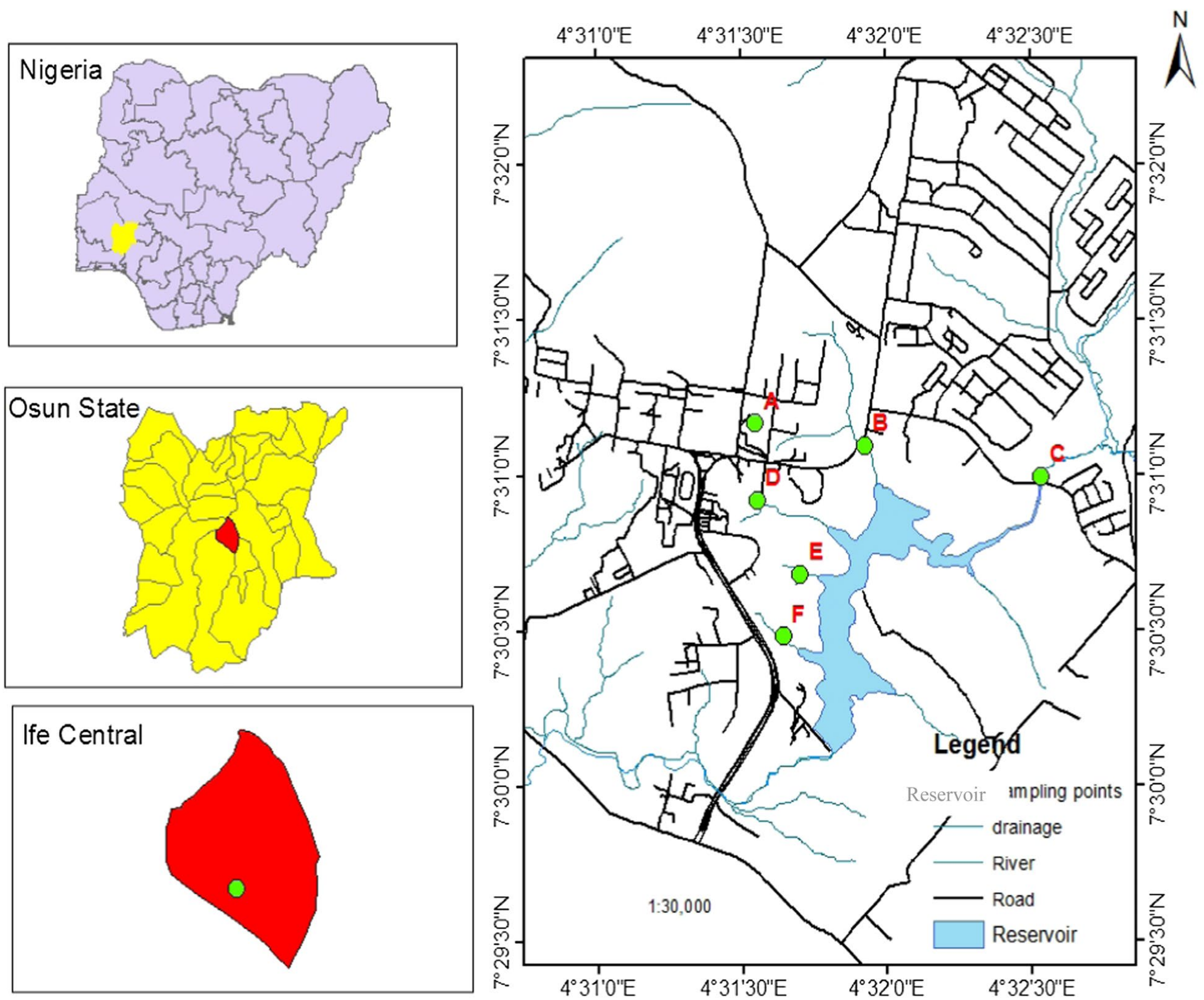

Fig. 1 Map of Opa Reservoir wetlands showing the sampling stations (inset: maps of Nigeria, Osun State, and Ife Central LGA), A—Road 7 Bridge site, B—OAU International School Site, C—Health-Sciences building Site, D—Gender Studies Site, and E—Road 1 Site

$$A = \frac{a \times b \times 1000}{c}$$

where A is the abundance of species per liter of original water source; a is the abundance of species in the counting chamber; b is the total concentrate volume of water used (1.5 mL); c is the original volume of water (30 L) (Bellinger & Sigee, 2010).

