Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 24(5): 161 – 181 (2020)
www.ejabf.journals.ekb.eg

Spatial and Temporal Distribution of Plankton in a Tropical Reservoir, southwestern Nigeria

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ARTICLE INFO

Article History:
Received: May 5, 2020
Accepted: June 28, 2020
Online: July, 2020

Keywords:
Awba reservoir,
Blue-green algae,
Zooplankton,
Temporal variation,
Nigeria

ABSTRACT

Spatial and temporal variations in the distribution of plankton of a tropical reservoir were investigated for six months. Chlorophyceae was richest in the phytoplankton community in term of the number of species and individuals. They were more abundant in the late rainy /early dry season with *Pediastrum simplex* and *Coelastrum chodati* being the dominant species. Constant species occurred only in Chlorophyceae, which included *Spirogyra*, *Closterium* sp., *Coelastrum chodati*, *Pediastrum simplex*, *Ulothrix zonata* and *Scenedesmus quadricauda*. Cyanophyceae developed mainly in the late dry season months (reached peak in March) with *Microcystis flos-aqua* being dominant. In the zooplankton community, Crustacea had the highest number of individuals and were more abundant in the late dry season. *Camptocercus* sp., *Bosmina* sp. and *Daphnia magna* were the main species. Rotifers had the highest species number with peaks observed in the late rainy/early dry season. The common species encountered included *Chromagaster* sp., *Epiphanes* sp., *Gastropus* sp., *Nolthoca* sp., *Trichocerca* sp., and *Brachionus* sp. The common protozoan species were *Ichthyophthrius*, *Chilodonella*, *Prorodon* and *Colpoda*. The diversity indices calculated varied spatially; phytoplanktonic organisms were more diverse in Station 1 with the least evenness, highest evenness occurred in Station 2. The increase in total number of taxa encountered in this study compared to previous studies and implication of *Microcystis flos-aqua* being the dominant blue- green algae were discussed.

INTRODUCTION

The quality and quantity of water in reservoirs are very important especially in reservoirs with multifunctional roles. The health of the aquatic ecosystem of lakes are very sensitive issues and lakes in different regions of the world particularly in developing countries are facing a variety of problems associated with anthropogenic activities and unsustainable use of their resources as demonstrated by **El-Serehy *et al.* (2018**). Deterioration of water quality in reservoirs results from excessive nutrients inputs, eutrophication, acidification, heavy metal contaminants, organic pollutants and obnoxious fishing practices as asserted by **Gupta (2014)**. The monitoring of water quality of reservoirs is important as it helps with the management of the eutrophication and productivity of the water body. Eutrophication has a considerable impact on the two main components of the plankton communities (phytoplankton and zooplankton) causing many changes in their abundance and species composition and affecting the relationships between them. Changes in the plankton community structure in relation to physicochemical parameters may be a first sign of deterioration in the water quality (**Ochocka and Pasztaleniec, 2016**). They also suggested that both plankton elements (phytoplankton and zooplankton) should be taken into account in the ecological status assessment of lakes. Studies on the structure and functioning of planktonic communities in reservoir ecosystems provide opportunities to investigate patterns of responses to cyclical variations and episodic disturbances as suggested by **Nogueira (2001)** Biomass, taxonomical composition and diversity of phytoplankton are part of the criteria on which the trophy of a water body might be assessed as suggested by **OECD (1982).** The habitat-template approach proposes that algal attributes are matched to opportunities provided by the environment and that there is an encouraging fit of phytoplankton species to the range of habitats described by the trophic spectrum as written by **Akin-Oriola (2003)**. The changes in the phytoplankton community can be particularly useful as an assessment tool, due to their rapid response to environmental stress. The qualitative and quantitative studies of phytoplankton may provide good indices of water quality and capacity of water to sustain heterotrophic communities as suggested by **Agarwal *et al*. (2018)**

Zooplankton is one of the most important biotic elements that impact all functional aspects of aqueous ecosystems including food chains and trophic networks, energy flow, and the circulation of matter as asserted by **Paturej *et al*. (2017)**. Species composition and abundance of zooplankton communities can be influenced by a number of physical, chemical and biological factors as demonstrated by **Sampaio *et al.* (2002)**. The composition and abundance of zooplankton have been reported to be significantly impacted by the trophic state of reservoirs **(Pinto-coelho *et al*., 2005; Paturej, 2006; Kudari and Kanadami, 2008 and Gonzalez *et al*., 2011)**

Awba Reservoir, a man-made lake on the Awba Stream, University of Ibadan serves as a source of water supply to the water treatment plant for domestic uses in the University. The Awba stream however receives untreated effluents from the staff and student residences, Zoological Garden, Faculty of Science laboratories and its environment. Recently, the lake has been earmarked for ecotourism alongside water supply; water-based tourism activities include boating, sailing, motor boating, swimming, skiing, and fishing activities, these are often less detrimental to water quantity and quality compared to many other human uses of water like agriculture, industry etc. as suggested by **Long (2012)**. Previous studies on the ecology of the reservoir were recorded, including **Mombeshora *et al.* (1981)** on the trace metal level; **Ugwumba and Adebisi (1992)**, on food and feeding relationship in fish; **Akin-Oriola (2003)**, **Chukwuka and Uka (2007)**; **Anago *et al*. (2013)** on plankton composition and **Aderogba & Ayoade (in press)** on trophic status . The aim of this paper was to update knowledge on the current status of limnology of the reservoir through assessment of the plankton composition and abundance of the Awba reservoir, Ibadan.

