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ASSESSMENT OF THE TROPHIC STATE OF AWBA RESERVOIR, IBADAN, SOUTHWEST NIGERIA

Adedolapo Abeke AYOADE[1*], Aishiat ADEROGBA[2]

[1]Hydrobiology and Fisheries Unit, Department of Zoology, University of Ibadan, Ibadan, Oyo State, Nigeria

[2]Ecology and Environmental Biology Unit, Department of Zoology, University of Ibadan, Ibadan, Oyo State, Nigeria

Abstract: This study was carried out to determine the trophic status of a tropical man-made lake that supplies water to the University of Ibadan community. Water samples were collected for six months and analyzed for physico-chemical parameters including total nitrogen, total phosphorus and chlorophyll-a. Phytoplankton samples were collected and analyzed using standard methods. The trophic level was calculated with the Carlson formula. The obtained mean total phosphorous was above the typical lake total phosphorus concentration. The total nitrogen: total phosphorus ratio of the lake was interpreted that nitrogen could be the limiting factor for primary production. The high correlation between chlorophyll-a and Secchi depth suggest that chlorophyll-a was the major light attenuating substance in Awba reservoir. Trophic state index values from total phosphorus, chlorophyll a and Secchi disc transparency of Awba reservoir exceeded the criteria at which lakes are interpreted as eutrophic. The abundant green algae and blue green algae give further evidence that the reservoir may be eutrophic.

Keywords: chlorophyll-a, TN: TP, secchi disc transparency, Awba reservoir.

INTRODUCTION

Degradation of the quality of water resources may result from waste discharges, pesticides, heavy metals, nutrients, microorganisms, and sediments. Hence the monitoring of water quality especially in the inland water bodies, aquifers, lakes, reservoirs, and lagoon, is important as it helps with the management of the eutrophication and productivity of the water body. Different water quality standards have been developed to aid in checking the extent of water pollution, and consequently to maintain these quality standards (Gupta, 2014; Gholizadeh *et al*., 2016). One of these is by Carlson (1977) that defines an index, termed trophic state index (TSI), which could tell about the trophic status and nature of the lakes. Based on this trophic index, there is further classification of eutrophication of a lake into oligotrophic, mesotrophic, and eutrophic. Since smaller lakes and reservoirs are more susceptible to human impact, these systems require close monitoring and evaluation (Oduwole, 1990).

Awba reservoir is a small man-made lake with a surface area of 6 hectares and mean depth of 5.5m. The reservoir provides water supply to the University of Ibadan community and has been recently earmarked for ecotourism. Various researches have been conducted on the ecology of Awba reservoir including food and feeding relationships, impacts of effluents, and benthic macro-invertebrates (Oduwole, 1990; Ugwumba and Adebisi, 1992; Adeogun and Fafioye, 2011). The aim of this study is to provide insight of the current status of the Awba reservoir by determining the trophic status according to chlorophyll-a levels, total phosphorus, transparency and phytoplankton community.

MATERIALS AND METHODS

Description of Study Area

The Awba reservoir (latitude 7° 26ʹ -7° 27ʹ N and longitude 3° 53ʹ-3° 54ʹ E) 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(Akin-oriola, 2003). The reservoir was constructed in 1964 and expanded to its present size in 1971 by damming the Awba stream at a point where it flowed through a natural valley. The dam is about 8.5 m high, 110 m long with a crest of about 12.2 m. The reservoir has a maximum length of about 700 m and a maximum depth of 5.5 m with a surface area of about 6 ha. Throughout the year, the water remains relatively constant, while excess water is made to spill away(Anago *et al*., 2013). The annual rain occurs from April to October with a characteristic August break during which the rain abates.