Statistical analyses

The data on flora and fauna collected from Opa Wetlands were analyzed using a combination of standard statistical procedures as follows:

Shannon–Wiener diversity index (*H*)

Shannon–Wiener index (*H*) (1984), a measure of species richness, was calculated as follows:

$$H^{'} = \frac{N\log N - \sum f_i \log f_i}{N}$$

where N is the total number of individuals sampled; f_i is the number of individual species sampled.

A standard of Shannon–Wiener index for interpreting the ecological condition of an ecosystem as reported by Reiss and Kröncke (2005) is shown in Table 2.

Table 1 The coordinates and characteristics and site description of the sampled location

	Grid coordinates		Site description and characteristics
Sites	Longitudes	Latitudes	
Site A	004° 32′ 32.1″ E	07° 30′ 59.6″ N	The water was brown in colour with dendritic drainage pattern and depth ranging from 30 to 60 cm (dry season) and 60 to 70 cm (wet season). The major activity around this site was fish farming and arable crop production
Site B	004° 31′ 55.5″ E	07° 31′ 05.6″ N	The drainage pattern was angular with water depth ranging from 20 to 30 cm (dry season) and 37 to 39 cm (wet season). The major activity going on around this site was farming with banana plantation being dominant
Site C	004° 31′ 33.2″ E	07° 30′ 55.1″ N	The drainage pattern was angular with water depth ranging from 2 to 8 cm (dry season) and 10 to 20 cm (wet season). The major crop of cultivation was cocoa
Site D	004° 31′ 42.1″ E	07° 30′ 40.9″ N	Wet, spongy, poorly drained peaty soil, dominated by bog and fern. The water at this site was exclusively from rainfall with water depth ranging from 1 to 4 cm (dry season) and 3 to 10 cm (wet season)
Site E	004° 31′ 38.5″ E	07° 30′ 28.9″ N	The drainage pattern was dendritic with water depth ranging from 20 to 30 cm (dry season) and 37 to 39 cm (wet season). The major activity around the wetland was palm oil processing
Site F	004° 31′ 32.8″ E	07° 30′ 10.0″ N	Open water having sedges as dominant vegetation. The drainage pattern is angular and the major source of water was the reservoir. The water depth ranged between 13 and 25 cm (dry season) and 20 and 60 cm (wet season). Animals observed in this site were frogs, snakes, cattle egrets, crabs and the major activity around the dam site was fish farming

Table 2 Shannon–Wiener index range for the health of an ecosystem

Result	Shannon–Wiener index (bits/individuals)
High	Status 4 <
Good	Status 4–3
Moderate	Status 3–2
Poor	Status 2–1
Bad	Status 1–0

Simpson's diversity index (SID)

Simpson's diversity index $(1-D)$ was calculated as follows:

$$D=\frac{\sum n(n-1)}{N(N-1)}$$

where D is the measure of diversity, computed as follows: N is the total number of all species counted; n is the count of species.

Margalef's diversity index (D)

Margalef's diversity index was calculated using the formula:

$$D=\frac{(S-1)}{\ln N}$$

where D is the Margalef's diversity index value; S is the number of species; N is the number of individuals.

Species evenness indices

Pieolu's Evenness index, which describes the relative distribution of the species, is expressed as:

$$J=\frac{H'}{\ln S}$$

where H' is the Shannon–Weiner diversity; $\ln S$ is the natural log of the total number of species recorded.