MATERIALS AND METHODS

The Awba reservoir on latitude 7° 26 ′ - 7° 27′ N and longitude 3° 53 ′ - 3° 54 ′ E(Figure 1) is located in the University of Ibadan, south western region of Nigeria about 160 km from the Atlantic Ocean coast at an altitude of 185 m above sea level as written in **Akin-Oriola (2003)**. The reservoir was constructed in 1964 with a maximum depth of 5.5 m and surface area of about 6 ha. The annual rain occurs from April to October with a characteristic August break during which the rain abates. The water of the lake is still with occasional multi-directional water movements due to wind effects. Wind action in the reservoir is minimal in the dry season and the high temperatures at this period result in thermal stratification of the water. It is surrounded by a modified tropical rain forest vegetation with aquatic macrophytes such as *Pistia stratiotes*, *Canna indica*, *Nymphae lotus*, *Banhima* sp. on its edges as written in **Akin-Oriola (2003)**.

Field sampling was conducted from October 2017 to March 2018 (October- January, late rainy/early dry season; February – March, late dry season) at monthly interval from three selected sampling stations on the reservoir. Plankton were collected with a 55 µm bolting silk plankton net and preserved in 4% formalin. One mL of a sub-sample was randomly taken from the bottle by using pipette and placed into a Sedgewick Rafter counting cell and slowly covered with a cover slip. Sorting, identification, and counting were carried out under a compound microscope. Plankton identification was analysed at the lowest possible taxonomic level according to the standard taxonomic references **(Whitford and Schumacher 1973; Needham and Needham 1974; Jeje and Fernardo 1987 and Nwankwo 2004).**

Diversity was evaluated using the Shannon Wiener index **(Pielou 1975)**. Margalef's Index (d) known as species richness index was calculated as given by **Margalef (1958)**. Evenness (E) expresses the degree of uniformity in the distribution of individual among the taxa was also calculated as given by **Magurran (1988)**. The Sørensen index by **Sørensen (1948)** was used to compare the plankton species compositions of the different stations. Species were classified according to their frequency of occurrence as: constant (50% or more), common (between 10% and 50%) or rare (below 10%), as described in **Gomes (1989)**.

RESULTS

Phytoplankton Composition and Abundance

The phytoplankton composition of Awba reservoir during the study period was represented by 7 families, 83 genera and 126 species. Chlorophyceae was the dominant form in the community in term of number of species (70) and abundance (9.63×10^5 organisms/mL). This was followed by Cyanophyceae with 28 species and 4.79×10^5 organisms/mL. Most abundant species were *Pediastrum simplex* (Meyen) Lemmermann (green algae, 1.78×10^5 organisms/mL), *Coelastrum chodati* Ducellier (green algae, 1.71×10^5 organisms/mL), *Closterium gracile* Breb. (desmid, 1.49×10^5 organisms/mL) and *Microcystis flos-aqua* (Wittr.) Kirchner (blue green algae, 1.04×10^5 organisms /mL) Table 1. The total number of species varied from 76 in Station 1 to 89 in Station 2. However, the highest phytoplankton abundance was recorded in Station 1(7.24×10^5

organisms /mL) and the least in Station 3(4.24 x 10^5 organisms /mL). Generally there was a gradual decrease in abundance of major phytoplankton group from Station 1 to Station 3 except Chrysophyceae and Euglenophyceae (Figure 2).

Legend: S1 – Station 1, S2- Station 2, S3- Station 3

Figure 1: A map of University of Ibadan Showing Awba Reservoir and Sampling Stations

Table 1: Relative abundance of phytoplankton organisms of Awba Reservoir, Ibadan, Nigeria

CHLOROPHYCEAE	Total Abundance (Organism/ mL)	%
Actinastrum hantschii	4000	0.23
Ankistrodesmus sp.	5000	0.29
Asterococcus limenticus	8000	0.46
Binuclearia tatrana	1000	0.06
Botryoccoccus sp.	9000	0.52
Chlamydomonas feneserata	5000	0.29
Chlorella vulgaris	32000	1.83
Cladophora sp.	1000	0.06
Clostidium retigerum	30000	1.72
Coelastrum angustae	39000	2.23
Coelastrum chodati	171000	9.78
Coelastrum morus	28000	1.60
Coelastrum probescideum	1000	0.06
Coleochaete orbicularis	2000	0.114

Coleoclaete scutata	1000	0.06
Crucigenia crucifera	1000	0.06
Crucigenia quadrata	1000	0.06
Dispora crucgenibides	1000	0.06
Dysmorphococcus variabilis	1000	0.06
Eudorina elegans	2000	0.114
Geminella minor	2000	0.114
Gloeocystis botryoides	10000	0.57
Gonphosphaeria wichurae	18000	1.03
Groenbladia neglecta	1000	0.06
Hematocccoccus lacustris	5000	0.29
Hormidium rivulare	4000	0.23
Hormidium subtle	2000	0.114
Hydrodictyon sp.	1000	0.06
Menoidium gracile	1000	0.06
Microspora amoena	22000	1.26
Mougeotia sp.	3000	0.17
Myrecia globosa	1000	0.06
Oedogonium sp.	7000	0.40
Ophiocytium sp.	1000	0.06
Oocystis vulgaris	1000	0.06
Palmellococcus minutus	1000	0.06
Palmellococcus protothecoides	4000	0.23
Palmodictyon varium	6000	0.34
Pandorina morum	2000	0.114
Pediastrum boryanum	4000	0.23
Pediastrum duplex	47000	2.69
Pediastrum simplex	178000	10.18
Protoccocus sp.	1000	0.06
Pseudendodonium sp.	1000	0.06
Quadrigula closteriodes	1000	0.06
Scenedesmus abundans	7000	0.40
Scenedesmus acuminatus	2000	0.114
Scenedesmus armatus	27000	1.55
Scenedesmus bijuga	1000	0.06
Scenedesmus oahuensis	5000	0.29
Scenedesmus obliges	2000	0.114
Scenedesmus opoiensis	3000	0.17
Scenedesmus polifica	7000	0.40
Scenedesmus quardricauda	30000	1.72
Schroederia setigera	1000	0.06
Schitochlamys gelatinosa	1000	0.06
Sorastrum sp.	1000	0.06