The vegetation of Awba stream and the reservoir has been described to be evergreen with grass interspersed by fair trees. Some of the hydrophytes include *Camellias gambia*, *Pistia stratiotes*, *Marsilea quadrifolia*, *Cyprus* sp. The shallow water surfaces along the northern and southern banks are covered with *Salvinia* sp., *Eichhornia crassipes* (water hyacinth). Submerged plants in the lake include *Ceratophyllum* species and *Utricularia* sp.(Popoola and Otalekor, 2011). Ugwumba and Adebisi (1992) reported that the fish fauna of the reservoir includes *Coptodon zillii*, *Heterotis niloticus, Barbus callipterus, Hemichromis fasciatus, Oreochromis niloticus, Sarotherodon galilaeus, Clarias gariepinus, Channa obscura* and *Alestes longipinnis*.

The reservoir serves the purpose of water supply, fish production and research amongst others. The reservoir receives effluents from the University

Correspondence: Hydrobiology and Fisheries Unit, Department of Zoology, University of Ibadan, Ibadan, Oyo State, Nigeria, Tel. +234-8033855807, email- kenpeadobece@gmail.com

community in the form of domestic waste water from different halls of residents, sewage and experimental waste water from science laboratories of several departments and also non-point sources such as erosion and leaching of chemicals from surrounding farmlands (Adeogun and Fafioye, 2011). Three sampling stations were chosen – Station 1(Latitude 7˚ 26′ 30.92″ N, Longitude 3˚ 53′ 13.19″ E) near entrance of the reservoir. Station 2 (Latitude 7˚ 26′ 32.93″ N, Longitude 3˚ 53′ 20.88″ E) almost middle of the reservoir. Station 3 (Latitude 7˚ 26′ 35.76″ N, Longitude 3˚53′27.98″ E) positioned near the dam wall.

Sampling and Analyses

Water samples were collected monthly from October 2017 – March 2019 in acid-washed 1 L polyethylene containers. Temperature, pH, Dissolved Oxygen, and Conductivity were determined *in situ* using SPER 850081 multi-parameter probe (Arizona, USA). The Secchi disc depth was determined *in situ* using a 20cm diameter disc (Wetzel and Likens, 2000). Total nitrogen and total phosphorus were determined spectrophotometrically according to APHA, 1998. The chlorophyll-a concentration of the prepared samples was determined spectrophotometrically using the acetone method (APHA, 1998). Phytoplankton samples were collected from surface water using bolting silk plankton net of 55 µm mesh size and preserved with 4% formalin.

The method used for examining algal biomass of trophic state index by Carlson (1977) was used to measure the Carlson trophic state index of the reservoir. Measurements of three variables namely Secchi disc transparency, Total phosphorus, and Chlorophyll-a , were used to calculate the trophic state index (TSI) value within the numerical tropical continuum. The trophic state index based on Secchi Depth, TSI (SD), and Trophic state index based on Chlorophyll-a, TSI (CHL-a) and that based on phosphorus TSI (TP) were calculated after Carlson (Akpan and Offem, 1993) using the following equations:

$$\text{TSI (SD)} = 60 - 14.41 \ln (\text{SD})$$

$$\text{TSI (TP)} = 14.42 \ln (\text{TP}) + 4.15$$

$$\text{TSI (CHL-a)} = 9.81 \ln (\text{CHL}) + 30.6$$

$$\text{CTSI} = \text{TSI (TP)} + \text{TSI (SDT)} + \text{TSI (Chl a)}/3$$

The total nitrogen concentration ranged between 23-1020 µg/L (398.83±384.57 µg/L). Monthly variation ranged from mean of 28.33±49.08 µg/L in October to 943.33±285.02 µg/L in January. Station 3 had the highest mean value of 495.67±455.19 µg/L and least was recorded in station 1 (237.33 ± 261.08 µg/L).

Where ln = natural log, TP is total phosphorus (µg/L); Chl a is chlorophyll a (µg/L); SDT is Secchi Disc Transparency (m); CTSI is Carlson Trophic State Index. Values less than 40 are associated with oligotrophy; a range between 40 and 50 is usually associated with the mesotrophy; index values greater than 50 are eutrophy Wetzel, 2001.

RESULTS

The surface water temperature of the Awba reservoir during the study period ranged between 26.9-30.1˚C (28.16±0.88˚C). The water temperature varied significantly with time, but not with station. Highest mean temperature was recorded in March (29.40±0.63˚C) while the lowest (27.17±0.31˚C) was in October.