Results

The phytoplankton assemblage of Opa Reservoir wetlands is presented in Table 3. A total number of 66 species belonging to six divisions (Cyanophyta, Chlorophyta, Baccillariophyta, Euglenophyta, Ochrophyta, and Charophyta) were recorded during the study period. The order of dominance in relation to species richness was as follows: Bacillariophyta (34 species), Charophyta (12 species), Cyanobacteria (7), Chlorophyta (6 species), Ochrophyta (6 species), and Euglenophyta (one species). In terms of abundance, Bacillariophyceae (56.54%) recorded the highest, followed by Chlorophyceae (38.63%), Charophyceae (3.18%), Cyanophyceae (1.11%), Ochrophyceae (0.48%), and Euglenophyceae (0.07%). Among individual species, *Synedra ulna* was the most abundant, followed by *Oedogonium* sp. and *Synedra* sp. Other phytoplankton species with relatively high abundances were *Humidophilia contenta*, *Closterium* sp., and *Navicula capitatoradiata*.

Stations E and F were remarkably and relatively high in both taxa richness and abundance, while stations A and B, respectively, recorded lower values. One-way ANOVA indicated that there was no significant

Table 3 Phytoplankton species occurrence and abundance (individuals/m^3) in the Opa Reservoir, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (February 2018–November 2018)

S. no	Taxon	Locations						Total
		Site A	Site B	Site C	Site D	Site E	Site F	
	Cyanobacteria							
1	*Anabaena* sp. 1	100	0	0	0	0	0	100
2	*Anabaena* sp. 2	0	0	0	0	0	200	200
3	*Anabaena* sp. 3	0	0	0	0	50	0	50
4	*Anabaena circinalis*	100	0	0	0	50	1800	1950
5	*Oscillatoria tenuis*	50	0	200	0	0	0	250
6	*Oscillatoria aghardii*	550	0	0	0	0	0	550
7	*Oscillatoria limosa*	50	0	0	0	0	0	50
	Bacillariophyta							0
8	*Asterionella gracillima*	100	0	0	0	0	1450	1550
9	*Bacillaria* sp.	50	0	0	0	0	0	50
10	*Cymbella lanceolate*	0	50	0	0	0	0	50
11	*Diatoma hiemale*	0	0	0	150	0	150	300
12	*Diatoma* sp.	0	0	50	150	50	0	250
13	*Diatomella balfouriana*	0	0	0	150	300	0	450
14	*Eunophora* sp.	0	0	0	0	200	50	250
15	*Eunotia naegelii*	0	100	0	450	400	0	950
16	*Eunotia obliquestriata*	0	0	0	0	0	50	50
17	*Eunotia* sp.	0	50	0	0	150	0	200
18	*Flagilaria crotonensis*	0	0	50	0	0	0	50
19	*Flagilaria* sp.	0	0	50	0	0	0	50
20	*Hantzschia amphioxys*	0	0	0	0	50	0	50
21	*Humidophilia contenta*	2300	0	100	0	4550	50	7000
22	*Mastogloia elliptica*	0	150	100	300	100	50	700
23	*Mastogloia* sp.	0	0	0	450	100	0	550
24	*Navicula capitatoradiata*	0	350	450	750	1600	0	3150
25	*Navicula cincta*	0	0	0	0	50	0	50
26	*Navicula cryptoceph*	0	0	0	150	0	0	150
27	*Navicula lanceolate*	0	0	50	0	50	0	100
28	*Navicula rhynchocep*	0	0	0	150	0	0	150
29	*Navicula* sp.	0	50	0	0	0	150	200
30	*Navicula viridula*	100	200	50	0	450	50	850
31	*Nitzschia* sp.	50	400	0	0	0	100	550
32	*Pinnularia borealis*	0	0	0	150	100	0	250
33	*Pinnularia gibba*	0	50	0	0	0	0	50
34	*Pinnularia lata*	0	0	0	150	0	0	150
35	*Pinnularia nobilis*	50	0	0	0	250	0	300
36	*Pinnularia* sp.	0	50	0	0	200	50	300
37	*Pinnularia viridis*	0	0	0	0	100	100	200
38	*Pleurosigma* sp.	0	50	0	0	0	0	50
39	*Synedra famelica*	300	0	50	600	150	1150	2250
40	*Synedra* sp.	0	250	100	11,250	3600	2100	17,300
41	*Synedra ulna*	2350	3500	13,300	12,900	39,700	49,750	121,500
	Ochrophyta							0
42	*Encyonema auerswaldii*	0	0	50	150	500	50	750
43	*Encyonema* sp.	0	0	0	0	50	0	50
44	*Gyrosigma acuminatum*	0	200	0	150	0	50	400