Spirogyra sp.	34000	1.95
Spirotaenia sp.	3000	0.17
Stigneoclonium carolinianum	1000	0.06
Tetraspora sp.	11000	0.63
Trebouria cladoniae	8000	0.46
Ulothrix amphigranulata	13000	0.47
Ulothrix terierrima	1000	0.06
Ulothrix variabilis	29000	1.66
Ulothrix zonata	58000	3.32
Volvox dissipathrix	3000	0.17
Volvox perglobator	6000	0.34
Volvox proliticus	16000	0.92
Zygnema sp.	26000	1.49
Subtotal	**963000**	**55.09**
DESMIDACEAE		
Cosmarium cucumis	32000	1.83
Closterium gracile	149000	8.52
Gonatozygon aculeatum	8000	0.46
Micraterias thomasiana	2000	0.114
SUBTOTAL	**191000**	**10.93**
CYANOPHYCEAE		
Anabaena azolla	13000	0.74
Aphanocapsa delicatissima	36000	2.06
Aphanocapsa elachista	3000	0.17
Aphanocapsa pulchra	59000	3.38
Capsosira sp.	1000	0.06
Chrococcus pactidus	1000	0.06
Chrysococcus turgidus	1000	0.06
Coelospharium kuetzingianum	19000	1.09
Coelospharium naegeliarium	8000	0.46
Cyanoptyche glococystis	9000	0.52
Glosocapsa alpicola	13000	0.74
Glosocapsa granosa	4000	0.23
Glosocapsa lacustris	1000	0.06
Glosocapsa magna	1000	0.06
Lyngbya aerugineocarulea	2000	0.114
Merismopedia convolute	6000	0.34
Microcystis aeruginosa	90000	5.15
Microcystis flos-aqua	104000	5.95
Microcystis pulverea	17000	0.97
Nostoc parmeloidies	4000	0.23
Nostoc piscinade	9000	0.52
Oscillatoria prolifica	11000	0.63

Oscillatoria sancta	51000	2.92
Phormidium angustisi	2000	0.114
Phormidum corium	7000	0.40
Phormidum teune	3000	0.17
Rivularia sp.	2000	0.114
Tolypothrix fragalis	2000	0.114
SUBTOTAL	**479000**	**27.4**
EUGLENOPHYCEAE		
Euglena caudate	26000	1.49
Euglena acus	8000	0.46
Euglena deses	12000	0.69
Euglena fusa	6000	0.34
Euglena pronaina	1000	0.06
Euglena spiroides	3000	0.17
Eugelena varibilis	1000	0.06
Trachelomonas ensifera	3000	0.17
Trachelomonas horrida	1000	0.06
Trachelomonas volgensis	1000	0.06
SUBTOTAL	**62000**	**3.55**
BACILLARIOPHYCEAE		
Amphipleura pellucida	2000	0.114
Cymbella sp.	2000	0.114
Cyclotella sp.	5000	0.29
Gyrosigma sp.	1000	0.06
Mastigloia sp.	6000	0.34
Navicula sp.	7000	0.40
Nitzschia sp.	7000	0.40
Rhizosolenia longiseta	1000	0.06
Synedra sp.	1000	0.06
SUBTOTAL	**32000**	**1.83**
CHRYSOPHYCEAE		
Amphichrysis compressa	3000	0.17
Chrysamoeba radian	3000	0.17
Chrysosphaera pacudosa	1000	0.06
Uroglenopsis sp.	1000	0.06
SUBTOTAL	**8000**	**0.42**
XANTHOPHYCEAE		
Tribonema sp.	13000	0.74
SUBTOTAL	**13000**	**0.74**

Chlorophyceae dominated the phytoplankton community in late rainy /early dry season. Cyanophyceae were encountered mainly in the late dry season months and reached peak in March (3.59×10^5 organisms/mL). Euglenophyceae also attained peak in abundance (7 species and 4.6×10^4 organisms/ mL) in late dry season months Figure 3. Constant species according to criteria used occurred only in Chlorophyceae which included *Spirogyra*, *Closterium* sp, *Coelastrum chodati* Ducellier, *Pediastrum simplex*, *Ulothrix zonata* (Weber & Mohr) Kutz. and *Scenedesmus quadricauda* (Turp.) Brebisson. The common blue-green algae included *Coelosphaerium*, *Polycystis*, *Nostoc*, *Anabaena*, *Aphanocapsa*, *Microcystis flos-aqua*, *Phormidium corium* (Ag.) Gom., *Oscillatoria prolifica* (Grev.) Gom., *and Glosocapsa granosa* (Berk.) Kutz. A large number of species were considered rare and represented by 35 green algae, 10 blue-green algae, 7 diatoms, 5 euglenoids, 3 golden algae and 1 yellow green algae.