There was significant difference in pH of the reservoir temporally ($P<0.05$), with least pH value in October (6.67±0.38) and highest in March (7.87±1.27). Station 3 had the highest mean pH of 7.17±0.5 and least value of 7.01±0.57 was recorded in station 1.

The dissolved oxygen concentration ranged between 10.2-15.6 mg/L (13.11±1.44 mg/L). Dissolved oxygen concentrations varied significantly with time and highest mean value was recorded in October (15.30±0.36 mg/L) and minimum in March (11.2±0.95 mg/L).

The Secchi disk depth (SDD) of Awba reservoir ranged from 0.56 -1.46 m (mean 1.01±0.29 m). It varied significantly with time, but not with stations. There was gradual increase in transparency from October, 2017 (0.64±0.13 m) to March, 2018 (1.31±0.03 m). Station 3 had the highest SDD of 1.10±0.33 m while station 2 had the lowest (0.99±0.31 m) Figure 1.

The conductivity of the reservoir did not vary significantly temporally and spatially. The conductivity in the reservoir ranged from 214-278 µS/cm (234.24±56.02 µS/cm) during the study period.

The total phosphorus concentration of surface water samples ranged between 88-3190 µg/L (679.78±788.64 µg/L). It varied significantly with time and was highest in March (2206.69±926.52 µg/L) and least in February (117.67±54.89µg/L). Station 3 had the highest mean value of 843.7±1167.46 µg/L and least was observed in station 2 (572.5±417.21 µg/L)(Figure 2).

Total Nitrogen to Total Phosphorus (TN/TP) ratio for the reservoir varied between the stations and highest value was obtained in station 3(0.09 – 6.19) Table 1.

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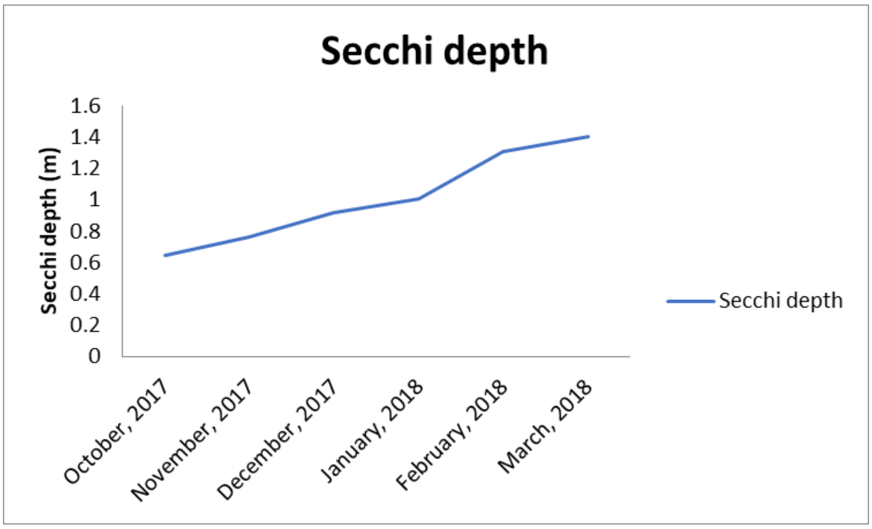

Fig. 1 Monthly Variation in Secchi Depth Transparency of Awba Reservoir.