Table 3 (continued)

S. no	Taxon	Locations						Total
		Site A	Site B	Site C	Site D	Site E	Site F	
45	*Gyrosigma* sp	0	0	50	0	0	0	50
46	*Geissleria* sp.	0	0	50	0	0	0	50
47	*Luticola* sp.	0	50	0	0	0	0	50
	Charophyta							0
48	*Closterium costatum*	0	0	0	0	100	0	100
49	*Closterium ehrenbergii*	0	0	50	0	750	50	850
50	*Closterium leiblenii*	0	0	50	0	100	0	150
51	*Closterium lunula*	0	0	0	0	0	50	50
52	*Closterium moniliferum*	0	0	0	0	50	0	50
53	*Closterium parvulum*	0	0	0	0	0	50	50
54	*Closterium rostatum*	0	0	0	0	100	0	100
55	*Closterium* sp.	6000	0	50	150	100	200	6500
56	*Spirogyra borgeana*	0	50	0	150	0	300	500
57	*Spirogyra californica*	0	0	0	0	200	50	250
58	*Spirogyra fluviatilis*	0	0	0	0	0	250	250
59	*Spirogyra* sp.	0	0	0	0	100	0	100
	Chlorophyta							0
60	*Ankistrodesmus falcatus*	0	0	0	0	0	50	50
61	*Asterionella Formosa*	0	50	0	0	0	1250	1300
62	*Hantzschia amphioxys*	0	0	50	0	0	0	50
63	*Oedogonium capillare*	0	50	0	0	0	0	50
64	*Oedogonium* sp.	0	1500	0	10,350	15,400	80,550	107,800
65	*Scenedesmus quadricauda*	0	0	50	0	0	0	50
	Euglenophyta							0
66	*Euglena gracilis*	0	0	0	0	100	100	200
	Taxa richness	14	20	20	19	33	29	66
	Abundance	12,150	7200	14,950	38,700	69,800	**140,250**	283,000
	Shannon–Wiener index	1.484	**1.820**	0.635	1.597	1.474	1.047	1.559
	Margalef index	1.382	2.139	1.977	1.704	**2.959**	2.447	5.337
	Simpson	0.680	0.711	0.207	**0.732**	0.620	0.544	0.666
	Evenness index	**0.315**	0.309	0.094	0.260	0.128	0.094	0.070

The bold values represent the highest level of the determined parameter in question

difference ($F = 1.344$, $df = 5$, $p = 0.223$) among the stations with respect to distribution of the species. Diversity indices were generally low in all the stations with station C recording the lowest values for both Shannon–Wiener and Simpson, while stations B and D recorded the highest values, respectively.

Zooplankton comprised a total of 36 species belonging to three animal phyla Protozoa, Rotifera, and Arthropoda (Table 4). In terms of species richness, Rotifera was the most species-rich (19 species) while Arthropoda and Protozoa recorded 13 and 4 species, respectively. The order of dominance among the groups was as follows: Rotifera (60%), Arthropoda (35.24%), and Protozoa (4.76%). Among the six sampled locations, site F had the highest number of zooplankton species followed by sites C, E, B, A, and site D. Station F again recorded the highest abundance followed by stations C, D, E, B, and A.

One-way analysis of variance indicated that there was a significant difference ($F = 6.18$, $df = 5$, $p = 0.00003$) in the spatial distribution of the organisms among the stations. Diversity indices based on Shannon–Wiener, Simpson and Margalef indicated that station F recorded the highest values, while station D recorded the lowest. However, the lowest evenness was recorded at stations F but increased slightly at site C, while other stations recording the highest possible value or one that is close to it.