Zooplankton Composition and Abundance

Three zooplankton taxa were identified and Crustacea made up the largest percentage (41.22% of total zooplankton number) with Protozoa being the least (19.85% of total zooplankton number), as in Table 2. However, rotifers (12) had the highest species number followed by protozoan (10). The species that were relatively more abundant were *Camptocercus* sp. (Cladocera, 12.98%), *Bosmina* sp. (Cladocera, 12.21%), *Daphnia magna* Straus, 1820 (Cladocera, 12.21%), *Chromagaster* sp. (Rotifer, 11.45%), *Notholca* sp. (Rotifer, 5.34%), *Ichthyophthrius* sp. and *Chilodonella* sp. (Protozoa, 4.58% each) and *Epiphanes* sp. (Rotifer, 4.58%). The highest zooplankton abundance occurred in Station 2(40%) and least in Station 1(29.6%) as in Figure 4. Rotifers dominated the zooplankton community in the late rainy/early dry season, while crustacean were more abundant in late dry season (Figure 5). The constant zooplankton according to criteria used was only microcrustaceans, *Bosmina* sp., and *Camptocercus* sp., while *Daphnia*, *Coleps* and *Cypridopsis* were common. Among the rotifers, the common species included *Chromagaster*, *Epiphanes*, *Gastropus*, *Nolthoca*, *Trichocerca*, and *Brachionus*. The common protozoan species were *Ichthyophthrius*, *Chilodonella*, *Prorodon* and *Colpoda*. The species considered to be rare were two crustaceans, three rotifers and six protozoans.

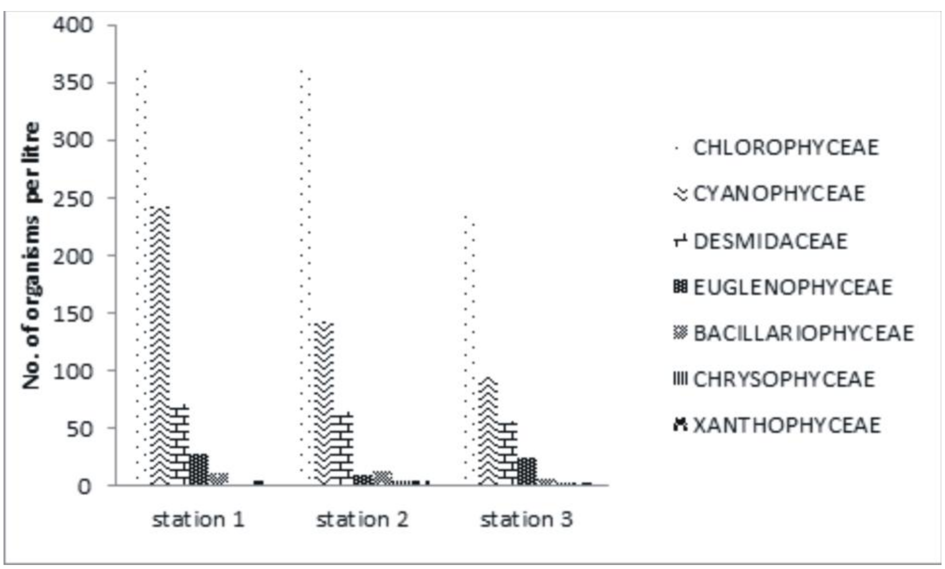

Figure 2: Spatial variation in abundance of major phytoplankton groups of Awba Reservoir

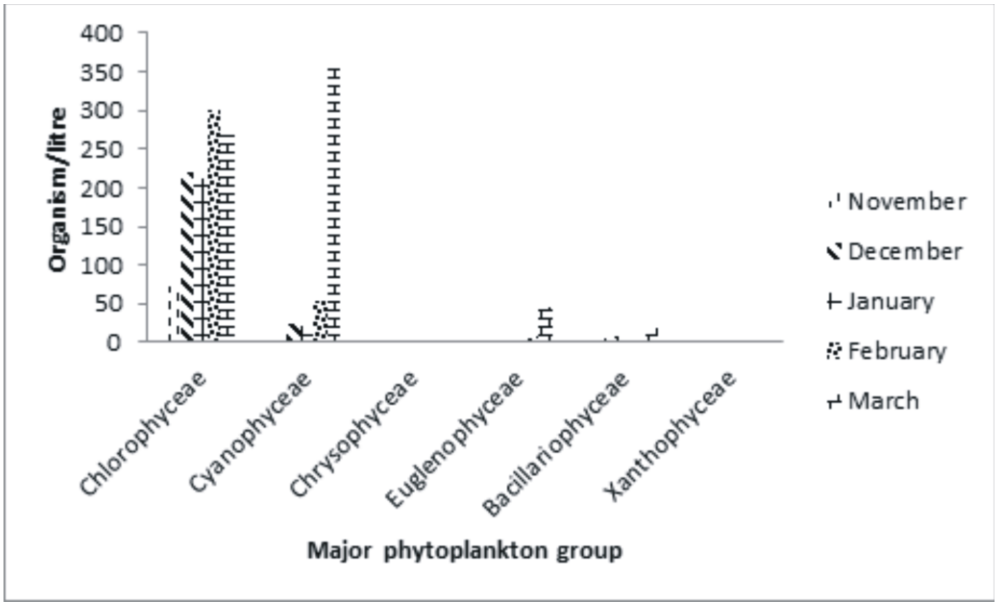

Figure 3: Temporal variation in abundance of major phytoplankton groups of Awba Reservoir

Table 2: Relative abundance of zooplankton organisms of Awba Reservoir, Ibadan, Nigeria

CRUSTACEA	**Total Abundance Organism/ mL**	**%**
Bosmina sp.	16000	12.21
Camptocercus sp.	17000	12.98
Daphnia magna	16000	12.21
Simocephalus sp.	1000	0.76
Cyclops sp.	1000	0.76
Cypridopsis sp.	3000	2.29
SUB TOTAL	**54000**	**41.22**
PROTOZOA		
Blepharisma sp.	1000	076
Chilodonella sp.	6000	4.58
Coleps sp.	3000	2.29
Colpoda sp.	3000	2.29
Frontonia sp.	1000	0.76