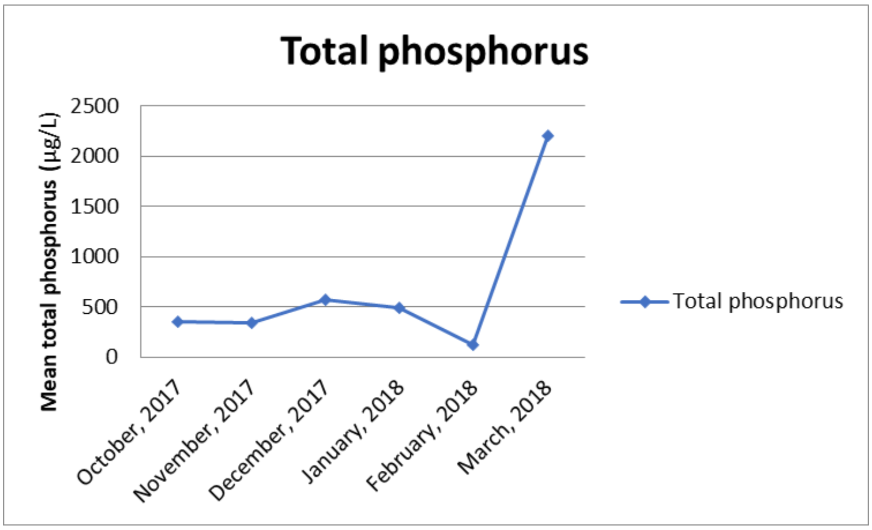

Fig. 2 Monthly Variation in Total Phosphorus Concentration of Awba Reservoir.

Table 1

Temporal variation in nitrogen: phosphorus ratio in three sampling points of Awba Reservoir

	Station 1	Station 2	Station 3
October	0.234	ND	ND
November	0.318	0.43	0.09
December	0.92	0.83	0.8
January	2.06	1.38	2.56
February	1.09	5.64	6.19
March	ND	0.17	0.2
Mean	**0.9244 ± 0.735086**	**1.69 ± 2.254784**	**1.968 ± 2.559**

ND: Not determined

Chlorophyll-a

Chlorophyll-*a* concentration of Awba reservoir during the study period ranged between 220-1310µg/L (649.5±369.57 µg/L). Chlorophyll-a varied significantly with time, being highest in March with 1290.33±261.06 µg/L and least in November (240.0±20.00 µg/L) Figure 3. Station 3 had higher chlorophyll-a concentration (730.17±469.13µg/L) than other stations (Figure 3). The relationship between the levels of some physico-parameters and the chlorophyll-a concentration in the reservoir, as determined by correlation coefficients is shown in Table 2. There was a strong correlation between total phosphorus and algal chlorophyll-a (r = 0.768). Secchi depth also had a strong positive correlation with chlorophyll-a (r = 0.8982).

Trophic State Indices

In the Awba reservoir, the total phosphorus and chlorophyll-a indices were close together and higher than Secchi depth index. During the period of study, the average TSI (CHL-a) and TSI (TP) was 94.79 and 98.19, respectively and highest value was recorded in March. However, the highest and least TSI (SD) was

66.43 and 55.15 and recorded in October and March, respectively (Table 3).

Phytoplankton Community

The phytoplankton group was represented by 83 genera and 126 species. Qualitatively Chlorophyceae (75 species) were best represented followed by Cyanophyceae (29 species). Euglenophyceae (10 species) and Bacillariophyceae (9 species) were moderately represented Figure 4. Chrysophyceae (4 species) and Xanthophyceae (1 species) were the least dominant. Quantitatively the order of importance of the taxonomic group was Chlorophyceae > Cyanophyceae > Euglenophyceae > Bacillariophyceae > Chrysophyceae > Xanthophyceae. *Pediastrum simplex* (10.2%), *Coelastrum chodati* (9.78%), *Closterium gracile* (8.52%), *Microcystis flos-aqua* (5.95%), *Microcystis aeruginosa* (5.15%) *Aphanocapsa pulchra* (3.38%), and *Ulothrix zonata* (3.31%) were the most frequently encountered species.