Table 4 Zooplankton species occurrence and abundance (individuals/m^3) in the Opa Reservoir, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (February 2018–November 2018)

S. no	Taxon	Locations						Total
		Site A	Site B	Site C	Site D	Site E	Site F	
	Rotifera							
1	*Anuraeopsis fissa*	0	0	0	150	0	50	200
2	*Argonotholca foliacea*	0	50	400	0	0	0	450
3	*Argonotholca* sp.1	0	0	50	0	0	0	50
4	*Argonotholca* sp.2	0	0	50	0	0	0	50
5	*Ascomorpha* sp.	0	0	0	0	50	0	50
6	*Asplanchna* sp.	0	50	0	0	0	0	50
7	*Brachionus falcatus*	0	0	100	0	0	200	300
8	*Filinia opoliensis*	0	0	0	0	0	150	150
9	*Hexarthra* sp.	0	0	0	0	0	50	50
10	*Keratella* sp. 1	0	0	0	0	50	850	900
11	*Keratella* sp. 2	0	0	0	0	0	50	50
12	*Keratella* sp. 3	0	0	0	150	0	100	250
13	*Keratella tropica*	0	0	0	0	0	50	50
14	*Lecane (monostyla) lunaris*	0	0	50	0	100	0	150
15	*Lecane* sp.	0	0	0	0	0	50	50
16	*Lepadella patella*	0	0	0	150	0	0	150
17	*Polyarthra remata*	0	0	0	0	0	100	100
18	*Trichocerca porcellus*	50	0	0	0	0	0	50
19	*Trichocerca* sp.	0	0	0	0	0	100	100
	Arthropoda							
20	*Calanus* sp.	0	0	0	0	0	50	50
21	*Chaoborus* sp. (larvae)	0	0	50	0	0	0	50
22	Copepod (calanoid) nauplius	0	0	0	0	100	50	150
23	Copepod (cyclopoid) nauplius	50	50	0	0	0	700	750
24	*Diaptomus* sp. 1	0	0	0	0	0	50	50
25	*Diaptomus* sp. 2	0	0	0	0	0	50	50
26	*Mesocyclops edax*	0	0	0	0	50	0	50
27	*Mesocyclops* sp.	0	0	100	0	50	0	150
28	*Moinodaphnia* sp.	0	0	0	0	0	50	50
29	*Paracyclops chiltoni*	0	0	0	0	0	300	300
30	*Senecalla calanoides*	0	0	0	0	0	50	50
31	*Senecella* sp.	50	50	50	0	0	0	100
32	*Thermocyclops inopinus*	0	0	0	0	0	50	50
	Protozoa							
33	*Vermamoeba* sp. 1	0	0	0	0	0	50	50
34	*Vermamoeba* sp. 2	0	50	50	0	0	0	100
35	*Vermamoeba* sp. 3	0	50	0	0	0	0	50
36	*Vermamoeba vermiformis*	50	0	50	0	0	0	50
	Taxa richness	4	6	10	3	6	**21**	36
	Abundance	200	300	950	450	400	**3150**	5250
	Shannon–Wiener index	1.386	1.792	1.923	1.099	1.733	**2.415**	3.039
	Margalef index	0.566	0.877	1.313	0.327	0.835	**2.483**	3.969
	Simpson	0.750	0.833	0.781	0.667	0.813	**0.856**	0.925
	Evenness index	1	1	0.684	1	0.943	0.533	0.597

The bold values represent the highest level of the determined parameter in question

Overall, copepod (cyclopoid) nauplius larvae were the most abundant followed by *Argonotholca foliacea*. In each sampled location and during the sampling period, Bacillariophyta had the highest occurrence among the phytoplankton, while Rotifera recorded the highest occurrence at sites F, C, and D among the zooplankton. Rotifera and Arthropoda were both the highest at site F while Protozoa had the highest occurrence at sites B and C. During the period of study, the phytoplankton had a higher species occurrence (65.3%) than the zooplankton (34.6%). In the same vein, phytoplankton recorded a much higher abundance (98.18%) than the zooplankton (1.82%).