Ichthyophthrius sp.	6000	4.58
Lacrymaria sp.	1000	0.76
Prorodon sp.	4000	3.05
Spirostomum sp.	1000	0.76
Urostyla sp.	1000	0.76
SUB TOTAL	**26000**	**19.85**
ROTIFERA		
Brachionus urceolaris	2000	1.53
Chromagaster sp.	15000	11.45
Epiphanes sp.	6000	4.58
Euchlanis sp.	3000	2.29
Gastropus sp.	5000	3.82
Keratella sp.	3000	2.29
Notholca sp.	7000	5.34
Ploesoma sp.	1000	0.76
Rotaria sp.	3000	2.29
Syndiaeta sp.	1000	0.76
Testudinella sp.	2000	1.53
Trichocerca sp.	3000	2.29
SUB TOTAL	**51000**	**38.93**

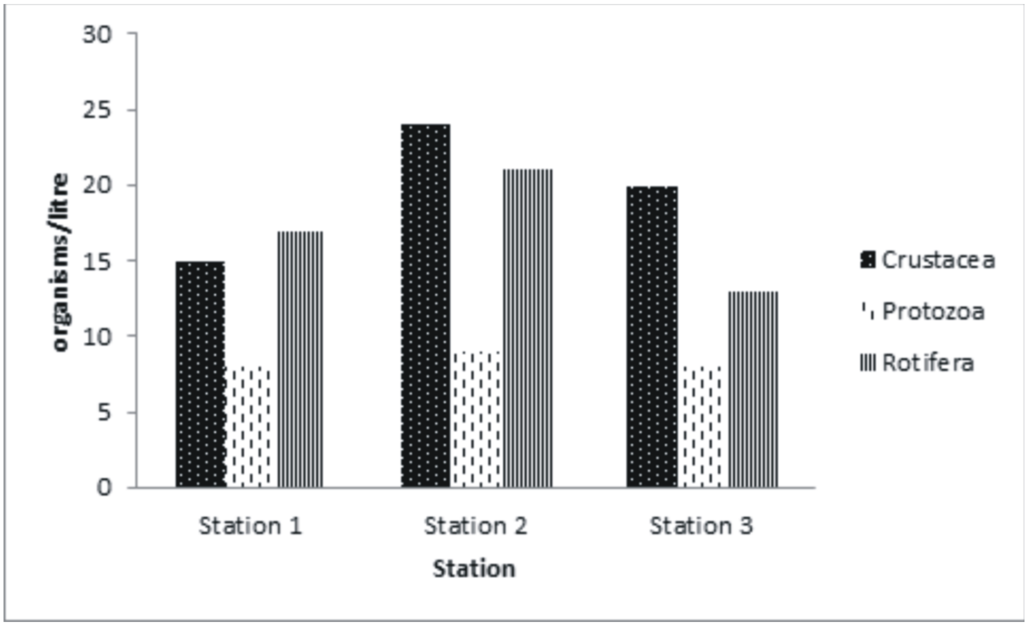

Figure 4: Spatial variation in abundance of major zooplankton groups of Awba Reservoir

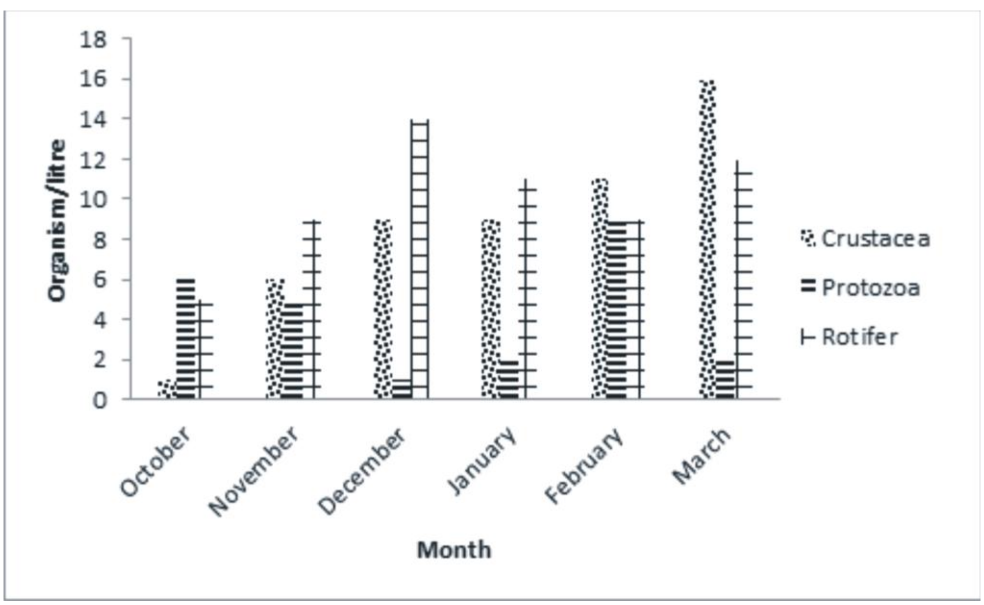

Figure 5: Monthly variation in abundance of major zooplankton groups of Awba Reservoir

Diversity Indices

Monthly variation occurred in diversity indices of phytoplankton of Awba reservoir; Shannon- Wiener index H' ranged from 2.25 to 3.47 being lowest in the early dry season months. Lower values of Margalef's index D and evenness E were also obtained during early dry season months (Figure 6). The diversity indices calculated varied spatially; phytoplanktonic organisms were more diverse in Station 1 with the least evenness, highest evenness occurred in Station 2 (Figure 7). Zooplankton diversity indices obtained were lowest in Station 3; highest D occurred in Station 2 (Figure 8). Sorenson's coefficient of community similarity showed that phytoplankton (0.64 – 0.68) and zooplankton (0.61-0.70) in the stations were alike/identical.