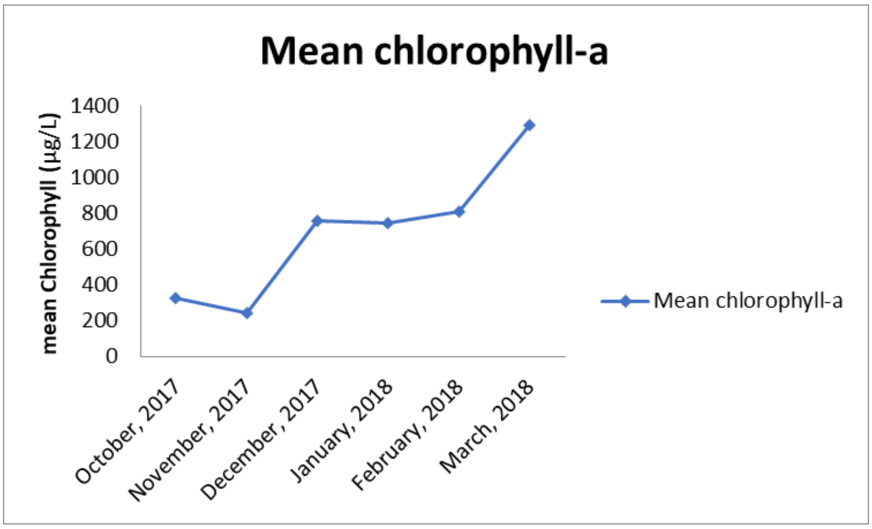

Fig. 3 Monthly Variation in Mean Chlorophyll-a of Awba Reservoir.

Table 2

Correlation coefficients for some physico-chemical parameters with Chlorophyll-a

	DO	SD	TP	TN	CHL-a
DO	1	-0.8050	-0.6637	0.2058	-0.6652
SD	-0.8050	1	0.5634	0.4015	0.8982
TP	-0.6637	0.5634	1	0.4081	0.7648
TN	0.2058	0.4015	0.4081	1	-0.1017
CHL-a	-0.6652	0.8982	0.7648	-0.1017	1

DO - Dissolved Oxygen, SD- Secchi depth, TP- Total Phosphorus, TN- Total Nitrogen, CHL-a - Chlorophyll-a

Table 3

Trophic state indices for Awba reservoir derived from Secchi depth, total phosphorus, and chlorophyll-a

Parameters/months	TSI (SD)	TSI (TP)	TSI(CHL-a)	Carlson TSI
October	66.43	88.65	87.40	80.83
November	63.96	88.22	84.36	78.85
December	61.20	95.65	95.63	84.16
January	60.00	93.57	95.50	85.02
Feburary	56.11	72.90	96.26	75.09
March	55.15	115.17	100.87	90.40
Average TSI	59.86	98.19	94.79	84.28

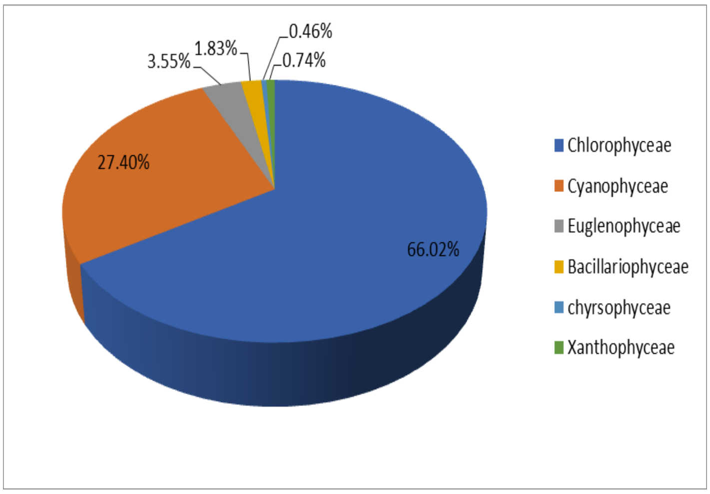

Fig. 4 Percentage Composition of Major Phytoplankton Groups of Awba Reservoir During Study Period**.**

DISCUSSION

The transparency of the water being lowest in October (period of heavy rainfall and flooding) could be due to influx of suspended particles from the catchment area. Most of the particles must have settled during the dry season months (November – March) due to lentic nature of the reservoir; this coupled with increase in sunlight intensity in dry season led to higher light penetration. According to general trophic classification of lakes and reservoirs by Wetzel (2001), the Awba Lake is eutrophic-hypertrophic based on mean Secchi disc depth of 1.01m (benchmark= 2.41 m, eutrophic).