Discussion

Opa Reservoir was considerably rich in phytoplankton, and most of the recorded species have been previously reported in Nigeria and tropical freshwaters (Atobatele, 2013; Sharma et al., 2013; Singh et al., 2013; Peresin et al., 2014; and Akindele & Olutona, 2017). Groups Bacillariophyceae, Charophyceae, Chlorophyceae, and Cyanophyceae which are the dominant phytoplankton in terms of species richness have similarly been reported as the dominant groups in different countries and continents of the world (Rodrigues et al., 2009; Tavernini et al., 2011; Wu et al., 2012; Atobatele, 2013; Peresin et al., 2014, and Akindele & Olutona, 2017). Some indicator species of eutrophication (*Anabaena circinalis*, *Euglena gracilis,* and *Brachionus falcatus*) were recorded in this study; hence, their occurrence could be an indication that the wetlands were organically polluted (Tanimu et al., 2011, and Singh et al., 2013).

Like many of the previous studies in Nigeria, members of the Phylum Rotifera dominated the zooplankton in the current study (Akindele & Adeniyi, 2013b; and Atobatele, 2013). The success of rotifers as plankton has been attributed to the following factors: parthenogenetic reproduction, presence of transparent lorica, and ability to adjust to environmental changes caused by climatic conditions (Rodríguez and Matsumura-Tundisi, 2000; Kutikova, 2002; Roche & Rocha, 2005). It is worth being mentioned that the ratio of phytoplankton to zooplankton in terms of taxonomic composition (~ 2:1) and abundance (~ 6:1) in the wetlands suggests that phytoplankton is autotrophic and is at the base of the food pyramid in an aquatic ecosystem. They are usually greater in numbers than heterotrophic animals up the food chain. A similar observation was observed by Akindele and Olutona (2017) in Osun River (Nigeria), and the relative distributions of phytoplankton and zooplankton in a freshwater system have long been described by Hynes (1970), i.e., phytoplankton > zooplankton in terms of abundance.

All indices used to determine the community structure of both phytoplankton and zooplankton indicated low biodiversity status at all stations. Shannon–Wiener diversity values increase with the number of species in a community, and the higher the values, the healthier the community (Maryam et al., 2010). Gencer and Nilgun (2010) explained that values above 3.0 show a stable and balanced habitat while values under 1.0 indicate pollution and degradation of habitat structure. Based on the Shannon–Wiener index for phytoplankton community structure, all but one site (site C) could be considered as being a poor wetland ($1 < H' < 2$) while all the sites had poor community structure ($1 < H' < 2$) based on Shannon–Wiener index for zooplankton. Margalef indices of the phytoplankton in the six stations and those of zooplankton in two stations indicated a moderate pollution, i.e., $1 < D < 3$, while the indices for zooplankton at two stations (A, B, D, and E) indicated a severe pollution, i.e., $D < 1$ according to Lenat et al. (1980). Simpson's diversity index $(1 - D)$ which is widely used for comparing diversity between various habitats (Simpson, 1949) also alluded to the pollution status of the studied wetlands. Values ranged from 0 to 1; values close to 1 indicate severe pollution and low diversity, while values close to 0 indicate high diversity and/or pristine condition (Kratzer & Batzer, 2007). Based on this, all the sites could be considered polluted considering Simpson's indices for zooplankton and also for phytoplankton.

Conclusions

The Opa Reservoir Wetlands may be described as having an unbalanced habitat structure based on their plankton compositions. Indicator species and community structure of the plankton also revealed that the wetlands are impacted. This could have some ecological and socioeconomic implications considering the fact that they are intrinsically a part of the adjoining reservoir which provides many ecosystem services. Hence, consistent monitoring of the Opa Reservoir Wetlands is suggested to sustain and/or enhance their biodiversity and ecological condition of the wetlands and the reservoir.

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Authors' contributions
AT performed the practical section, collected the samples, and analyzed the data. HA and VF conceived the idea, helped in designing the study, supervised the preparation of the experiment, and helped in writing the manuscript. EO assisted in analysis of data and proof reading of the manuscript. All authors read and approved the final manuscript.

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