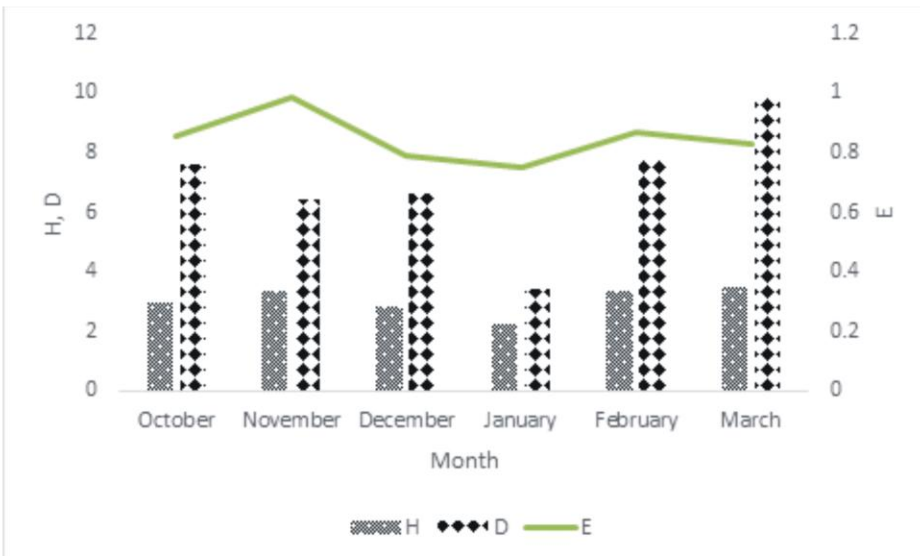

Figure 6: Monthly variation in phytoplankton diversity indices of Awba reservoir

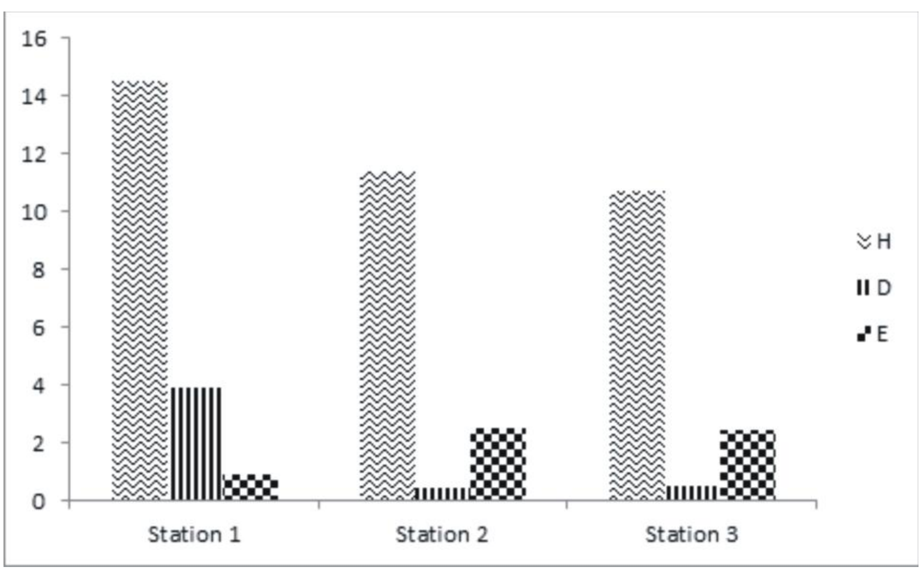

Figure 7: Spatial variation in phytoplankton diversity indices of Awba reservoir

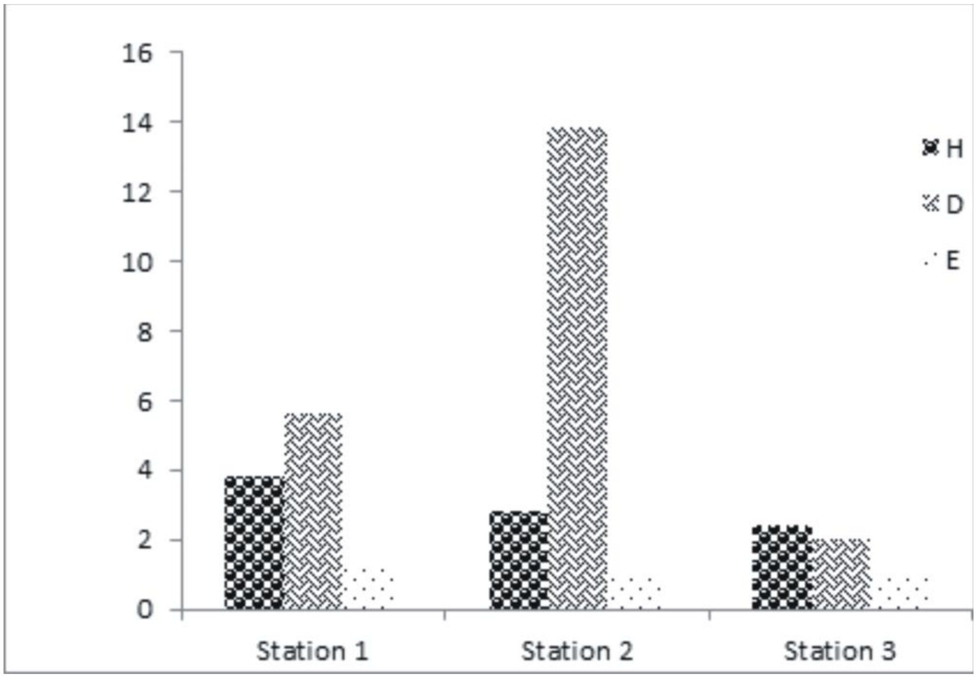

Figure 8: Spatial variation in zooplankton diversity indices of Awba reservoir

Table 3: WHO (1999) guidelines for algal bloom characterization

Acute Health Effects	Cyanobacteria (cells/mL)	Microcystin-LR* (µg/L)
Low	< 20,000	< 10
Moderate	20,000 to 100,000	10 to 20
High	100,000 to 10,000,000	20 to 2,000
Very High	> 10,000,000	> 2,000