Phosphorus acts as valuable nutrient for plant growth and fundamental element in the metabolic reactions of plants and animals. It is also considered as an important factor affecting the trophic status of lakes (Pandit, 2002). The obtained mean total phosphorous (679.78±788.64 µg/L) was above the typical lake total phosphorus concentration of 10 – 40µg/L (Snoeyink and Jenkins, 1980) as well as standard of 25µg/L for drinking water (NESREA 2007). This could be due to anthropogenic activities such as farming, influx from laboratories and washing/bathing taking place in residential areas around the reservoir. The mean total phosphorus also exceeded the benchmark (80 µg/L) suggested by Wetzel, 2001 for eutrophic water. The higher mean total phosphorus in March could be due to concentration effect as a result of reduced water volume.

Lower total nitrogen content during rainy season month can be corresponded to the dilution effect of the fall and high-water level (Rakocevic-Nedovic and Hollert, 2005). Nutrient availability to phytoplankton can be evaluated by comparing the ratio of total nitrogen to total phosphorus. According to Wetzel (2001), a nitrogen: phosphorus ratio less than 16:1 generally indicate that a lake is nitrogen limited and a ratio greater than 16: 1 indicate a lake is phosphorus limited. The N:P ratios in all the sampling sites being lower than 7 can be interpreted that nitrogen could be the limiting nutrient for primary production. Nitrogen limitation in lakes water could arise from application of fertilizer with more P than N (e.g. 10:43:0 as N:P: K) to farmland in catchment areas (Ayoade *et al*., 2019). According to Galvez-Cloutier and Sanchez (2007), TN/TP ratios are low in eutrophic lakes and high in mesotrophic and oligotrophic lakes. This suggests advanced degradation (eutrophic) condition of this water body.

Increase in chlorophyll-a concentration during the peak of dry season in Awba Reservoir is an indication of higher algal biomass during the study period, which can be correlated to favourably warm water temperature in the water body and elevated total phosphorus content as revealed in its significant positive correlation. The correlation between chlorophyll-a and Secchi depth being high suggest that chlorophyll-a was the major light attenuating substance in Awba reservoir. This is similar to Carlson (1977), where correlation between Secchi depth and chlorophyll-*a* was high (0.93) but Rakocevic-Nedovic and Hollert, 2005 suggested light attenuation in Lake Skadar was most likely due to clay particles due to low correlation (r= 0.6) between both parameters.

Based on the classification of Carlson (1977), trophic state index values that exceed 50 are eutrophic; since trophic state index calculated using Secchi disc, phosphorus and chlorophyll *a* in Awba reservoir exceeded 50, this suggest that the reservoir is eutrophic. A lake situated in nutrient rich area may be naturally eutrophic. Nutrients carried into water bodies from non-point sources such as agricultural run-offs, fertilizers and sewage, will all increase biomass and can cause oligotrophic lake to become hypereutrophic. Awba reservoir might receive fertilizers from farming activities around and within the university, and it is a collection point for many pollutants such as chemicals, waste water(containing detergents) and animal wastes washed into it from Science Departments, halls of residence and the Zoological garden (Anago *et al.*, 2013).

The abundant green algae and blue green algae give further evidence that the reservoir may be eutrophic (Reynold, 1984). Some of the blue green algae including *Microcystis* spp. encountered in the reservoir have the ability to fix atmospheric nitrogen as a nutrient source (Wetzel, 2001) and this could help to reduce the nitrogen limitation condition, thus the growth of these algae are favored. In Awba reservoir, the mean TSI based on chlorophyll-a (94.79) was higher than TSI based on Secchi depth (59.86). This could indicate that large particulates such as colonial and filamentous algae frequently encountered in this reservoir dominate (Carlson, 1983).

In conclusion, Awba reservoir was in eutrophic/hypereutrophic condition with nitrogen being the limiting factor to algal growth. Efforts should be made to reduce phosphate load coupled with long-term monitoring for better estimation of the state of the reservoir.

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