[a]Microcystin-LR is commonly used to represent microcystin congeners due to widely available data and known toxicity

Source: Wyoming Department of Environmental Quality Water Quality Division 2018

DISCUSSION

Phytoplankton Composition and Abundance

Non-motile green algae formed a major component of the phytoplankton community of the Awba reservoir with the larger green algae *Pediastrum simplex* and *Coelastrum chodati* being more abundant. According to **Shubert (2003)**, the non-motile greens are ubiquitous and widely distributed in aquatic habitats throughout the North American continent. Chlorophyceae were also best represented in Lake Awasa, Lake Skadar and Thomas dam **(Kebede and Belay 1994; Rakocevic-Nedovic and Hollert 2005; Ibrahim and Nafi'u 2017)**. This is contrary to the report of **Akin-Oriola (2003)** and **Olagbemide (2011)** that blue-green algae dominated the phytoplankton community of

Awba reservoir, although the quantitative differences between the present study and the former may be due to expressing the abundance in organism/mL thus cells in the colonial organism were not counted in this study . Generally there is an increase in total number of taxa encountered in this study compared to previous studies: 14 taxa, **Akin-Oriola (2003)**; 43 taxa, **Olagbemide (2011)** and 49 taxa, **Anago *et al*. (2013)**. This could be due to difference in methods of collection and sampling stations and also this suggests gradual eutrophication of the Awba reservoir according to **Lepistö and Rosenström (1998**), phytoplankton diversity in eutrophic waters is the highest compared to other types of trophic waters. Also several dominant species encountered in this study among the Chlorophyceae, Cyanophyceae (*Aphanocapsa*, *Anabaena*, *Microcystis*) and Euglenophyceae (*Euglena acus* Ehrenberg) are characteristic of eutrophic and mesotrophic lakes. The increase in the number of species according to the theory of intermediate disturbances **Reynolds *et al*. (1993)** was probably due to the slight changes in the ecosystem for example high nutrient concentration as reported by Aderogba and Ayoade (forthcoming).

Microcystis species, the predominant blue-green algae in the Awba reservoir are capable of rapid uptake of phosphate and nitrogen and hence producing large surface blooms and out competing other phytoplankton as asserted by **Xie *et al.* (2003)**. Under conditions of nutrient enrichment or eutrophication, the blue-greens are known to proliferate and form noxious blooms in freshwater environments **(Reynolds 1984, Stoyneva 2003)**. The bloom proportion reached by the *Microcystis flos aqua* and *M. aeruginosa* (Kūtz) in the reservoir during the late dry season is supported by the stratified nature of the reservoir **(Ganf 1974; Akin-Oriola 2003)**. The formation of blooms also depends on retention time, type and age of water body as well as calm weather conditions with low turbulence of water (Bucka 1989). The development of phytoplankton blooms in eutrophic lakes is attributed to their ability to accommodate reduced nitrogen to phosphorus ratios, low edibility due to their large colony sizes coupled with large herbivore regulation of other taxa **(Barica 1994, Paerl and Tucker 1995)**. **Aderogba and Ayoade (forthcoming)** reported low TN/TP ratio and advanced eutrophication of the reservoir.

M. aeruginosa blooms cause several environmental problems, including bad odor, bottom-layer hypoxia and the problem of greatest concern is the production of hepatotoxic cyanotoxins called microcystins by **Harke *et al*. (2016)**. Cases of human poisoning as demonstrated by **Jochimsen *et al*. (1998)**, livestock intoxication **(Beasley *et al*. 1989)**, and mass mortality of wildlife **(Miller *et al*. 2010)** caused by microcystin contamination have been reported. Moreover, recent studies suggest increasing frequency of toxic (microcystin-producing) *M. aeruginosa* blooms in response to climate change as **(Paerl and Otten 2013)**. The cyanobacteria densities (479,000 organism / mL) recorded in this study indicate high acute health effects/risk according to **WHO (1999)** guidelines for algal bloom characterization (Table 3). The Wyoming Department of Health (2018) identifies threshold values for microcystin ($\geq$ 10 µg/L) and cyanobacteria density ($\geq$ 20,000 cells/mL), above which a recreational use advisory will be issued. Subsequently, Wyoming Department of Health will inform the water management agency, and notify local health authorities of the situation and provide information on common cyanobacteria and cyanotoxin related symptoms. Also, Wyoming Department of Environmental Quality (WDEQ) will notify public water supplies with intakes located on the surface water or downstream of surface water. The excessive abundance or blooming of eutrophic species has detrimental effects on the domestic, industrial and recreational uses of water and is in many cases a direct motivation for restorative measures **(Bryant 1994)**. Thus, Awba reservoir may not be suitable for recreation/ecotourism in its present state.

The green algae being less abundant in the late dry season during the period of study could be due to thermal stratification of the water of Awba Lake in dry season **(Akin-Oriola 2003)**, and once stratification is stabilized, the non-motile greens begin to sink and decline in the water column, and sedimentation increases. Non-motile greens appear to be restricted to a relatively short growth period defined by a narrow range of environmental conditions within which to successfully compete with a mixed assemblage of phytoplankton **(Happey-Wood 1988)**. Thus seasonal succession was observed in the Awba reservoir and cyanophytes dominated in the late dry season.

The variation in the phytoplankton species richness and diversity with sampling points agreed with the findings of **Sekandende *et al*. (2004)** in the satellite lakes of lake Victoria basin (Tanzania side) and **Eyo *et al*. (2013)** on the great Kwa River.

Zooplankton Composition and Abundance

The total number of species encountered in the zooplankton community of Awba reservoir in the present study differed in number and composition from the 13 species as given by **Chukwuka and Uka 2007** and five species by **Anago *et al.* (2013)**. Species composition and abundance of zooplankton communities can be influenced by a number of physical, chemical and biological factors as demonstrated by **Sampajo *et al*. ((2002)** especially temperature, quality and availability of food, competition and predation. The dominance of cladocerans in the zooplankton community of Awba reservoir during period of study could result from selective feeding by the invertebrate predators including fish on small-sized zooplankton like rotifers. Predation by invertebrates has a greater impact upon microzooplankton than on macrozooplankton, frequently reducing the abundance of the former as asserted **Zaret (1980)**. Predation by fish may affect zooplankton structure, in accordance with the fish feeding mode: selective feeders, by differential capture of organisms, tend to eliminate large species, which are replaced by less vulnerable small forms **(Brooks and Dodson 1965)**; filter-feeding planktophage fishes do not actively select their preys and therefore more evasive species avoid predation whereas small forms are captured, thus diminishing zooplankton densities **(Drenner *et al*. 1982)**. Cladocerans were also dominant in Nigeen lake and Keenjhar lake **(Jan *et a*l. 2015; Rao and Azmi 2019)**, and attributed to temperature enhancing rapid hatching of eggs, high nutrient conditions and food availability as suggested by **Pandit (1989)**. However, **Chukwuka and Uka (2007)** reported rotifers as the dominant group and **Anago *et al*. (2013)** encountered the copepod *Thermocyclops* as the most abundant.

Cladocerans have been claimed to be good indicators of trophic state in lentic ecosystems. In Europe, the size range of species has been used as an indicator of water quality. According to **Gannon and Stemberger (1978)**, species of *Bosmina* are good indicators of lake trophic state. Species such as *Bosmina longirostris* (O. E. Mūller), having a great ability to utilize colonial cyanophyceae as food, exhibit a greater tolerance to their blooms as suggested by **Fulton and Paerl (1987)**, so that they become abundant in such conditions and may be considered bioindicators of eutrophication **(Matsumura-Tundisi 1999).** Thus, the predominance of *Bosminia* and *Camptocercus* sp. in the reservoir suggests they feed on the colonial cyanophyceae and chlorophyceae that were dominant in the phytoplankton community and this further confirmed the eutrophic state of the reservoir. *Bosmina longirostris* has been observed in eutrophic environments such as Barra Bonita Reservoir **(Matsumura-Tundisi 1999)** and Billings Reservoir complex **(Sendacz & Kubo 1999)** both in Brazil, however, **Güntzel (2000)** observed that among the six reservoirs on Tietê River, *Bosmina hagmanni* Stingelin, 1904 was most abundant in the less eutrophic ones.

Temporal variation and succession in zooplankton species was observed in the reservoir. Cladocerans reached peak in late dry season months coincided with bloom of *Microcystis aeruginosa* and *M. flos aqua* that could serve as food source. According to **Campbell and Haase (1981)**, quality and quantity of food can alter species composition as well as the abundance of the species, since particular organisms are highly selective about the size and the type of phytoplankton they eat.

The frequently encountered protozoan species (*Chilodonella* spp., *Ichthyophthirius)* in the Awba reservoir could cause fish diseases. Protozoans exhibit rapid and exponential reproductive strategies (e.g. *Chilodonella* spp. and versatile, resilient life stages e.g. *Ichthyophthirius multifiliis* Fouquet which have allowed parasitic protozoans to colonise aquatic environments globally). Among fish protozoans, *Ichthyophthirius* and *Trichodina* are two of the most predominant genera globally **(Lom and Dyková 1992)**. *Ichthyophthirius multifiliis* is one of the most contagious ciliophoran parasites of fishes (**Matthews 2005; Dickerson 2006**). This parasite accounts for significant economic losses in aquaculture, the ornamental fish trade and epidemics in wild fish populations, resulting in mass mortalities **(Matthews 2005)**. The ciliated protozoan *Ichthyophthrius multifilis* infects several species of freshwater fish worldwide **(Dickerson and Findly 2014)**. It causes high mortality associated with ichthyophthiriasis ("white spot disease") in farmed fish, while low-level infections occur in wild fish.

The genus *Chilodonella* includes free-living ciliated protozoa as well as pathogenic species for freshwater species, with *Chilodonella hexasticha* **(Kiernik, 1909)** and *Chilodonella piscicola* (**Zacharias, 1894**) being the most important ones. These parasites cause outbreaks with high mortalities among farmed freshwater fishes with great economic losses as demonstrated by **Li *et al*. (2018)**. Heavy infection resulted in emaciation and mass mortalities. Infection in the gills caused severe degeneration, necrosis and consequent degradation of the branchial epithelium and occlusion of the capillaries. Infection also induced massive proliferation of chloride and mucus cells and also caused hyperplasia of the lining filamental epithelium**. Paperna and Van As (1983)** reported pathological and histopathological changes induced by infection of *Chilodonella hexasticha* (Kiernik) in wild and cultured cichlid fishes from Israel and South Africa.

In conclusion, the phytoplankton and zooplankton community of the Awba reservoir have increased species composition and abundance during the study period compared to previous studies. The abundance/bloom of *Microcystis flos aqua* further confirmed the advanced eutrophication of the reservoir.

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